IGSTC
INDO-GERMAN SCIENCE AND TECHNOLOGY CENTRE

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Annual Report
2020-21

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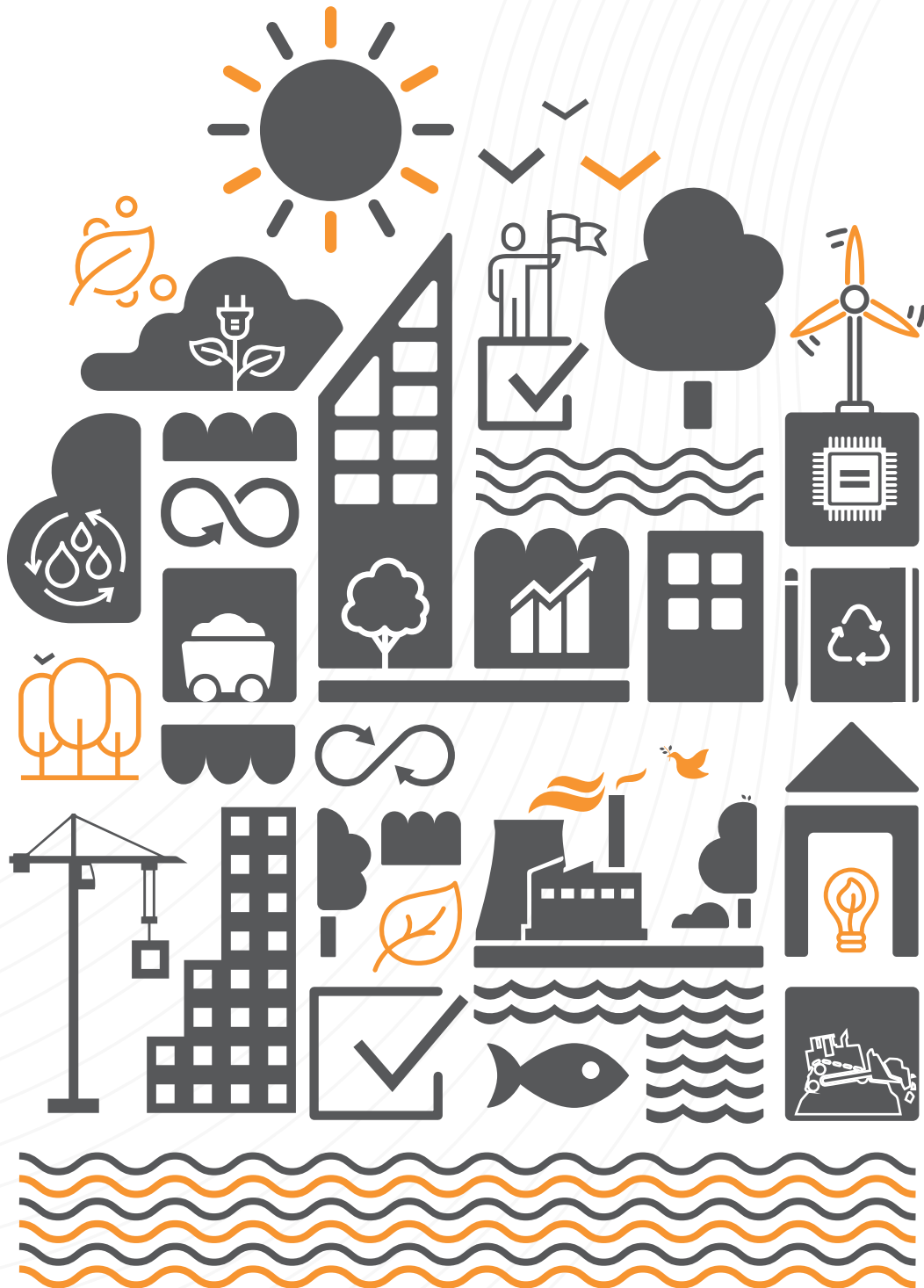
The Indo-German Science & Technology Centre (IGSTC) has been established to facilitate Indo-German R&D projects and networking through substantive interactions among Government, academia/research systems and industry to foster innovation for the overall economic and societal developments of both the countries.

IGSTC AIMS TO

01

Play a proactive role in facilitating participation of industry in joint R&D+I projects.

02

Provide/assist in mobilizing resources to carry out industrial R&D+I projects.

03

Promote electronic exchange and dissemination of information on opportunities in bilateral science & technology cooperation. The Centre will also prepare/compile state-of-the-art reports on topics of interest with the help of highly qualified scientists and technologists from both the countries.

04

Provide advice to institutes and industries from both the countries on the possibilities of Indo-German cooperation and help identify suitable partners.

05

Facilitate and promote Indo-German collaboration in Science and Technology (S&T) through substantive interaction among Government, academia and industry.

06

Encourage Public-Private Partnerships (PPP) to foster elements of innovation and industrial application and cultivate a culture of cooperation between science and industry.

07

Nurture networking between young and mid-career scientists and technologists to develop a sense of mutual trust, leadership and entrepreneurship.

08

Develop cooperation through the identification of scientists and scientific institutions of the two countries.

09

Organize workshops, seminars, training programmes and other types of events on topics of mutual interest.

# CONTENT

The Year 2020-21 at a Glance

IGSTC perpetuates to grow the Indo-German partnership in Science & Technology through its programmes and plays a crucial link in enabling collaborative research through numerous Indian and German academic institutions and industries. On 14th June 2020, IGSTC completed a decade of operations since its foundation in 2010. To date, IGSTC's flagship programme namely the 2+2 scheme has supported 44 projects partnering research institutions, academia and industries creating a network of more than 190 organisations. Several publications, patents, few startups, technologies commercialisations and capacity building of young engineers, science graduates and technologists have been achieved through the 2+2 projects scheme. IGSTC's bilateral workshop program has networked around 2700 scientists and industry personnel in 54 institutions in India & Germany through 27 workshops. The workshop program has also given exposure to around 1000 early researchers. IGSTC also implemented the extramural programme of DST-Max Planck

Society through partners groups and mobility grants. IGSTC's programmes addressed key national priorities of both India and Germany through important thematic areas including Advance Manufacturing, Medical Technology, Embedded System, Sustainable Energy / Environment, Water & Wastewater Technology, Waste to Wealth, Smart Cities, Bioeconomy, Information & Communication Technology, etc. During the 2015 Inter-Governmental Consultations between India and Germany, the tenure of IGSTC was extended with enhanced funding. The IGSTC-CONNECT Plus programme in association with Humboldt Foundation which was launched to support short-term research stays in India and Germany supported three fellows up till now. Branching out into next decade, IGSTC intends to launch multiple programs like industrial fellowships, women in science & engineering research, paired early career fellowship in applied research, etc. The multiple avenues of research funding through IGSTC will certainly help accelerate the Indo-German partnership.

INDO-GERMAN NETWORK THROUGH IGSTC PROGRAMMES

Spread of institutions and industries across India & Germany
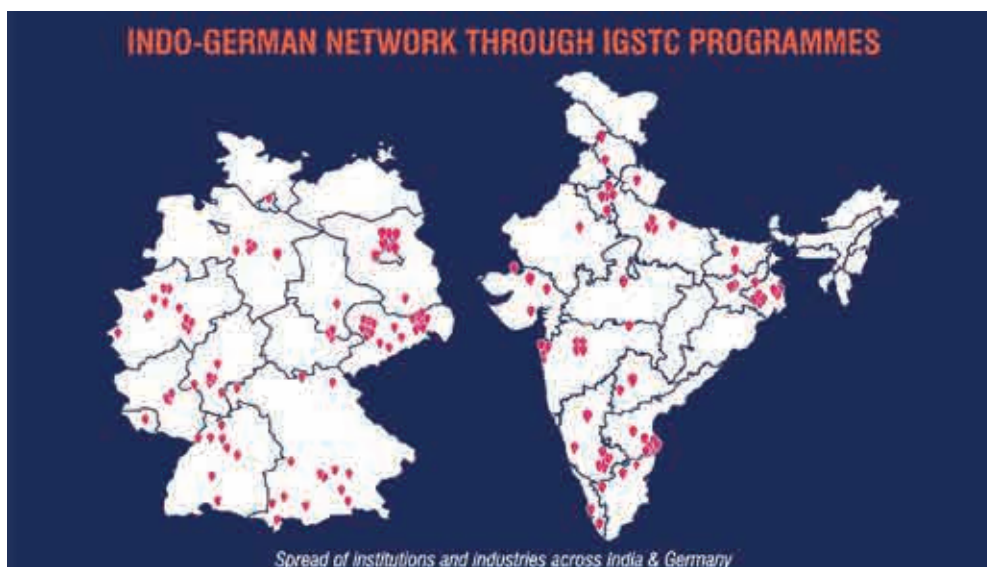
During the year 2020-21, IGSTC supported 25 joint projects in 2+2 mode in emerging areas of (i) sustainable energy (ii) advanced manufacturing (iii) biomedical devices and technology (iv) water & wastewater technologies (v) smart cities (vi) bioeconomy. Four new projects from Call 2019 in the overall thematic area "Bioeconomy" started in March 2021. Currently, ongoing IGSTC Projects involve more than 100 project partners from academia and industry from India and Germany with total project investment (from BMBF and DST) of estimated ₹ 157 Cr or € 18 million. There are 19 (2+2) projects already completed. A special call for bilateral virtual workshops was launched during this period. The Call has been launched in place of IGSTC Open Call for Workshops. Two virtual workshops under the areas of advanced automotive steels and charging technologies for heavy duty vehicles were organized. Approximately 500 Indian and German scientists, policy officers, young researchers and technologists benefitted from these workshops.

The 2+2 Call 2020 on Additive Manufacturing (AM) was launched on 14th December 2020. The Call will target innovative technologies in the area of AM and IGSTC is expecting good response to the call. A call promotion event was organized on 12th November bringing together key experts and policymakers from India and Germany to discuss about the current status and updates on Additive Manufacturing and how to draft a successful 2+2 proposal. An online matchmaking platform was also launched by IGSTC to ease the process of finding partners in academia and industry for building a mutually beneficial consortium for long-term collaboration. IGSTC expects that all such initiatives will help the scientific community to leverage their technical expertise and accelerate their research from lab to market with the help of industries & bilateral collaboration.
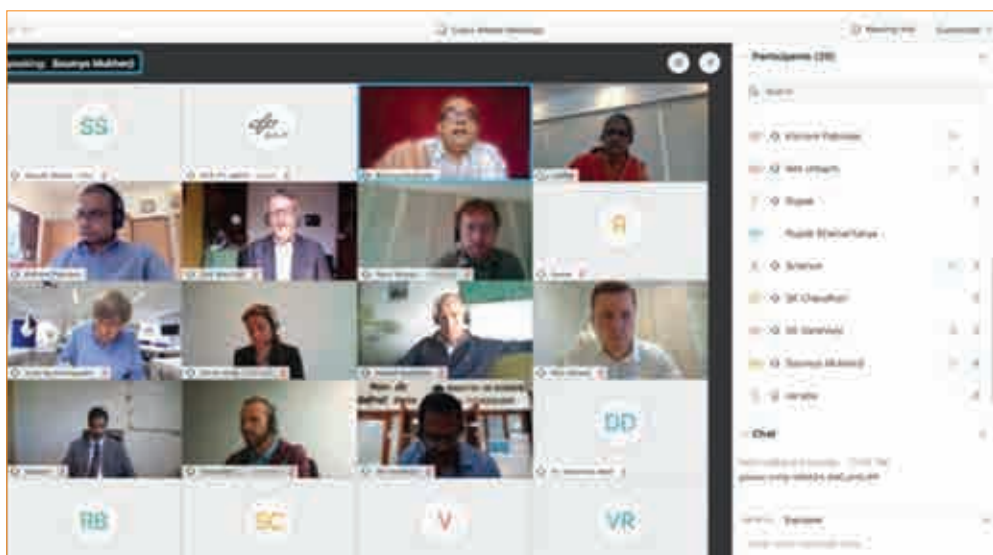
Joint Scientific Committee meeting for Call 2019

This period witnessed changes in the Governing Body of IGSTC. Mr Sanjiv Rangrass, Group Head - R&D, Sustainability and Projects, ITC Limited, Kolkata replaced the outgoing member Mr Anjan Das, CII in November. Ms. Andrea Frank, Head, Field of Action, Science and Research at Stifterverband was nominated in place of Prof Eberhard Abele, TU Darmstadt. IGSTC places gratitude towards the contribution of Mr Das and Prof Abele to IGSTC board.

Mr. Madhan has taken over the position to lead the bilateral Indo-German Science and Technology Centre (IGSTC) as its Director on 29th December 2020 and looks forward to catalyzing Indo-German Science & Technology partnerships.

The 11th Governing Body (GB) meeting of IGSTC was held on 4th March 2021 through virtual mode. The GB focused holistically on IGSTC's 2 + 2 flagship programme, thematic areas for future grant calls and new programmes to be taken up etc.

11th Governing Body Meeting of IGSTC

Indian and German Co-Chairs also approved four projects of Call 2019 recommended by the Joint Scientific Committee.

GOVERNING BODY

Sanjeev Kumar Varshney
DST
Indian Co-Chair

Kathrin Meyer
BMBF
German Co-Chair

Vishvajit Sahay
DST

Gerold Heinrichs
DLR-PT

G Padmanabham
ARCI

Philipp Von Ritter
German Embassy

Sandeep Verma
IIT Kanpur & SERB

Andrea Frank
Stifterverband

Sanjeev Rangrass
ITC

Clas Neumann
SAP

PROGRAMME ACTIVITIES

2+2 PROJECTS

2+2 PROJECTS CALLS

IGSTC intends to catalyse innovation centric projects by synergising the strength of research/academic institutes and public/private industries from India and Germany. It is aimed at supporting joint R&D+I projects of industrial relevance by means of "2+2 Mode of Partnership" (R&D+I projects with the participation of at least one Indian and one German research institution as well as one Indian and one German industry partner).

Salient Features of 2+2 Partnership

Project proposal is expected to produce insight and exploitable research results leading to new technologies, products and/or services.

Funding is provided in the form of grants amounting up to ₹ 350 lakhs per project from Indian side and up to € 450000 from German side, for a period of up to three years.

Indian industry partners are expected to contribute 50% of their eligible cost and German industry partners are expected to contribute as per rules laid by AVGO.

Academic/research partners receive 100% of the eligible cost.

The proposal will be evaluated by a Joint Scientific Committee consisting of experts from both India and Germany.

Projects are evaluated on the following points:
(a) novel innovativeness
(b) IPR sharing/protection
(c) industrial relevance
(d) scientific credential
(e) relevance of partnership.

PARTNERS
- Min. 4 & Max. 6
- India - 1 academic/research institute + 1 industry
- Germany - 1 academic/research institute + 1 industry

DURATION
- 3 years
- Extendable up to 2 more years

FUNDING
- Indian side - ₹350 lakhs
- German side - € 450000

THEMATIC AREAS
- Energy
- Water
- Manufacturing
- Biotechnology
- ICT
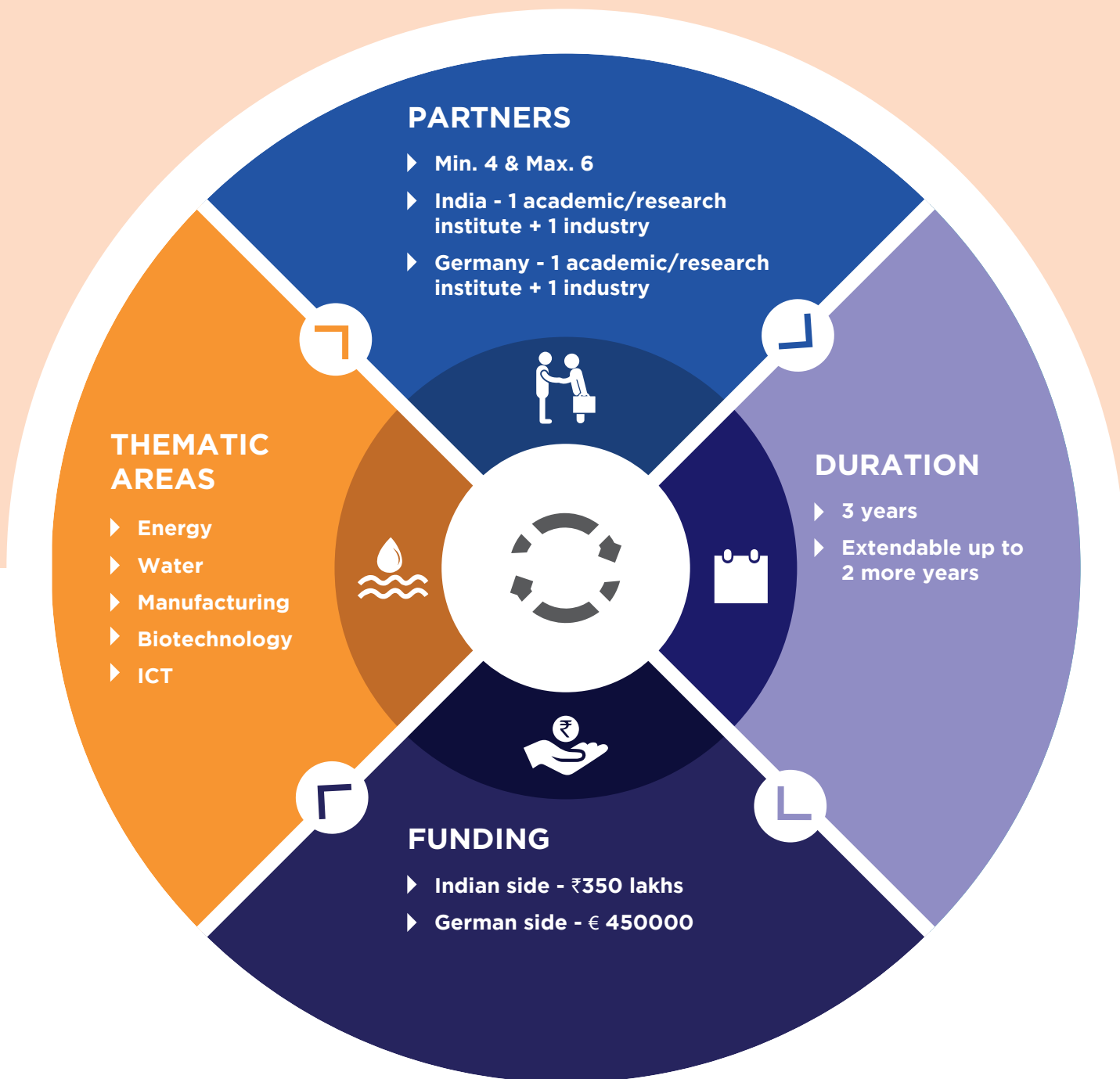
SMART CITIES

SMART & WISE

Smart and reliable water and wastewater infrastructure systems for our future cities in India and Germany

B S Murty
IIT Madras (IITM)

S Vellaiappan
Tamil Nadu Water Investment Company (TWIC), Chennai

Ulrich Dittmer
TU Kaiserslautern (TUK)

Martina Scheer
Ingenieurbuero Scheer (IBS) Oberstdorf

Gerald Angermair
tandler.com GmbH (TAN) Buch am Erlbach

PROJECT BRIEF

The Indian project partners (IIT Madras and Tamil Nadu Water investment Company Limited), as well as the German partners (University of Kaiserslautern, Engineering Office Scheer and tandler.com) are working on the overall project goal to support the implementation of reliable and sustainable water and wastewater infrastructure systems (WIS) with added value in terms of smart cities. The targets of the project are to develop planning methods and tools to successfully face current and future challenges on the three linked levels of conventional, advanced, and smart water & wastewater infrastructure systems. E.g. automated planning based on mathematical optimisation to improve conventional sewerage system planning with incomplete planning database. Research on advanced level involves the integration of decentralised and resource-oriented approaches as well as improved water pollution control. Smart WIS research provides interfaces for WIS integration in smart city planning. The methods and tools will be sampled in pilot areas in India (e.g. Coimbatore) and Germany. Research results will be disseminated through training programs and utilization in planning services for local planners and decision-makers.

PROGRESS MADE/ACHIEVED

WIS measures to improve smart city concepts

An extensive literature research on the subject Smart City and water infrastructure was carried out. At an in-house workshop in Chennai on 10th December 2018 the country-specific ideas of smart city concepts were discussed and brought together. The team has defined targets for water infrastructures in smart cities.

According to the Smart City Charter published by the German Federal Institute for Research on Building, Urban Affairs and Spatial Development a Smart City is also "climate-neutral and resource-efficient – it promotes eco-friendly mobility, energy, heat, water, sewage and waste concepts and contributes to making municipalities carbon-neutral, green and healthy". Similarly, Indian literature highlights that the Smart City is first a sustainable city and not merely a connected City or a digital City. According to the Indian Ministry of Housing and Urban Affairs the Indian Smart City Mission promotes cities that "provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart Solutions".

The participants of the workshop identified the water and wastewater infrastructure measures which have a potential to improve smart water concept in cities. In a first step, they answered the question which measures in water supply, urban drainage and sewage treatment have a high potential to benefit smart cities. In the second step, the questions about the goal of the smart concepts were answered. In the course of this discussion, it became apparent that similar ideas in Germany and India are

very different in detail. It is noted that India's water quality could be significantly improved by the introduction of smart quality monitoring. Both in India and in Germany, water loss management and leak detection issues are linked to the concepts for smart water supply. From the German point of view, topics such as energy saving and the improvement of environmental protection (e.g. consideration of micro pollutants) are therefore very important. In India, the focus is primarily on the construction, renewal and replacement of supply and disposal infrastructure and a benefit of the smart technology for problem analysis. In both Germany and India, there is a desire for automation of operation and maintenance. During the workshop, it was noted that a key overarching goal of smart water infrastructure must be there to provide and generate information. Therefore, different sensors and new technologies have to be used. An aspect that is important in the context of "Smart City" development or Smart Water Supply Systems is cost of metering. For the participants in the workshop, it is obvious that the disciplines of water supply, drainage and wastewater treatment must be considered together in the planning of smart cities.
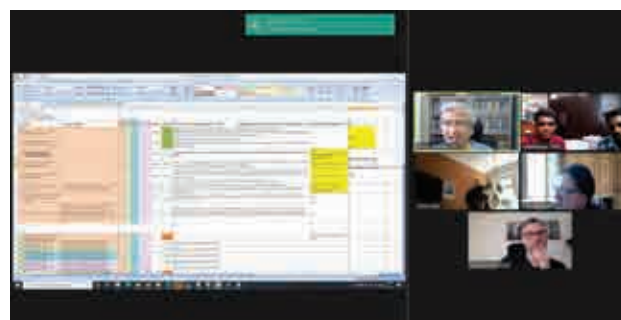
Online meeting of the project team discussing the current work plan

SALIENT RESEARCH ACHIEVEMENTS

- Commonalities and differences between planning processes in Germany and India have been identified; lacunae in conventional planning processes for application to sustainable and smart cities have been identified.

- A classified list of measures and targets for a smart city in the areas of water supply, rainwater management, wastewater and integrated systems has been created.

- A flow chart and a description text were developed by IBS with inputs from all the project partners for retrofitting of existing sewerage systems. As base, the consideration of conventional experienced planning procedure was used. Advanced and smart topics that are currently not used regularly in practice were added.

- A flow chart has been developed by TWIC with inputs from all the project partners for greenfield planning of sewerage systems. Here as well conventional planning was considered, and advanced topics were added.

- Work on flow charts for storm water management and flooding due to heavy rain has been started. All flow charts were adapted consequently based on new findings during application to the pilot cases.

PUBLICATIONS

- Dilly, T. C.; Schmitt, T. G.; Dittmer, U. (2020): Wasserinfrastruktur für Smart Cities: Entwicklung von Instrumenten für eine ganzheitliche Planung für Deutschland und Indien. Seite: 56/1 – 56/8. Gewässerschutz - Wasser - Abwasser, Aachen 2020, ISBN 978-3-938996-58-4

GENERAL PUBLIC RELATION ACTIVITIES

The project team participated actively in seminars, workshops, exhibition and trades either with presentations or with transfer of our project work in public discussions or private talks:

- Seminar "Innovation and Knowledge for Sewer Technology", Sewer Renovation and Operation, part 3 "Smart Cities and Heavy Rain", May 6th 2020: Ingenieurbuero Scheer, Tandler.com: SMART&WISE - Smart and reliable water and wastewater infrastructure systems for our future cities in India and Germany

- SMART&WISE – virtual trade stand at trade show event "Innovation and Knowledge for Sewer Technology" on May 6th 2020: TREND TELEPORTER – the Virtual Exhibition: University of Kaiserslautern, Ingenieurbuero Scheer, Tandler.com: Timo Dilly (Technische Universität Kaiserslautern and Dr. Martina Scheer (Ingenieurbuero Scheer) explain further how companies can engage with the SMART&WISE project for designing sewer networks in future cities in this India/Germany joint project.

PH.D. / MASTER THESIS SUPERVISED

- Ph.D thesis of Mr. Timo Dilly in progress. Planned to be finished in 2021.
- Ph.D. thesis of Mr. Amin E. Bakhshipour submitted in 2020. Graduated in 2021. "Optimizing hybrid decentralized systems for sustainable urban drainage infrastructures planning"
- M. Tech. Thesis of Mr. Aakash Dev was completed in June 2020. "Optimal implementation of wastewater Recycling"
- M. Tech. Thesis of Mr. B. Shivakumar completed in June 2020. "Design of districting metering areas in water distribution networks".
- M. Tech Thesis of Adwait Bharade (to be completed in June 2021. "Integrated planning and design of water supply and sewerage systems".
- M. Tech Thesis of Dinesh Borse (to be completed in June 2021). "Key performance indicators for planning and design of water infrastructure"
- M. Tech Thesis of Subhashish Jena (to be completed in June 2021). Condition assessment of existing water supply networks.

Contact Details

bsm@iitm.ac.in
vellaiappan@twic.co.in
gerald.angermair@tandler.com

theo.schmitt@bauing.uni-kl.de
info@ib-scheer.de

ECO-WET

Efficient coupling of water and energy technologies for smart sustainable cities

Naran Pindoriya
IIT Gandhinagar

Sriniwas Singh
MMM University of
Technology Gorakhpur

Arvind Rajput
GIFTCL, Gandhinagar

Janki Jethi
GIFTCL, Gandhinagar

Markus Duchon
fortiss GmbH, Munich

Julia Singer
Sonnen GmbH
Wildpoldsried

PROJECT BRIEF

Smart cities are envisioned to efficiently use two most critical resources: water and energy. Advanced techniques are being developed to conserve water. Similarly, renewable energy resources and smart devices are being implemented to meet the increasing electricity demand of the large population.

In reality, water management and energy efficiency are complementary to each other. On one hand, electricity from the renewable sources can be used to run water pumps or other components of the water treatment system while on the other hand, during the oversupply of electricity from renewable energy sources, water pumps can be made operational to create a balance of energy demand-supply in the electrical distribution network.

Coupling of cross-commodity infrastructure and integration of energy storage is a challenge for smart cities. With respect to ICT this project addresses the challenge to bring intelligence closer to the device, which leads to distributed design. In such a system highly integrated components from different sectors interact with each other to use available resources more efficiently and increase the overall performance.

This project envisions a smart city infrastructure with efficient water and energy distribution networks in a distributed manner. The water-energy Nexus with advanced

energy storage and the use of renewable energy resources has not yet been available. The project will implement a software platform with progressive optimization algorithms to interconnect different infrastructures and enable their real-time monitoring and control. Fostering the utilization of renewable energy sources, advanced storage technologies will be deployed and integrated, which allows for modular and distributed operation of infrastructures.

The main goal of the project is the energy-efficient management of electricity and water by complementing both critical resources (energy and water infrastructures) in the smart sustainable cities. The core scientific research is to enhance the overall efficiency by coupling of these most essential infrastructures, through advanced ICT and intelligent computational framework.

MAIN OBJECTIVES

- The integration of advanced energy storage technology and renewable energy sources to enable the coupling and modularization of electricity and water infrastructures.

- Hardware and software platform to improve energy efficiency and water management. A software platform that allows real-time monitoring, analysis and controlling based on the IEC 61499 industrial standard with the grounding of systems engineering techniques.

- Optimization techniques for energy- efficient management of both water and electricity in the purview of the infrastructural constraints in the smart sustainable cities.

PROGRESS MADE/ACHIEVED

fortiss GmbH

- Deployed new version of Optimization and forecasting algorithms into ECOWET Energy management System at the test bed.

- Organization of regular Bi-weekly Telco meetings and other coordination activities.

- Organized virtual consortium meeting on July 2020.

- Collection, aggregation and validation of initial sample data at the testbed.

- Assisted project partners in preparation of Deliverable report 3.1.

- Feasibility study and analysis of usecases for Phase-2 proposal.

- Developed new hybrid forecasting techniques for solar energy forecasting.

- Prepared deliverable report 3.2 on data acquisition and real-time controlling.

IITGN

- Developed optimization framework for optimal integration of distributed energy resources and battery management in a simulation environment.

- Developed forecasted on-site solar PV generation algorithm for improved optimization and decision making.

- Procured and deployed hardware layer to set up the test bed (STP and WTP) at GIFT city.

- Preliminary software layer integration - Integrated the forecast-optimization code with iEMS software

- Procurement and setting up the hardware at GIFT city's STP and WTP.

- Integrate software-hardware layer at testbed location and demonstrate proof of concept (POC) of efficient energy management at usecase levels.

- Developed speed control algorithm for the automation and control of aeration blower for GIFT city's STP.

- Developed "Wifi-Relay" to operate CDI from Raspberry Pi through wireless at STP, Gift City.

sonnen GmbH

- Provided necessary Software details for real-time controlling of battery system

- Simulation of the battery and solar PV system for ECOWET phase 2

- Evaluation of ECOWET project outcome to commercial product

- Set up monitoring for battery systems deployed at GIFT City

- Built operating schedule for battery systems deployed at GIFT City during use-case development phase

- Small modification of battery systems for Indian and project requirements

- Prepared battery system installation information for Indian partners

- Designing and assembling the battery switching boxes for the respective use case

- Installation of the battery switching boxes at STP

GIFT city

- Troubleshooting for batteries with sonnen (German counterpart) for seamless communication

- Finalization of internet connectivity protocol

for testbed with partners

- Installation of various Raspberry Pi namely, load and generation Pi at STP and WTP.

- Upgradation of workstation operating system and software (for example, Windows 10 from home to professional).

- Modification in WTP and STP PLC Programming for providing the data through Modbus.

- Installation and configuration of PV Inverter at STP and WTP with their respective generation Pi.

MMMUT

- Worked on deployment of Harmonic Estimation tool named "Pymonics" based on MEMO-ESPRIT algorithm.

- Worked with IIT-Gn and fortiss GmbH for integration of DSO with pymonics tool for data fetching at the test bed.

- Performed Harmonic/Interharmonic analysis on some loads involved in the several use-cases at GIFT city testbed.

SALIENT RESEARCH ACHIEVEMENTS

Hardware layer deployment:

The hardware required for successful deployment of software layer was installed at both the STP and WTP facility.

A diagrammatic presentation of hardware integration at STP facility is shown in Figure 1 below. Field raspberry PIs are deployed to monitor the solar PV generation and load demand. The data from the field raspberry PIs will be communicated to workstation through central raspberry Pi. The workstation runs the forecast-optimization-iEMS software layer. Based on the collected data the software layer delivers the optimal BESS charging and discharging references. The workstation communicates the optimal references to the BESS via the central raspberry Pi controller. The network switch is deployed to enable communication access to the ICT/IoT devices deployed at usecase levels.
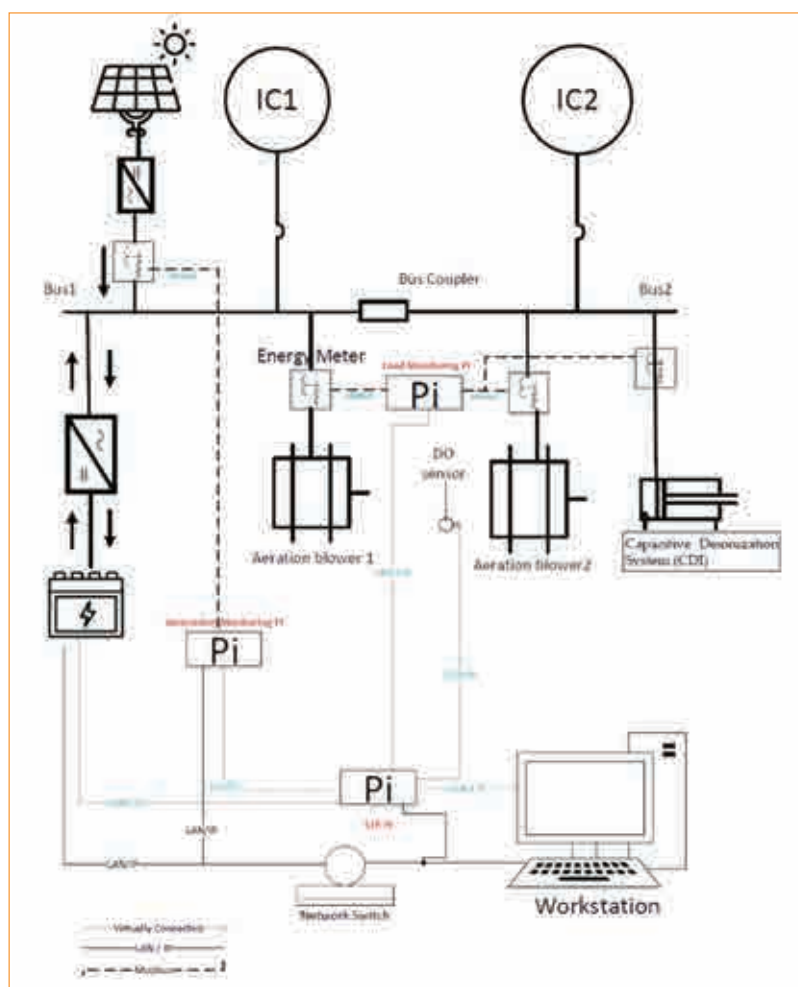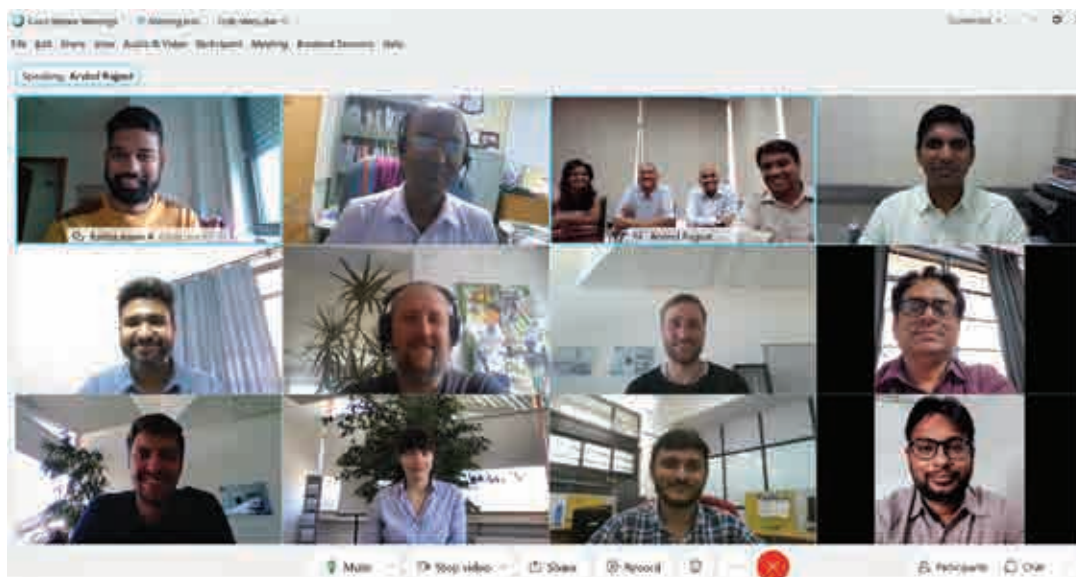
Hardware deployment at STP, GIFT city

Similar instructional hardware procedure is followed at WTP location and the diagrammatic presentation is shown in Figure 2. The team achieved the level of TRL 6 & TRL 7 and are working on TRL 8 (Actual system completeness and flight qualified through test and demonstration). Currently the hardware deployment is done at both STP and WTP level. The team is working on hardware-software integration, communication and protocol layers at readiness level for STP location and after successful integration of hardware-software layers the same will also be carried out for WTP.
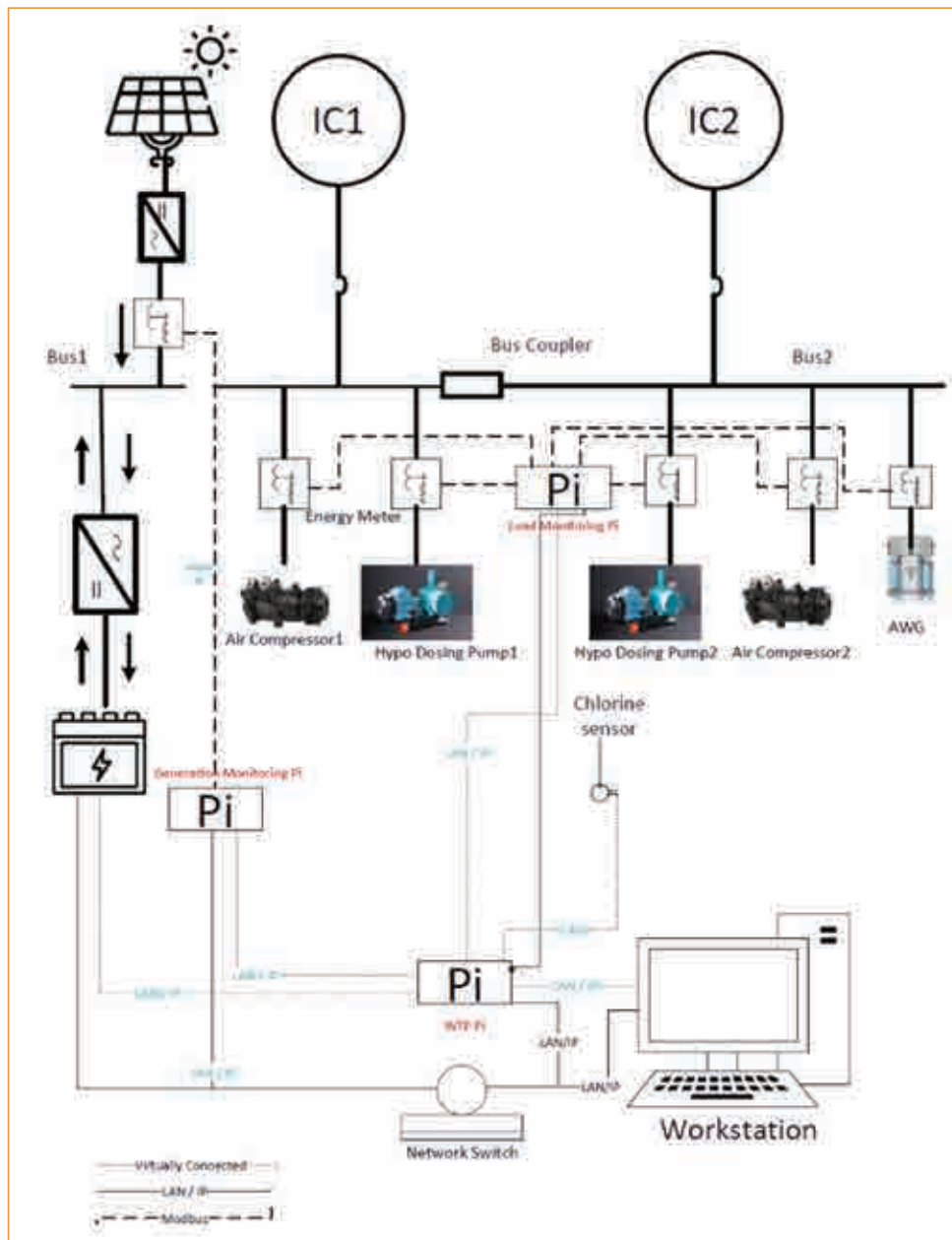
Hardware deployment at WTP, GIFT city

PUBLICATIONS

01

Suthar S, Pindoriya NM. Energy management platform for integrated battery-based energy storage–solar PV system: a case study. IET Energy Systems Integration. 2020 Aug 21;2(4):373-81.

02

Ankit Kumar Srivastava, A N Tiwari, S. N. Singh, Venkatesh Pampana & Markus Duchon, "Harmonic frequency estimation with MEMO-ESPRIT Technique using MATLAB and Python", IEEE UPCON 2020.

03

S. Sukumar, N. Pindoriya, A. Ahuja and R. Verma, "Forecast and Energy Management System (F-EMS) Framework for Optimal Operation of Sewage Treatment Plants," 2020 21st National Power Systems Conference (NPSC), Gandhinagar, India, 2020.

04

Venkatesh Pampana, Daniel Lavin, Ankit Kumar Srivastava & Markus Duchon, "SuperCap -Python: An Open-source Python based Super capacitor Modelling Package", Energy Web Journal. (submitted revised version).

05

Jan Mayer, Venkatesh Pampana, Michael Bernard, Denis Bytschkow, Thomas Stohl, Pragya Gupta, and Markus Duchon, "Holonic architectures for IoT-empowered energy management in districts", WF-IOT 2021 IEEE Conference. (Accepted for publication).

GENERAL PUBLIC RELATION ACTIVITIES

(i)   Organised a workshop titled "Energy Management for Smart Sustainable Cities" at IIT Gandhinagar during 5-6 February 2020. The expert lectures were delivered by the project partners and other delegates. Also, All the participants and delegates had visited Gift City and learned about the various test-beds of the project.

PH.D. / MASTER THESIS SUPERVISED

Master of Technology (M.Tech.) thesis supervision

(i)   Daniel Lavin, "Assessment of Machine Learning Models for Photovoltaic Power Forecasting", supervised by Prof. Sandra Hirche, M.Sc. Alexandre Capone, Chair of Information-Oriented Control, TU Munich, and M.Sc. Venkatesh Pampana, Fortiss GmbH.

Ongoing Ph.D. supervision

(i)   Ankit Kumar Srivastava, " Investigations on Harmonic Estimation in Modern Power Systems" under supervision of Prof. A. N. Tiwari and Prof. S. N. Singh, Dept. of Electrical Engineering, MMMUT Gorakhpur.

Contact Details

naran@iitgn.ac.in
snsingh@iitk.ac.in
arvindkumar.rajput@giftgujarat.in
janki.jethi@giftgujarat.in

duchon@fortiss.org
J.Singer@sonnen.de

IDC-WATER

Integrated diagnostics of contaminants in water supply and management system

Debiprosad Roy Mahapatra
IISc Bangalore

J Manjula
Bigtec Labs Pvt. Ltd.
Bangalore

Rudolf J. Schneider
BAM, Berlin

Michael Voetz
Sifin diagnostics GmbH
Berlin

PROJECT BRIEF

Project proposes to develop a system for monitoring water quality in terms of specific bacterial cell/DNA and pharmaceutical residues. The system will consist of the following components: (1) an in-line water sample collection and enrichment compartment, (2) a system of microfluidic cartridges for bacteria cell capture, culture, amplification, and detection in a short period of time, (3) a system of micro-fluidic cartridges for capture and detection of pharmaceutical residues in short period of time, (4) an integrated board that hosts all the compartments 1-3, reagent supply units, detection units and performs automated diagnostic tasks and a similar counterpart with micro-PCR for off-line diagnostics, (5) a software framework to operate the integrated system, analyze the data collected over time and provide an appropriate early warning. The system will be designed in such a way that it can be installed in the water pipelines in the water treatment plant settings and in building infrastructure settings for remote monitoring. Target specification for detection of pathogen would be less than 100 cells in 1 CFU/ml and nanomolar concentration of target DNA detection within an hour. Targets for detection of pharmaceuticals will be a concentration of 100 ng/L and within a measurement time cycle of 10 minutes.

A Development of bead-based immunoassays. Amoxicillin (AMX): for a direct immunoassay, antibodies are immobilized on magnetic beads functionalized with protein G. Diclofenac (DCF): for an indirect immunoassay, a hapten derivate, the activated ester of DCF, is coupled to amino-functionalized magnetic beads to form a bead-based competitor for the final competitive assay

PROGRESS MADE/ACHIEVED

1. A detailed product requirement specification document has been developed including national and international standards and recommendations, and technology gap analysis have been carried out jointly by all partners. Various product development milestones have been followed and product design, fabrication, unit testing have been carried out (IISc). More tests will be required. The unit test results around the cartridge operation is being reviewed jointly by IISc and Bigtec for the Cell/DNA cartridge performance and arriving at product specification. In the reporting period, it was found that both types of immunoassay, direct and indirect, have to be realised on the system. Finally, the diclofenac indirect and the amoxicillin direct immunoassays have been taken on magnetic beads. Bead-based assays, utilizing magnetic particles, have been employed to successfully establish microtiter plate-based colorimetric ELISAs (BAM). Amoxicillin antibodies have been immobilized on protein G-coated beads, while for diclofenac, a competitor was established by immobilizing a DCF hapten to amino-functionalized magnetic beads. A microfluidic chip has been designed and produced (cleanroom) to evaluate the performance of the assays in the flow scheme. A combination with electrochemical (amperometric) detection was envisaged (BAM)

2. A modification of the microfluidic set-up for the final prototype was discussed, adding extra valves and mixing chambers and special zones to the chip layout (BAM, bigtec, IISc, sifin). Cell culture cartridge has been designed and improvised to integrate separate fluidic lines for reagents avoiding any sort of contamination and false positive or false negative results (IISc). The cartridges were fabricated and tested with successful results of culture of 1CFU/20mL of E. coli detected using the optical method and electrochemical impedance method (IISc). A pre-filtration unit was designed and tested to check for the efficiency of filtration in the presence of a controlled sample with known cell concentration but eliminate larger size contaminants and to send a controlled quality of sample without unwanted inhibition into the cartridge (IISc). Subsequently, the study monitored the general condition of the sample in terms of pH, Total Dissolved Solid, temperature, and turbidity (IISc). An integrated board for the product prototype has been designed, and various integrated tests are in progress (IISc). In this integrated board or platform, a modular approach has been adopted to integrate various components to operate the two different systems of cartridges.

3. The water sample from the pre-filtration unit is sent to an automated meso-fluidic bioreactor cartridge designed for cell culture/enrichment (IISc). The developed technology has achieved a quick detection time of less than an hour for detecting a concentration of few 100 cells cultured from 1 CFU/20ml of original water sample in the cartridge (IISc). Batch operation in a software-controlled manner has been planned for further testing and validation toward in-line remote monitoring. Optical spectroscopy technique with optical fibers to the detection unit were established and tested for detection of cell growth in the cartridge as part of a preliminary laboratory test and basic technology feasibility study (IISc). Various product development

milestones have been followed, and product design, fabrication, unit testing have been carried out (IISc). More tests will also be required for parametric study for cell efficient cell culture. The unit test results around the cartridge operation are being reviewed jointly by IISc and Bigtec for the Cell/DNA cartridge performance and arriving at product specification. Component level testing and validation for the upstream and downstream process of the prototype will be carried out, addressing issues on component reliability in operation and robustness.

4. Additional quantitative measurements of water quality such as pH, temperature, turbidity, total dissolved solids (TDS) are established at the laboratory level. These features are getting incorporated into the integrated system (IISc). Water sampling and contamination-free culture for direct loading into cartridge will be carried out to validate the sterility of the fluidic interface (valves, tubing, storage tank, cartridges) free from contaminants before loading of sample into culture zone (IISc). Contamination-free repeated culture and wash were tested. The tests involve using the cartridge with its fluidic interfaces to evaluate the components coming in contact with the previous batch

culture. These tests validate the effect of the wash buffer (IISc). The bacterial cell growth environment inside the cartridge was optimized (IISc).

5. 16S rRNA Primers and probes have been designed and tested by Bigtec for the detection of 16S rRNA gene to do the preliminary screening for the presence of total bacteria present in contaminated water samples using Bigtec's already existing portable micro-PCR device. Further, primers and probes have been developed and are being tested for the detection and characterization of Shigella, Salmonella, and STEC (Shiga toxic E. coli). PCR has been performed for these designed sets of primers to confirm their specificity with regard to the identification of the respective bacteria. Linearity and limit of detection was determined for the STEC (Shiga toxic E. coli) assay.The assay is found to be linear over 7 orders of magnitude(from 2.12E+09 to 2.12E+03) with a limit of detection (LOD) of 131 copies/mL for STEC (Shiga toxic E. coli) spiked in water samples (bigtec). Easy to use, room-temperature stable, and dried down tube format for the PCR components was optimized for PCR using direct culture samples.
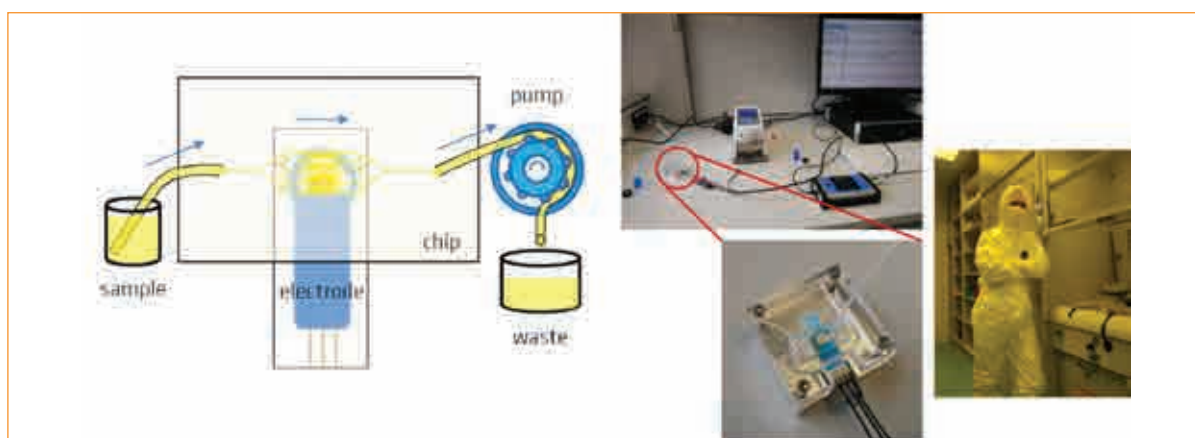
Establishing a model system to study bead-based immunoassays in a microfluidic chip set-up at BAM.

> **To summarize, the project has solved the core technological problems related to various detection with the required sensitivity and specificity. These core components will now be integrated into the integrated platform as proposed, for which laboratory prototype for the system is under development and various unit level testing.**

PUBLICATIONS

01

Alexander Ecke and Rudolf J. Schneider, Pitfalls in the Immunochemical Determination of β-Lactam Antibiotics in Water, Antibiotics 2021, 10, 298

02

Subhan Shaik, Aarthi Saminathan, Deepak Sharma, Jagdish A Krishnaswamy, D Roy Mahapatra. Monitoring Microbial Growth on a Microfluidic Lab- on-Chip using Electrochemical Impedance Spectroscopic Technique. (in press, April 2021, DOI: 10.1007/s10544-021-00564-1) 2021.

03

Sumana Das, Bhamy Maithry Shenoy, Rohith Sali, Madhusmitha Mishra and D. Roy Mahapatra. Enhanced Electrical Lysis of Cells in a Micro-device with Nano-composite Electrodes. (Under review) 2021.

04

B.M. Shenoy, G.M. Hegde, D. Roy Mahapatra, Field enhancement in microfluidic semiconductor nanowire array, Biomicrofluidics, 2020, 14, 064102.

05

G Satpathy, GK Chandra, E Manikandan, D Roy Mahapatra, S Umapathy. Pathogenic Escherichia coli (E. coli) detection through tuned nanoparticles enhancement study, Biotechnology Letters, 2020, 42, 853-863.

06

Deepak Kumar Khajuria, Ramakrishna Vasireddi, Manish Kumar Priydarshi, Debiprosad Roy Mahapatra. Ionic Diffusion and Drug Release Behavior of Core-Shell Functionalized Alginate- Chitosan-Based Hydrogel. ACS Omega, 2019, 5 (1), 758-765.

Contact Details

droymahapatra@iisc.ac.in
manjula.j@bigtec.co.in

rudolf.schneider@bam.de
m.voetz@sifin.de

BIO-CUINGE

Biotechnology for the recovery Germanium, Indium and Copper from industrial copper dust waste

T R Sreekrishnan
IIT Delhi

S K Ziauddin Ahammad
IIT Delhi

G Venkat Saravanan
Laksmi Life Sciences
Coimbatore

Katrin Pollmann
Helmholtz Zentrum
Dresden Rossendorf, Dresden

Jana Pinka
GEOS Ingenieurge sellschaft
Mbh, Halsbrücke

PROJECT BRIEF

Germanium (Ge) and Indium (In) are important elements for the high-tech industry and their future supply is not assured. Copper (Cu) dust waste from smelters hold Ge and In, however, there is no technology for their recovery from these dusts. Further, the large volume of the produced Cu dust waste is a challenge for Cu smelters. This project proposes to develop environment-friendly and commercially viable technology for the recovery of In and Ge while decreasing the volume of Cu dust waste. The project encompasses preferential (bio) leaching of Ge and In from Cu smelter dust waste by optimizing various parameters followed by selective sorption. This project is very novel as it will apply the highly selective and sensitive siderophore and peptide- based biosorptive biocomposites to recover In^{3+}, and Ge^{4+} from the leachate. This approach will also be applied to the waste from Cu metal powder and mold manufacturing for recovery of Cu. The project, for the first time, will attempt selective flotation for recovery of Cu mineral from Cu smelter dust with the help of biosorptive biocomposites. This project brings the (bio)leaching and reactor operations expertise of IIT Delhi together with design and production of biosorptives biocomposites of HZDR along with mine waste remediation know-how of GEOS with product characterization and life cycle assessment of LLS. Further, this project fits the "waste to wealth", smart city campaign of India and recovery of critical element for Germany.

PROGRESS MADE/ACHIEVED

Following work packages have been successfully completed:

- Collection and transportation of all the industrial Cu dust waste to IITD, HZDR and GEOS

- Quantification and mineralogy of all the metals and their phases present in the industrial Cu dust waste

- Identification of best combination of biological and chemical leaching for maximum release of Ge and In (>70%) and minimum release of Cu (< 30%)

- In-silico screening of bio-ligands using DFT calculations that have high specificity and sensitivity towards target metal

- Characterization of the interaction of peptides (arginine-arginine) with Cu smelter dust waste

- Proof-of-concept for ability of peptides to achieve particle separation

### Partner 1 (IIT Delhi) & Partner 2 (LLS)

- Collection of samples from Hindustan Zinc Limited (HZL), 4 samples from Hindustan Copper Limited (HCL) and 3 samples from Laxmi Life Sciences (LLS)

- Chemical leaching of samples in 5 types of leaching reagents (Ultrapure water, HCl, HNO3, H2SO4 and NaOH) carried out and completed

- Elemental and mineralogical characterization of the samples by ICP-MS, SEM-EDX and XRD.

Partner 3 (HZDR)

- Material Liberation Analyses on 4 different copper samples from Khetri Copper Ltd. and 5 different Zinc samples from Hindustan Zinc Ltd.

- Binding experiments with in-house phage clones with copper binding amino acid motifs were tested with CuO as model target

- Estimation of thermodynamic parameters on chemical synthesized peptides using Isothermal Titration Calorimetry (ITC)
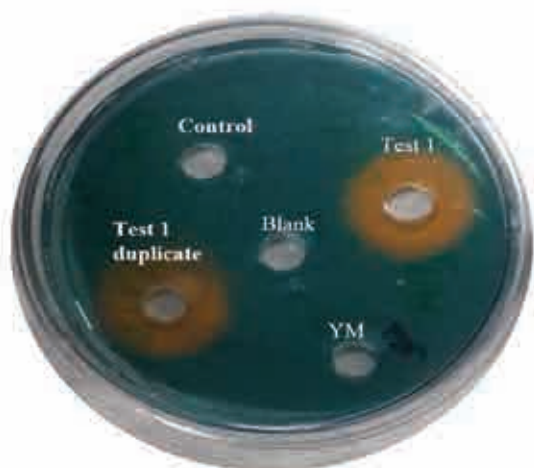

Sample holder in four places

Test 1 and duplicate	Supernatant of inoculum in Siderophore inducing medium (SIM)
YM	Supernatant of Inoculum in Yeast malt media
Control	Supernatant of Inoculum in SIM with $FeCl_3$
Blank	Supernatant of SIM without Inoculum

Partner 4 (GEOS)

- Literature search on possible processing options for Ge-containing ores and materials potentially applicable for the current project work;

- Drying and preparation of sample material from Hindustan Copper Limited (HCL) and Hindustan Zinc Limited (HZL) for partners (HZDR, IITD) and characterization of the samples via external service provider (ALS labs);

- Experimental testing of the found approaches with the available sample materials which included acidic and alkaline digestion and leaching test series with Cu-containing sample material from HCL and Zn-containing sample material from HZL.
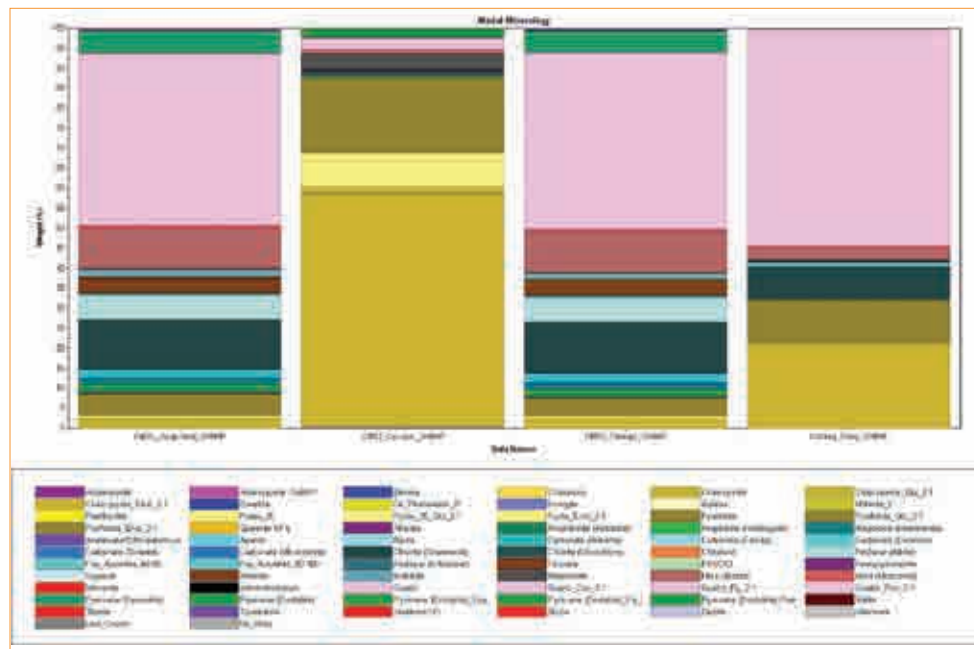
Schematic representation of the modal mineral composition of the samples, related to the area of the particles (top: broken down by mineral type; bottom: broken down by material class).

Visit of Dr. Jana Pinka from G.E.O.S. on the occasion of the last in person project meeting in early March 2020 at the IGSTC office in Gurgaon, India before the corona shutdown.

From left to right of the picture – Deepchandra Joshi (PhD student, IITD), Jana Pinka (GEOS), Anirudh Gupta (Post-doc, IITD) and Partho Mondal (PhD student, IITD).

Contact Details

sree@dbeb.iitd.ac.in
zia@iitd.ac.in
venkatsaravanan.g@lakshmilife.com

k.pollmann@hzdr.de
j.pinka@geosfreiberg.de

Water & Wastewater Technology

CLEANWATER

Modular lightweight wastewater treatment units made with TRC for rural and periurban dwellings

Ravindra Gettu
IIT Madras

Smitha Gopinath
CSIR-Structural Engineering
Research Centre, Chennai

Mohit Raina
Raina Industries
Mumbai

Till Quadflieg
RWTH Aachen University
Aachen

Oliver Hentzschel
Betonwerk Hentzschel GmbH
Elsterwerda

PROJECT BRIEF

Wastewater Treatment (WT) is an essential prerequisite for a healthy society. Still 90% of the worldwide used water enters the environment untreated. Most rural and periurban regions of developing countries have no access to a wastewater treatment plant (WTP), because current mid/big size WTPs require large power supply and space. Currently septic tanks or soak pits are used in many regions that could be replaced with modular and lightweight WT units, which are easy to transport and handle in hard-to-reach locations. The realization of these required systems is possible through the development of high-strength and lightweight materials. By using durable materials, the operating and maintenance costs could be kept as low as possible, which is an important decision criterion concerning the orders. The aim of this project is the realization of an innovative lightweight, modular WTP made with textile reinforced concrete (TRC). The advantage of a modular WTP design lies in a decentralized production facility, whereby all the necessary plant components have to be delivered to the construction site and assembled. Within the project, a design suitable for the innovative material will be developed. Furthermore, the textile reinforcement and concrete matrix will be developed according to the application. These fundamental developments are followed by

designing, dimensioning, numerical simulation using finite element analysis and testing structural components and realization of a demonstrator in form of a complete WTP including proof of bearing capacity and function control on site. In addition, from an economic point of view a suitable production and transportation process, as well as a business case for efficient sale and distribution are developed.

PROGRESS MADE/ACHIEVED

Partner 1: IIT Madras

A concrete matrix has been developed while considering the need for larger aggregate size for TRC, availability of material components in India and the cost of the concrete mixtures. The effect of the addition of different binders and aggregates (e.g., fly ash, ground granulated blast furnace slag, quartz sand, crushed sand etc.) on the mechanical and durability properties of the matrix was studied through material tests. Pristine textiles from ITA were assessed for their

tensile capacities. Uncoated textiles from ITA were coated with SBR (as used at ITA) and epoxy (local product, equivalent to that used at ITA) and assessed for tensile strength, to check the possibility of in-house coating, to avoid the shipping of coated textiles. TRC composites made with the fine-grained matrix and ITA textiles (3 layers) were cast and tested.

Partner 2: CSIR-SERC

Feasibility of the type of textile to be used in TRC WTP, which was received from German partner ITA, has been investigated by conducting uniaxial tensile measurements. Based on the results obtained, an Indian textile equivalent to ITA specifications has been identified towards improving the cost effectiveness of TRC WTP in Indian context for future mass applications. Experimental investigations were carried out to determine the influence of textile layer positing in TRC on the response behaviour, towards finalization of design of TRC WTP. The loading and their combinations to be considered for the design and finite element analysis of TRC WTP has been
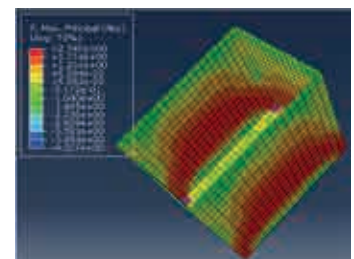

FE model of Cylindrical WTP
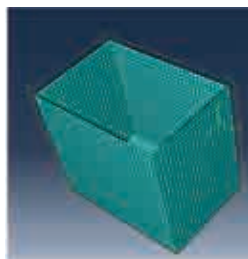
FE model of Rectangular WTP
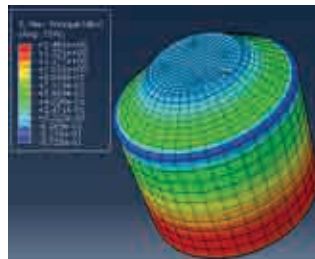
Max Principal Stress in Cylinder- LC4

*Max Principal Stress in Rectangular- LC4*

Load Combination 4 (LC4): Tank full with no earth pressure

Partner 3: Raina Industries

For the development of a transport concept, the limiting factors (including availability, size and maximum load weights) of the means of transport were defined. The maximum dimensions for transportation were derived from the design of the equipment, this includes the lengths as well as the weight dimensions. The necessary requirements for the production process were derived from the limitations of transport and the processing properties of textile concrete. Trials were carried out for placement of textiles and creating small mock curvilinear samples replicating the wall thickness of the STP Plants. Design mix for the manufacturing of the STP Plants was conceived and basic testing carried out to investigate an appropriate design mix from the commercial perspective.

Partner 4: ITA RWTH Aachen

Tensile tests were performed on high- performance fiber materials commonly used as concrete reinforcement. Based on mechanical and economic properties of high-performance fibre materials and resulting textile properties, a preselection has been conducted leading to the elimination of ravings with finesses below 1200 tex and above 4800 tex as well as the elimination of carbon fibres. In accordance with the progress of the development of the concrete matrix, the grid opening of the textile reinforcement was adjusted. Based on this, tensile tests and flexural stiffness tests were carried out with two coating systems (styrene- butadiene-rubber and epoxy resin). A first quantity of textile is sent in coated condition to the Indian partners to perform composite and textile comparative tests. After feedback from the partners, further textile is sent to perform structural component tests.
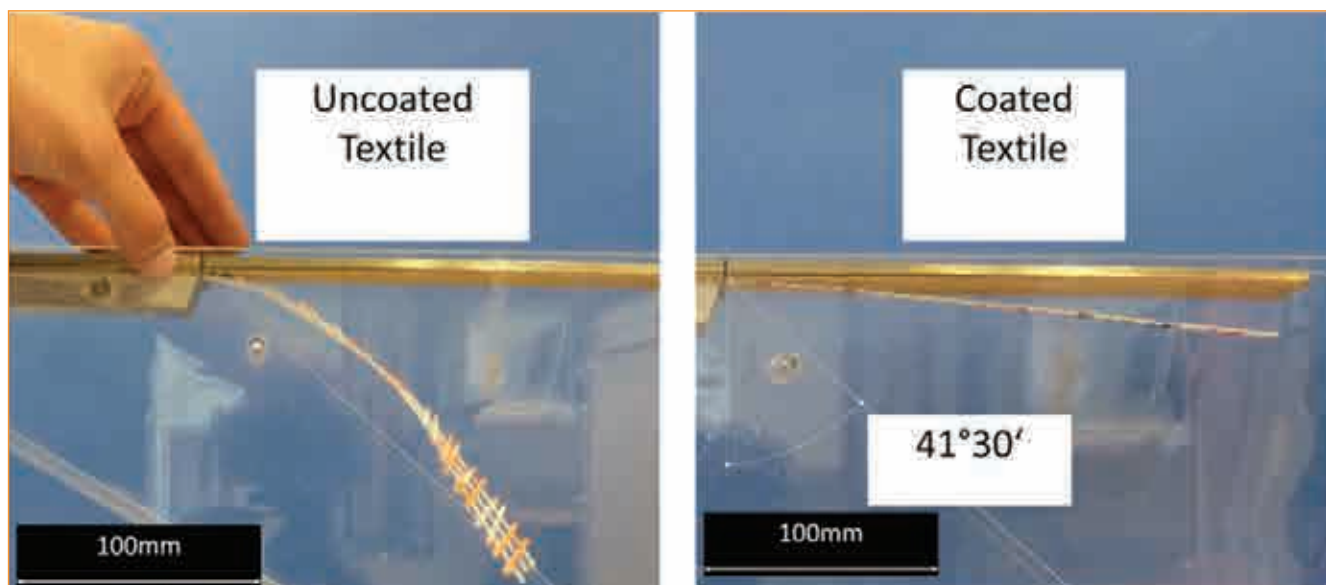
Bending stiffness of coated and uncoated textile

Transportation system in Germany

Contact Details

gettu@iitm.ac.in
smithag@serc.res.in
raina@raina-industries.com

Till.Quadflieg@ita.rwth-aachen.de
oh@hentzschel-beton.de

EFECTROH2O

Effect-based monitoring demonstrates efficiency of electrically-driven water treatment processes to remove salts and micropollutants from process water

Indumathi M Nambi
IIT Madras

Sajid Hussain
Tamilnadu Water Investment Company Limited (TWIC) Chennai

Henner Hollert
Goethe University rankfurt

Viktoria Urban née Schiller
Eurofins Agroscience Services Ecotox GmbH, Niefern-Öschelbronn

PROJECT BRIEF

The project aims at improving the process of water treatment in industries in order to reduce harmful toxicological effects in receiving environments. We seek to recycle process streams and recover resources, and thus improve the techno-economic feasibility of Zero Liquid Discharge plants. One promising technology to address the problems of desalination and dye removal is Capacitive Deionization (CDI). Compared to reverse osmosis, flow CDI can deal with highly concentrated brines and suffers less from organic fouling. Micropollutants, will be removed by a synergetic combination of CDI and Advanced Oxidation Processes. The novel treatment technologies will be scaled-up and piloted in the textile industry. The findings will enable replication and transfer to other key industries. Water quality and treatment efficiency will be monitored by emerging effect-based methods (EBM), which are complementary to chemical target analyses. The advantage of EBM is that they provide a holistic indication of toxicological effects from complex mixtures typical of process waters, which covers unknown oxidation by-products and synergistic effects. A bioassay test battery will be developed and transferred from Germany to India. EfectroH2O targets the United Nations Environment Programme Sustainable Development Goals 6 to "Ensure availability and sustainable management of water and sanitation for all" by contributing to the reduction of water consumption in water scarce regions such as India.

PROGRESS MADE/ACHIEVED

- Initial lab scale fixed CDI trials with synthetic samples that mimic actual wastewater were performed.

- Characterizations of actual wastewater samples were done and SPE cartridges were sent to Germany for further analysis.

- Lab scale studies on FCDI was done with synthetic wastewater and lab scale AOP

studies with electro-peroxone treatment method to treat synthetic waster with dyes doped were also performed.

The initial experiments without membranes resulted in no change in the conductivity values. In the presence of membranes without a power supply, a reduction of around 3 percent of the initial conductivity value was observed during the 20-minute cycling of synthetic wastewater. With the power supply, a reduction of around 69% (from 9.5mS to 3mS) was observed
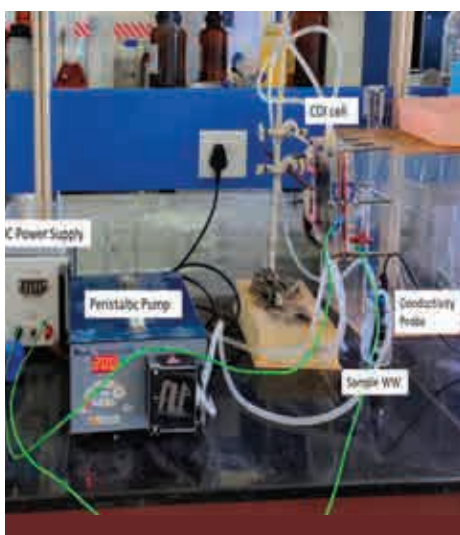
CDI setup with power supply, pump, CDI cell, conductivity probe, and sample wastewater.

Apart from conducting experiments, there has been exchanges with the industrial partner to obtain the real wastewater data, dyes that are in use, and surfactants that are used in the processes of the industries in Tirupur.

In the case of FCDI experiments, around 21% removal was observed with just activated carbon of 15% as a slurry in a CV mode of 1.2V and 100mA current. Further experiments need to be conducted with additive agents to remove the salinity. However, these experiments were extremely energy efficient. In the case of AOP treatment (electro-peroxone) 98% degradation of dyes, 95% reduction in COD, and 30% salinity were observed in constant current mode with 300mAh and 0.5 liters/minute oxygen as input. Further studies will be conducted with several reactive dyes and various electrodes (varying surface area, materials, oxygen flowrate).

Time series of the reduction of target parameters

For future work, further studies to explore the influence of some other novel electrode materials to improve salt removal efficiency in the presence of dye in synthetic wastewater as well as real wastewater.

Contact Details

indunambi@iitm.ac.in
sajidhussain1@twic.co.in

hollert@bio.uni-frankfurt.de
ViktoriaUrban@eurofins.com

DEMO-Multi-WAP

Demonstration of Multi-WAP results leading to novel, validated multiplexed, label-free fiberoptic biosensor array system for waterborne pathogen detection.

V V Raghavendra Sai
IIT Madras, Chennai

V Sandhya Sowjanya
ChemBioSens Pvt Ltd
Chennai

Claus-Peter Klages
TU Braunschweig
Braunschweig

Vitaly Raev
TU Braunschweig
Braunschweig

Mahavir Singh
Lionex GmbH
Braunschweig

PROJECT BRIEF

The aim of DEMO-Multi-WAP is to bring to the market a device and ready-to-use test kits ('plug & play' cartridges) for waterborne pathogens detection. As evidenced by the success of the Multi-WAP project, there is a clear unmet need to move our technology from TRL 4 (current status) to TRL 6-7 at the end of DEMO-Multi-WAP project. The platform is a multiplexed, rapid, label-free, and real-time method for continuous monitoring multiple waterborne pathogens present in water samples at low cost and high sensitivity (>90%). The team expects that they will be able to realize this by building upon a highly sensitive array sensor system concept which has been validated for different biomarkers. The array sensor system and the U-bent fiber optic probes (IITM and CBS) are inherently compatible with low-cost interrogation and will be supplemented with further cost- and volume-reducing developments which have already been shown in a lab-context. Apart from relying on existing antibodies at LIONEX, the team will further investigate and produce stable biofunctionalized plasma-treated and silanized fibers (IOT and LIONEX) to further boost the performance testing (All partners). A commercial product is the clear end focus of the partners, given that the consortium is made up entirely of SME, startups in incubation, research organizations.

Thus, both disposable sensors cartridges and the optoelectronic device are directly linked to the Multi-WAP project and shall be an excellent demonstration of IGSTC 2+2 program project "Multi-WAP".

In the process of realizing a reliable and affordable technology for multiplexed waterborne pathogen detection, IIT Madras has successfully realized some of the milestones towards large-scale

fabrication of the U-bent probes, currently up to 200 probes/day. A paper cartridge is developed to hold the probes firmly. The batch processes for decladding of the fibers using HF based etching, quality control and surface functionalization are established. ChemBioSens Pvt Ltd. has initiated work on market assessment for the proposed problem of multiplexed pathogen detection system. A thorough literature survey for the global waterborne pathogen burden, WHO recommendations for pathogen levels in drinking water, and the state-of-the-art techniques for pathogen detection and their limitations was carried out. The team anticipated that municipal water treatment plants, beverage industry and effluent water treatment plants have been considered as potential sectors that can benefit from this technology. As of now, work on verification and identification of the potential customer base for this technology is in progress. At IOT the new reactor design was developed for simultaneous plasma-treatment and silanization of 8 U-bent probes, mounted into a cartridge, and a model was built. Work on a discharge uniformity and thermal stability of a reactor are in progress. The principal ability to use low-cost simple HV-generator was approved. Work on the safety unit development and process parameters optimization are in progress. In this period of report at LIONEX, a first a Failure Mode and Effects Analysis (FMEA) and Risk Analysis first drafts were prepared according to DIN EN ISO 14971 and will be finalized after the detailed system and interface specifications released. Product Development Process (PDP) first Draft is prepared defining objectives and responsibilities. Design of labelling/instruction of use progressing well. LIONEX working intensively on selecting further batches of the final arrays' biomarkers. Further batches of quality-controlled anti-LAM, anti-E. coli, anti-FimH and anti-fliC antibodies were produced. The optimization of antibodies immobilization done at LIONEX in the label free protocol on octet platform using different buffers and concentration. The kick-off meeting of partners involved in the 2+2 project "DEMO-Multi-WAP" was organized by LIONEX and held virtually. Apart from the virtual meetings mentioned above, there is intense communication between the different partners working on the project. This takes the form of frequent email communication as well as direct calls to discuss specific issues.

PROGRESS MADE/ACHIEVED

Partner 1: IIT Madras:

Towards Objective 1.1 - the large-scale fabrication of U-bents probes using silica optical fibers (M1-M6), on IIT Madras has realized fabrication of about 200 probes/day. The batch processes for decladding of the fibers, quality control and surface functionalization are established. With a new bending machine set-up under development, the team hope to reach the target of fabrication of 400 to 500 probes per day in the next two months. Due to COVID-19 related limitations, they are delayed in realizing this task by two months.

The work for "Objective 1.2 Array sensor system – Fabrication & assembly process establishment, evaluation and validation (M7-M21)" has already started. A paper cartridge for a U-bent probe for easy handling is developed. Processes for quality monitoring and control are being established.

Partner 2: ChemBioSens Pvt Ltd (CBS):

As part of the Objective 4.1: To gain enhanced understanding of the market and end user needs, and of limitations of current technologies, ChemBioSens has worked on gathering the information on the potential industrial and government sectors that may require pathogen monitoring. The preliminary report on Market assessment is ready. CBS has also enrolled for INCUBATE program run by Gopalakrishnan- Deshpande Centre (GDC) at IIT Madras for a detailed Market assessment including customer discovery and other potential areas for the technology under development. A detailed report on Market Assessment due by month 21, will be partly made ready by August 2021 to help swiftly realize the technical specifications, realization and demonstration of the technology.

Partner 3: Institut für Oberflächentechnik (IOT), Technische Universität Braunschweig

OB2.1: Design and construction of two types of up-scaled reactors for DBD-based plasma pretreatment and vapor-phase silanization.

Design of the reactor for simultaneous plasma-treatment and silanization of 8 U-bent probes, mounted into a cartridge, was developed and a model from borosilicate glass was built. Work on a discharge uniformity and thermal stability of a reactor are in progress. As the next approach the team is designing a reactor with separated plasma zone and silanization zone. For a plasma treatment it is necessary to build a discharge zone of quartz or ceramic (SiO2 or Al2O3-based) which are insulators and stable in water-containing plasma. This zone can be not thermostated and a treatment can be provided at ambient temperature. The silanization zone, from another side, can be built of metal (Al) with good thermal conductivity to provide stable silanization conditions. Silanization zone can

be made removable to provide periodical cleaning from deposited APTMS oligomers. On models of a reactor for simultaneous treatment of 32 sensors arranged in a 2D matrix consisting of 4 lines with 8 sensors each.

WP-related milestones: MS3: Plasma treatment with adapted low-power high-voltage generator

Milestone 3 is achieved. Plasma treatment with extremely cheap HV generator is possible in general. Work on treatment stability and treatment conditions optimization are in progress. Work on electrical modification of the ozone generators to provide necessary safety units – both for user safety and for overload/short-circuit – is in progress.
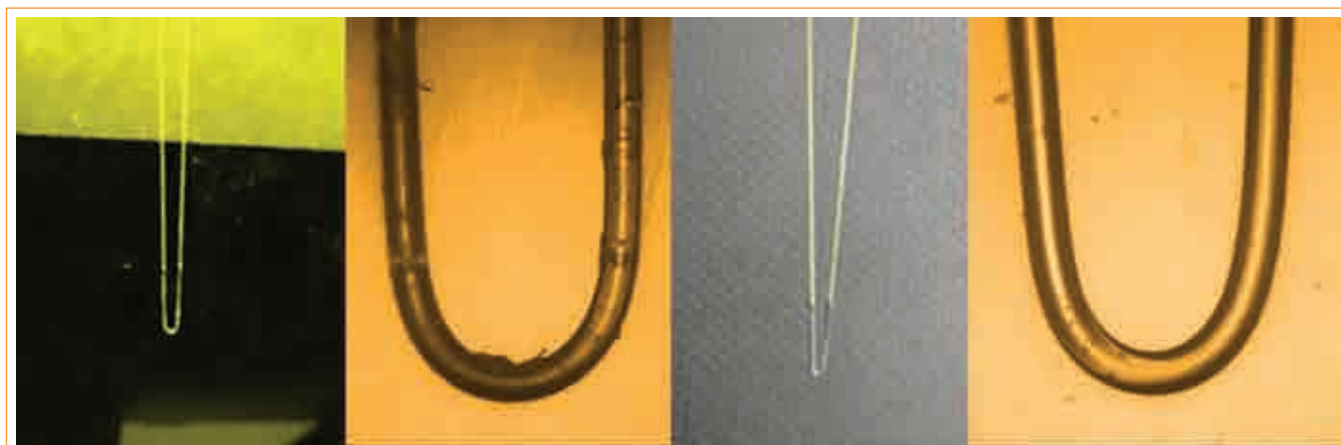
Probe quality control - Photographic and microscopic images of probes with and without a precipitate over the decladded surface of the U-bent region, showing the probes without any remanescentes of silica cladding during 96 PCR tube plate based decladding with fresh HF

Partner 4: LIONEX

WP3: PDP and Performance evaluation

One of the final goals for WP3 planning and specifying/placing the regulatory requirements. Based on the data which will be determined through WP4 by the market observation, a diagnostic evaluation should be made. In addition, the development inputs should consider legal requirements (guidelines) and regulatory requirements (e.g. standards), which result from the targeted markets. Testing is limited

to laboratories certified under the Clinical Laboratory Improvement Amendments, to perform moderate and high complexity tests. The development is particularly emphasized here and in Development Input Performance Specification (Pflichtenheft), especially the validation studies.

A draft file summarizing Development Input Tender Specification was prepared and will be finalized after the detailed system and interface specifications released through WP1.
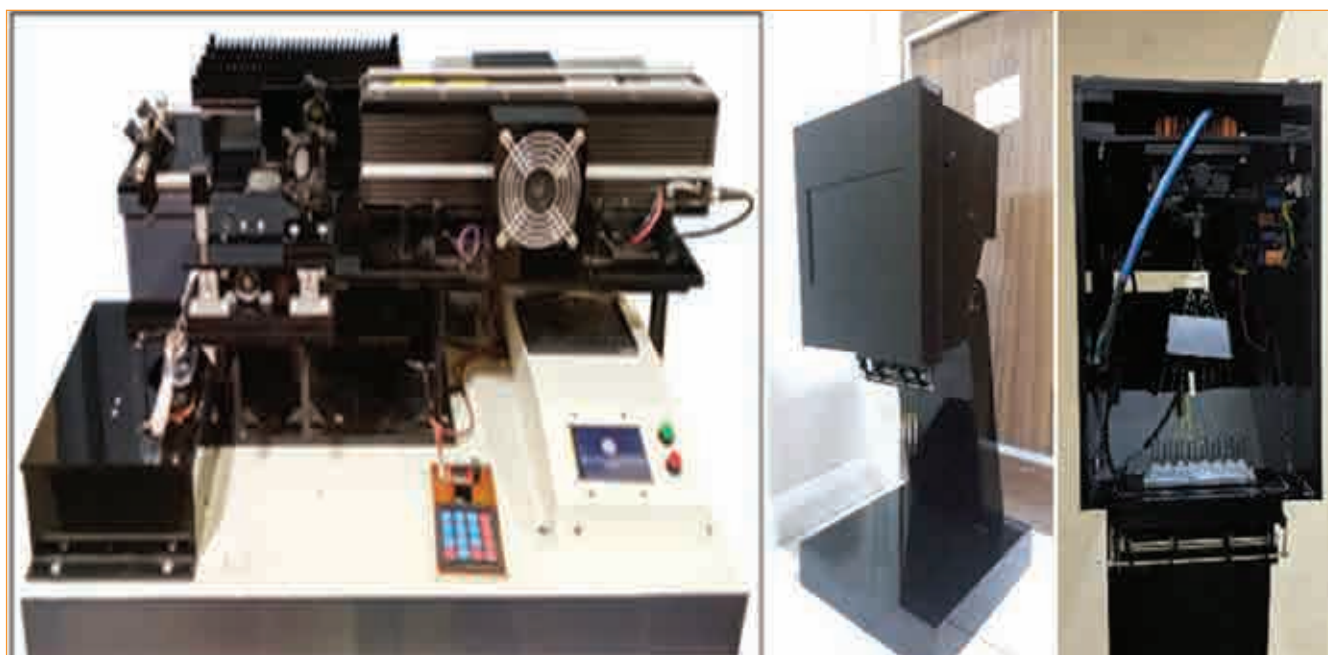
3rd Generation CO2 Laser based fiber bending machine for automated U-bent probe fabrication (left); Fiberoptic array sensor working model for multiplexed detection of pathogens with a provision for on-board computer (right) developed during the phase 1 of Multi-WAP project.

SALIENT RESEARCH ACHIEVEMENTS

- A transfer of technology from IIT Madras to M/s Ricovr Healthcare Inc., USA, a US based start-up for a large-scale fabrication of U-bent silica fiber optic probes is in the planning stage. It may be noted that they took license of the IP generated as part of MultiWAP phase-I project. At least two of these patents filed by IIT Madras was supported by IGSTC. Ricovr Inc hopes to realize up to 10,00,000 probes per month. These probes will be used by Ricovr Inc to develop oral diagnostic devices.

- Design of the reactor for simultaneous plasma-treatment and silanization of 8 U-bent probes, mounted into a cartridge, was developed and a model was built.

- Work on a discharge uniformity and thermal stability of a reactor are in progress.

- The principal ability to use low-cost simple HV-generator was approved. Work on the safety unit development and process parameters optimization are in progress.

- According to DIN EN ISO 14971 a Failure Mode and Effects Analysis (FMEA) and Risk Analysis first drafts were prepared and will be finalized after the detailed system and interface specifications released through WP1.

- PDP- first Draft is prepared defining objectives and responsibilities.

- LIONEX working intensively on selecting further batches of the final arrays' biomarkers. Further batches of quality-controlled anti-LAM, anti-E. coli, anti-FimH and anti-fliC antibodies were produced.

- The optimization of antibodies immobilization done at LIONEX in the label free protocol on octet platform using different buffers and concentration.

PUBLICATIONS

01

Plasmonic biosensors for bacterial endotoxin detection on biomimetic C-18 supported fiber optic probes; Hariharan Manoharan, Prasanta Kalita, Shalini Gupta, V.V.R. Sai; Biosensors and Bioelectronics, Volume 129, 2019, pp 79- 86.

02

Graphene oxide coated U-bent plastic optical fiber based chemical sensor for organic solvents. Divagar, M., Gowri, A., John, S., & Sai, V. V. R.;Sensors and Actuators B: Chemical, 2018, 262, 1006-1012.

03

Fiber optic sensor for continuous liquid level monitoring; Allwyn S Rajamani, Divagar M, V V R Sai; Sensors & Actuators A Physical, 2019

04

Controlled In Situ Seed- Mediated Growth of Gold and Silver Nanoparticles on an Optical Fiber Platform for Plasmonic Sensing Applications, H Manoharan, KC Dharanibalaji, VVR Sai - Plasmonics, 2019

05

Plasmonic biosensors for bacterial endotoxin detection on biomimetic C-18 supported fiber optic probes, H Manoharan, P Kalita, S Gupta, VVR Sai – Biosensors and Bioelectronics, 2019

Contact Details

vvrsai@iitm.ac.in
chembiosensindia@gmail.com

c-p.klages@tu-braunschweig.de
info@lionex.de

CANDECT

Cluster-composite nanofibre membranes for rapid, ultra-trace detection of waterborne contaminants

Thalappil Pradeep
IIT Madras, Chennai

Amrita Chaudhary
Inno Nano Research Pvt Ltd
Chennai

Andrea Iris Schäfer
KIT, Karlsruhe

Hansjörg Fader
Fader Umwelttechnik (FAD)
Karlsruhe

PROJECT BRIEF

Elevated arsenic (As) concentrations in water are faced by about 200 million people worldwide and has become one of the biggest challenges in the context of water purification. Long-term exposure to arsenic from drinking-water and food can cause cancer and skin lesions. Contamination of drinking water by As is one of the major concerns for India as well as Germany. Prevention of further exposure to arsenic by the provision of safe water supply for drinking, food preparation and irrigation of crops to the affected communities is important. Monitoring of As contaminated water is an important aspect in implementation of arsenic removal technologies in the affected areas. The development of suitable sensor technologies using advanced materials that can be integrated to hand-operated pumps or decentralised water supplies is the subject of this proposal. Consortium of IITM, INR, KIT and FAD are working towards a solution in the form of affordable technology which can be implemented in the form of luminescence based arsenic sensor system with atomically precise quantum nanoclusters.

Nano clusters consist of a well-defined metal core which is protected by ligand shells such as thiols, phosphines, etc. Some of the metal nano clusters [like gold (Au), silver (Ag) and so on] are known to be luminescent in nature. But their applicability in the field of sensors is often limited due to their instability in various conditions. In this project, atomically precise clusters with specific interactions with inorganic and organic contaminants developed by IIT Madras will be incorporated in electrospun fibres for the detection of heavy metal ions in water at

ultra-trace levels and porous substrates. This technology can be developed further into a sensor device for arsenic in drinking water. After numerous trial and error attempts with many cluster systems, a system of Lipoic acid (LA) protected Ag clusters used with Tris(2-carboxyethyl) phosphine (TCEP) has been demonstrated for sensing arsenic at sub ppm concentrations and the team is working on further improvement in the sensor performance. The current stage of work involves study of the interfering ions (various cations and anions) present in field water which can affect the sensor performance and to devise an effective methodology for their elimination.

INR has evaluated the available designs for luminescence based sensing using mobile attachment and the necessary approach for its implementation in the present project has been identified. INR has developed a backbone of the device for smartphone based readout for a proposed fiber mat sensor which can be used for the measurement of arsenic in contaminated water. Apart from that, water samples from various sites in West Bengal, India were collected and analyzed using ICPMS to know the current level of arsenic contamination.

PROGRESS MADE/ACHIEVED

Partner 1 – IIT Madras

1. Studies have shown that response of Ag29@DPPP to As(III) in water was inconsistent due to solubility issues. Hence repeatability could not be achieved. Incorporation of new phosphine ligands in Ag29 clusters was found to be degrading clusters. Hence efforts towards new cluster system development were started. A system of Ag29(L)12 – TCEP was developed which can be used for sensing As(III) in water as lipoic acid protected clusters are water soluble. Linear response to As(III) in sub ppm regime was observed and it was repeatable. Ag29(L)12 – TCEP system also showed response to As(V). Consistency in the results was tested using fluorescence spectroscopy and visual verifications (by exposing samples to UV light).

2. Interference from various anions and cations that are likely to be present in groundwater was studied.Development of suitable methodology to eliminate interfering ions in the sensing medium is under progress. NMR spectroscopy and fluorescence lifetime measurements have been performed to understand the sensing mechanism. Synthesis of other water soluble clusters with better properties such as higher luminescence and better stability are in progress for improvements in the developed As sensor.

3. Sensor performance to be tested with field water samples from As-affected places. As solid phase (strip-based) sensors are cost effective, easy to use and to integrate with an electronic monitoring device, Ag29(L)12 – TCEP sensor system which has been developed in the solution phase, its translation in the solid phase for sensing As is in progress.

4. For solid state sensing, the cluster immobilized electrospun fiber mats have been developed which are luminescent in nature. Arsenic sensing experiments with the luminescent mats are in progress. IIT has sent solidified luminescent Ag29 cluster samples to KIT for further development of solid phase sensor, in view of suitable sensor unit and methodology. The processes and other details developed so far have been communicated. Production of next batch of materials to be sent to KIT is in progress. Development of a device that can be connected to smartphone, to be used for trials of solution phase sensing of As samples.
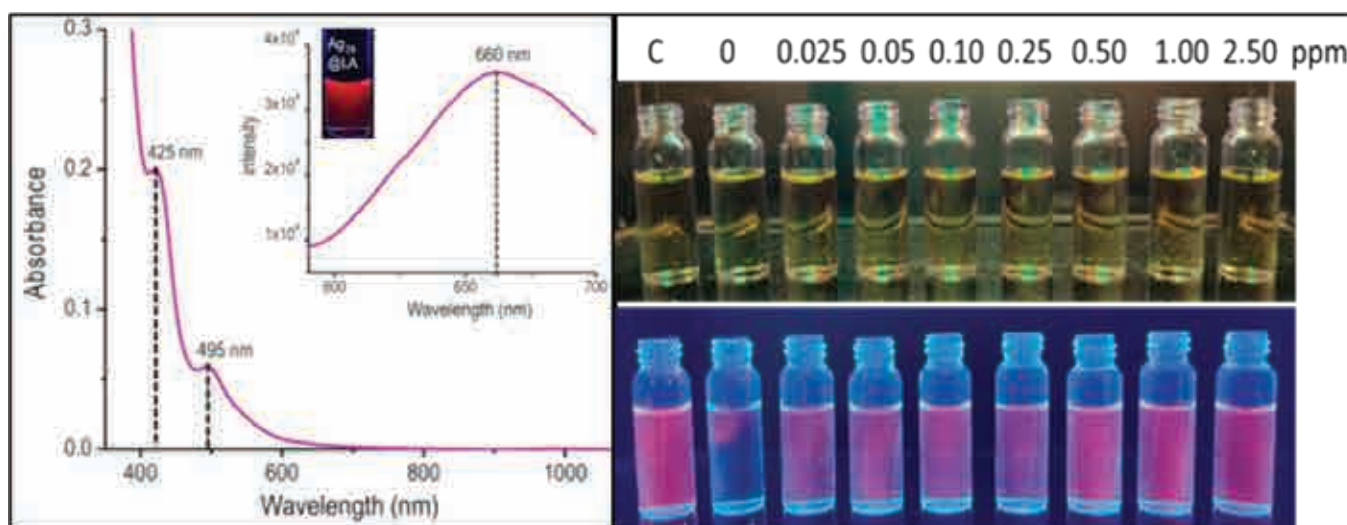
The UV–Vis spectrum of Ag29(L)12 with maximum at 425 nm and inset shows optical image under UV light and emission at 660 nm. Optical image of Ag29(L)12–TCEP system to As(III/V) at ppb level concentrations under visible and UV light.

Partner 2 –Inno Nano Research

Designs available for luminescence based sensing and readout using mobile attachment were evaluated and approach necessary for the implementation in present project was identified. Various electronic hardware components necessary for the building of mobile attachment were identified. Exact LED excitation source and filters necessary for the attachment will be dependent on the luminescent cluster-nanofiber composite; so final design and integration of components will be decided after completion of the work on sensing element. Design for sensor holder was made. Prototype was 3D printed. Various components for filter based excitation and readout methodology were integrated with smartphone. An android app was developed for sensor readout using smartphone camera.

Water samples from various sites in West Bengal India were collected and analyzed using ICPMS to detect Arsenic contamination. Water samples from various sites in Nalgonda District, Telangana, India were collected and analyzed using Fluoride ion selective electrode to detect Fluoride contamination. Water samples from various sites in Nallampatti, Erode, India were collected and analyzed using GC-MS to detect Pesticide contamination. Water samples from various locations (river) were collected and analyzed using ICPMS to detect Chromium contamination.
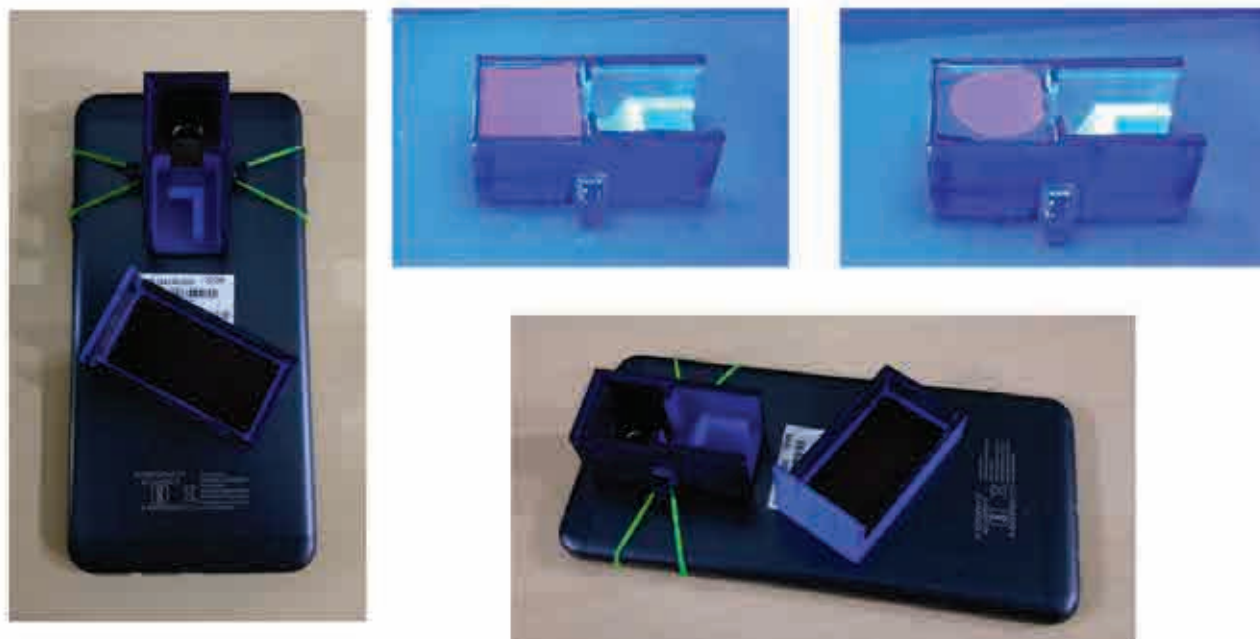
Design of the sensor holder developed by INR.

Partner 3 -- KIT Karlsruhe

1. Experiments to improve the sensor response using different electrospun matrices is taking place at IAMT (KIT). However, the extensive development of cluster chemistry at IIT Madras is being the limiting factor for the optimization of the methodology and has caused delays in the delivery of results. To date not sufficient materials are available to develop methods at KIT (total supplies 120 mg).

2. Research has focused on the development of another relevant aspect, the detection of As (III) and As (V) using inductively coupled plasma mass spectrometry (ICP-MS) in the presence of other pollutants, including salts and organic waste, which constitutes a challenge. The analytical method using an instrument funded in this project has been developed to address this problem and is now fully functional and used in research for As removal.

3. Extensive work has been carried out on the validation of the coupling of the field flow fractionation (FFF) with ICP-MS. With this methodology the detection of As in organic matter is now possible and interactions can be identified. The sensitivity calibration of FFF will allow analysis of real organic samples with traces of As.

4. Substantial alternative work has been carried out on the removal of As (V) and As (III) by nanofiltration with variable salt concentration and organic matter. A publication "Removal of arsenic(V) by nanofiltration: Impact of water salinity, pH and organic matter" was published in the Journal of Membrane Science and second publication "Removal of arsenic(III) via nanofiltration: contribution of organic matter interactions" was submitted to Water Research (major revisions are being processes right now). A third publication investigation ultrafiltration is in preparation. These methodologies will allow the

characterization of sensor mats in real conditions (in the presence of organic matter).

5. Overall, the year has been extremely productive at KIT-IAMT and the completion of the project requires a sufficient amount of materials from IIT such that suitable luminescence materials can be set up and the tests intended for KIT-IAMT and FAD become possible. An extension of the project towards sensing of other contaminants (as originally proposed) and alternative As

removal technologies would be a very logical next step to contribute solving the global challenge of dissolved contaminants.

Partner 4 - Fader Umwelttechnik (FAD)

Fader has been most helpful in identifying and delivering real water samples to KIT which are being investigated in removal investigations. The limiting materials from IIT Chennai are currently making the planned investigations impossible.
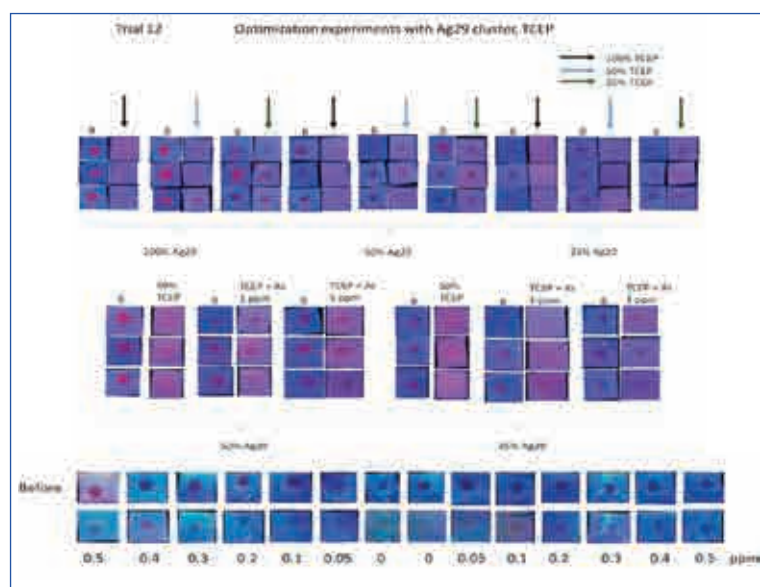
Optimization experiments for the solid state arsenic sensing with the cluster immobilized electrospun fiber mats produced by ESPIN Nano Model- V2 at IIT Madras

Contact Details

pradeep@iitm.ac.in
camritam@gmail.com

Andrea.Iris.Schaefer@kit.edu
info@fader.de

Advanced Manufacturing

PPAM

Metal powder production for additive manufacturing

Saptarshi Basu
IISc Bangalore

Suman Chakraborty
IIT Kharagpur

Suvankar Ganguly
Tata Steel Ltd.
Jamshedpur

Cameron Tropea
TU Darmstadt

Hans-Jürgen Odenthal
SMS group GmbH

PROJECT BRIEF

For manufacturing of objects using laser powder bed fusion (LPBF), a fine metal powder is solidified in layers using a focused laser beam. The properties of the product depend strongly on the uniformity of size and consistency of the powder particles. This project addresses the production of steel powder for LPBF using close-coupled atomization and strives to better understand and model the process to achieve a uniform size and porosity of the powder particles. Generic experiments, numerical simulations and pilot plant operations are used in combination to develop validated, predictive capabilities and design guidelines for full-scale facilities. Scientifically, the challenge lies in modelling the complex liquid metal atomization involving extreme process conditions and material properties. The results will be of immediate competitive benefit to the collaborating companies, one as a manufacturer of such powder production facilities and one as an end-user. Improved quality, lower cost and an expanded product design parameter space can be expected.

The main objectives of the research include

- Improved understanding of atomization nozzle design and operating parameter influence on particle size distribution and powder properties.

- Development of validated, physics-based semi-empirical models allowing predictive-numerical simulations of the deformation, atomization and solidification stages for powder production. Increase TRL of predictive capabilities from 2 to 6.
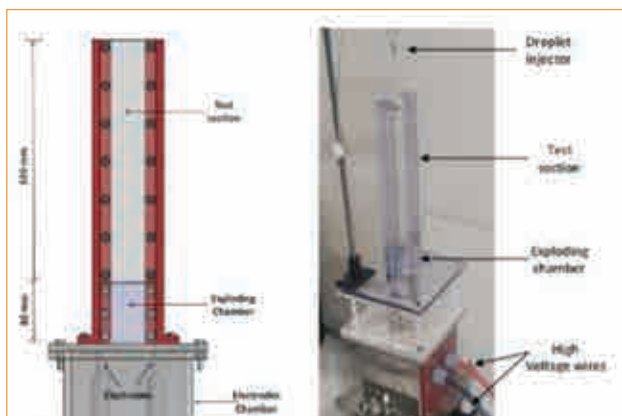
- Realization of improved nozzle designs and operation in production facilities.

- Realization of narrow powder size distribution with close-coupled atomization.

- Characterization of improved mechanical properties of laser powder bed fusion manufactured components with powder of decreased polydispersity.

- Achievement of lower powder production costs.

PROGRESS MADE/ACHIEVED

Partner 1: IISc

During the reporting period, academic partner IISc has made contributions to the work packages 3 (Adaptation/Development of shock-tube facility), and 5 (Atomization model development).

The shock tube setup and supersonic flow wind tunnel have been fabricated for carrying out shock droplet interaction experiments. In the shock tube setup, an exploding wire technique is used to create a shock wave. In this technique, a high impulse current is passed through a copper wire, resulting in a rapid Joule heating. The heat produced causes melting and vaporization of the copper wire. The whole process of melting and vaporization has a duration in the scale of microseconds and results in a formation of a dense column of metal vapour. Expansion of this metal vapour results in a generation of a cylindrical shock wave. This cylindrical shock wave is constrained into a two-dimensional rectangular channel, which transforms a cylindrical blast wave into a plane shock wave.

Partner 2: IIT Kharagpur

During the reporting period IIT Kharagpur has made contributions to the work package 4 (numerical simulation of shock-droplet interaction and its perspective in close-coupled atomization)

and work package 9 (Validation of numerical simulations and atomization model).

WP9: Validation of numerical simulations and atomization model Compressible gas dynamics within the atomizer

With an aim to validate the numerical model of the gas dynamics within the atomizer, the flow of air (assumed to be an ideal compressible gas) inside the close-coupled atomization chamber is investigated. The pressure at the inlet to the air flow was maintained at a constant value for a particular simulation, the value itself being varied in the range 500 kPa to 2000 kPa. The pressure at the outlet of the atomization chamber was set at ambient value (100 kPa). The initial state inside the atomization chamber was also set at 100 kPa.

Two sets of simulations have been performed up to now: (a) three-dimensional simulations of the atomizer without the metal nozzle attached and (b) two-dimensional simulations of the atomizer assembly. Now, two-dimensional axisymmetric simulations are being performed for further understanding the effect of reducing the number of dimensions on the final flow field. Apart from the flow of air, the flow of argon gas has also been studied to find the effect of changing fluid properties on the flow field.

Shock tube facility at IISc Bangalore
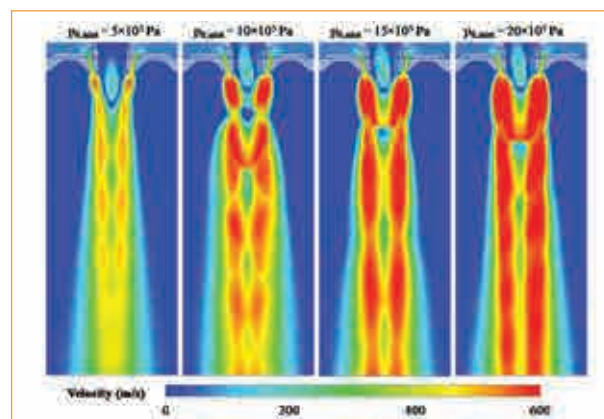
Velocity filed in the atomizer for different values of the inlet pressure.

Partner 3: Tata Steel

During the reporting period Tata Steel has made contributions to the work packages 10 and 11. (Development of test procedures and powder properties for quality assurance including benchmarks configurations)

WP10: Specification and assessment of powder properties

Test strategies that will be applied to the finished metal powder are shown in Figure below. The powder produced under this project will be examined for its dynamic properties (stability, flow energy, aeration ratio, and flow rate sensitivity), shear properties (cohesion, compression strength), and bulk properties (bulk density, compressibility, and permeability). After this, an ASTM standard dog bone specimen will be fabricated from this powder. These specimens will be further used for mechanical testing (Uni-axial tension and DIC).
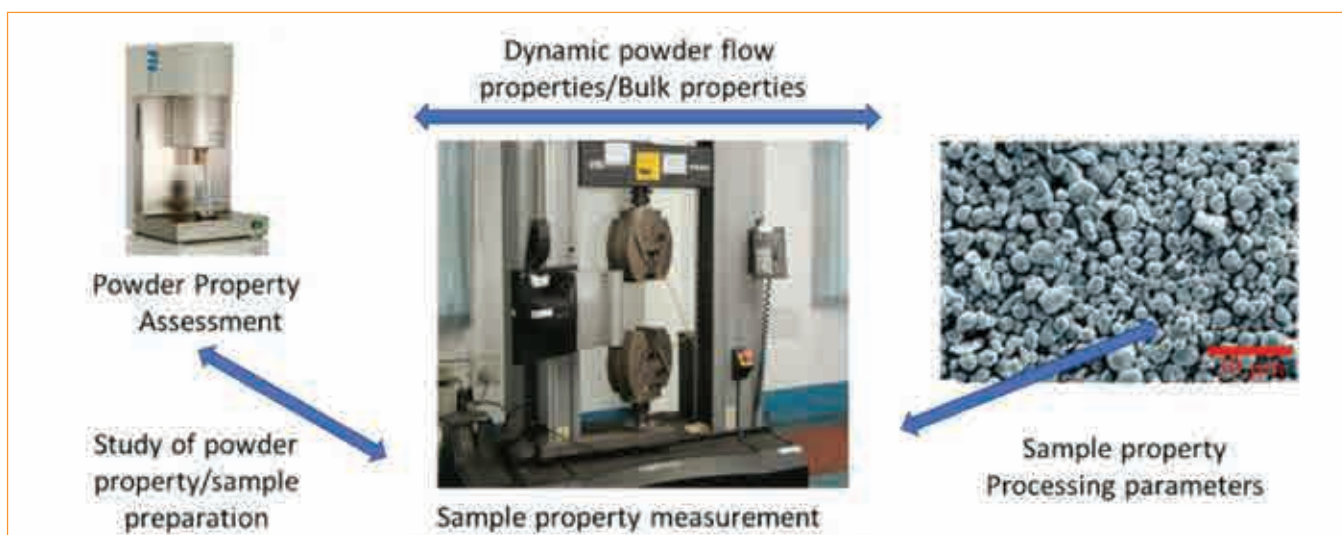
Representation of metal powder assessment and test strategies

Partner 4: TUDa

During the reporting period TUDa has made contributions to the work packages 1 (Dimensional analysis for research facility), 2 (Experiments in research facility), 5 (Atomization model development), 7 (Results comparison: Research facility and pilot plant), and 9 (Validation of numerical simulations and atomization model).

While during the previous reporting period an experimental study of the process characteristics of the close-coupled atomizer setup had been conducted, during the present reporting period, a strong focus has been put on investigating the atomization result by performing and evaluating phase Doppler measurements of local particle size and velocity distributions within the spray. Due to the extreme process conditions, i.e., small time and length scales, this has been found to be a particularly difficult task. Consequently, great care has been taken in setting up an optical configuration suitable for the task. Furthermore, after identifying several inaccuracies in the commercially available laser and phase Doppler software, an entire software package for evaluating the data has been developed in Mathworks MATLAB. As a result, accurate phase Doppler measurements have been shown to be feasible in the entire operational range of the atomizer.

Partner 5: SMS Group

During the reporting period SMS group has contributed to work packages 1 (Dimensional analysis for research facility), 5 (Atomization model development), 6 (Implementation of atomizer model in code), 8 (Measurement of powder properties for validation), 9 (Validation of numerical simulations and atomization model) and 11(Experimental additive manufacturing: Sample property measurements).

WP5: Atomization model development

During the last year, different strategies to model the atomization process and to improve the stability of the OpenFOAM solver have been considered. The numerical model developed so far is an Euler-Euler-Lagrangian model consisting of two sub-models. The model consists of an Euler- Euler approach coupling the liquid and gaseous phase and a Lagrangian approach, which calculates the droplet diameter distribution in a post-processing manner.
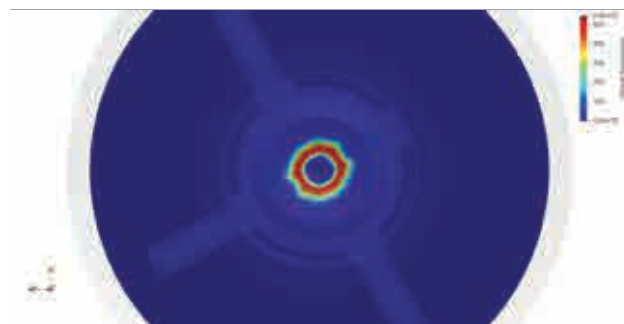
Euler-Euler simulation of TUDa experiment no. 85, full 3D model, velocity distribution in horizontal cut-plane 26 mm below the nozzle.

SALIENT RESEARCH ACHIEVEMENTS

In the shock droplet interaction experiments, following objectives have been achieved:

- Design, fabrication, installation, and testing of shock tube setup is completed.

- Experimental data pertaining to shock-droplet interaction with water droplet is obtained and is being analysed.

- Design, fabrication, and installation of supersonic flow wind tunnel setup is completed.

In metal powder property assessment and its strength testing, following objectives have been achieved:

- The particle size distribution, surface morphology and composition of metal powder supplied by SMS group has been completed and validated with provided data.

- Tensile test results done at TATA steel matches fairly well with the results of SMS group.

In the laboratory facility, the following achievements have been made:

- The phase Doppler particle analyzer has been set up for measuring particularly small particles exposed to a supersonic flow.

- Particle size and velocity measurements have been successfully performed for varying set points of operation.

- A comprehensive software package has been developed and implemented, which is capable of analyzing and statistically assessing phase Doppler data.

- The influence of the fluid mass flow rates on the atomization result has been investigated and documented.

PUBLICATIONS

Sharma, S.; Singh A. P.; Basu S.: On the dynamics of vortex-droplet co-axial interaction: insights into droplet and vortex dynamics, Journal of Fluid Mechanics, 2021

PH.D. / MASTER THESIS SUPERVISED

Apell, N. (2019): Experimental Investigation of the Influence of Mass Flow Ratio in Close-Coupled Atomization on Droplet Size Distribution. Master thesis. Technische Universität Darmstadt, Darmstadt, Germany. Institute for Fluid Mechanics and Aerodynamics.

Wilkens, Y. (2019). Investigation of metal powder properties in powder bed based additive manufacturing and their influence on process and part properties (German language). Master Thesis RWTH Aachen University, Institut für Eisenhüttenkunde, Lehrstuhl für Werkstofftechnik der Metalle.

Schrimpl, T. (2021): Experimental Investigation of the Close-coupled Atomization Using the Phase Doppler Measurement Technique. Bachelor thesis. Technische Universität Darmstadt, Darmstadt, Germany. Institute for Fluid Mechanics and Aerodynamics. (ongoing)

Contact Details

sbasu@iisc.ac.in
suman@mech.iitkgp.ernet.in
suvankarganguly@tatasteel.com

ctropea@sla.tu-darmstadt.de
hans-juergen.odenthal@sms-group.com

TransLearn

Robot skill transfer from simulation to real world deployment in manufacturing industries and warehouses

Laxmidhar Behera
IIT Kanpur

Swagat Kumar
Tata Consultancy Services (TCS)
New Delhi

Torsten Kroger
KIT Karlsruhe

Rainer Bischoff
Kuka Deutschland GmbH
Augsburg

PROJECT BRIEF

Industry 4.0 will be driven by two basic technologies: AI and Robotics – and especially the combination of both – allowing robots to learn skills and tasks without explicitly programming them. Learning and optimizing complex and interactive robot manipulative skills through reinforcement learning algorithms is a multifaceted challenge and an unsolved problem. With the goals of (i) significantly reducing robot programming costs and (ii) reducing robot cycle times, the project plans to develop reinforcement learning algorithms running in massively parallelized, cloud-based physics engines. This system learns and optimizes task-specific robot and machine skills that can be transferred to and deployed on physical robots. Project plans to develop concrete demonstrations of novel solutions for real use cases stemming from the manufacturing industry and warehouse automation. The solutions will rely on robot learning in a cloud-based simulation environment as well as optimization during real-world execution.

PROGRESS MADE/ACHIEVED

The consortium made significant progress in developing methods for learning safe robot motions. Fast robot movements are essential for industrial manufacturing processes to enable short cycle times and thus high throughput. Despite the fast motions, learning procedures must ensure that neither the robot nor its environment is getting damaged while exploring the environment. For this purpose, a method that prevents kinematic joint limits from being exceeded during the exploration process was developed. The method will be presented at this year's IEEE International Conference on Robotics and Automation (ICRA). In addition, a technique to prevent collisions and violations of dynamic joint limits was developed. The source code for both methods has been made publicly available. Furthermore, the consortium developed a method that enabled successful sim2real transfer for a peg-in-hole task even without randomization of the simulation environment. The method combines the Operational Space Control Framework (OSC) with a neural network that can be trained in a simulation environment due to accurate system identification. The approach was presented at the IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS) in October 2020. In addition, the consortium developed a new technique for learning 6-D grasps, which can leverage both image data and tabular data to predict grasping probabilities by using a hybrid neural network. With regard to the imitation learning, the consortium developed a new approach to enable learning of complex tasks. A high-level module segments the sequence of primitive actions from human demonstrations, while a low-level module executes these primitives on a real robot. By combining a Convolutional Neural Network (CNN) and a Recurrent Neural Network (RNN) with Connectionist Temporal Classification (CTC) loss, the sequence of task primitives could be efficiently segmented from given video demonstrations.

Partner IITK

Deliverable 4: Multi-robot coordination with shared models

In this work, IITK has addressed the problem of optimal routing and relative motion control in a network of robots. The path planning scheme has been designed using an artificial potential function employing optimal routing parameters. The optimal routing variables, such as routing probability and the transmission rate are obtained using a discrete optimization problem. To deal with the disturbances and uncertainties in the physical system, an adaptive second order sliding mode control (SOSMC) scheme has been proposed for the relative motion control of the networks of robots, where the disturbances are estimated using a novel disturbance observer and the controller parameters are updated online using an adaptive tuning algorithm derived based on Lyapunov's theory. The robustness of the proposed path planner and the control scheme are validated through simulation as well as through real-time experimentation based on Pioneer P3-DX robots. The extension of this work will consider static/dynamic obstacles in the environment.

Partner TCS

Deliverable 5: RL based algorithms for hand-eye coordination and visual servoing

TCS has designed a framework for feature agnostic visual servoing in an eye-in-hand configuration. The method uses the raw camera images to estimate joint velocities of a robot in a reinforcement learning (RL) setting. We have proposed a new method for faster training of the RL model. As a result, we could significantly reduce the training time required to learn a robotic reaching task using raw RGB monocular images. The algorithm is trained in simulation; however, the resulting policy can be directly transferred to a real robot.

Deliverable 7: Learning from human demonstration on a real/physical system and experience-based optimization of applications
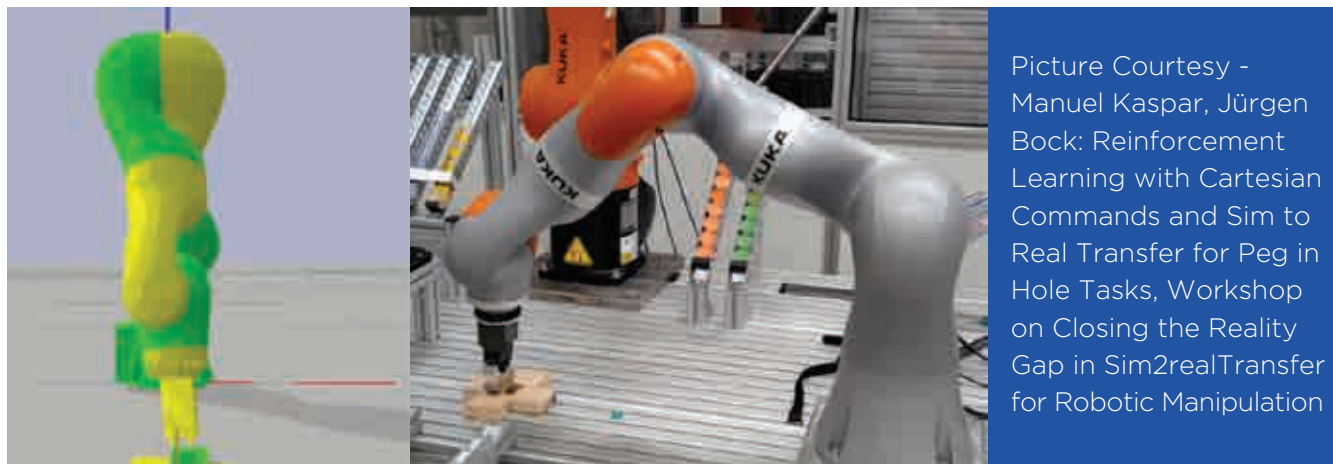
TCS has proposed a task stitching methodology for combining subtasks to generate a complex task from human video demonstration.

Partner KIT

Milestone E6: Learning of collision-free and torque-limit trajectories developed and evaluated.

As part of this milestone, KIT have developed an approach to learn online generation of collision-free and torque-limited trajectories for industrial robots. A neural network, which is trained via reinforcement learning, is periodically invoked to predict future motions. For each robot joint, the network outputs the kinematic state desired at the end of the current time interval. Compliance with kinematic joint limits is ensured based on the results from milestone E5 (Learning of online trajectories subject to kinematic constraints developed and evaluated). Given the current kinematic state and the

network prediction, a trajectory for the current time interval can be computed. The predicted motion is executed only if a collision-free and torque-limited way to continue the trajectory is known. In practice, the predicted motion is expanded by a braking trajectory and simulated using a physics engine. If the simulated trajectory complies with all safety constraints, the predicted motion is carried out. Otherwise, the braking trajectory calculated in the previous decision step serves as an alternative safe behavior. For evaluation, up to three simulated robots are trained to reach as many randomly placed target points as possible. We have shown that our method reliably prevents collisions with static obstacles and collisions between the robots, while generating motions that respect both torque limits and kinematic joint limits. Experiments with a real robot demonstrated that safe trajectories can be generated in real-time.


Picture Courtesy - Manuel Kaspar, Jürgen Bock: Reinforcement Learning with Cartesian Commands and Sim to Real Transfer for Peg in Hole Tasks, Workshop on Closing the Reality Gap in Sim2realTransfer for Robotic Manipulation

*Simulated and real setting*

Partner KUKA

The use of simulation environments and the design of simulation models is an ongoing task for KUKA within this project.

Within this reporting period KUKA finished the work on the selected two use cases "end-of-line tests for connectors" and "control of an

omnidirectional carry platform" as well as on another additional use case, called "Hot-Wire". All use cases have been evaluated in detail and have given important insights into possibilities and limitations of transfer learning and the related requirements. In the last project period KUKA will use those insights and results to work on vision based grasping tasks.
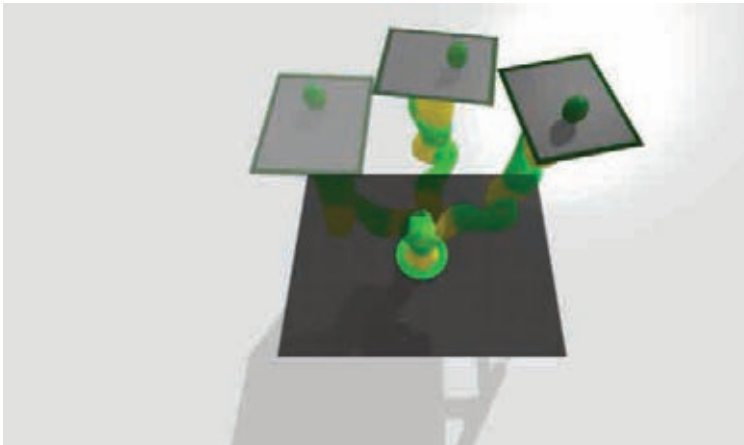
TrueÆdapt applied to a balancing task:
The robot has learned to keep a ball at the same spot on a plate while moving along a reference trajectory.
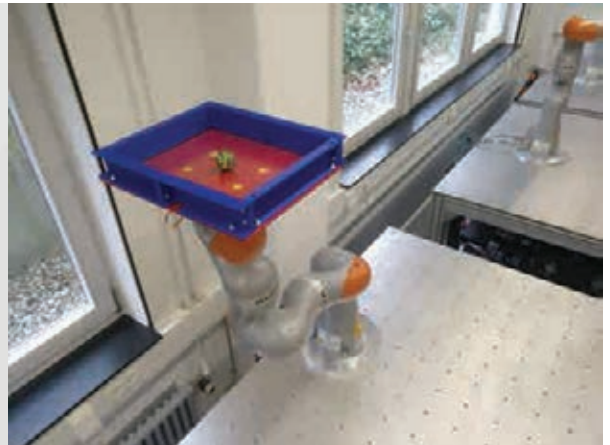
Real-world setup for sim-to-real transfer

Picture courtesy - Jonas Kiemel, Pascal Meißner, Torsten Kröger: TrueÆdapt: Learning Smooth Online Trajectory Adaptation with Bounded Jerk, Acceleration and Velocity in Joint Space, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Las Vegas, 2020

SALIENT RESEARCH ACHIEVEMENTS

Transfer Learning

In the field of transfer learning, the team mainly focused on the successful transfer of learning grasping in simulation and then transferring this knowledge to the real world. Regarding this, the team developed a novel technology, where a special image tensor for evaluating 6D grasps is used. From an overview point cloud over a bin, a 2D depth and color image is rendered from the gripper perspective. For a later, successful transfer we perform domain randomization on the color image and add noise to the depth image. Additionally, as we know the position of the CAD objects, we render-in the CAD meshes in depth and color. All these images are stacked into the channel dimension of the image tensor. A hybrid neural network, that has one branch for analyzing the image and one branch for analyzing tabular data can predict the grasp probability like it can lower the probability if there is no point cloud information for a grasp because it is far at the side of the bin, where the 3D camera could not get any point cloud data.

PUBLICATIONS

01

Jonas Kiemel, Pascal Meißner, Torsten Kröger: TrueRMA: Learning Fast and Smooth Robot Trajectories with Recursive Midpoint Adaptations in Cartesian Space, IEEE International Conference on Robotics Automation (ICRA), Paris, 2020

02

Amrut Sekhar Panda, Ravi Prakash, Laxmidhar Behera, Ashish Dutta: Combined Online and Offline Inverse Dynamics Learning for a Robot Manipulator, IEEE IJCNN, Glasgow, UK, 2020

03

Ankur Kamboj, Ravi Prakash, Jayant Kumar Mohanta, Laxmidhar Behera: Discrete-Time Lyapunov based Kinematic Control of Robot Manipulator using Actor-Critic Framework, IEEE IJCNN, Glasgow, UK, 2020

04

Jonas Kiemel, Pascal Meißner, Torsten Kröger: TrueÆdapt: Learning Smooth Online Trajectory Adaptation with Bounded Jerk, Acceleration and Velocity in Joint Space, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Las Vegas, 2020

05

Manuel Kaspar, Juan D. Muñoz Osorio, Jürgen Bock: Sim2Real Transfer for Reinforcement Learning without Dynamics Randomization, IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), Las Vegas, 2020

06

Ravi Prakash, Laxmidhar Behera, Mohan Santhakumar, Jagannathan Sarangapani: Dual-Loop Optimal Control of a Robot Manipulator and Its Application in Warehouse Automation, IEEE Transactions on Automation Science and Engineering (TASE), 2020

07

Nandanwar, Anuj, Ranjith Ravindranathan Nair, Laxmidhar Behera: Fuzzy inferencing-based path planning with a cyber-physical framework and adaptive second-order SMC for routing and mobility control in a robotic network, IET Cyber-systems and Robotics 2, no. 3 (2020): 149-160.

08

Jonas Kiemel, Torsten Kröger: Learning Robot Trajectories subject to Kinematic Joint Constraints, IEEE International Conference on Robotics Automation (ICRA), Xi'an, 2021

Contact Details

lbehera@iitk.ac.in
swagat.kumar@tcs.com

torsten@kit.edu
Rainer.Bischohff@kuka.com

NearNetMAC

Design and development of near–net–shape manufacturing process for light weight high strength Aluminium composite and engineering components by squeeze infiltration technique for automotive and aerospace applications

T.P.D. Rajan
CSIR-National Institute for Interdisciplinary Science and Technology (NIIST), Trivandrum

H. Sundaramurthy
Fenfe Metallurgicals Bangalore

Thomas Gries
RWTH Aachen University Aachen

Farbod Nezami
CIKONI GmbH Stuttgart

PROJECT BRIEF

An increased demand for lightweight materials with high specific strength, stiffness and better tribological properties have accelerated the development, diversification and use of metal-matrix composites (MMCs). The objectives of the present investigation are development of processing method for Carbon (C) fibre reinforced Aluminium (Al) MMCs by liquid metal infiltration process. Preforms of high modulus continuous C-fibre will be produced by advanced textile technologies like 3D-weaving in a near-net shape form based on the expertise of ITA der RWTH Aachen University, and the squeeze infiltration processing of Aluminium composite will be carried out in the CSIR-NIIST. The Indian industrial partner, Fenfe Metallurgicals will develop and supply the suitable Al-alloy for the infiltration and industrial scale processing and evaluation of connecting rod and heat sink components. The German industrial partner, CIKONI GmbH will provide the conceptual and detailed part design based on the textile and infiltration process as well as the structural analysis. The developed near-net-shape component will be evaluated and on successful development the industrial partners will manufacture the components for Indian and German OEMs.

OBJECTIVES

- Process development and demonstration of Aluminium Carbon (Al-C) fibre composite manufacturing using squeeze infiltration technique.

- Process development and system integration of near-net-shape preforms for metal matrix composite manufacturing using 2D/3D-weaving or 2D/3D-braiding processes.

- Development of design and analysis tools using advanced numerical simulation techniques.

- Setup lab scale and plan for pilot scale demonstrations for selected automotive and aerospace components like connecting rods and heat sinks.

- Development of a business plan for full scale commercialisation of MMCs based products developed as a part of this project.

PROGRESS MADE/ACHIEVED

Partner 1: Institut für Textiltechnik (ITA) der RWTH Aachen University

Milestone 2: Process know-how for textile processing of continuous carbon fibre preforms.

Although the milestone was considered achieved in the last report, further results of the project have shown that additional work and investigations are necessary. For one thing, some of the weave patterns of the complex 3D bindings were not implemented correctly. The experimental space was limited accordingly. In order not to reduce the scientific scope, the project consortium decided to partially redevelop the bindings.

The preparations of the demonstrators show that the draping of the near-net-shape can also be of great industrial importance, accordingly, draping tests were included as necessary in the test scope.

The milestones were divided accordingly. The following results were achieved in the current project year:

- The incorrect weaves were identified and redesigned. The weaving trials are scheduled for April 2021 and can be done with the same material.

- A test method for drape behaviour was developed, manufactured and evaluated with the faulty weaves. The drape tests will be carried out following fabric manufacture.

The milestone has been partially achieved. The outstanding results and new tests increase the scientific validity and industrial reach of the project.
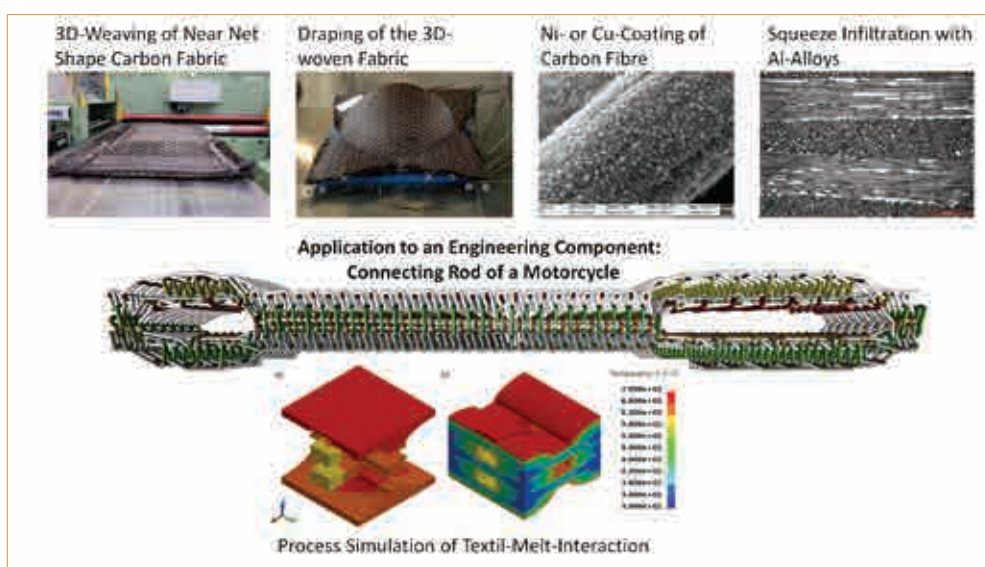
Partner 2: CIKONI GmbH

Milestone 3: Process know-how for squeeze infiltration of carbon fibre reinforced AI-MMC

- A comprehensive simulation chain for infiltration of 3D preforms was developed.

- The numerical prediction of the permeability of an orthogonally woven 3D textile is investigated using an ICFD solver. For this purpose, a mesoscopic unit cell is flowed through and the permeability is determined using the relevant flow parameters.

- The squeeze-infiltration of the preform was numerically investigated.

- A coupling of physical effects with simulation structure was performed.
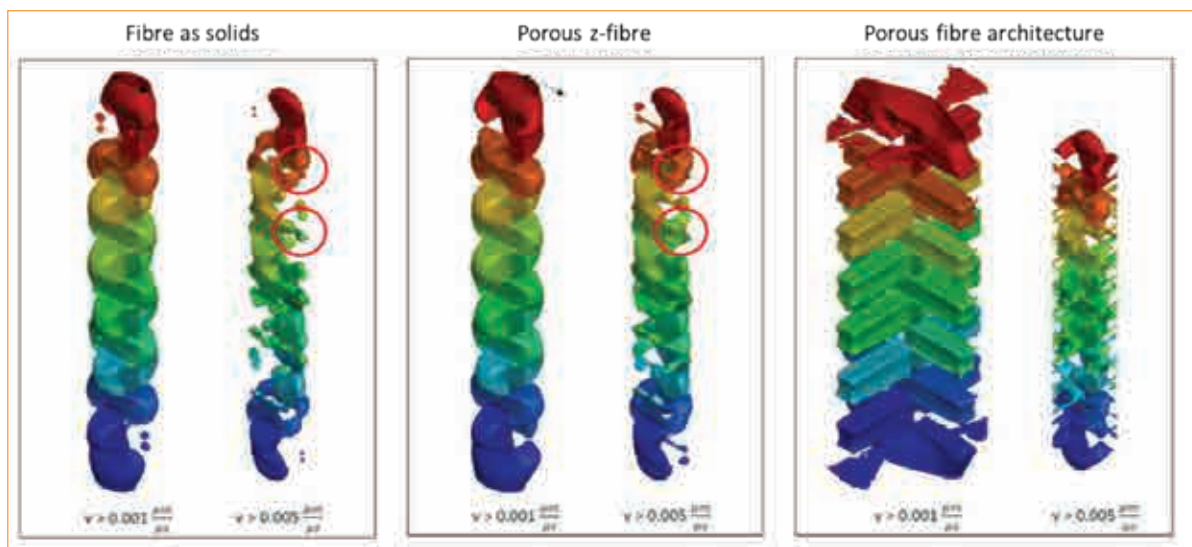
Comparison of velocities using iso surfaces for the flow along the Z-fibre. Here the fluid pressure is marked in colour
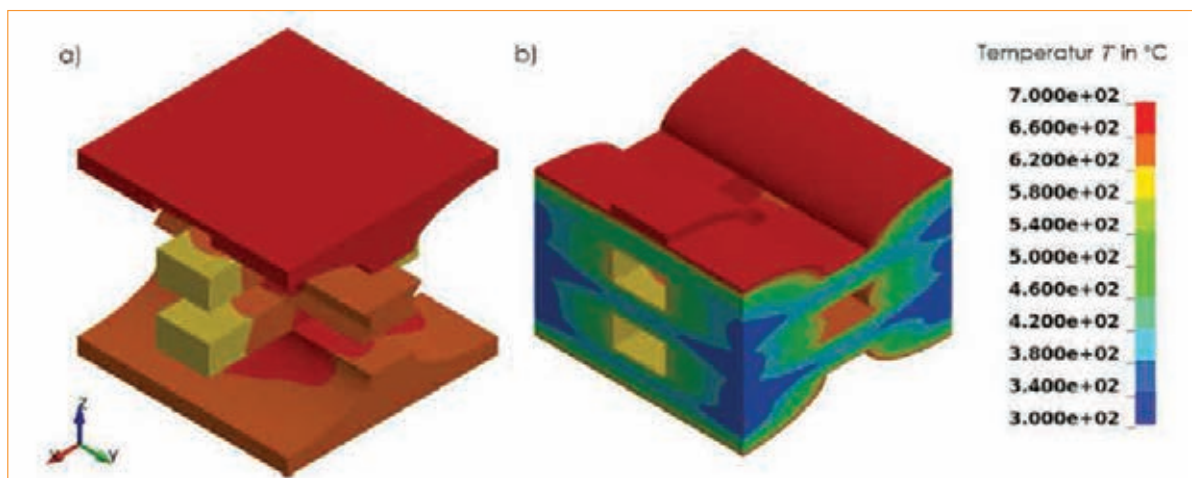
Temperatures a) of the matrix and b) of the fibres of the centre cell

Partner 3: CSIR - National Institute for Interdisciplinary Science and Technology (NIIST)

Milestone 1: Surface treatment process for continuous carbon fibre and its preforms

After successful desizing and subsequent coating with copper was already achieved in the first

reporting year, the following results were achieved in the current reporting year:

- Desizing by pyrolysis in a protective atmosphere was successfully transferred to 3D textiles (ITA and CSIR-NIIST).

- The optimized Cu coating has been achieved in electrodeposition technique by optimizing the electroplating process parameters. As a result, fine grained, and uniform Cu coating was observed on all the three types of PAN based carbon fibres. (CSIR-NIIST)

- Additionally, to the Cu coating a Nickel (Ni) coating process has been established by (1) an electroless coating and (2) by electrodeposition. An adjustable thick but even coating was achieved. (CSIR-NIIST)

A successful method for desizing and subsequent coating with Cu or Ni was developed on a laboratory scale and experimentally confirmed (TRL 4 to 5). All processes are easily scalable and suitable for series applications.

The milestone and all sub-milestones have been successfully achieved.
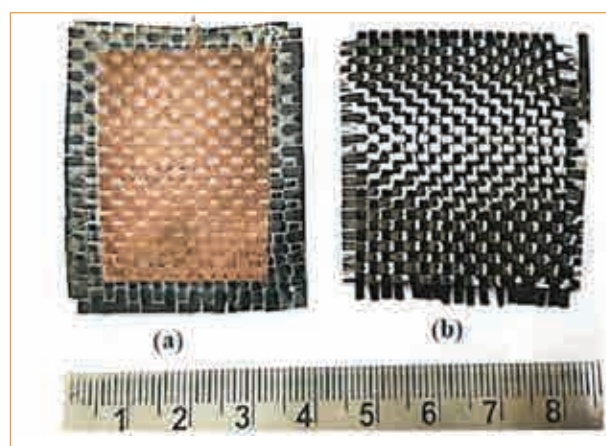
Cu electrodeposited bidirectional Cf (b) uncoated and thermally treated unidirectional Cf-input current 1A and 10 mins coating time
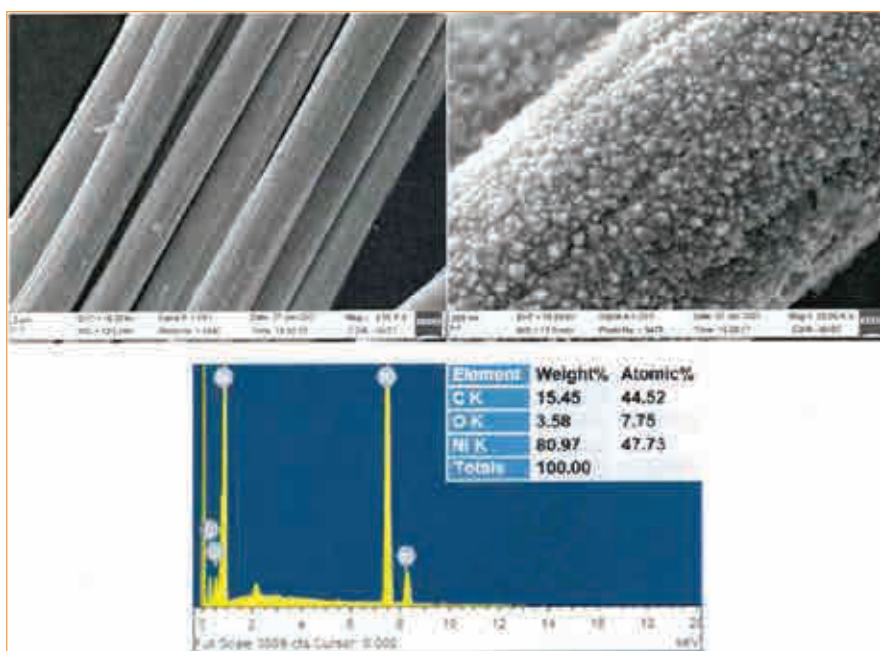
SEM and EDS images of Ni electroplated carbon fibre

Partner 4: Fenfe Metallurgicals, Bangalore, India

Development and casting of matrix Aluminium alloy: The objectives of the milestone have been reached. The following work has been carried out:

- The process layout of the squeeze infiltration has been established and tested with different carbon fibre fabrics. The relevant process parameters have been investigated with unsized carbon fibre fabrics and A356 aluminium

- The Aluminium ingots for the matrix to be used for the squeeze infiltration of Aluminium alloy have been supplied to CSIR-NIIST.

PUBLICATIONS

01
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Akhil, M.G.; Arsha, A.G.; Manoj, V.; Rajan, T.P.D.; Pai, B.C.; Huber, P.; Gries, T.: "Metal fibre reinforced composites" In: Joseph, Kuruvilla; Oksman, Kristiina; George, Gejo; Wilson, Runcy; Appukuttan, Saritha (Eds.): Fibre Reinforced Composites: Constituents, Compatibility, Perspectives, and Applications. - Duxford ; Cambridge ; Kidlington : Woodhead Publ., 2021, S. 479-514, doi:10.1016/B978-0-12-821090-1.00024-7

02
—————————
T.P.D. Rajan, Akhil S. Karun, M.G. Akhil, A.G. Arsha: "Foundry Processing Techniques for Functionally Graded Engineering Components", Indian Foundry Journal, 2020, Vol. 66(5), 16-19

03
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Pradeep K. Rohatgi, Ajay Kumar P, Nagaraj M. Chelliah, T.P.D. Rajan: "Solidification processing of cast metal matrix composites over the last 50 years and opportunities for the future", JOM, 2020, 72, 2912-2926

04
—————————
Pradeep K. Rohatgi, Ajay Kumar P, Nagaraj M. Chelliah, T.P.D. Rajan: "Solidification processing of cast metal matrix composites over the last 50 years and opportunities for the future", JOM, 2020, 72, 2912-2926

05
—————————
M.G. Akhil, A.G. Arsha, Vishak Manoj, R.L. Vishnu, T.P.D. Rajan, and B.C. Pai: " Squeeze Infiltration Processing and Structural Characteristics of Lightweight Aluminum-Carbon Metal Matrix Composites", Transactions of the Indian National Academy of Engineering, 2021, 6, pages41-48, httDS://doi.ora/10.1007/s41403-020-00172-0

Ph.D. / Master thesis supervised

- Project results will be partially integrated into the PhD-thesis of Philipp Huber (ITA).

- Mr. Akhil M.G., the SRF / PA III has registered for the Ph.D. Programme at CSIR-NIIST

The following student thesis have been supervised in the reporting period:

- Lürbke, R. "Experimental characterisation of the residual compressive strength after impact of 3D multilayer fabrics made of carbon fibres"; Student thesis at ITA RWTH Aachen University

- Umar, E.; Öztas, K.: "Investigation of the relationships between the textile architecture and the mechanical and processing properties of fibre composites made of 3D carbon fabric"; Student thesis at ITA RWTH Aachen University

- Luders, H.; Bothe, J.: "State of the art in research and technology on mechanical properties of 3D woven fibre composites"; student thesis at ITA RWTH Aachen

- Sonnenberg, D.; Zemlin, B.: "Production and properties of long and carbon fibre reinforced aluminium composites"; Student thesis ITA RWTH Aachen University

- Nguyen, C.: "Meso-scale modelling and simulation of 3D woven composites ";Student thesis at RWTH Aachen University

- Hummler, T.: "Economic efficiency analysis of 3D woven composites using process cost calculation"; Master thesis at ITA and Chair of Management Accounting RWTH Aachen University

- Orhan, I.; Andreas, A.; Paskaran, P.: "Experimental characterisation of 3D woven carbon fibre composites"; Student thesis at ITA RWTH Aachen University

- Holder, L.: "Development of a simulation methodology for the infiltration process of a metal matrix composite material"; Master thesis at IFB Stuttgart and CIKONI

- Schurek, T.: "Simulative study about the influence of the temperature on the infiltration time of a metal matrix-composite material"; Bachelor thesis at IFB Stuttgart and CIKONI

Contact Details

tpdrajan@niist.res.in   Thomas.Gries@ita.rwth-aachen.de
fenmet@gmail.com   nezami@cikoni.com

STEEL4LTC

High strength spring steels with reduced
low temperature creep for light weight designs

**Koteswararao
V. Rajulapati**
University of Hyderabad

G. Balachandran
JSW Steels Salem Works

Robert Brandt
Universität Siegen

Steffen Klapprott
Muhr und Bender KG
Weißensee

PROJECT BRIEF

Downsizing and light weight design of all automotive components especially in chassis area is underway. Higher stress acts on spring material due to its light weight design. The springs being used currently may not withstand very high stresses. Hence, there is a pressing need for the development of advanced spring steels with a combination of higher tensile strength (>2000 MPa), adequate ductility, improved low temperature creep resistance and better high cycle fatigue properties. This could be achieved by suitable alloying strategies, fabrication technologies and heat treatments. This consortium is aimed at developing an advanced spring steel grade with the improved mechanical properties by lab scale, pilot scale and industrial scale melting by continuous optimization of process parameters, fabrication technologies and heat treatments. The underlying micromechanics of plasticity leading to better mechanical properties in comparison to current state of the art materials will be determined by comprehensive microstructural characterization. Detailed experiments will be conducted and a phenomenological description will be developed to understand the improved low temperature creep properties based on the micromechanisms deduced. The role of residual stresses in imparting better low temperature creep properties and high cycle fatigue life will also be investigated. Springs will be manufactured out of the developed steel with optimized chemical composition and field tests will be conducted. This development of a new spring steel grade will be achieved by close interaction between a steel maker (JSW), academic institutes (UoH and USI) and the spring manufacturer (MUB).

PROGRESS MADE/ACHIEVED

Steel4LTC consortium has defined the alloying strategy, fabrication and heat treatment technology within the tight limits imparted by our industrial partners. Owing to the fact that the consortium is targeted to produce a new steel grade for lightweight spring applications, the alloying strategy was defined to vary only C, Si, Cr, Mn, V and Al contents. Fabrication technology is set according to the industrial partners. Heat treatment technology limited to quench & tempering (QT) process either by means of furnace or inductive. Thus, the consortium achieved the milestone #1 viz. Define an alloying strategy, fabrication and heat treatment technology for a new high strength spring steel.

SAE 9254 (0.53 C, 1.32 Si, 0.71 Cr, 0.69 Mn) steel grade was considered to optimize the heat treatment parameters to achieve milestone #2, i.e. ultimate tensile strength (UTS) in the range of 2000-2200 MPa with reduction of area (RoA) higher than 20%. As reported in section 4, the experiments performed by academic partners revealed that UTS more than 2100 MPa with RoA of 30% can be achieved by furnace QT process.

According to the recommendation of the German industrial partner MUB, the consortium set the target for RoA to be persistently higher than 30% for UTS in the range of 2000-2200 MPa. Furthermore, the steel grade must have high resistance to the low temperature creep (LTC), i.e. time dependent deformation at RRRR–8°C. Since these two criteria can't be meet by SAE 9254 steel grade, the alloying and heat treatment strategy requires the necessary adjustments, i.e. strength mainly contributed by precipitation hardening, solid solution strengthening mechanisms. In this aspect, the knowledge gained on the impact of heat treatment parameters on the mechanical properties and the microstructural features (a part of work done relevant to the milestone #3 - Get a better understanding of the microstructure, tensile deformation, LTC behaviour and HCF behaviour of the newly developed alloy steel) can be applied to develop the new steel grade with required mechanical properties. LTC rate controlling mechanism in spring steel is formulated as localized plasticity along with phase transformations in soft phase like retained austenite. Thus, the creep resistance of new steel grade is expected to be improved by wisely choosing the alloying elements that lowers the retained austenite quantity / stability. The alloying elements Si, Mn and Ni are acting as austenite stabilizers and subsequently result in higher austenite quantity. By refining the grain sizes, the alloying element V promotes higher quantity in the case of austenite localization exclusively on the grain boundaries. So, new steel grade with improved LTC resistance can be developed by strategic variation of the above discussed alloying element quantities.


Resonance based high cycle fatigue machine installed at UoH (left), and hands-on experience of PhD students on HCF equipment during a training session in PI's lab by service engineers (Right)

Partner 1: University of Hyderabad (UoH) involved in performing slow strain rate test (SSRT) followed by analytical characterization to investigate the localized plastic deformation as the "probable" rate controlling low temperature creep (LTC) mechanism. With this work, UoH will support USI in achieving deliverable #1, i.e. experimental based hypothesis of LTC controlling mechanism. On the other hand, UoH will be engaged in extensive HCF tests to achieve the objective #3 by getting a better understanding of tensile and HCF behaviors.

Partner 2: JSW with support of academic partners is involved in adjusting the alloying content according to requirements for a new steel grade with superior LTC resistance. These details would assist to meet the deliverable #2. Besides, JSW is supporting USI in the studies of influence of processing technologies on microstructural inhomogeneities.
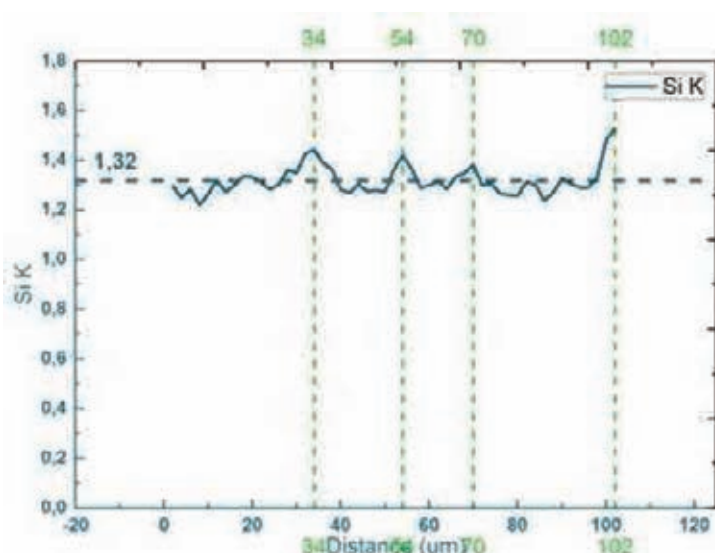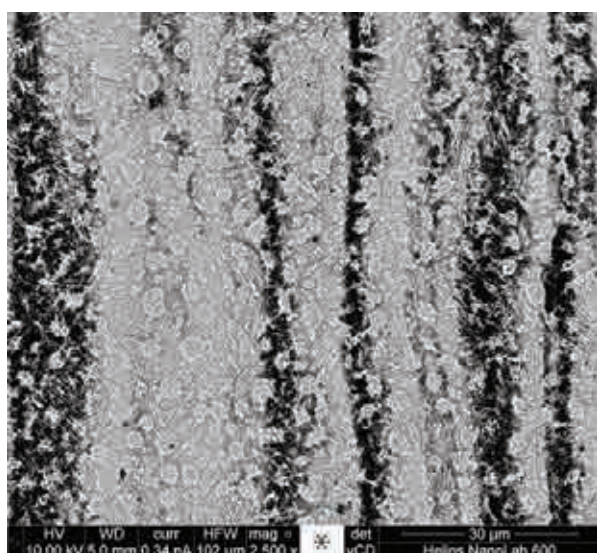
segregation bands along the rolling direction (left); SEM-EDS analysis revealed the Si segregation (right).

Partner 3: Universität Siegen (USI) Based on the own research experience and available literature on LTC behaviour in QT steel, the hypothesis of inhomogeneous plastic deformation leading to a load partitioning between the components of a martensitic structure along with transformation induced plasticity is entirely formulated as responsible LTC mechanism in QT steel. To verify this formulated LTC hypothesis, USI has set-up a list of LTC experiments at various stresses and temperatures in the temperature range of RRRR–8°C in close collaboration with TU-Dortmund. These experimental results are required for deliverable #1. Stress and temperature step tests will be performed to identify the responsible LTC rate controlling mechanism by determining activation volume & activation energies respectively. Besides, the planned axial and diametral strain measurements will deliver the evidence on the possibility of phase transformation as LTC controlling mechanism

Partner 4: MUB is offering their technical expertise and supporting the consortium in setting up the heat treatment parameters in achieving the objective #2 Profound proposal of steel grade and heat treatment by means of induction heat treatment.

PUBLICATIONS

General Public Relations Activities

The consortium organized a web based "Indo-German workshop on advanced automotive steels (IGWAAS-2021)" on March 04-05, 2021 with support of IGSTC. The themes of this workshop are planned in such a way that each session represents an important aspect of high strength steel (HSS) such as steel making / hot forming, fatigue characteristics, low temperature creep and characterization. The speakers were chosen from internationally renowned organizations, in such a way that both Indian and German sides are equally represented as well as a perfect blend of academia and industry was ensured. In total, 363 participants were registered for the event from different parts of the world. Through this workshop, innovative ideas were cultivated for the development of new generation HSS. In-depth scientific advancements as well as technological requirements were discussed in this workshop. The exchange of ideas was mutually beneficial and would be of direct relevance towards successful execution of the ongoing "Steel4LTC" project.
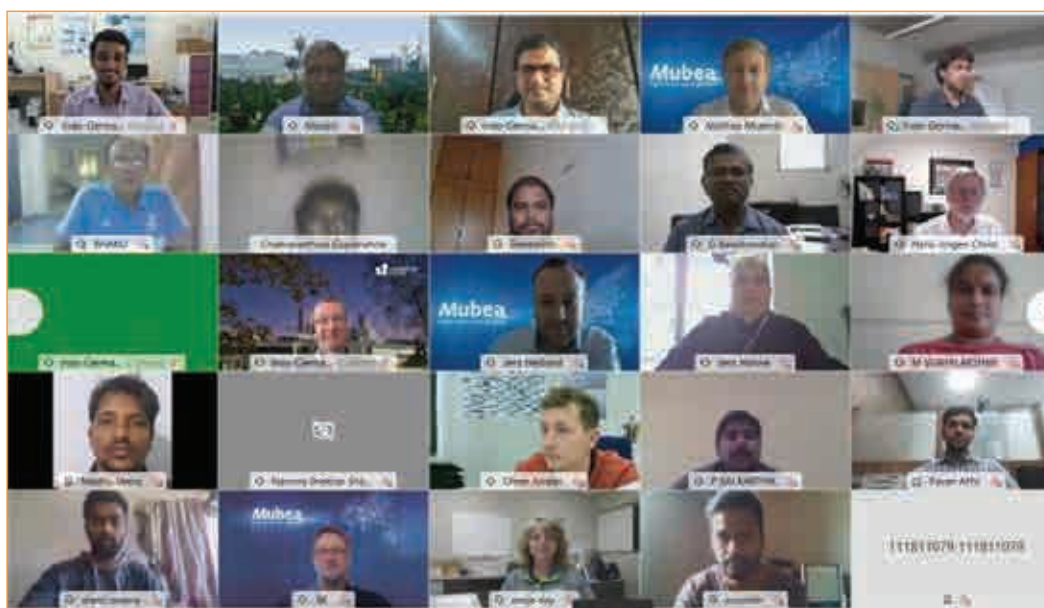
PH.D. / MASTER THESIS SUPERVISED

Prof. Robert Brandt, USI is supervising a PhD thesis within the frame of this project. Currently, a Master thesis is also offered.
Prof. Koteswararao V. Rajulapati is supervising two PhD theses within in the frame of this project. The two senior research fellows employed in this project, i.e., Mr. Mohsin Hasan and Mr. K. Nanda Kishore have also registered for PhD (Materials Engineering) in UoH.

Contact Details

kvrse.uoh@gmail.com
g.balachandran@jsw.in

Robert.brandt@uni-siegen.de
steffen.klapprott@mubea.com

Sustainable Energy/ Environment

HERCET

Development and validation of a cost–effective hybrid electric drive solution for small two wheelers for reducing CO_2 emission

A Ramesh
IIT Madras (IITM)

S J Dhinagar
TVS Motor Company
Hosur (TVSM)

Jakob Andert
RWTH Aachen University
Aachen (RWTH)

Lars Posdena
VEMAC GmbH & Co KG
Aachen (VEMAC)

PROJECT BRIEF

The objective of this project is to develop a cost-effective hybrid two-wheeler fulfilling the requirements of reduced CO2 and other emissions and improved fuel economy. IIT Madras and RWTH Aachen will develop and integrate simulation models of the engine and the vehicle along with the electric drive for sizing the important components and will arrive at the suitable topology and control strategies. The hybrid electrical drive control units and the battery management system will be developed by VEMAC GmbH, Germany. TVS Motor Ltd., India will do the design, component procurement and integration on test bed and vehicle. The proposed hybrid control strategies will be experimentally evaluated and fine-tuned in the laboratory in IIT Madras on a special test rig. Integration on the two-wheeler, calibration for performance and evaluation on the test bench and outdoor test track will also be done by TVS Motors. One prototype vehicle will be evaluated in Germany for fine tuning the control logic. Finally, the potential for reduction of fuel consumption and CO2 emissions will be evaluated against a targeted value of 25% in the chassis dynamometer in TVS Motors.

PROGRESS MADE/ACHIEVED

Partner 1 – IITM

Milestone 3 - Develop engine simulation model, Milestone 4- Validate engine model with measurements

A map-based engine model was first developed based on the data provided by TVSM (TVS Motors). This can be used to check the data flow and integration with other models of the entire vehicle. Detailed physics-based engine simulation model is being developed based on literature and adaptations as required for the engine to be simulated. This model is in the final stages of development and validation. The methodology and sub-models required for this simulation were chosen based on the engine in question and validation with the first set of engine measurements at low speed has been conducted. Further experimental data is being collected and the model is also being fine-tuned for validation at different operating conditions.

An experimental setup has been created using the engine provided by TVSM. Instrumentation for performance, cylinder pressure and emissions has been integrated and low speed experiments have been completed. Due to

vibration problems at high speed, the setup is being upgraded currently and subsequently full load and speed range experiments will be completed. There has been a delay due to COVID lockdowns and other limitations due to that within and outside the institute as a lot of fabrication work and integration is needed at this stage.

Experimental test facility at IITM with dismantled vehicle provided by TVS
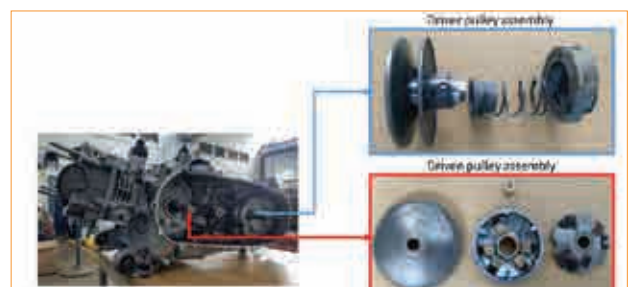
Exploded view of CVT

Partner 2 – TVSM

Milestone 10 - Evaluation with respect to cost, package size, driving distance and emissions

A Control oriented optimization framework is proposed to evaluate different powertrain configurations with respect to the financial cost, package size, driving distance and emissions with an optimal controller which can guarantee global minimizations of the objective function. The framework details are as mentioned below

- Methods of numerical optimization: Particle Swarm Optimization & Genetic Programming

- Cost function for minimization with respect to CO_2 emission, fuel consumption, increase of driving distance, weight increase due to hybridization, increase in financial cost due to hybridization

- Method used for optimal control design: Dynamic Programming

- Control oriented model: 5 topologies

- Order of the Control oriented model: Four (engine speed, actual transmission ratio, SoC, fuel consumption)

- Control input for the Control oriented model: Power of the EM & requested gear ratio

- Target drive cycle: WMTC for Class 1 vehicle

- Method of numerical differentiation: Euler's method

The Control oriented optimization framework is presented in the following diagrams
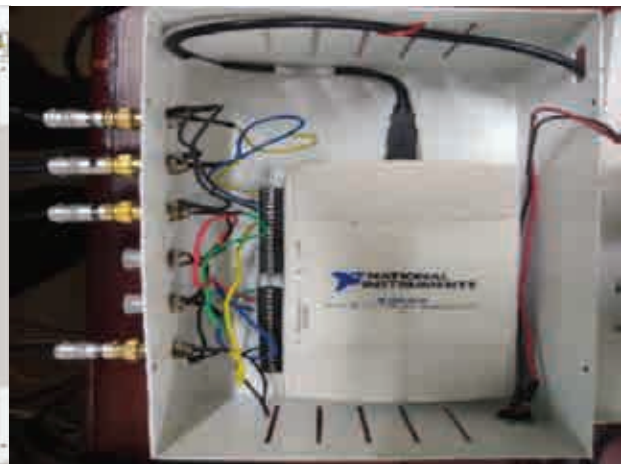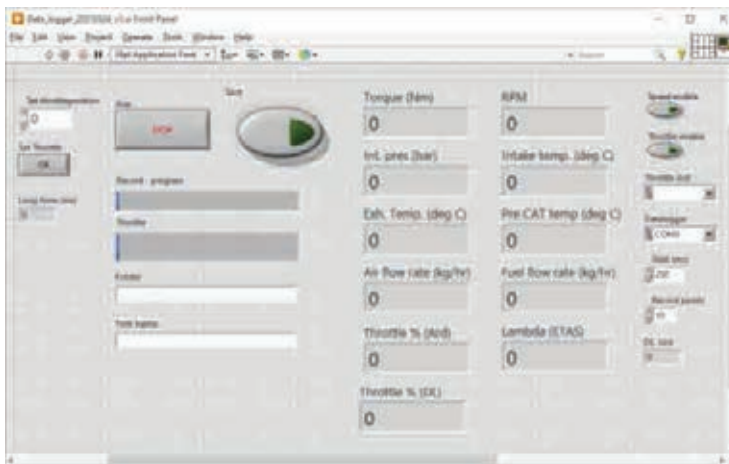
LabVIEW panel and NI module for data acquisition

Partner 3 – RWTH

Milestone 3 - Concept generation, definition and decision on hardware, software models

Since the model generation is divided between the project partners, it had to be ensured that the interfaces of each model are clearly defined beforehand to enable an efficient and timesaving workflow. Therefore, a HERCET framework was developed which not only defines all relevant components such as vehicle, engine, electric machine etc. in different subsystems, but also all relevant interfaces between them by means of signal name, signal description and unit. The framework was discussed deeply, shared with and already used by all project partners. With this, it is possible to easily share models between project partners and build them into a simulation of the entire scooter quickly. The objective is completed, and the framework is widely used.

Milestone 7 - Develop and validate vehicle model

For the vehicle model, a one-dimensional physical vehicle model was developed based on state of the art physical correlations for two-wheelers. This includes common driving resistances such as air resistance, roll resistance and grade resistances. Moreover, a driver model was implemented which controls the gas and brake lever. For a first step, the vehicle model was parametrized using values given in literature and TVS data.

For a more detailed parametrization and validation of the model, test drives with a conventional TVS Jupiter scooter were executed on a test track in Aachen. Here, the acceleration of the base vehicle from 0 – 60 km/h, the maximum speed as well as coast down curves were recorded.

In a next step, the vehicle model will be validated based on the measurements done with the base vehicle TVS Jupiter. Moreover, the measurements will also act as a reference for the hybrid topology simulation.

TVS Jupiter on test track gathering measurements for the vehicle model validation in Germany

Partner 4 – VEMAC

Milestone 8 - Evaluate different hybrid controller architectures and methods of integration with the engine controller

Different suitable "Hybrid control Unit" topology proposals had been prepared by VEMAC and discussed with the help of all project partners. In order to accelerate the implementation in a prototype vehicle, different levels of integration have been considered. Based on these concepts two final approaches to the level of integration into the HCU-HW have been developed. Out of these approaches the conservative target topology around the HCU was chosen. This topology keeps a good balance between level of freedom to implement new hybrid control strategies and the amount of development

necessary to integrate already proven external systems like the ECU, BMS and the inverter for the electrical motor. Preliminary examination and measures were conducted to be able to carry over proven hardware components and subsystems onto the future 48V hardware prototypes. Based on these first results a suitable prototype hardware was provided to VKA in order to be able to equip a four-wheeled-demonstrator vehicle. This HCU-Prototype is usable for the planed software development environment as well as the hybrid topology with the respective requirements and properties of the inputs/outputs. Further adaption to that prototype is planned for later phases of the project to adapt the hardware to the 48V-system and the final microcontroller topology.

PHD/ MASTER THESIS SUPERVISED

PhD thesis – "Evaluation of different control strategies for SI engines for use in hybrid powertrains" – Student: Pradeev E.

01

Master thesis – "Development of a Simulation Model of a SI Engine for hybrid Applications for Implementation in a Hardware in the Loop Platform" – Student: Raghav Kakani.

02

Master thesis – "Development of quick engine start strategies for port fuel injected SI engine" – Student: Abhiram Shenoi.

03

Contact Details

aramesh@iitm.ac.in
sj.dhinagar@tvsmotor.com

andert@vka.rwth-aachen.de
posdena@vemac.de

CO₂BIOFEED

CO$_2$ and Biomass as feedstock for the production of energy carriers and chemical intermediates

Asim Bhaumik
Indian Association for
the Cultivation of Science
Kolkata (IACS)

Biswajit Chowdhury
IIT (ISM) Dhanbad

Praveen K Chinthala
Reliance Industries Ltd. (RIL)
Jamnagar

Thomas Ernst Müller
Ruhr-Universität
Bochum (RUB)

Jens Hannes
RWE Power
Aktiengesellschaft (RWE)
Essen

Gernot Nell
Parr Instrument GmbH
Frankfurt

PROJECT BRIEF

Catalytic processes that are ecologically and economically beneficial form the basis of sustainable value chains in industry. Currently, fossil resources are used as the primary raw materials for the production of fuels and raw materials for the chemical industry. In the project CO$_2$BioFeed, a consortium of academic institutions and industry partners from India and Germany are collaborating to establish CO$_2$ and biomass as a sustainable feedstock for producing high value chemical intermediates such as epoxides and acrylates. More precisely to use CO$_2$ from renewable sources as an oxidizing agent for the epoxidation of short-chain alkenes, where CO is obtained as a valuable side-product. CO$_2$ is also used as a carboxylating agent for short-chain alkenes to produce acrylic/ methacrylic acid. The main goal of the project is to confirm the performance of the catalysts under industrial conditions, scale one key process step to industrial scale, and assess the cost benefits as well as the environmental impact of the process route. The novel value chain provides access to large volume intermediates that are characterized by the fact that all carbon stems from sustainable sources.

PROGRESS MADE/ACHIEVED

IACS/ISM/RIL - The work on epoxidation of propene and ethene has been initiated in India. Here functional MOFs (Cr-MIL-101, Fe-MIL-101) were synthesized through solvothermal crystallization in autoclave at re-flux conditions. These highly porous support materials were impregnated with reactive Ru and Ag nanoparticles (NPs) through wet imprignation. The catalysts were sent to Germany for evaluating alkene epox-idation using CO_2 as solvent and/or oxidant.

IACS/ISM - For NiO@SBA-15 nanocomposite materials with ca. 13 % Ni(II) loading a high BET surface area of 409 m2 g–1 and weak surface acidity was determined (IACS). Catalytic activity of NiO@SBA-15 was tested at IIT (ISM). The materials showed good catalytic efficiency for conversion of ethanol to hydrocarbon fuels, specifically C1 and C4 hydrocarbons (methane, ethene, propene and butene) at moderate temperatures (300 °C) together with the production of hydrogen.

RIL - RIL's high pressure fixed bed reactor is ready for performance evaluation. Discussions with various vendors was completed to upgrade the equipment. Due diligence for procurement of online analyzers is complete and procurement is under progress. The data generated serve as input for process simulation. RIL, RWE and RUB joined in discussing the safety concept necessary for any test runs on the pilot plant scale.

RUB - Process simulation was initiated and modelling of first benchmark processes was completed. Furthermore, CO_2-activation and adsorption of atomic oxygen on oxide surfaces was tested successfully with a Ce-catalyst made at RUB, thus, deriving first process simulation data. Catalysts from the Indian project partners are currently in various stages of testing. First measurements have shown that for activation of CO_2 temperatures of more than 300°C are required. On the basis of these results Parr constructed a prototype high-temperature Berty-reactors with design temperature up to 500°C. Parallel to the experimental work, process simulation is ongoing and life cycle assessment has been started. In parallel projects, students have started to evaluate alternative process routes for producing ethene.

RWE Power - RWE, RIL and RUB joined in discussing the safety concept necessary for any test runs on the pilot plant scale. The most suitable site for the respective reaction system as well as safety, legal and technological limitations of the sites and materials needed are currently being evaluated.

Parr Germany - The combined knowledge of the consortium in the areas of catalyst and process development was used to outline a Mini-Plant fitting our purpose. A novel high-temperature Berty-reactor was engineered by Parr and reached RUB in the first quarter of 2021. For further process validation and development an on-line gas chromatograph was obtained with project funding and integrated for analytical purposes with the experimental Berty-reactor into an existing setup at RUB.

Due to restrictions caused by the COVID-19 pandemic there was delay in both of the countries to get all of the equipment ready for evaluating catalytic activities.
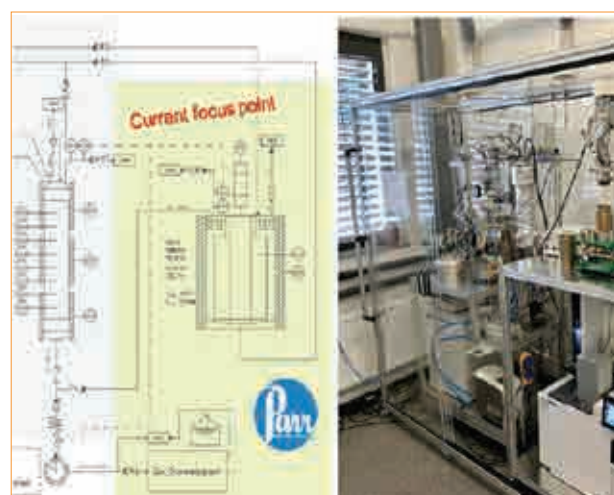
Extract from the flow diagram showing the heart of the test facility at RUB (left) with integrated catalytic fixed bed reactor (grey background), Berty-reactor and gas chromatograph (green background) as well as photograph of the test stand (right). The high-temperature Berty-reactor and the gas chromatograph are seen in the photograph on the righthand side.

SALIENT RESEARCH ACHIEVEMENTS

1. NiO@SBA-15 NPs showed good catalytic activity for conversion of bio-based ethanol to C1 - C4 hydrocarbons at 300 °C together with H_2.

2. Indium (In) based catalysts produced styrene oxide with 57% conversion and 90% selectivity in the presence of O_2.

3. Ceria (Ce) based catalysts showed excellent performance towards uptake of "O"-atoms from CO_2

4. Built for high temperature and pressure tolerance, a new Berty-reactor was developed for studying CO_2 adsorption and desorption as well as recording microkinetic data.

5. A high pressure fixed-bed reactor was commissioned for demanding process parameter.

6. Catalytic conversion of propene to acrolein was achieved in a fixed bed reactor using O_2 as an oxidant

PUBLICATIONS

01

Aerobic Oxidation of Styrene over Indium-Impregnated Mesoporous Silica: Distinctive Effect of Supports on Epoxidation Activity. Prangya Paramita Das and Biswajit Chowdhury, Chemistry Select, 2020, 5(38), pp. 11882-11889

02

CO2 Hydrogenation over Functional Nanoporous Polymers and Metal-Organic Frameworks. Arindam Modak, Anindya Ghosh, Asim Bhaumik and Biswajit Chowdhury, Advances in Colloid and Interface Science 2021, 290, 102349, DOI 10.1016/j.cis.2020.102349
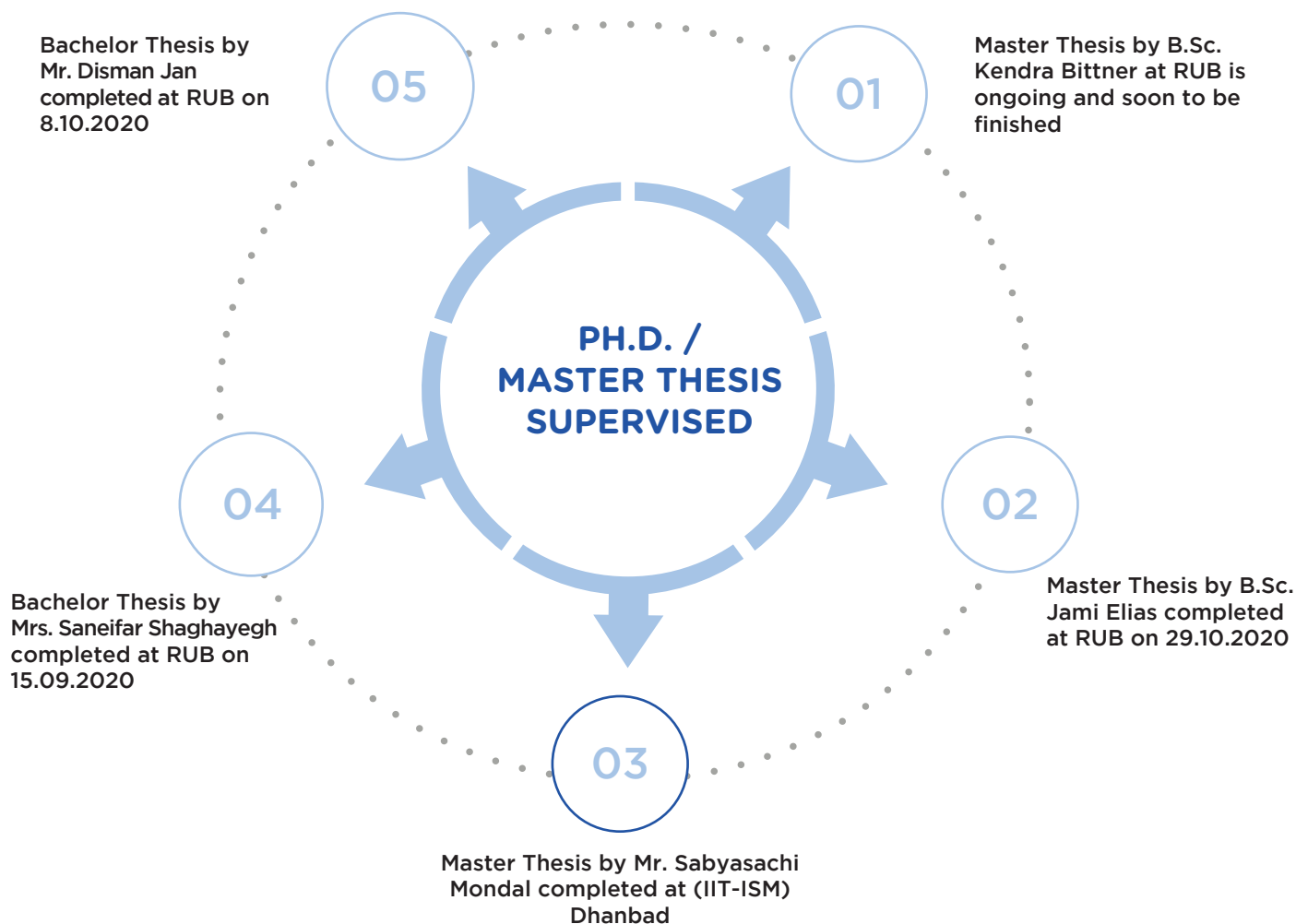
03

Catalytic conversion of biomass derived glycerol to value added chemicals. Kushanava Bhaduri, Anindya Ghosh and Biswajit Chowdhury, Book Chapter, Catalysis for Clean Energy and Environmental Sustaina-bility (Springer), 2020, Vol 1. Page 459-499 Biomass Conversion, eBook ISBN 978-3-030-65017-9.

04

Catalytic transformation of ethanol to methane and butene over NiO NPs supported over mesoporous SBA-15. Sauvik Chatterjee, Kushanava Bhaduri, Arindam Modak, Manickam Selvaraj, Rajaram Bal, Biswajit Chowdhury and Asim Bhaumik, Molecular Catalysis, 2021, 502, 111381.

05

Hydrogenation and Hydrogenolysis with Ruthenium Catalysts and Application to Biomass Conversion. Thomas E. Müller, Book Chapter, Ruthenium - an Element Loved by Researchers, InTech Open, 2021, Vol. 2, Page 41-68, DOI 10.5772/intechope.97034.

Bachelor Thesis by
Mr. Disman Jan
completed at RUB on
8.10.2020

Master Thesis by B.Sc.
Kendra Bittner at RUB is
ongoing and soon to be
finished

05

01

**PH.D. /
MASTER THESIS
SUPERVISED**

04

02

Bachelor Thesis by
Mrs. Saneifar Shaghayegh
completed at RUB on
15.09.2020

Master Thesis by B.Sc.
Jami Elias completed
at RUB on 29.10.2020

03

Master Thesis by Mr. Sabyasachi
Mondal completed at (IIT-ISM)
Dhanbad

Contact Details

biswajit72@iitism.ac.in
abhaumik68@yahoo.co.in
praveen.chinthala@ril.com

thomas.mueller@ls-csc.ruhr-uni-bochum.de
jens.hannes@rwe.com
Gernot.Nell@parrinst.de

RESERVES

Resource and energy reliability by co-digestion
of veg-market and slaughterhouse waste

S V Srinivasan
CSIR-CLRI
Chennai

Santosh Kumar
Ramky Enviro Engineers
Chennai

Dirk Weichgrebe
Leibniz Universität
Hannover

Titus Lehmann
Lehmann GmbH
Pöhl

PROJECT BRIEF

This project "RESERVES" is intended to find a solution for the organic wastes generated from wholesale vegetable markets and slaughterhouses in urban cities. The project aims to demonstrate the feasibility of biogas production and energy output during co-digestion of vegetable, Fruit & Flower market waste (VFF) and slaughterhouse waste (SHW) in India. Sampling and variations of the market's waste generation in terms of composition and biogas potential were studied and published in an international journal in which major wastes generated from wholesale Koyambedu Market Complex have been evaluated. Based on the waste composition studies, with vegetable wholesale market waste, lab scale batch and continuous studies have been carried out to identify the optimum ratio for co-digestion and OLR respectively. Also, a pilot plant has been installed and commissioned along with the bio-extruder, manufactured by Lehmann-UMT GmbH and the study is being conducted in the premises of Central Leather Research Institute, Chennai and operated by Indian and German partners collaboratively. Since July 2019, the plant has been commissioned and is being operational until February 2020. Analysis of potential pathogen removal has been conducted for the extruder pre-treatment. The Life Cycle Assessment studies and concept for utilisation of biogas has also been carried out.

PROGRESS MADE/ACHIEVED

Vegetable market and slaughterhouse wastes are used as substrates for anaerobic co-digestion, in which lab scale batch & continuous reactor and pilot scale studies with and without bioextrusion pre-treatment were carried out.

In lab scale batch and continuous studies with co-digestion and pretreatment using bio-extrusion, enhancement of biogas/biomethane yield was observed. The maximum biogas yield of 618.5 mLN/g oDM was obtained in 1:3 mixing ratio of SHW and VFF. Based on the results, the pilot plant was designed with bio-extruder as pre-treatment manufactured by Lehmann-UMT GmbH and dewatering unit supplied by Ramky, Indian industrial partner to meet the project requirements with operating capacity of 500 kg/day and the same has been installed, commissioned and operated at CLRI, Chennai. The pilot plant operation results in the specific biogas yield of 0.78 m3/kg oDM for the bio-extruded waste, which is 44.4% higher than for non-extruded waste (only shredded). The composition of the methane was constantly ranged between 50 to 62%, respectively.

Based on the operational results of the pilot plant, the environmental pollution potential was determined using the LCA software Umberto®. The specific environmental impact of the supplied substrate mixture and the electricity used were determined equal to 0.23 mPt/MJ and 23.07 mPt/MJ, respectively. The environmental impact for the amount of biogas produced was calculated as 117.5 $kgCO_2$-eq per day and 116.33 $kgCO_2$-eq for fermentation residues (digestate). However, the biogas can be substituted for natural gas which has a higher GHG emission (CO_2-eq) factor of 56.1 gCO_2-eq/MJ. Thus, through the pilot plant operation alone with a biogas production of 45 m³/d, around 90.88 $kgCO_2$-eq/d can be saved. The current practice of dumping vegetable market and slaughter house waste can also be avoided by further processing and using the digestate as fertilizer. This would save a net emission of 64.9 $kgCO_2$-eq/d (emission factor 139 gCO_2-eq/kg digestate). For the KWMC's daily waste of 200 t/d, this would mean a total saving of 62.3 t CO_2-eq/d. Moreover, the bio-extruder and the

digester were identified as the system components with the highest values of the relative difference in the specific environmental impacts as the pilot plant was operated with smaller capacity. At higher plant capacities, the specific environment impacts due to these components will be lower.

Suitable biogas utilization studies were evaluated using multiple-criteria decision analysis (MCDA) to compare different options for using biogas in India based on the pilot plant results. Three techniques (water scrubbing, pressure swing adsorption and membrane filtration) for upgrading biogas to biomethane quality, three different processes for combined heat and power generation (stirling engine, gas turbine and fuel cell) as well as the direct use of the biogas for cooking with a gas flame were analyzed. The results of the MCDA showed that Stirling engine and gas turbine options are the best alternatives if the heat generated by the CHP systems can be used. Otherwise, the option of using the biogas directly for cooking should be preferred.

Based on the overall outcome of the pilot plant studies and subsequent sustainability assessment, the organic waste management through co-digestion and pretreatment has been demonstrated which will also help the stakeholders/urban planners during their planning and execution. Further, enhanced biogas yield and utilisation of digestate as organic fertiliser would attract the stakeholders and Government to implement the waste to energy technologies either as decentralized or in centralized manner so as to meet the national missions and Sustainable Development Goals (SDGs) of United Nations.

Black centered Salmonella colonies on SS agar plate (Raw digestate), after composting (15 days, absence of colonies)
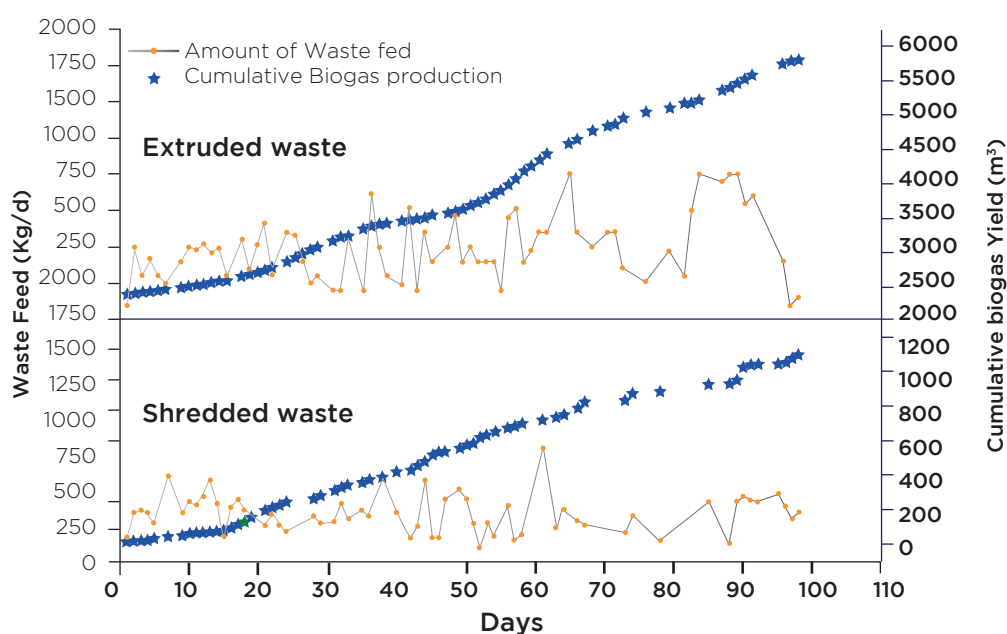
PILOT PLANT

Digester inoculum seeding was started in April 2019 with the seed sludge collected from the anaerobic digester of nearby sewage treatment plant (Perungudi, Chennai) and biomethanisation plant (Koyambedu, Chennai). Initial feeding of waste into the pilot plant was started during first week of April 2019 with vegetable market waste and slaughterhouse waste at regular intervals for 2 months for acclimatization of biomass and stabilisation of the digester. After 2 months, the regular feeding of waste has been started with vegetable market waste collected from KWMC and slaughterhouse waste collected from Perambur slaughterhouse without Bio-extruder pretreatment (with shredder alone). This operation was continued for another 8 months (July 2019 – Feb 2020) with interruptions due to choking of pipeline, Shredder motor breakdown and logistical difficulties in waste collection. However, the biogas yield during this period has been regularly monitored using online biogas flowmeter which recorded the cumulative biogas production from the digester. Based on the cumulative biogas produced and waste fed, the SBY is found to be 0.54 m3/kg oDM.

Subsequently after exchange of parts from the bio-extruder screws in January 2020, the plant operation was resumed with shredder and bioextruder for extrusion pretreatment. During this period there was some logistical issues in collection of waste and COVID-19 lock down have been implemented from mid of March to end of June 2020.

After partial lifting of COVID-19 lock down, the pilot plant operation resumed with bio-extruder pretreatment in July 2020 and operated with the organic waste collected from campus and nearby shops. Regular feeding of the pilot plant with slaughterhouse and vegetable market waste has been carried out from August to October 2020. During this period the SBY is found to be 0.78 m3/kg oDM. It was observed that, Bio-extrusion pretreatment of waste resulted in increase of SBY by 44.4%.

The cumulative biogas production from shredded vegetable and slaughterhouse waste during the constant operational period of 3 months are shown in fig 7. Similarly, the cumulative biogas production from combined shredded and bio-extruded waste is also shown in Fig.7. The biogas composition showed that the methane content ranged between 50 – 62% and H2S concentration in the raw biogas varied from 290 to 1520 ppm, which has been scrubbed and reduced to less than 40 ppm after passing through biogas purification system.

Cumulative biogas production of pilot plant with bio-extruder and without Bio-extruder(Shredded waste)

The pilot plant established at CLRI, Chennai under this RESERVES project has been successfully demonstrated for co-digestion of vegetable market waste and slaughter house waste using bioextruder as pre-treatment. This pilot plant with proven technology at TRL 8- can be used as demonstration model plant to stakeholders and policy makers involved in the waste management of smart cities. Further, it shall also be used for basic and advanced training for operating personnel in Indian biogas plants to improve their skills. To conduct such trainings, all the project partners shall together apply for funding for the expenses. This may help the Indian biogas industry flourish with proper collaboration and exchange programs.

The outcome of the project created better visibility for proper substrate management and pretreatment of waste generated in urban areas through co-digestion and Bio extruder as pretreatment. In addtion, the results showed considerable increase in biogas production through co-digestion and pre-treatment with bio extruder. The destoner proposed in this project, as emphasised by German partners will not be of much use due to various market waste those cannot float and pass through and requires additional manpower for the same. So a proper segregated waste feed will suffice.

With respect to co-digestion concept of this project, the results are encouraging for the urban stake holders to consider, the different bio-reserves available in the urban area for proper substrate management for anaerobic digestion to get maximum biogas yield. In addition, the plant growth studies have also shown nutrient potential of the digestate for utilisation in urban areas for enhancing green development addressing of Government of India missions (Swachh Bharat and Smart cities) and UN's SDGs (Sustainable cities & communities, Zero Hunger, Climate action and life on land).

Aerial view of the pilot plant

Digester with top mounted twin agitator

Project Progress meeting in CSIR-CLRI with all the partners

Contact Details

svsrinivasan@clri.res.in
karthik@ramky.com
Santosh@ramky.com

weichgrebe@isah.uni-hannover.de
info@lehmann-umt.de

SELBA

Advanced lithium Ion transporting solid electrolytes for solid-state lithium batteries

A. S. Prakash
CSIR-Central Electrochemical
Research Institute, Chennai

S. Sampath
Indian Institute of
Science Bangalore

M. Venkateswarlu
Amara Raja Batteries Ltd.
Tirupati

Maximilian Fichtner
Karlsruhe Institute
of Technology

Thomas Soczka-Guth
Daimler AG

PROJECT BRIEF

The development of safe and cost-effective high energy density all-solid-state lithium batteries can realize the dream of sustainable road transport system. Mainly two reasons are driving the research on such systems. First, the state-of-the-art lithium-ion batteries (LIBs) with liquid electrolytes (LEs) pose safety and reliability issues due to their flammability and instability under harsh conditions. Second, the use of Li metal as an anode is not possible at the moment which limits the energy density of the batteries. In this regard, solid electrolytes (SEs) exhibit several advantages: SEs suppress Li dendrite formation, non-flammable and enable high power density for all-solid-state batteries (ASSBs). Despite their obvious advantages, the use of SSBs is currently delayed by the limited availability of stable and high performant Li+ transporting SEs.

The proposed research in SELBA directly addresses these key challenges via two routes. In one approach, the surface of selected Li+ transporting SEs will be modified suitably to attain increased interfacial stability and to reduce the grain boundary resistance. In a second approach, novel Li-containing and glassy fluoride compounds with high stability will be screened, and selected systems will be developed for enhanced Li+ conductivity and integration in solid-state battery cells.

PROGRESS MADE/ACHIEVED

Partner 1: CSIR-CECRI, India

As stated in the proposal, in the first 15 months CSIR-CECRI had planned to synthesize and characterize solid electrolyte in the form of powder and thin films with further scaling up of synthesize procedure. The team synthesized free standing polymer composites of the solid electrolyte, which shows conductivity of 10-9 Scm-1. Further CSIR-CECRI will optimize the conductivity and stability of the solid electrolytes and their films in coming months.

Partner 2: IISc, Bangalore

Tantalum (Ta) doped Lithium lanthanum zirconium oxide (LLZO) has also been synthesized using a sonochemical-high temperature method. The impedance of the interface drastically reduces when Molten Li coat / LLZTO / molten Li coat is used as against Li foil / LLZTO / Li foil cell. The ionic conductivity is estimated to be 3.5 x 10-4 S/cm. Modification of electrolyte using polymer such as PVDF and PEO and carbon leads to a drastic reduction of interfacial resistance. Further characterization of the interface using microscopy and vibrational spectroscopy is in progress.

Partner 3: Amara Raja Batteries, India

- Insertion based electrode active material $LiNi_{0.33}Mn_{0.33}Co_{0.33}O_3$ NMC synthesised and optimised cathode processing protocols.

- To understand the fabrication process, prototype Li-ion cell of pouch type are fabricated with graphite and NMC respectively as anode and cathode.

- Liquid electrolyte is used as an electrolyte and tested at ambient temperature. The lab scale test results are very encouraging.

- The work on solid electrolyte scale-up to few tens of grams are in progress.

Partner 4 & 5: Karlsruhe Institute of Technology & Daimler AG

KIT & Daimler worked on the synthesis & characterisation of garnet-type lithium metal fluoride solid electrolytes. The garnet-type lithium metal fluorides ($Li_3Na_3Al_2F_{12}$; M=Al, Sc, In) were fabricated by mechanical milling under an Ar atmosphere. In a typical synthesis of $Li_3Na_3Al_2F_{12}$, the starting materials of LiF, NaF and AlF3 were weighed out in their intended stoichiometric proportions and loaded into zirconia pot with zirconia balls (O = 3 and 10 mm). The precursor mixtures were mechanochemically milled via high energy planetary ball-milling (Pulverisette 7, Fritsch, GmbH) for 30 h at 600 rpm. The resulting ball-milled product was pressed into pellets using 1 ton pressure. Then the pellets were placed in a graphite crucible and heated at 300 °C for 3 h under an Ar atmosphere in tubular furnace.

The $Li_3Na_3Sc_2F_{12}$ and $Li_3Na_3In_2F_{12}$ were also prepared by the same solid-state high energy ball-milling process, but no heating the materials after ball-milling because high pure garnet-type cubic phase was formed during ball-milling. The phase purity and crystallographic structure of synthesized lithium metal fluoride garnet, $Li_3Na_3M_2F_{12}$ (M= Al, Sc, In) compounds were studied by carrying out the Rietveld refinement using GSAS software. FESEM images of different synthesised compounds are shown below.

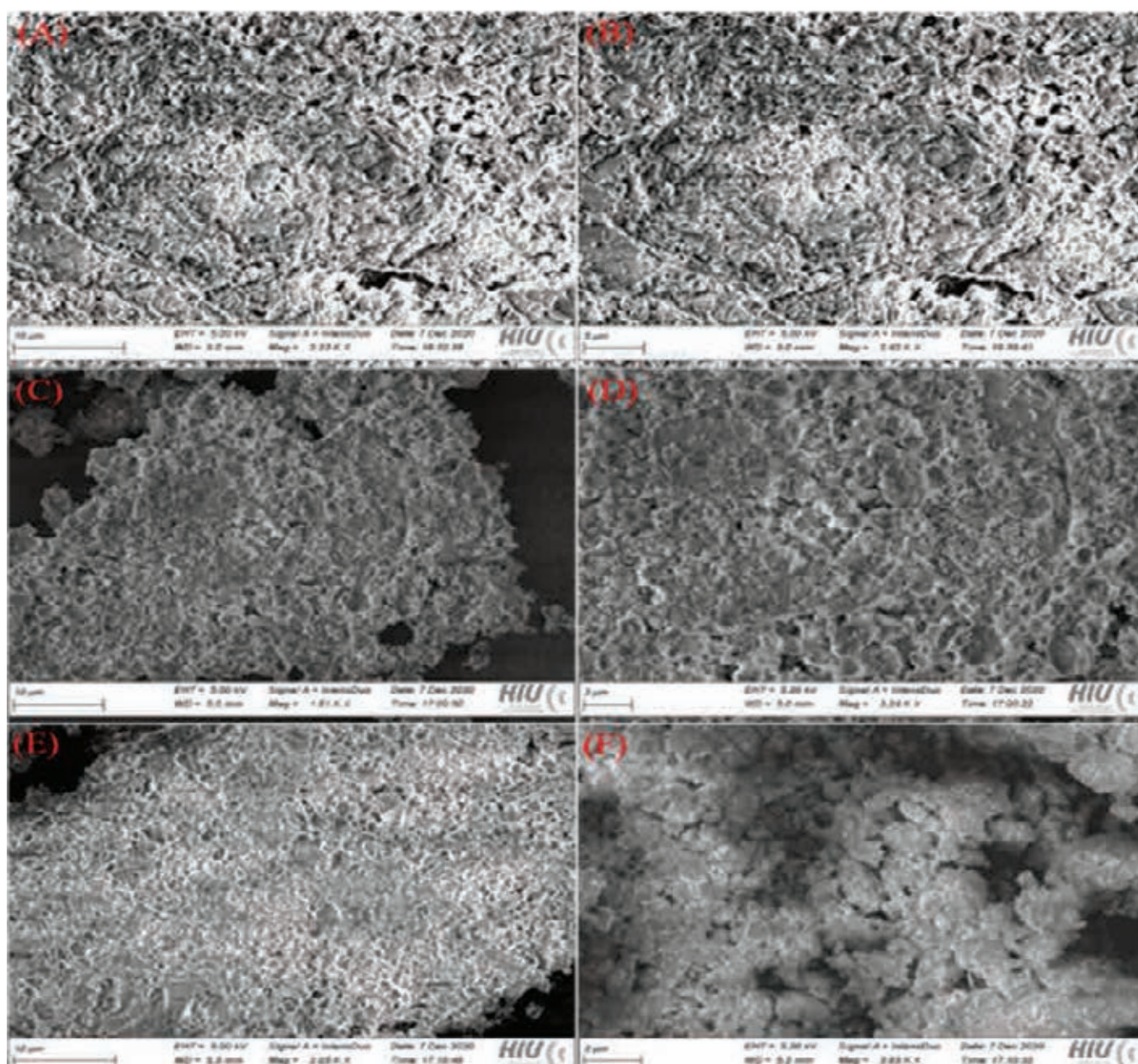

Photograph of Free standing LLZO Membrane

Photograph of Free standing LLZO Membrane

Photograph of solid electrolyte discs (2cm²) obtained from the free standing film

Photograph of solid electrolyte discs (2cm²) obtained from the free standing film

Different magnified FESEM images of (A, B) $Li_3Na_3Al_2F_{12}$, (C, D) $Li_3Na_3Sc_2F_{12}$ and (E, F) $Li_3Na_3In_2F_{12}$

Contact Details

prakash.as@gmail.com
sampath@iisc.ac.in
mvu@amararaja.co.in

m.fichtner@kit.edu
andreas.hintennach@daimler.com

LABELONIK

Roll–to–roll printed electronic labels for temperature, humidity and tampering detections

Debansu Chaudhuri
Indian Institute of Science
Education and Research Kolkata

Rohitt D Mistry
Holographic Security
Marking Systems Mumbai

Frank Ellinger
Technische Universität
Dresden

Moazzam Ali
Saralon GmbH
Chemnitz

PROJECT BRIEF

The project aims to establish a test production line for printed electronic labels by roll-to-roll gravure printing. The label comprises a first coil (to receive 13.56 MHz from a smartphone), a rectifier (to convert AC into DC), a ring oscillator (to generate 1-1000 Hz, ~10 mA), a resistive sensor (to control the output frequency of the ring oscillator) and a second coil (to generate magnetic field to be detected by the Hall sensor of the smartphone. The resistive sensor can detect a change in temperature or humidity or a damage in the label. The proposed label has huge market potential in the field of anti-counterfeiting, food packaging and biomedicine cold storage logistics. A proof-of-concept label has been successfully tested by the consortium partners using standard electronic components (TRL-4). The consortium brings experts of circuit design, functional inks, organic transistors and roll-to-roll gravure printing at one platform to guarantee the success of the project.

A LABELONIK label on a package communicating with a smartphone.

PROGRESS MADE/ACHIEVED

Partner 1: SAR

Task 2.3: Printed FET (month 07-18)

Task 3.2: Sheet fed printing of the ring oscillator (month 13-24)

Printed transistor

SAR has patent technology of printing vertical source drain structure on plastic. Source and drain are made of PEDOT:PSS. IISER has provide SAR different semiconducting small molecules. SAR made ink with these molecules. SAR spin coated these inks on top of vertical source drain structure. After that SAR printed BaTiO3 based dielectric ink on top of it. After that silver gate electrode was printed Unfortunately, none of the semiconducting small molecules showed transistor behavior. The reason is not clear to SAR. In the project was planned that IISER will support SAR to develop printed semiconducting small molecules. But because of COVID-19, nobody from SAR could travel to IISER to learn the technique of semiconducting small molecules based OFET.
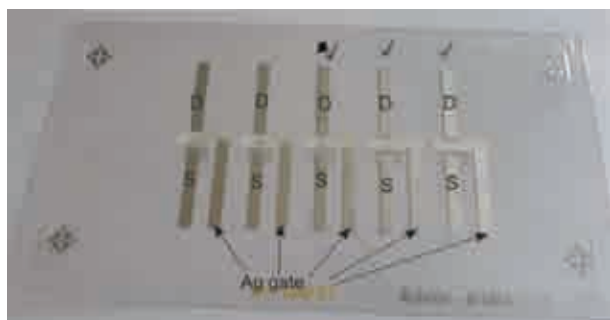
Fully printed transistor on PET

Partner 2: TUD

Task 3.1: Advanced device characterization and oscillator design (month 07-24)

Task 5.1: Circuit design of the complete integrated label (month 07-36)

Milestone MS2 – 1st Generation Label Prototype

In tasks T3.1 and T5.1, a prototype of the previously reported current starved ring oscillator and integrated label was arranged, fabricated using standard PCB technology and off the shelf components, as well as characterized.

Partner 3: IISER

Task 2.1: Synthesis & self-assembly of n-type semiconducting rylene diimides (month 01-36)

Exceptional ambient stability in n-type transistors.

Since the electrical and ambient stability of the n-type semiconductors are of prime significance in this project, the group at IISER K focused on developing new n-type semiconductors materials that could outperform known degradable candidates. With this objective in mind, following molecules were synthesized as shown in Figure below. The molecules shown in red colour are some of the previously reported benchmark n-type semiconductors.
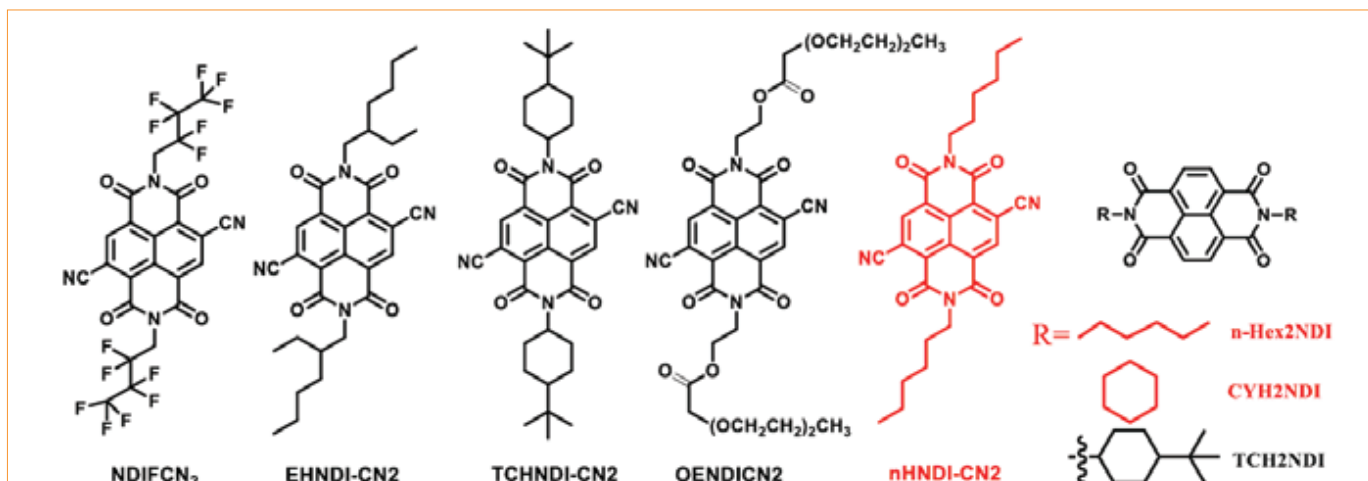
Chemical Structure of the compounds prepared/under preparation.

Among the series of molecules shown, **NDIFCN$_2$** has shown a lot of promise. Its ease of synthesis from inexpensive starting materials, high solubility in relatively beningn solvents such as toluene, and an exceptional ambient stability in the device active layer is some of the desirable attributes. The high ambient stability is ascribed to an extremely low lying LUMO (-4.3 eV) and the presence of highly hydrophobic perfluorinated sidechain, which can inhibit the diffusion of moisture through the active layer. Diffusion of moisture is known to cause large trap densities in the active layer and at the dielectric interface. The device characterises and the stability tests support observations.

Partner 4: HSMS

Deliverable D1: Roll-to-roll gravure printed resistive sensor

Task 6.1: Roll-to-roll gravure printing of resistive sensor (month 01-09)

Resistive sensor ink was supplied to HSMS by SAR. But HSMS could not do the testing with the ink. HSMS is severely affected by COVID-19 and not able to work in its full capacity. The managing director and many managers of HSMS are affected by the corona virus. Once the Covid-19 subsides, HSMS will become active again with full force for the project.

Task 6.2: Roll-to-roll gravure printing of rectifier (month 10-18)

This task could not be done because this is depended on Task 6.1. The plan was that HSMS will gain some experience while printing simple resistive sensor. Then only HSMS will start working on complicated printing of rectifier.

Publications

Incorporating Redox Conjugate Pair to Attain Electrical Bistability in Polymer Semiconductors, BK Barman, NG Ghosh, I Giri, C Kumar, SS Zade, R Vijayaraghavan, Nanoscale, 2021(DOI: 10.1039/d1nr00960e)

Contact Details

dchaudhuri@iiserkol.ac.in
Rohit@holotechonline.com

frank.ellinger@tu-dresden.de
moazzam.ali@saralon.com

PYRASOL

Smart Cities integrated energy supply, carbon sequestration and urban organic waste treatment through combined solar sludge drying and pyrolysis

S V Srinivasan
CSIR-CLRI
Chennai

Santosh Kumar
Ramky Enviro Engineers
Chennai

Dirk Weichgrebe
Leibniz Universität
Hannover

Ulrich Suer
Biomacon GmbH
Rehburg

PROJECT BRIEF

Collection, treatment, and disposal systems of urban wastes in Indian Smart Cities as well as in other urban centers have to be managed and organized with an integrated and interactive approach. Through this PYRASOL project, simple and robust processing technologies for urban organic waste will be combined in a synergetic manner and further developed to improve sanitation and welfare, supply regenerative energy, convert waste into products and reduce the carbon footprint of Smart Cities by an innovative organic waste drying system using the solar natural chimney effect followed by a highly efficient single-chamber pyrolysis. The project aims to offer an innovative approach to transform urban organic waste into biochar and energy in urban areas. Thus, the optimum process and operation parameters of the solar dryer will be determined and pyrolysis process with a unique condensing boiler system will be developed and investigated. This is supplemented through a comprehensive evaluation of the value-added chain from urban organic waste into biochar and energy and the application of biochar for land reclamation (long-term fertilizer, heavy metal adsorbent, etc.). As the generated biochar and heat are consequently utilized as the process chain, this project contributes to the Zero Waste Approaches of Smart Cities in India. To this end, fruitful cooperation of experienced researchers and engineers from India and Germany were forged and a targeted exchange and training schedules are elaborated.

PROGRESS MADE/ACHIEVED

Partner 1: CLRI

Lab scale pyrolysis of other fibrous organic waste such as tender coconut, sugarcane bagasse and cauliflower stem at different operating conditions

In addition to the lab scale pyrolysis experiments carried out with different ratios of Banana Peduncle, Municipal Sewage sludge (MSS) and Digestate in 1st year, pyrolysis experiments with other mixing ratios of Banana Peduncle and Sewage sludge obtained from 2nd set of solar drying experiments at temperature of 600oC, heating rate of 10oC/min and holding time of 60 min were carried out. Subsequently, pyrolysis of additional fibrous organic waste generated from urban areas such as tender coconut, cauliflower stem and sugarcane bagasse were

also carried out at different temperatures (400oC, 500oC and 600oC), heating rates (10 and 15oC/min) and holding times (30 and 60 min) as additional deliverables as the implementation of pilot plant is delayed due to COVID-19, pandemic. The biochar yields of individual and mixed substrates at different conditions were determined.

Lab scale pyrolysis unit at CLRI, Chennai

Partner 2: Ramky

Solar Drying - Process design and detail planning of pilot plant, guideline, and manual for operation and maintenance

Ramky has participated all the meetings with CLRI and ISAH for the finalisation of preliminary and structural design of the chimney effect solar dryer and initiated the activities towards its construction. In addition, a detailed discussion has been carried out for layout arrangements and detailed specifications of floor heating system by recirculation of hot water coming out of the pilot scale pyrolysis unit. A detailed bill of quantities has been arrived based on the structural designs made. A detailed plan was also made for fabrication of mixing system inside the solar dryer for effective mixing of sludge and Fibrous Organic Waste.

Arriving at the technical specifications for the monitoring equipment such as weather station, pyranometer, anemometer and data logging systems has been carried out based on the research requirements with the

consultation with CLRI and ISAH. A detailed guideline and manual for operation and maintenance will follow as soon as the installation process is done.

Partner 3: ISAH, Leibniz Universität

Emission analysis from pyrolysis of biomass mixtures

For urban organic wastes, pyrolysis is known to be an eco-friendly technology compared to traditional oxidative thermal treatments. However, about 40-50% of the devolatilized materials are still released as CO_2, CO, CH_4, H_2O, organic volatiles and NOx precursors. This to an extent, can be controlled through tailored design of pyrolysis variables for the feedstock. For this, the analysis must start from a micro-scale pyrolysis.

Scale up analysis of the pyrolysis of biomass mixtures – TG scale and lab scale pyrolysis

The Biomacon pilot plant is an existing design for pyrolysis of wood-like residues. It has shown potential in Germany and other

European countries. However, in the tropical environment of India, the Biomacon pilot plant is to be studied considering the large variations in urban organic waste. Thus, scale-up experiments with the planned feedstock of this project can be demonstrated for its effectiveness. This is because a) it can help in improving the future iterations of pyrolysis reactor design b) it can help to investigate and conclude the changes required in a pyrolysis reactor for the feedstock that are characteristic to Chennai/India.

Partner 4: Biomacon GmbH

Pyrolysis - Process design and detail planning of pilot plant, guideline, and manual for operation and maintenance

Biomacon manufactured A C63-F model pyrolysis machine in Rehburg-Loccum for the PyraSol project, fitted in a container and shipped to the project site in Chennai in July–August 2020. A detailed guidelines/manual for installation, operation and maintenance is provided by Biomacon GmbH along with the container to ensure an uninterrupted operation

and maintenance. Moreover, a series of trainings are provided to the technicians of ISAH and CLRI through video conferencing.

As reported in the previous progress report, the pyrolysis machine has a thermal rating of 63kW. Besides, the machine can be operated with a minimum power Pmin= 30kW. The feed must have a water content of less than 30% and the inorganic content must not exceed 10%. The out-flow temperature is max. 95°C. For condensing technology, an exhaust gas heat exchanger is externally related and adapted to the system requirements. To achieve a condensing effect, the heat exchanger requires a return temperature of approx. 30° C.

Biomacon Pyrolysis reactor for the project Pilot Plant

PUBLICATIONS

01

Nair R.R., Mondal M.M., Weichgrebe D. (2020) Investigation of Biochar from Co-pyrolysis of Banana Peduncle, Sewage Sludge and Anaerobic Digestate using ATR-FTIR and TGA, Journal of Biomass Conversion and Biorefinery.https://doi.org/10.1007/s13399-020-01000-9
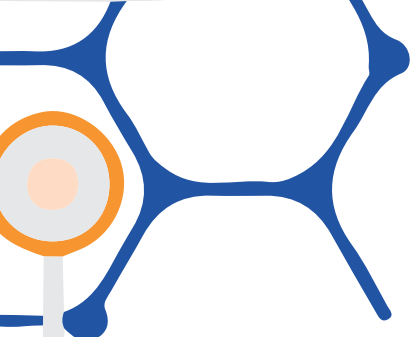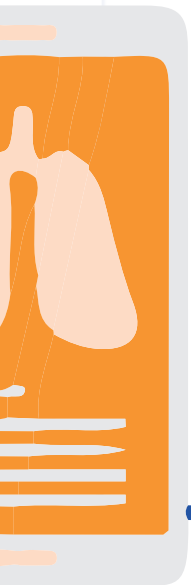
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Nair R.R., Mondal M.M., Weichgrebe D. (2019) Investigation of biochar from co-pyrolysis of sewage sludge, anaerobic digestate and banana peduncles, 28th European Biomass Conference & Exhibition EUBCE 2020, July 6-9, 2020, Marseille, France. (oral presentation)

Contact Details

svsrinivasan@clri.res.in
santosh@ramky.com

weichgrebe@isah.uni-hannover.de
info@biomacon.com

BIOMEDICAL
TECHNOLOGY

SIBAC-D2P

Experimental and clinical evaluation of a new measurement and evaluation method based on dynamic corneal deformation of the eye by a defined air pulse and its recording using Scheimpflug technology for the purpose of determining biomechanical parameters of the human cornea

Abhijit Sinha Roy
Narayana Nethralaya
Foundation, Bangalore

Sven Reisdorf
OCULUS Optikgeräte
GmbH, Dresden

PROJECT BRIEF

The project aims to establish a test production line for printed electronic labels by roll-to-roll gravure printing. The label comprises a first coil (to receive 13.56 MHz from a smartphone), a rectifier (to convert AC into DC), a ring oscillator (to generate 1-1000 Hz, ~10 mA), a resistive sensor (to control the output frequency of the ring oscillator) and a second coil (to generate magnetic field to be detected by the Hall sensor of the smartphone. The resistive sensor can detect a change in temperature or humidity or a damage in the label. The proposed label has huge market potential in the field of anti-counterfeiting, food packaging and biomedicine cold storage logistics. A proof-of-concept label has been successfully tested by the consortium partners using standard electronic components (TRL-4). The consortium brings experts of circuit design, functional inks, organic transistors and roll-to-roll gravure printing at one platform to guarantee the success of the project.

PROGRESS MADE/ACHIEVED

A novel software tool for advanced biomechanical simulation of patient corneas for predicting biomechanical outcomes after refractive surgery and for diagnosis of corneal degenerations such as keratoconus.

The SIBAC consortium (partnered by Narayana Nethralaya Foundation, Bangalore; OCULUS Optikgeräte GmbH, Dresden) in phase 2 developed a novel software tool for advanced biomechanical simulation of patient corneas and to use the software for predicting biomechanical outcomes after refractive surgery and for diagnosis of corneal degenerations such as keratoconus. In addition, the SIBAC project has resulted in the development and launch of the world's first advanced simulation software called AcuSimX ™. The objective of AcuSimX is to combine 3-D tomography of corneas and mechanical deformation measurements from Corvis-ST (OCULUS Optikgerate Gmbh, Germany) into an inverse finite element model refined by artificial intelligence to yield post-operative corneal biomechanical stiffness before any surgery 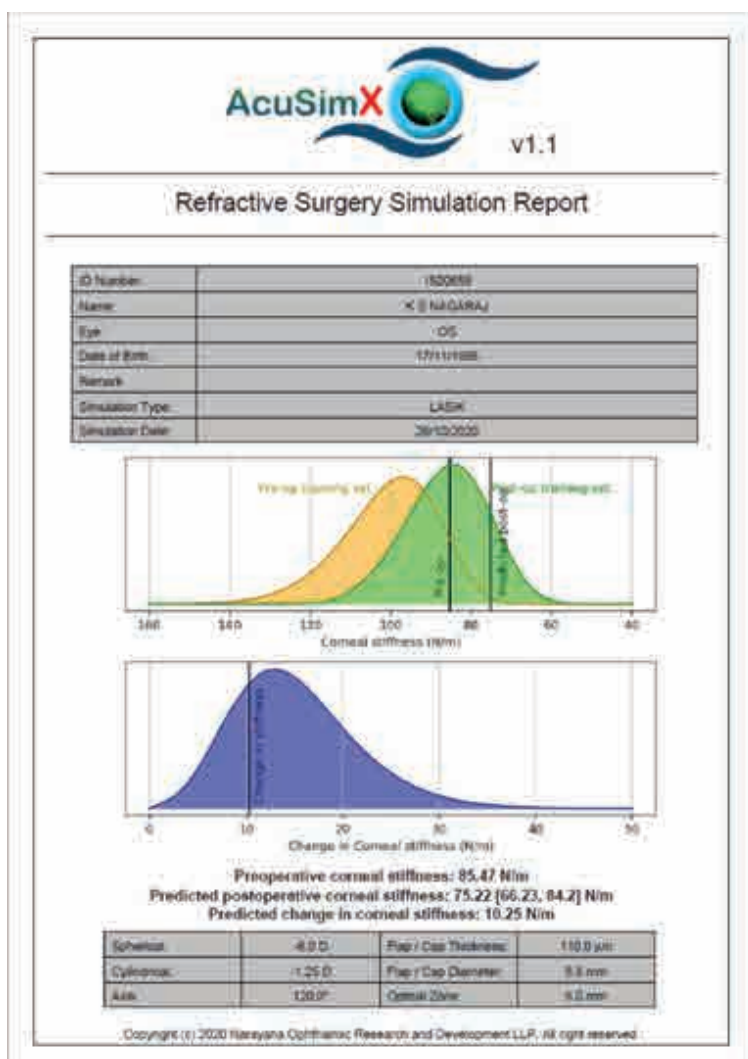or intervention is performed. Thus, the surgeons can perform a virtual surgery using AcuSimX and also test the effect of different surgical parameters on possible biomechanical stability of the corneas. OCULUS Optikgerate GmbH, Asia has also agreed to market and promote the software in South-East Asia, China and Australia in the first round of commercialization with no financial overheads. AcuSimX will be marketed and sold through Narayana Ophthalmic Research and Development LLP and OCULUS Optikgerate Gmbh Asia to customers.

Postoperative stiffness (in vivo) – In this, the postop Corvis measurement is directly processed to calculate the corneal stiffness (N/m).

LASIK – In this, the preop Pentacam and Corvis measurement is processed to perform an inverse finite element solution to determine the corneal biomechanical properties. Then these properties and postoperative geometrical mesh is used to calculate the postoperative corneal stiffness. The postoperative geometrical mesh is calculated using the patient refractive error (sphere, cylinder, axis) and surgical parameters (such as Flap/Cap diameter). This simulation report can be exported from the software as a pdf.
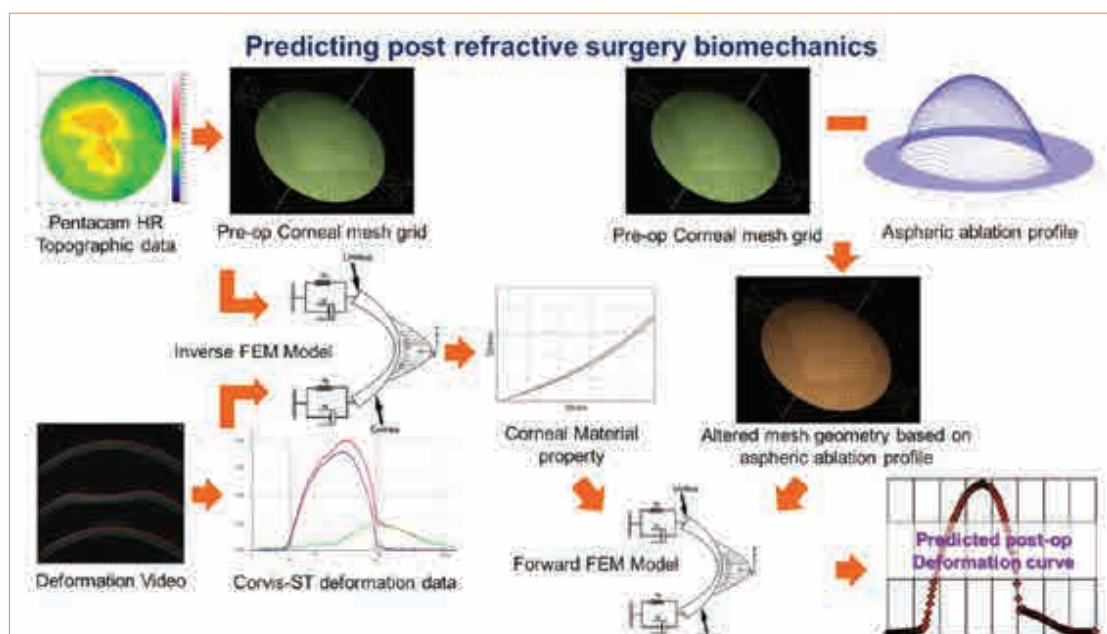
Schematic of software tool predicting post-refractive surgery biomechanics

Refractive Surgery Simulation Report — AcuSimX v1.1

Preoperative corneal stiffness: 85.47 N/m
Predicted postoperative corneal stiffness: 75.22 [66.23, 84.2] N/m
Predicted change in corneal stiffness: 10.25 N/m

population database, the change in corneal stiffness is also plotted as the blue histogram. The predicted change in corneal stiffness of the given patient is also plotted as a vertical black line. This report shows that the software calculated a preoperative stiffness of 85.47 N/m, a postoperative stiffness of 75.22 N/m with its 95% confidence interval and the change in corneal stiffness of 10.25 N/m. This report can also be printed to give the patient.

The entire process of finite element mesh generation, biomechanical simulation and artificial intelligence driven population comparison is done completely automatically by AcuSimX. This makes AcuSimX the only software tool of its kind to put the power of simulation in the hands of the clinicians. The population database was used to validate the

accuracy of the predictions. The database is subject to change as data

from other customer sites becomes available.

For SMILE and PRK, similar reports are generated. AcuSimX is a standalone software and does not require any proprietary tools to do the simulations.

For glaucoma simulations, the postoperative (in vivo) selection can be used directly to derive the stiffness of the cornea.

NNF have also come up with a new nomogram for ectasia prediction using outcomes of the AcuSimX software. This will be deployed in future versions of the software. The nomogram is basically decision tree of parameters to identify at risk corneas (see figure below).

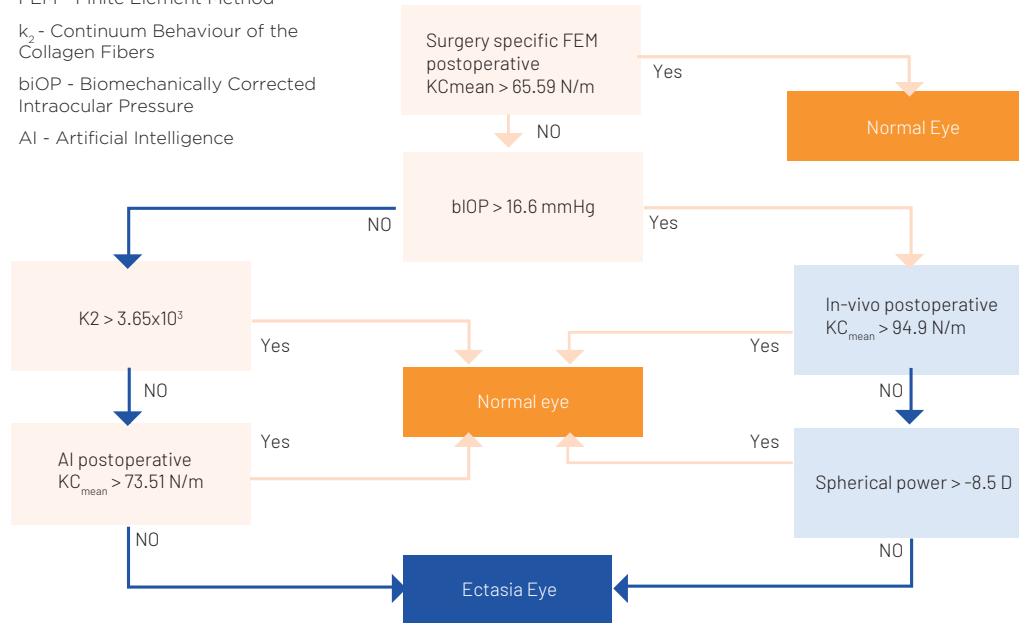## Nomogram for Ectasia risk assessment using AcuSimx

KC$_{mean}$ - Mean Corneal Stiffness

FEM - Finite Element Method

k$_2$ - Continuum Behaviour of the Collagen Fibers

biOP - Biomechanically Corrected Intraocular Pressure

AI - Artificial Intelligence

Surgery specific FEM postoperative KCmean > 65.59 N/m — Yes → **Normal Eye**

NO ↓

bIOP > 16.6 mmHg — Yes → In-vivo postoperative KC$_{mean}$ > 94.9 N/m

NO →

K2 > 3.65x10^3 — Yes → **Normal eye**

NO ↓

AI postoperative KC$_{mean}$ > 73.51 N/m — Yes → **Normal eye**

In-vivo postoperative KC$_{mean}$ > 94.9 N/m — Yes → **Normal eye**

NO ↓

Spherical power > -8.5 D — Yes → **Normal eye**

NO ↓

Ectasia Eye

Patents

A System and Method of Artificial Intelligence and Tomography Imaging of Human Cornea International publication number: PCT/IB2018/051716.

Contact Details

asroy27@yahoo.com   sven.reisdorf@oculus.de

SOUND4ALL PHASE 2

Re-engineering high-end audiometric devices for robust and affordable audiological testing

Dinesh Kalyansundaram
IIT Delhi, New Delhi

Kapil Sikka
AIIMS, New Delhi

Amit Chirom
AIIMS, New Delhi

Werner Hemmert
TU Munich, Munich

Thomas Resner
PATH GmbH
Germering

PROJECT BRIEF

Hearing impairment is one of the most common forms of disability and is widespread in countries like India. Children in rural areas suffer from this because of malnutrition and inadequate medical facilities. In urban areas, many adults are continuously exposed to high levels of noise, particularly in their work environments (e.g., in factories or construction sites). With regular screening, hearing impairment may be detected early and treated. While screening of newborns for hearing loss is slowly gaining momentum in India, it needs to be more widespread. However, monitoring children and adults regularly is almost non-prevalent. This is because the currently available screening equipment is expensive. Further, such equipment may only be used by specialists, who are in shortage. In this project the team will completely re-engineer such a screening device in order to (i) significantly bring down its cost, and (ii) enable it to be used by laypersons in the same manner that one uses blood pressure monitors or thermometers. More widespread availability of low-cost screening devices will enable their usage in schools, small healthcare centers, factories and construction sites. However, in order to significantly reduce the cost of screening devices, the newly designed devices will

need to use a completely different hardware and software architecture, without sacrificing the quality of the screening. Developing such architectures and evaluating them are the main scientific goals of this project. In particular, the consortium will rely on two main techniques: (i) offload the involved signal processing algorithms onto a mobile phone, and (ii) instead of using expensive and specialized probes, as is the case in existing screening equipment, they will use commercially available off-the-shelf components.

Rapid prototyping techniques also helped to explore many variants of ear probes. Further, the project team investigated the use of smartphones in hearing screening, which proved itself helpful. Project in Phase 1 developed promising prototypes for an ear-probe and a small smartphone assisted standalone device. Phase 2 will be governed by integrating both into a single well-tuned device, while at the same time optimizing all components for manufacturing techniques like injection molding. Further the project wants to proceed with improving user experience with sensor data gathered outside the ear probe.

PROGRESS MADE/ACHIEVED

Probe comparison study

In collaboration with AIIMS, the team set up a comparison study to investigate the performance of PATH's EPDP and LT probes. EPDP probe tip is currently used in the Sound4All device, and they want to check if the LT probe tip would be an option, too.

Sensors of the prototype

TUM and PATH started working on adding sensors to the prototype. An inertial measurement unit (IMU) is used to detect and monitor the orientation of the device using a combination of a 3D-Accelerometer and 3D-Gyro. They have also added two proximity sensors and ambient light sensing (ALS) modules, which are located on the side of the S4A device. And finally, for monitoring the probe fit and to possibly determine the ear that is currently measured, the capacity of the copper tapes mounted on the probe tip was recorded and evaluated.

The prototype prepared, after the clinical trial was found to have issues with fitting in pediatric population and poor sensitivity and specificity in rural and noisy background. To improve the probe fit two types of probes have been provided by PATH namely EPDP and LT. AIIMS team got the institute ethical clearance for evaluation of the probes in clinical settings on 22nd Oct 2019. Screening of pediatric population with these probes measuring DPOAE and TEOAE has been started and is currently in progress. But unfortunately, there has been frequent interruption in the work due to severe COVID pandemic in Delhi.

Actual experimental setup to calibrate speaker 1 and 2

Contact Details

dineshk@iitd.ac.in
kapil_sikka@yahoo.com
amitchirom@gmail.com

samarjit@tum.de
daniel.mueller@tum.de
rosner@pathme.de

MIDARDI-D2P

Microfluidic based detection of microbial communities and antibiotic responses in the management of diabetic foot ulcers – demonstrator to prototype

K Satyamoorthy
Manipal University
Manipal

Dhananjaya Dendukuri
Achira Labs P. Ltd.
Bangalore

Dr. Harald Peter
Fraunhofer IZI-BB
otsdam-Golm

Joerg Nestler
BiFlow Systems GmbH
Chemnitz

PROJECT BRIEF

Diabetic foot ulcers (DFU) are often associated with type 2 diabetes and are therefore still being an increasing issue both in Europe and India. Though infected ulcers require proper antibiotic therapy, rapid and accurate detection of polymicrobial communities in the wound environment are critical in proper wound management. Current lab-based methods require two or more days for such a test.

The MIDARDI consortium has been developing a microfluidic-based lab-on-a-chip for rapid (<1 hour) and accurate detection of different types of bacteria, their virulence/fitness factors, and antibiotic resistant genes that may contribute to the dominance of certain types in DFU settings. The detection module (instrument) will aid clinicians in the decision- making process to improve specific outcomes that would concomitantly improve wound healing per se in DFU scenario. Further, it would provide a better understanding of the underlying microbial communities to develop treatment regimens to suit responses to individuals' lifestyle modifications.

A previously developed demonstrator system will be extensively validated to obtain data on the robustness of the results against variations of sample, temperature, humidity, reagents, manufacturing tolerances, etc., and to identify potential issues. The whole system will be optimized and developed towards a system prototype. Aspects addressed include storage stability, cost and other previously identified issues. A second iteration testing series will finally be run. Besides that, the applicability to other market areas will be investigated, thus improving the commercial perspectives of the development.

PROGRESS MADE/ACHIEVED

Milestone 1.1: Redesign of several functional blocks of the cartridge, e.g. for amplification has started and preliminary experiment are ongoing. However, due to the SARS-CoV-2 pandemic the work is still ongoing.

Milestone 1.2: Instrument was further developed, being more robust and portable than before. However, due to the SARS-CoV-2 pandemic the work especially on sample prep module is still ongoing.

Milestone 1.3: Standardization of the LAMP assay with genomic DNA of nine strains of S. aureus has been carried out. The team has also carried out LAMP assay standardization of other bacterial species.

Partner 1 (Manipal School of Life Sciences, MAHE)

In MIDARDI-D2P, Manipal focused on standardized an isothermal amplification method to incorporate in the point of care device being developed. Isothermal amplification methods are a streamlined, exponential way of identifying the target nucleic acid sequences, without the need of an external thermal cycler. The independence from a thermal cycler enables for the device to be used in any healthcare setting without reliance on external machinery or specially trained personnel. LAMP enables rapid amplification of DNA with high specificity and efficiency. An inner primer containing sequences of the sense and antisense strand of the target DNA initiates LAMP assay followed by the new strand DNA synthesis which is carried by the outer primer.

LAMP primers for 16S rRNA region of 8 bacterial species were designed using primer explorer software with default parameter settings. Standardization of the LAMP assay with genomic DNA of nine strains of Staphylococcus aureus has been carried out. MAHE also carried out LAMP assay standardization of other seven bacterial species namely Acinetobacter baumannii, Enterococcus sp., Escherichia coli, Streptococcus, Proteus mirabilis, Citrobacter sp. And Pseudomonas aeruginosa.

Partner 2 (Achira Labs)

Previously, Achira had built a readout instrument for the integrated BiFlow cartridges. This instrument electronically controls the pumping of the fluid as well as heating and cooling in the cartridge. They had established the proof-of-concept by performing a fully automated microarray hybridization of 16S rDNA on Biflow cartridge to detect Proteus, Enterococcus and Staphylococcus species. The next step is to collect more data to statistically verify the results and establish the specificity and sensitivity of the readout protocol.

In line with the goals of this project, Achira focused on building a lower-cost portable version of the reader for fluorescence detection and interfacing with BiFlow's microfluidic cartridge. A prototype reader with CMOS camera and custom low light detection hardware and algorithms, which can fit on the palm of a hand and shows excellent linear fluorescence detection performance down to low pg/mL has now been built. The estimated cost of this reader is under USD 1,000. Achira believes the detection performance of this reader will be sufficient for scanning the microarray for the MIDARDI project. The team have also tested the performance of the instrument to perform a LAMP based test and readout in case it is necessary for the goals of this project. Good temperature control and a proper amplification curve was seen.


Photograph of a fluorescence reader developed by Achira Labs Pvt. Ltd.

Partner 3 (Fraunhofer)

Within this project phase of MIDARDI-D2P, Fraunhofer further expanded the microarray layout to allow a detection of additional bacterial species in parallel to relevant antibiotic resistance genes. Fraunhofer included probes for Citrobacter sp. and the following beta-lactamase resistance genes: VIM, NDM, OXA-48 and mecA. For this iteration of microarray development, the team has still used both sense- and antisense probes. After further results and final validation, the team can adapt the DNA-microarray and select the best sense or antisense probes for array optimization.

Partner 4 (BiFlow Systems)

A first set of cartridges for evaluation in India has been manufactured. However, due to COVID-19 situation, shipments to India became difficult so that shipment and further testing had to be postponed. Cartridges with microarrays spotted by Fraunhofer have been tested on an in-house instrument for validation of the experiments carried out in the previous project (MIDARDI) in March 2019. A new, more narrow spot spacing of only 300Qm was used in agreement between Fraunhofer and BiFlow. The results of 2019 experiments were confirmed and process flow was re-established. In contrast to experiments in the "old" MIDARDI project, glass slides instead of COP slides were used as substrate for spotting to investigate whether signal intensity can be improved.
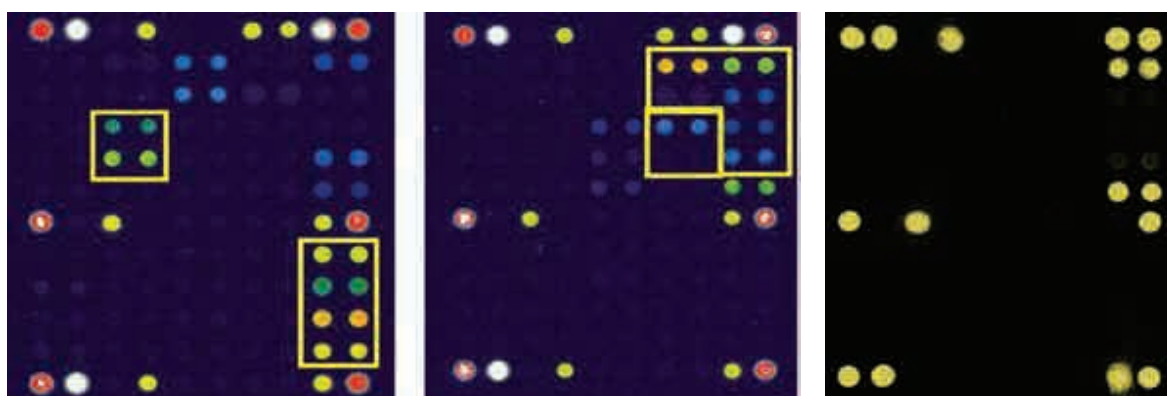
False-color images of DNA-microarrays, hybridized with fluorescent-labelled DNA from reference isolates. Simultaneous detection of Acinetobacter baumannii + NDM resistance gene (left), Staphylococcus + mecA resistance gene (right)

PATENTS FILED

Partially based on results of MIDARDI project, BiFlow filed a patent on December 23, 2021: DE10 2020 134 915.7, "Microfluidic arrangement with inlet actuation"

PH.D. / MASTER THESIS SUPERVISED

Partially based on results of MIDARDI project, BiFlow filed a patent on December 23, 2021: DE10 2020 134 915.7, "Microfluidic arrangement with inlet actuation"

Contact Details

ksatyamoorthy@manipal.edu

d.dendukuri@achiralabs.com

harald.peter@izi-bb.fraunhofer.de

j.nestler@biflowsystems.com

Bioeconomy

AUTONUTRI

On-site multi ion monitoring system for on-line nutrient-laden water control in vertical hydroponic systems to minimize environmental impact

Uday Annapure
ICT Mumbai

Vishal G. Warke
HiMedia Laboratories P. Ltd
Mumbai

Rainer Gransee
Fraunhofer IMM, Mainz

Oliver Stegen
RM Geraetebau Oliver Stegen
Reinheim

HiMedia R & D Testing facilities at Igatpuri,India

PROJECT BRIEF

Downsizing and light weight design of all automotive components especially in chassis area is underway. Higher stress acts on spring material due to its light weight design. The springs being used currently may not withstand very high stresses. Hence, there is a pressing need for the development of advanced spring steels with a combination of higher tensile strength (>2000 MPa), adequate ductility, improved low temperature creep resistance and better high cycle fatigue properties. This could be achieved by suitable alloying strategies, fabrication technologies and heat treatments. This consortium is aimed at developing an advanced spring steel grade with the improved mechanical properties by lab scale, pilot scale and industrial scale melting by continuous optimization of process parameters, fabrication technologies and heat treatments. The underlying micromechanics of plasticity leading to better mechanical properties in comparison to current state of the art materials will be determined by comprehensive microstructural characterization. Detailed experiments will be conducted and a phenomenological description will be developed to understand the improved low temperature creep properties based on the micro-mechanisms deduced. The role of residual stresses in imparting better low temperature creep properties and high cycle fatigue life will also be investigated. Springs will be manufactured out of the developed steel with optimized chemical composition and field tests will be conducted. This development of a new spring steel grade will be achieved by close interaction between a steel maker (JSW), academic institutes (UoH and USI) and the spring manufacturer (MUB).

NOMIS

Non-enzymatic microfluidic electrochemical multiplex sensor for cost-effective soil testing

Gorachand Dutta
IIT Kharagpur

Amit Rastogi
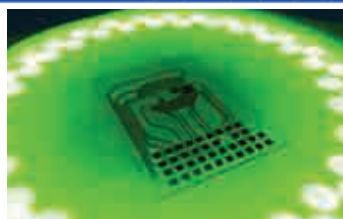Coromandel International Ltd.
Secunderabad

Bernhard Wolfrum
TU Munich

Joachim Wiest
cellasys GmbH, Kronburg

Nutrient sensor platform

PROJECT BRIEF

Fertilizers and pesticides can exhibit moderate to lethal levels of toxicity in humans. Although they are used in farm-fields to boost agricultural productivity, these chemicals move up through the food chain, which leads to biomagnification. Most of the reported methods for the detection of fertilizer and pesticides in the soil are expensive, have a short shelf life, and are difficult to realize as a device outside laboratories. By combining the complementary expertise of the Indian and the German partners, the project aims to address this unmet challenge by developing an efficient multiplexed device for the detection of nitrate (a major fertilizer-based soil/ground water contaminant in India and Germany) and organophosphates (a class of pesticides) in soil samples. The device will comprise a microfluidic platform integrated with printed electrodes based on analyte-sensitive ink formulations and will facilitate the regular screening of nitrate and organophosphates to monitor the quality of soil samples. Envisioned for commercial marketing, the device will be an important step towards sustainable agriculture, which will significantly improve the livelihood of rural farming communities in the countries and help in safeguarding water resources from pollution. Additionally, through the development of a user-friendly soil testing device in this project, awareness on environmental protection will be enhanced.

CIRCULTEX

Circular urban cultivation systems with re-useable textile growing substrates

Harshata Pal
Amity University
Kolkata

Sanjit Debnath
BCKV, Kalyani

Suhrid Chandra
HariMitti Agro P. Ltd.
Kolkata

Bastian Winkler
University of
Hohenheim

Christoph Riethmueller
DITF, Denkendorf

Michael Walz
Eschler Textil GmbH
Balingen

PROJECT BRIEF

Urban agriculture is integral part of sustainable city development, providing ecosystem services like air quality regulation, cooling, an appealing appearance and food production. Urban agriculture moved as trend into urban environments in form of vertical farming, rooftop and community gardening. Besides space, soil as cultivation substrate is scarce. Textile is light-weight and adaptive compared to other substrates and thus very suitable for soilless urban cultivation systems. The proposed project aims at the development of a re-useable textile cultivation substrate following a plant performance-based approach. In addition to plant and system specific properties, the dimensional stability of the textile will be taken into account during the development to allow for re-usability of the substrate through cleaning. Thermo-mechanical and a biological cleaning process will be developed and evaluated. Subsequently, existing urban farming systems will be technically adapted to the textile substrate to improve resource-use efficiency and include an appropriate substrate cleaning process. In combination with a market analysis and target group segmentation (community gardening; urban farming for self-sufficiency; professional indoor, greenhouse and vertical farming) the value proposition and the financial feasibility will be translated into novel business models to support the market growth of urban farming. Circular, light-weight and resource- efficient urban farming with re-usable substrate may inspire urban inhabitants, triggers sustainable consumer behaviour and lead to a societal transition towards bioeconomy.

Plants grown using textile substrate © Bastian Winkler / Gruenfisch e.V.

SENSVERT

Development and evaluation of automated sensors for a highly-efficient nutrition management system in Indoor vertical farming

Murtaza Hasan
ICAR-IARI, New Delhi

Shivendra Singh
Barton Breeze Gurgaon

Heike Mempel
Hochschule Weihenstephan-
Triesdorf, Freising

Mohamed Bourouah
Hahn-Schickard
Schwenningen

Georg Brückner
Sondermaschinenbau
Brückner GmbH Marktgraitz

PROJECT BRIEF

The importance of vertical farming systems to produce foods like leafy greens, herbs or vegetables is increasing worldwide. Vertical farming means a highly efficient crop production that maximizes the obtainable yield per cultivation area. By using multiple levels, supplied with artificial led-lighting and completely isolated cultivation conditions, a very precise and controlled crop cultivation is possible year-round. Next to the climatic conditions, the availability of nutrients, by a precisely monitored and continuously customized nutrient solution on a single ion level will be crucial for an optimal and closely controlled plant cultivation with a high product quality. On the other hand, the use of simple sensors for EC and pH to serve as fertigation management is still predominant in horticultural companies equipped with hydroponic systems worldwide. Therefore, the main objective of the research approach is the development of an automated sensor system for a highly efficient nutrient management system in vertical farms. The addition of specific ions into the nutrient solution will be based on the rate of withdrawal by the roots and plant specific needs.
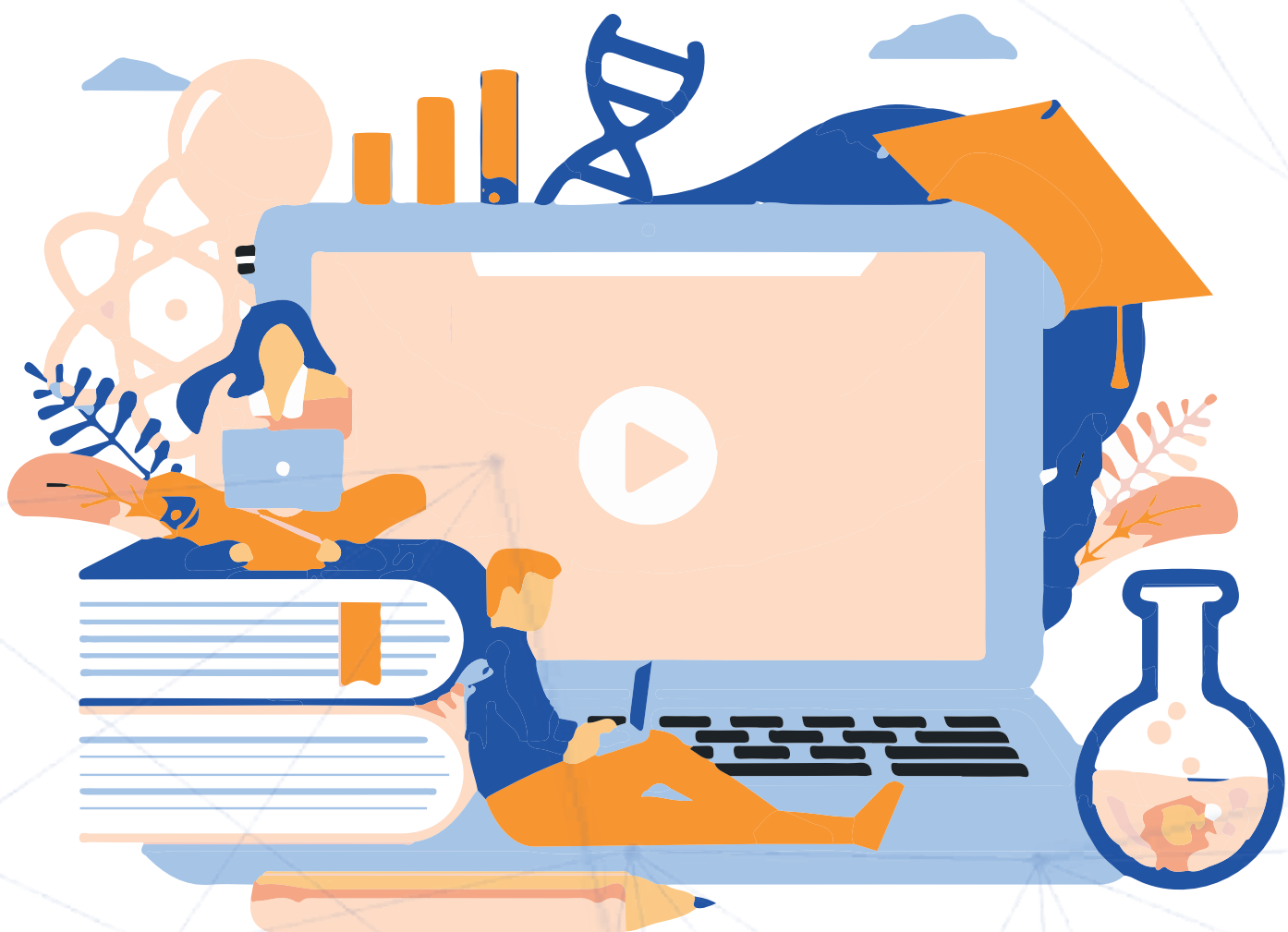

Vertical farming setup at Barton Breeze
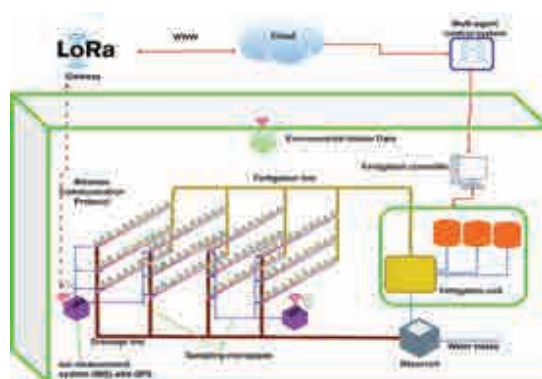
Overview of the proposed vertical farming system

WORKSHOPS

INNOVATIVE CHARGING TECHNOLOGIES FOR HEAVY DUTY VEHICLES (ICHARGEHDV)

18 February 2021

The Indo-German workshop on innovative charging technology for heavy duty vehicles (IChargeHDV) was organized on February 18, 2021. by ifeu – Institut für Energie- und Umweltforschung Heidelberg GmbH and The Energy and Resources Institute (TERI), New Delhi. The workshop co-ordinators were Mr Sharif Qamar, TERI and Udo Lambrecht, ifeu. It aimed to provide a platform for policy makers, infrastructure developers, research and development institutes, and leading industry players in freight transport technology/rolling stock supply to advance industrial research partnership in catenary truck technology, which is of interest for both the nations. This IGSTC supported joint Workshop, intended to enable stakeholders to share on-field experience in the sector, combined with an overview of strategies to support each other in reducing the GHG emissions and pollutants from the freight transport sector. The workshop is one of the few first steps towards enhancing the technological partnership between nations under the ongoing bilateral projects like promotion of transformation to sustainable and climate friendly electro mobility by networking young scientists from India & Germany.

The workshop witnessed participation from various key stakeholders like leading scientists, policy persons, government officials, etc. from both the countries and involved serious deliberations on the benefits as well as challenges in the IChargeHDV sector.


The inaugural session was moderated by Ms Lena Stiller, Transport Policy Advisor, GIZ GmbH. Mr R Madhan, Director, Indo-German Science and Technology Centre (IGSTC) delivered the welcome address. He emphasized the need to build collaborations between industry and academia towards innovative and sustainable solutions. He encouraged that the outcome of the workshop may lead to initiate new bilateral cooperation through joint projects.

The joint opening remarks were delivered by Mr Udo Lambrecht, Board Member, ifeu (Germany) and Mr Shri Prakash, Distinguished Fellow, Transport & Urban Governance, TERI (India). Mr Lambrecht, Executive Board Member, ifeu, was pleased to see so many experts joining the virtual Indo-German workshop about innovative charging technologies for heavy duty vehicles. He touched upon the climate crisis, which is becoming increasingly apparent and

emphasized that the international community must push innovative approaches to reduce GHG in the coming years.

The workshop had different session on Pilot Project Steering & Management, Overhead Supply System Technology, E-Highways – Regulatory Framework, Retrofit Technology - Conventional to IMC, Platform for collaboration – Indian OEMs & R&D projects drawing key eminent scientists & speakers for the same.

The workshop resulted in key discussions regarding the requisites for electric highways and best possible ways to implement the project in India.
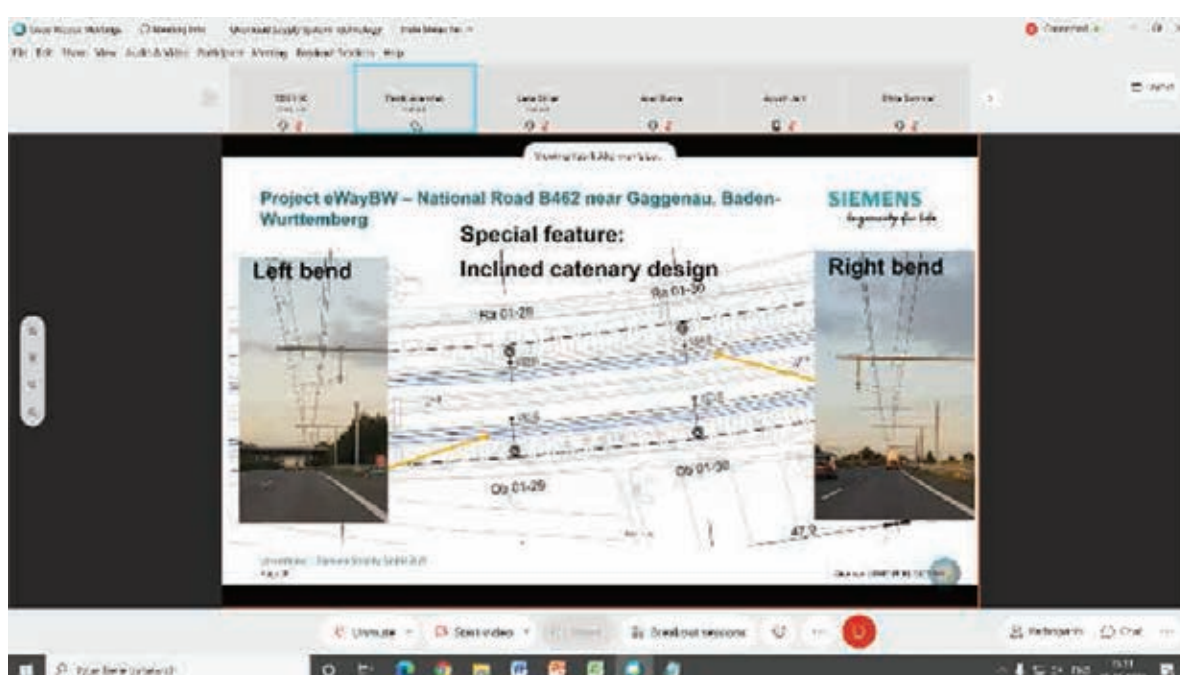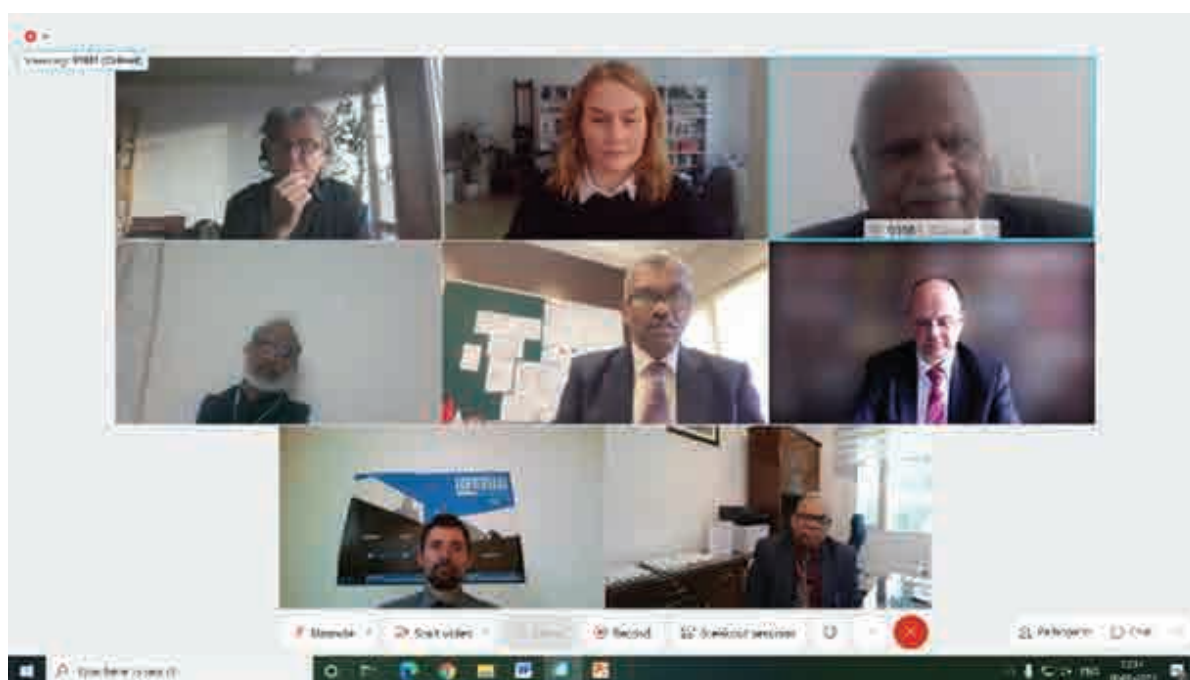
Welcome address of the workshop

Indo-German Workshop on advanced automotive steels (IGWAAS)

4-5 March 2021

IGWAAS - 2021 was jointly organized by both Indian and German academic partners, i.e. University of Hyderabad (UoH) and Universität Siegen (USI) respectively, in close collaboration with Indian and German industries, JSW Steel Works Ltd, Salem (JSW) and Mubea Fahrwerksfedern GmbH, Weissensee (MUB) respectively of IGSTC ongoing 2+2 project Steel4LTC on 4 – 5 March 2021. The workshop coordinators were Dr Koteswararao V. Rajulapati, UoH and Prof Robert Brandt, USI.

Steel is an important and indispensable structural material in automotive sector. In a continuous effort to make lightweight vehicles without compromising on efficiency, there have been several recent scientific and technological developments in the automotive steels. New grades of high strength steels

(HSS) are being adapted while considering lightweight, optimal design, safety missions and efficiency. Therefore, there is a need to understand the current trends and state of the art in steel development, fabrication and manufacturing technologies, microstructural development, mechanical properties, design, safety, fuel economy etc. The workshop discussed these trends in various steel grades that are currently employed in automotive vehicle manufacturing. The themes of the workshop represented an important aspect of high strength steel (HSS) such as steel making /hot forming, fatigue characteristics, low temperature creep and characterization.
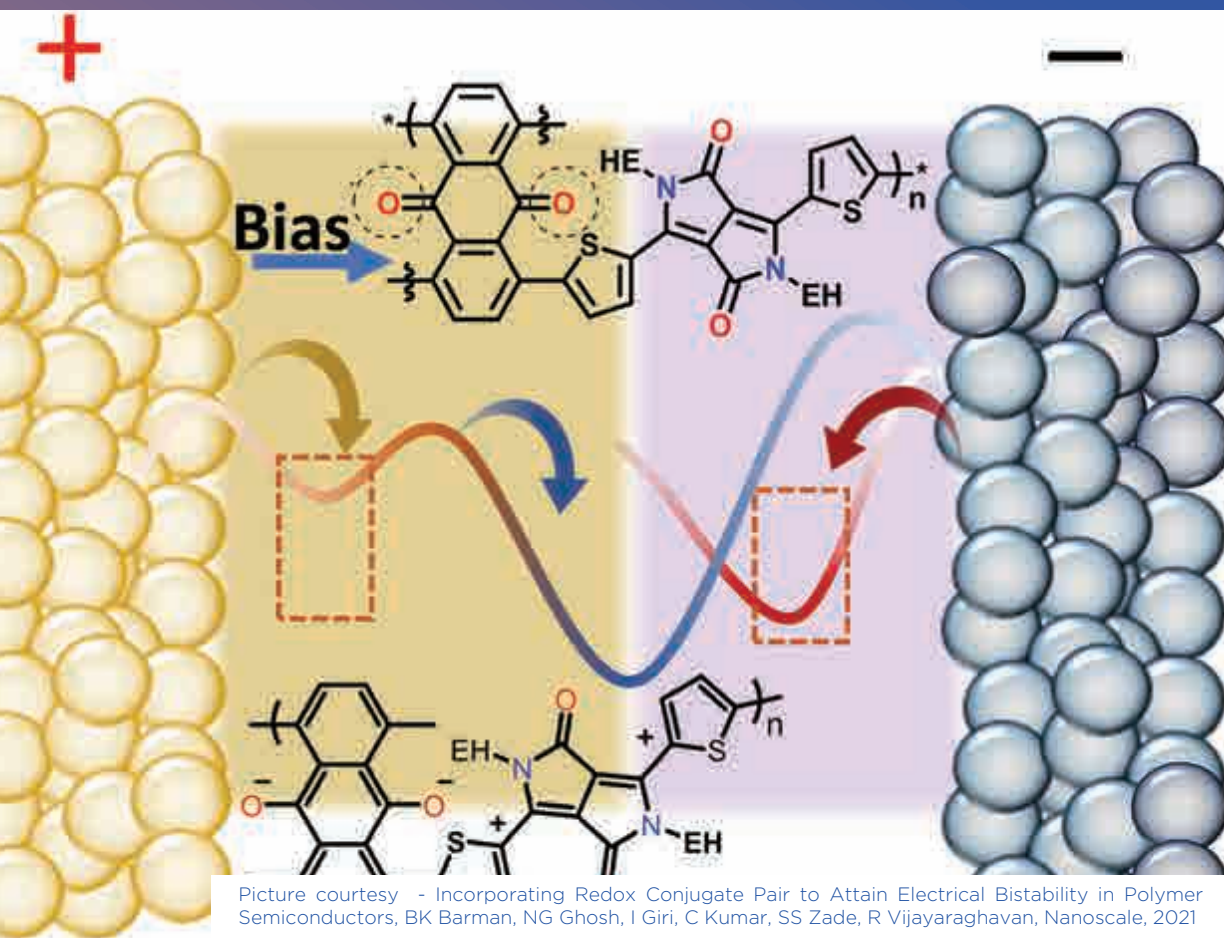
The inaugural address was given by Prof Ulf Richter, Chancellor, University of Siegen and Prof P Appa Rao, Vice-Chancellor, University of Hyderabad.

Mr R. Madhan, Director, IGSTC appreciated the efforts of organising such a wonderful workshop. He was hopeful that the networking through this workshop will lead to further joint collaborations in applied research with the active involvement of industry. The workshop attracted more than 300 participants from academia, industry, govt. agencies, etc.
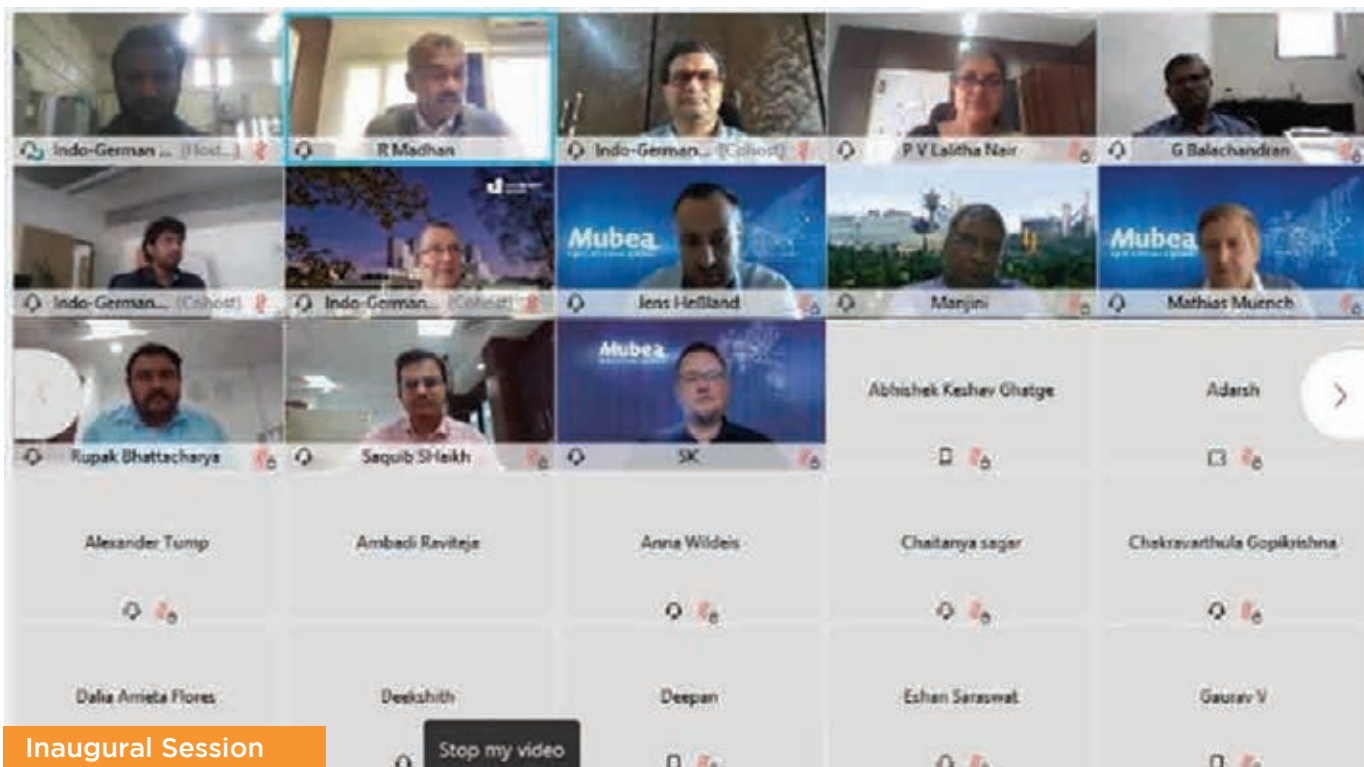
Inaugural Session

Technical Session

Through this workshop, innovative ideas were cultivated for the development of new generation High Strength Steel (HSS). In-depth scientific advancements as well as technological requirements were also discussed.

Picture courtesy - Incorporating Redox Conjugate Pair to Attain Electrical Bistability in Polymer Semiconductors, BK Barman, NG Ghosh, I Giri, C Kumar, SS Zade, R Vijayaraghavan, Nanoscale, 2021