



igstc

INDO-GERMAN SCIENCE AND TECHNOLOGY CENTRE

ANNUAL REPORT
2021-22



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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

1

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

2

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

3

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.

4

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

5

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

6

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

7

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

8

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

9

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

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The Year 2021-22 at a Glance

IGSTC continues to enhance the Indo-German partnership in Science & Technology through its programmes and plays a crucial link in enabling collaborative research through numerous Indian and German research institutions and industries. 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 199 organisations. Several publications, patents, few startups, technology developments and capacity building of young engineers, science graduates and technologists have been achieved through the 2+2 project scheme. IGSTC's bilateral workshop program has networked approximately 2700 scientists and industry personnel from 54 institutions in India & Germany through 27 workshops. The workshop program has also given exposure to approximately 1000 early researchers. 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. The Year 2021-22 was a seminal year as IGSTC launched key programs viz. Industrial Fellowships, Women in Science & Engineering Research (WISER), Paired Early Career Fellowship in Applied Research (PECFAR) and Small Immediate Need Grants (SING). The above programme shall act as a catalyst and bridge the

Indo-German research partnership at different levels like early, mid-career and women researchers.

During the year 2021-22, 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. 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 an estimated ₹ 147 Cr or € 18 million. IGSTC's Open Call for workshops was resumed and six workshops under this call shall be held in various parts of India and Germany. These workshops play an important role in connecting relevant stakeholders for future collaborations.

A workshop on Artificial Intelligence was organised by IGSTC which brought key scientific experts together from India & Germany. The workshop helped to enlarge knowledge networks and identify fields of mutual interest for future collaboration. This two-day virtual workshop had one plenary lecture on each day by outstanding scientists from India & Germany followed by five parallel sessions (AI for Sustainability, Trustworthy AI, AI for Healthcare, Mathematical Foundations of AI/ML and Autonomous Robotics) to discuss interesting and relevant sub-thematic areas for cooperation.

The 2+2 Call 2020 on Additive Manufacturing (AM) attracted a significant amount of interest and six projects were recommended for funding. These projects will work on transforming cutting-edge research into products and services for the benefit of society in the key areas of AM like materials technology, biomedical implants, etc.

The IGSTC Industrial Fellowship programme was launched on 14th June 2021. The Fellowship is offered at two levels, PhD Industrial Exposure Fellowship (PIEF) and Post-Doctoral Industrial Fellowship (PDIF). Call 2021 of Industrial Fellowship selected 20 candidates (10 PDIF and 10 PIEF) from various institutes of India. Next call of IGSTC Industrial Fellowship 2022 was open from 1st February 2022. The Industrial Fellowship programme has generated a lot of interest among young Indian researchers and stirred up the urge to perform industrial research in Germany from an early stage. IGSTC hopes this fellowship will create a unique niche.

First of its kind program for lateral entry for female researchers in joint R&D projects between India and Germany - Women Involvement in Science and Engineering Research (WISER) was launched by IGSTC on 24th November 2021 for encouraging female researchers in joint R&D projects. The program was launched in the presence of eminent female scientists from both countries. From India, Dr. Tessy Thomas, DRDO and Dr. Muthayya Vanitha, ISRO, welcomed and appraised the program. From Germany Prof. Nicola Marsden, University of Applied

Sciences Heilbronn and Prof. Petra Lucht, Technical University Berlin explained the need of such programs for enhancing woman participation in research.



Launch of Paired Early Career Fellowship in Applied Research (PECFAR) on 01.02.2022

Further, to support proposals/initiatives that require modest funding to kick start or have the potential to embark on good bilateral Indo-German collaboration, IGSTC launched the new initiative Small Immediate Need Grants (SING) on 27th December 2021. Application submission for this programme is open throughout the year.

IGSTC's bilateral workshop program has networked approximately 2700 scientists and industry personnel from 54 institutions in India & Germany through 27 workshops.



Dr Chandrashekhar & Mr Linder inaugurating the new IGSTC office

On 1st February 2022, IGSTC launched a new fellowship programme called "Paired Early Career Fellowship in Applied Research" (PECFAR) to provide opportunity to early-career scientists & engineers with potential in their field to explore Indian and German research landscape on various aspects, including entrepreneurship, collaborative research, and innovation and sharing of lab facilities and infrastructure.

An important milestone was the inauguration of IGSTC's new office premise at the campus of Department of Science & Technology (DST), Government of India, New Delhi. The Inauguration was held on 21st February 2022 in the august presence of Dr Srivari Chandrasekhar, Secretary, DST and H.E. Walter J. Lindner, German ambassador to India and Bhutan.

IGSTC launched a new fellowship programme Paired Early Career Fellowship in Applied Research (PECFAR) to provide opportunity to early-career scientists & engineers.



IGSTC signs MoU with Tata Steel Ltd., Left: Dr Debashish Bhattacharjee, Right: Mr R. Madhan

To enhance the public-private partnerships in the frontier areas of Science & Technology, IGSTC signed a Memorandum of Understanding (MoU) with Tata Steel and Letter of Intent (LoI) with BASF on 21st March 2022 in the presence of Mr S.K. Varshney, Head, International Cooperation, DST and Indian Co-Chair IGSTC Governing Body; Dr Steffen Norbert Koch, Minister and Head of Economic Department, German Embassy; Dr Debashish Bhattacharjee, Vice President Technology & New Materials Business, Tata Steel Ltd., Mr Kamesh Gupta, Chief - Graphene Business, Innoventure and Innovation, Technology & New Materials Business, Tata Steel Ltd. and Dr Dietmar Hueglin, Director BASF Innovation Campus Mumbai and officials from DST & Indo-German Chamber of Commerce.



*IGSTC signs LoI with BASF
Left: Mr R. Madhan, Right: Dr Dietmar Hueglin*

IGSTC has created an inclusive ecosystem of Indo-German funding opportunities for researchers and technologists to strengthen the pathways for industrial research.

Governing Body



Sanjeev Kumar Varshney
DST
Indian Co-Chair



Vishvajit Sahay
DST



Sandeep Verma
IIT Kanpur & SERB



Tata Narasinga Rao
ARCI



Sanjiv Rangrass
ITC



Kathrin Meyer
BMBF
German Co-Chair



Martin Goller
BMBF



Philipp von Ritter
German Embassy



Andrea Frank
Stifterverband



Clas Neumann
SAP

Indo-German Science & Technology Centre

A joint initiative by the Department of Science & Technology (DST), Government of India and the Federal Ministry of Education and Research (BMBF), Government of Germany to catalyse Indo-German strategic R&D partnerships.

2+2 Projects

Thematic based bilateral R&D+I project of industrial relevance by means of "2+2 mode of participation" of at least one Indian and one German research/academic institution and one Indian & one German industry.

Total Financial Support:

₹ 350 Lakh
(Indian institute & industry together)

€ 450000
(German institute & industry together)

The grant is for a period of 3 years

Phase-2

It is an opportunity to selected 2+ 2 projects with promising results to apply for an extension up to two years with additional financial support to cover the gap between the validation in relevant environment and system qualification.

Women Involvement in Science and Engineering Research (WISER)

Lateral entry for women researchers/technologists to be part of ongoing project in India/Germany.

The grant will also cover one visit per year for short stay up to 1 month in host country.

Total Financial Support:

₹ 39 Lakh (Indian awardee)

€ 48000 (German awardee)

Small Immediate Need Grants (SING)

Modest funding support to initiate proposals with a potential to embark on Indo-German collaboration.

Total Financial Support:

€ 10000/Proposal

Bilateral Workshops

Platform for substantive interaction between scientists/researchers from academia and industry from India & Germany to explore new avenues for Indo-German scientific collaborations.

Total Financial Support:

Up to ₹ 25 Lakh / € 30000

IGSTC Industrial Fellowships

Exposure of PhD students/researchers from India at a German industrial setup to promote applied research and technology development.

Total Financial Support:

PhD Industrial Exposure Fellowship:
€ 1500/month (for 3-6 months)

Post Doctoral Industrial Fellowship:
€ 2500/month (for 6-12 months)

Single round trip economy class airfare including visa fees and medical/travel insurance

Paired Early Career Fellowship in Applied Research (PECFAR)

Two-way exchange of researchers in pairs to explore Indo-German research landscape.

Total Financial Support:

€ 2300 per month/fellow
(1-2 months)

Single round trip economy class airfare including visa fees and medical/travel insurance

IGSTC Connect Plus

Mobility grant for successful Indian & German Indo-German Frontiers of Engineering Symposia (INDOGFOE) Connect awardee to promote scientific exchange & networking.

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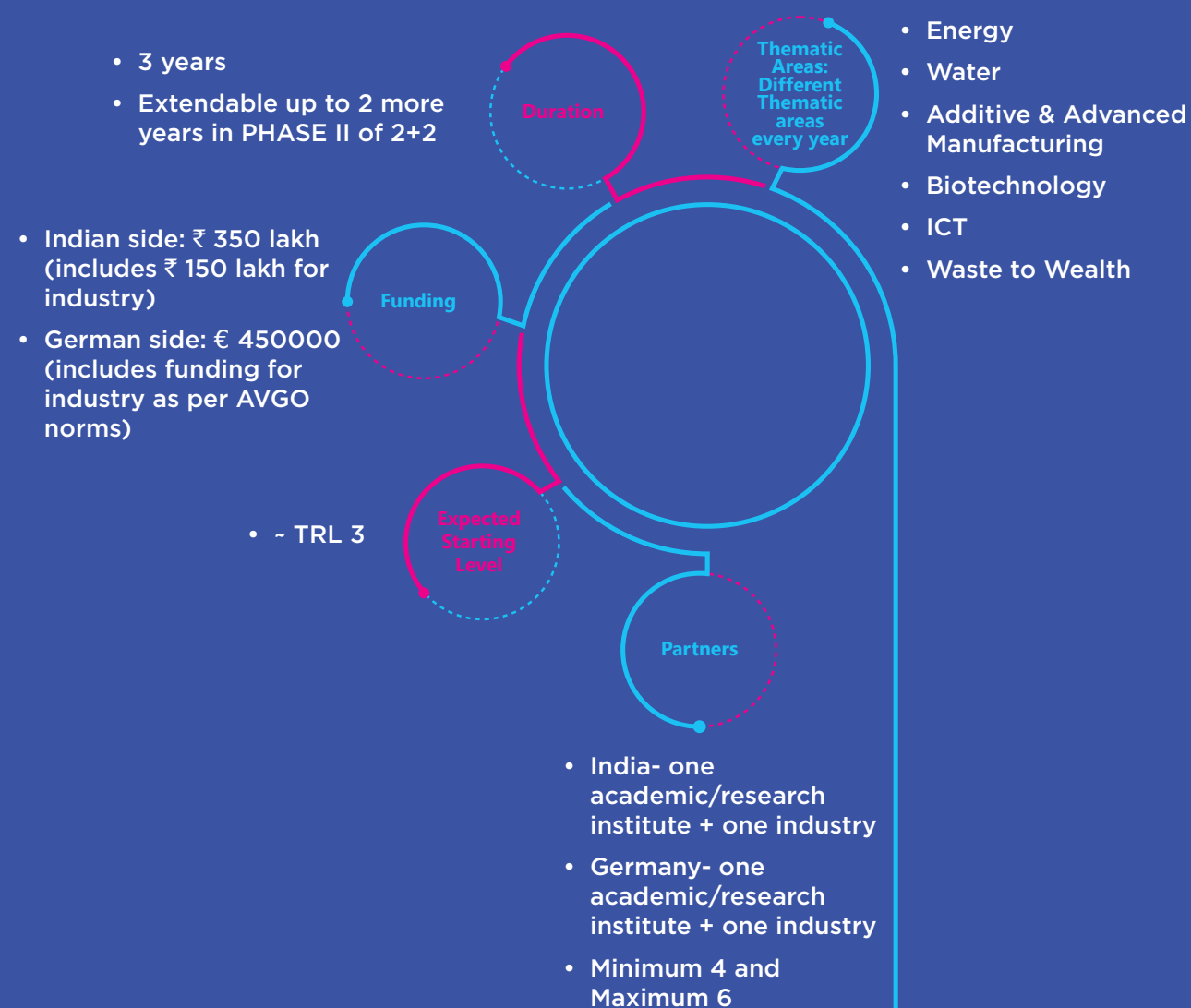


company/igstc

2+2 Projects

IGSTC intends to catalyse innovation centric joint R&D+I projects of industrial relevance by means of “2+2 Mode of Partnership” with the participation of research/academic institution and

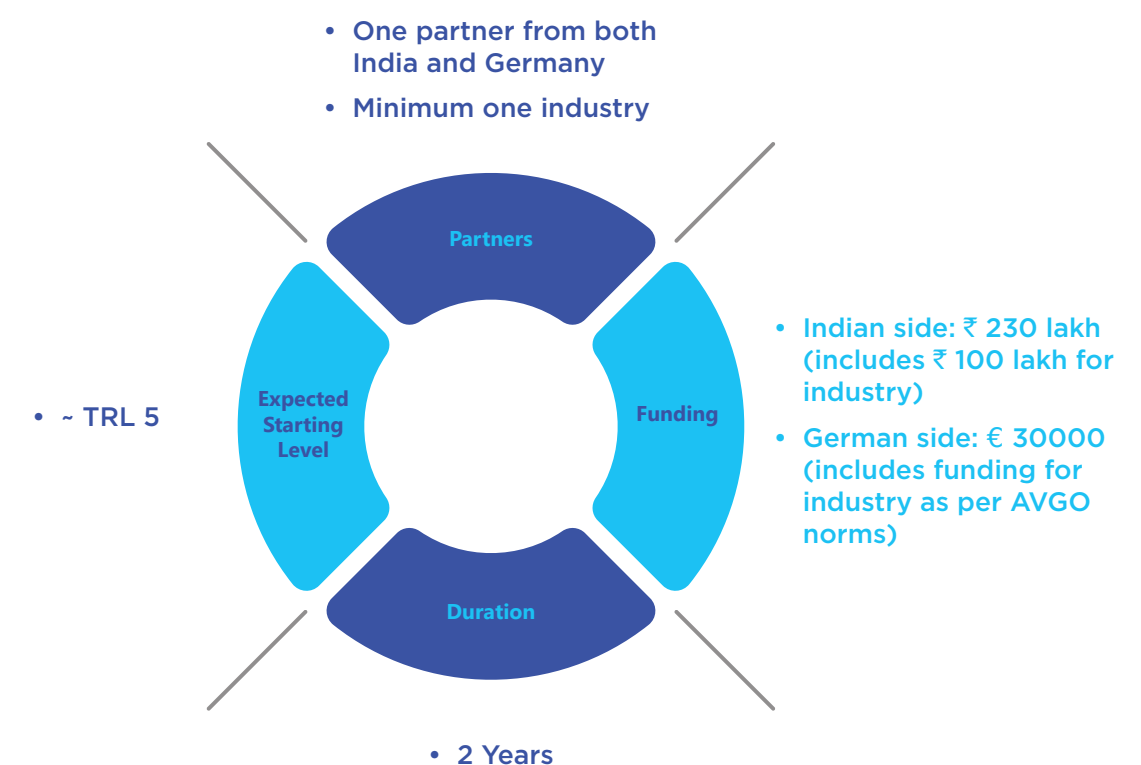
public/private industry from both India and Germany. The project proposal is expected to produce insight and exploitable research results leading to new technologies, products and/or services.



PHASE II of 2+2

It is an opportunity to selected 2+ 2 projects with promising results to apply for an extension up to two years with

additional financial support to cover the gap between the validation in relevant environment and system qualification.



For more information
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AgriTech



CirCulTeX

Circular urban cultivation systems with re-useable textile growing substrates

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Project Brief

Urban agriculture is integral part of sustainable city development for providing ecosystem services like air quality regulation, cooling, 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 inspires urban inhabitants, triggers sustainable consumer behaviour and leads to a societal transition towards bioeconomy.

Progress made/achieved

Partner 1

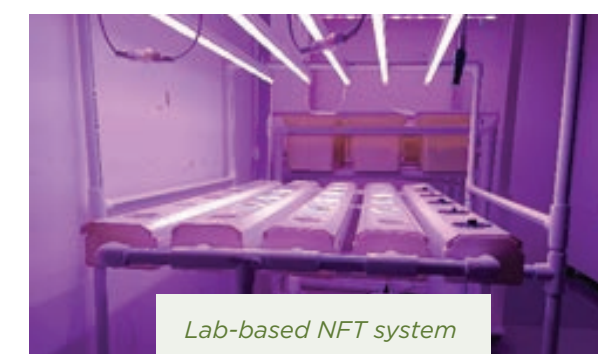
Amity University, Kolkata (AUK)

Indoor lab based hydroponics systems Dutch Bucket system and Nutrient Film technique (NFT) system has been established. Italian basil and tomato seeds are in the process of germination in coco choir for checking the optimal requirements for running the lab-based system by cultivating these plants.

Plant root samples from salt stressed region has been collected and microbial culture is under process for formulating novel PGPM from root endophytic microbes to assess plant growth character and stress resistant properties under lab-based hydroponics system.



Lab-based Dutch bucket system



Lab-based NFT system

Partner 2

Bidhan Chandra Krishi Viswavidyalaya (BCKV)

Deep Water Culture (DWC), NFT and Dutch Bucket systems for Hydroponics and aquaponics have been developed under poly house structure. Test run will be done with the existing substrate which will be replaced by the textile-based substrate in future experimental events.

Partner 3

Harimitti Agro Pvt Ltd (HMA)

Small scale NFT hydroponics systems are developed to optimize the business model unit that will be economically viable by the urban community and accessible for space with control of water temperature during summer along with the shade net in roof or terrace garden.

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.



Partner 4

University of Hohenheim (UHOH)

UHOH installed a hydroponic NFT systems in a greenhouse with 256 planting spaces and individual water reservoirs for carrying out experiments with multiple crops and textiles. In addition, three terrabioponic cultivation systems are under construction in a cold house.



Partner 5

German Institutes of Textile and Fiber Research (DITF)

At DITF, a similar hydroponic NFT setup was installed in the technical hall with 128 planting spaces. In addition, they installed a technical setup for carrying out textile characterization experiments to analyze water holding capacity, capillary effects and air/water-filled pore spaces of the textile structures.

Partner 6

Eschler Textile GmbH (ETF)

Existing textile structures of Eschler Textile GmbH were screened, the characteristics compared with the requirement list and seven promising, yet different textile structures selected for the initial experiments.



Publications

'Re-useable textile substrates for sustainable soilless crop cultivation in urban agriculture', Bastian Winkler, Jędrzej Cichocki, Bilitis Vanicela, Christoph Riethmüller, Michael Walz, Sanjit Debnath, Anwesha Chatterjee, Proma Ghosh, Vasu Vijayaragavan, Suhrid Chandra, Harshata Pal, Abstract accepted (on 28th March 2022) as Poster-Presentation at ICABR conference on 5th to 8th July 2022.

SensVert

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

Project Brief

In hydroponic systems, continuous monitoring of the ion ratios of nutrient solutions along with EC, pH and temperature promises an increase in the nutrient use efficiency and plant productivity with better control over the desired traits in the cultured crop, such as secondary metabolite profile, taste and appearance. Significant advances have been made in recent years to overcome the technical obstacles on the way to an ion-specific fertigation system. Most of these works investigated the control of the ion interference effect, which hinders the measurements of the concentration of single ions in complex solutions. However, a fully functional automated fertigation system to measure and control the concentration of the five major macronutrients, including PO_4^{4-} and Mg^{2+} is yet to be investigated, along with the comparison between automated ion specific fertigation management & traditional, EC and pH, based fertigation management.

To explore these issues and find a plausible solution, Sens Vert Project aims to develop an automated Internet of Things (IoT) based ion-specific sensor system to integrate into the hydroponic systems for continuous monitoring of NPK (Nitrogen, Phosphorus, Potassium), Ca and Mg. As a first step, framework of technical specification for an ion specific nutrient monitoring system for horticultural production was established. Furthermore, the experimental methods to evaluate such a system, as well as the requirement for the software of the different modules in a system for automated ion specific nutrient monitoring was defined.

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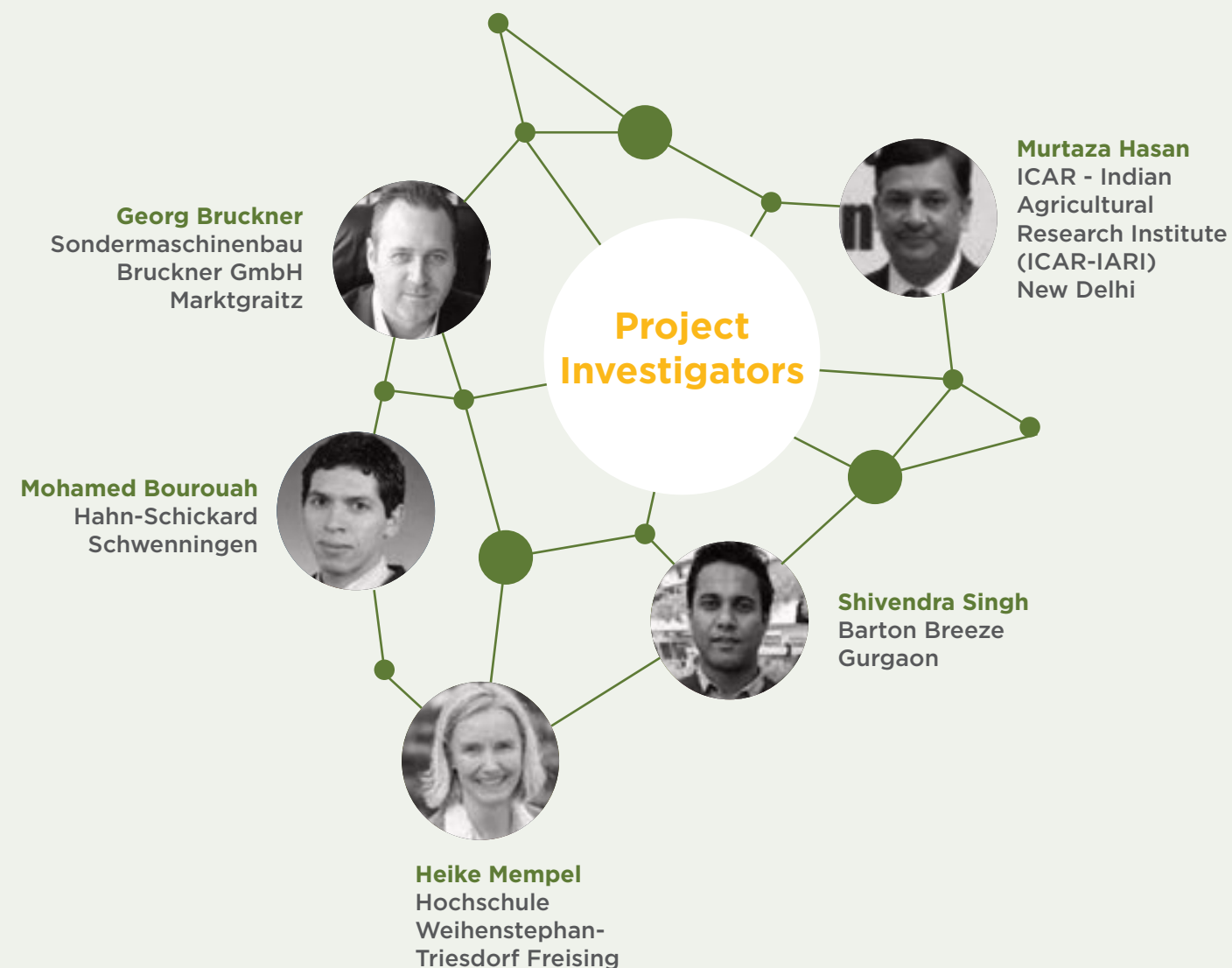
The project partners Hochschule Weihenstephan Triesdorf and Sondermaschinenbau Brückner GmbH (SMB) agreed on the specifications of the hydroponic test unit to be constructed by SMB as the centrepiece with high precision IoT stock solution dosing unit. The requirements and constraints of the plant-sensor interface during the development of the first prototype of the Sensor array at Hahn-Schickard Institute (HS) were specified. Simultaneous, experiments were conducted at ICAR - Indian Agricultural Research Institute (ICAR-IARI) with the cooperation of Barton Breeze and at Hochschule Weihenstephan-Triesdorf Freising (HSWT) helped to define the framework parameters (expected pH and nutrients ppm ranges, expected amount of suspended particles, & rate of changes in the solution) for the operation of the sensor system.

Subsequently, test units were set up at ICAR-IARI and HSWT to gather data for ion selective nutrient management. A fully functional hydroponic test unit was set up at IARI to monitor the parameters like pH, EC and water usage under different culture scenarios to determine the regular ranges of ion concentration, changes in ion ratios during the culture period and test the integration of sensors in an indoor vertical farm under laboratory conditions. A working

procedure for spectrophotometric analysis of nutrient solution samples to validate the ion selective monitor system was established.

The results of these measurements, along with the calculated concentrations of standard solution serve as the reference to evaluate the readings of the ions selective electrodes (ISEs). Single salt solutions with known concentrations were prepared at HSWT and sent to HS, with the aim of gathering data for a calibration strategy. The results of these early measurements showed that different sensitivities of individual electrodes called for suited calibration strategies and narrowing the measurement range may result in better accuracy. The first prototype of the sensor array including probes for NO_3^- , K^+ and pH has arrived at HSWT. The fertigation dosing unit constructed by SMB have arrived at HSWT in May 2022.

The first prototype of the sensor array including probes for NO_3^- , K^+ and pH has arrived at HSWT.



Progress made/achieved

The most important goals of these packages were the identification of the specifications, planning creation of a test unit and the development of the sensor platform. The activities of the individual project partners are listed below:

ICAR-IARI & Barton Breeze

- Information related to technical specifications of the ion-selective sensors and plant production system in vertical farming mainly consisting of leafy green vegetables were shared with HSWT and SMB Brückner GmbH.
- IoT and sensor controlled infrastructure for vertical farming in the greenhouse have been developed at Centre for Protected Cultivation Technology (CPCT), ICAR-IARI, New Delhi.
- Development and installation of sensor & IoT based auto dosing system for crops in vertical farming is under process and evaluation shall be completed by June 2022.
- Standardization of sensor values for nutrient management of leafy green crops will be completed by the end of the year.
- Design and development of automatic nutrient sensors for efficient water and nutrient management in vertical farming systems are in process.
- Potentiometric and photometric sensors for nitrogen, phosphorous, potassium, magnesium, calcium, EC and pH are designed and developed with a desired accuracy and tolerance of 1-2 ppm and 5-10 ppm.

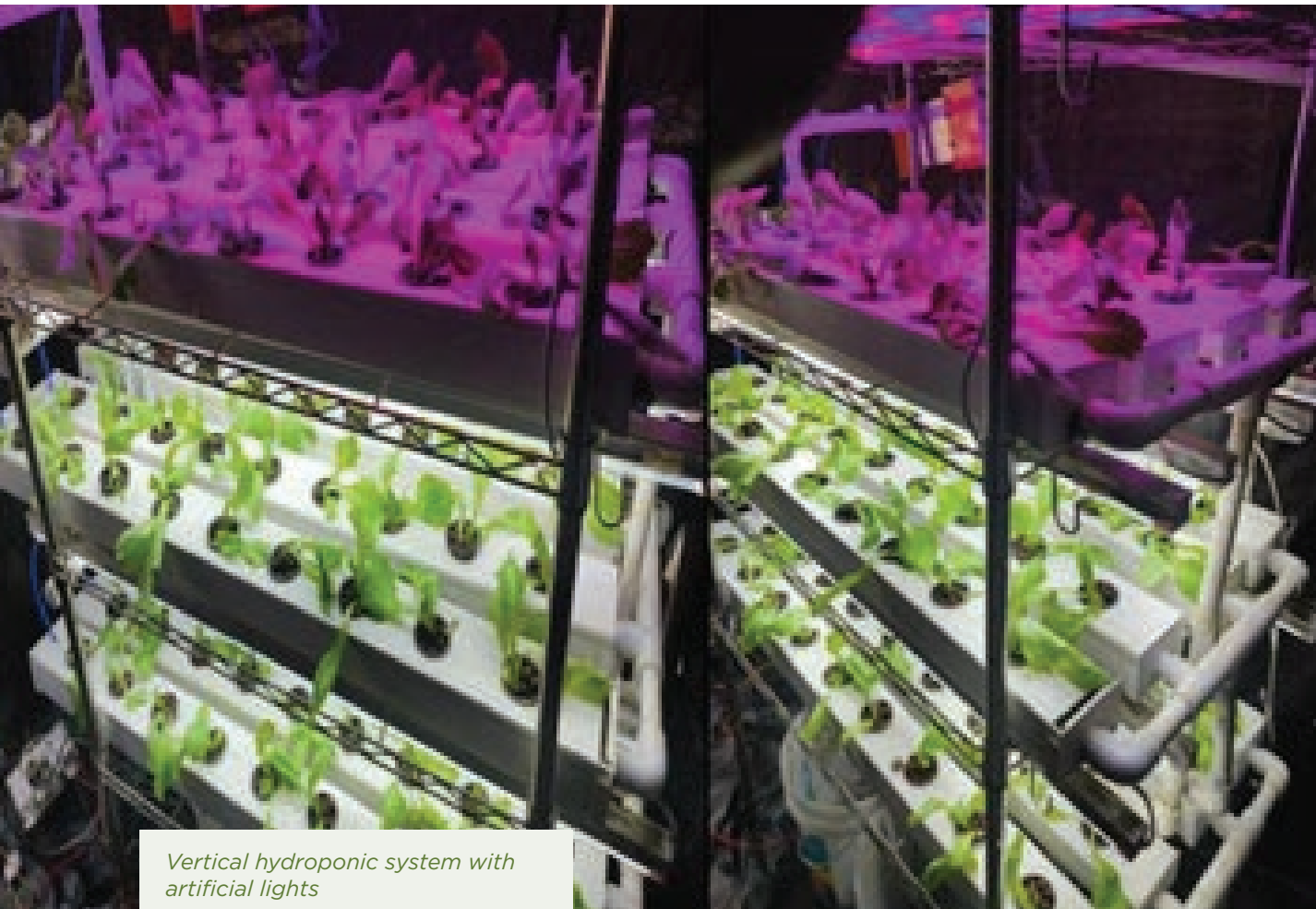


Hochschule Weihenstephan Triesdorf

- The stock solution injection unit developed at Sondermaschinenbau Brückner GmbH, is due to arrive at the HSWT at the beginning of May and is expected to be ready for installation in a testbed array including the ISE sensors shortly after.
- The first prototype of the ISE-sensor array developed at Hahn-Schickard Institute has been delivered to HSWT for test runs and calibration with standard solutions.

Both, the sensor array and injection unit are equipped with user interfaces for data acquisition & integration of the two components to yield a prototype fertigation monitoring unit.





Vertical hydroponic system with artificial lights

Hahn-Schickard Institute

- The first version of ion selective electrode readout unit is developed and tested by Hahn-Schickard with standards of a known solution. It can measure pH, nitrate, potassium and calcium ions. Additional channels for phosphate and magnesium are not yet tested. Due to the chip shortage, Hahn-Schickard had redesigned the electronics with other available complements.
- The first milestone has been completed with the shipment of the ISE-Sensor to the HSWT for further test runs and future integration into a hydroponic test unit.

Sondermaschinenbau Brückner GmbH

- The test unit for dosing nutrient solutions was manufactured according to the specifications and requirements.
- The first prototype was completed and will be delivered to the HSWT soon.

Publications

Smart Urban Farming Technology. Technical Bulletin. TB-ICN: 270/2022. Murtaza Hasan et al. 2022.

Conferences/Presentations

Two abstracts related to the project have been accepted for submission for poster contributions in the International horticultural congress 2022. One of these will be submitted as a full text proceeding.

- Design and Development of Automatic Nutrient Sensors for Efficient Water and Nutrient Management in Vertical Farming Systems
- Identification of variations in nutrient uptake ratios of Pak Choi (*Brassica rapa*) as an indicator for the potential of ion-specific nutrient management

NOMIS

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

Project Brief

Fertilizers and pesticides used in farm to boost agricultural productivity can exhibit moderate to lethal levels of toxicity in humans. These chemicals move up through the food chain and leads to biomagnification. Various methods reported 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. Hence, by combining the complementary expertise of the Indian and the German partners, NOMIS 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. This device will comprise a microfluidic platform integrated with printed electrodes based on analyte-sensitive ink formulations and 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.

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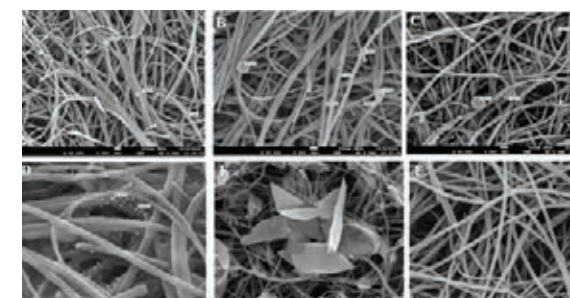
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Progress made/achieved

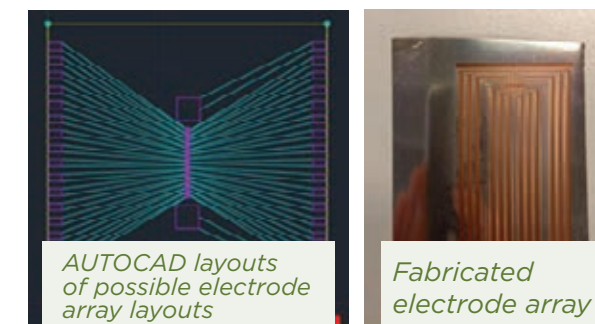
IIT Kharagpur

Synthesis of Cu-NPS (Copper-nanoparticles)/CNTs (Carbon nanotubes) composite for NO₃⁻ sensing

IIT Kharagpur has provided 2 possible protocols for making of CuNPs/CNTs composite for NO₃⁻ sensing. Furthermore, optimization of the electrode platform, sensing performance and selectivity for nitrate was done for both approaches. A simple electrochemical deposition strategy was opted instead of chemically synthesised Cu/CNT composite material as a nanointerface platform. In case of chemically synthesised Cu/CNT composite material, the characteristic response for nitrate was not seen and background currents were high. This may be attributed to possible oxidation of copper NPs in the material. Partners from TU Munich suggested the usage of electrodeposited copper NPs on their electrode surface compared to modification with chemically synthesised composites. In this regard, IIT Kharagpur has utilised a facile electrochemical deposition method for copper NPs deposition on MWCNT, since the latter provides a higher surface area for deposition of copper NPs.



SEM Images for Cu/CNT Composite



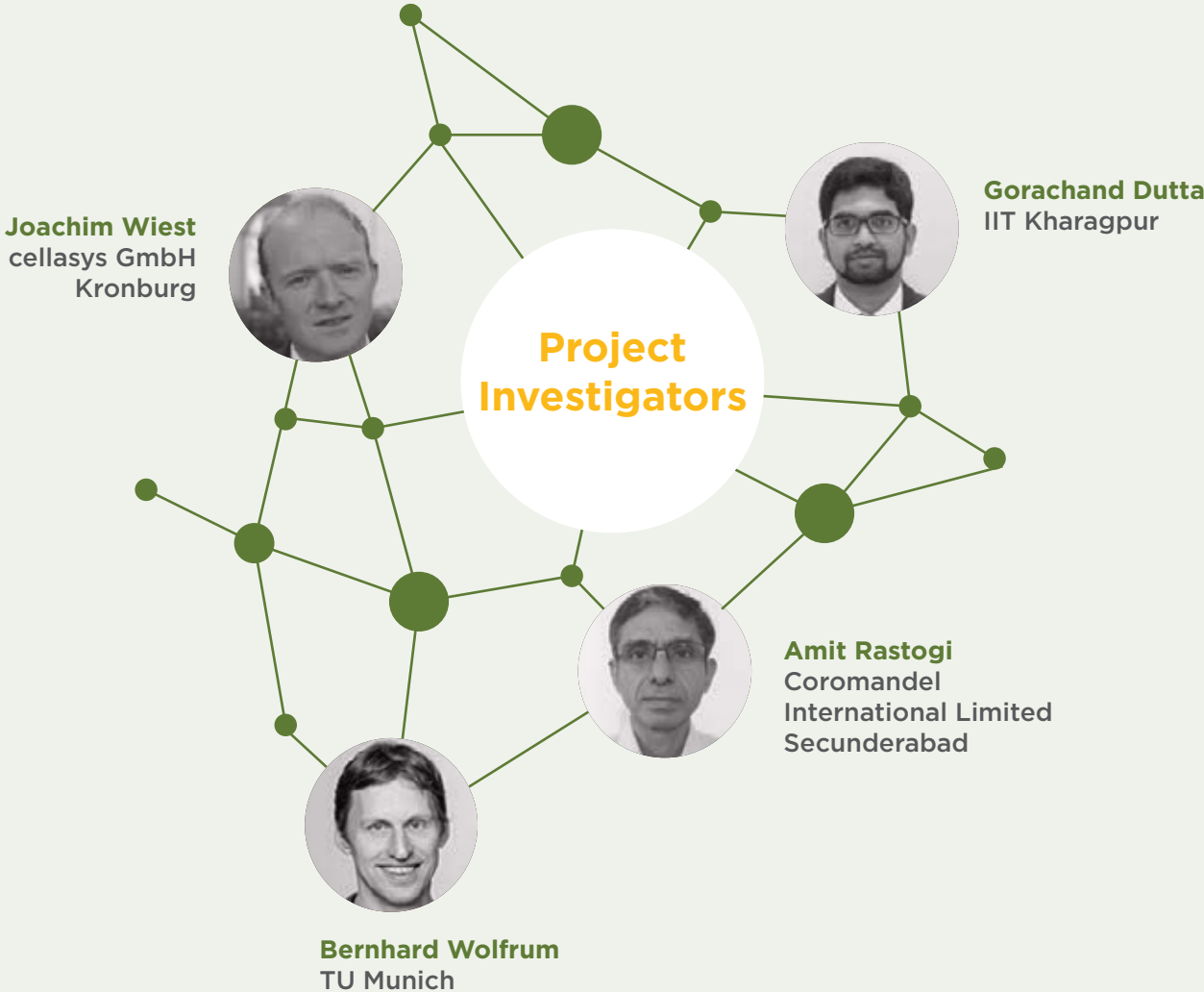
Ink formulation

Protocol prepared by the IIT Kharagpur was further configured and optimized to accommodate different substates which will be used in the final product. Furthermore, possibilities to make ink formulation of the composite to facilitate its deposition during the fabrication step requires further changes in protocols for production of CuNPs/CNTs composite.

TU Munich (TUM)

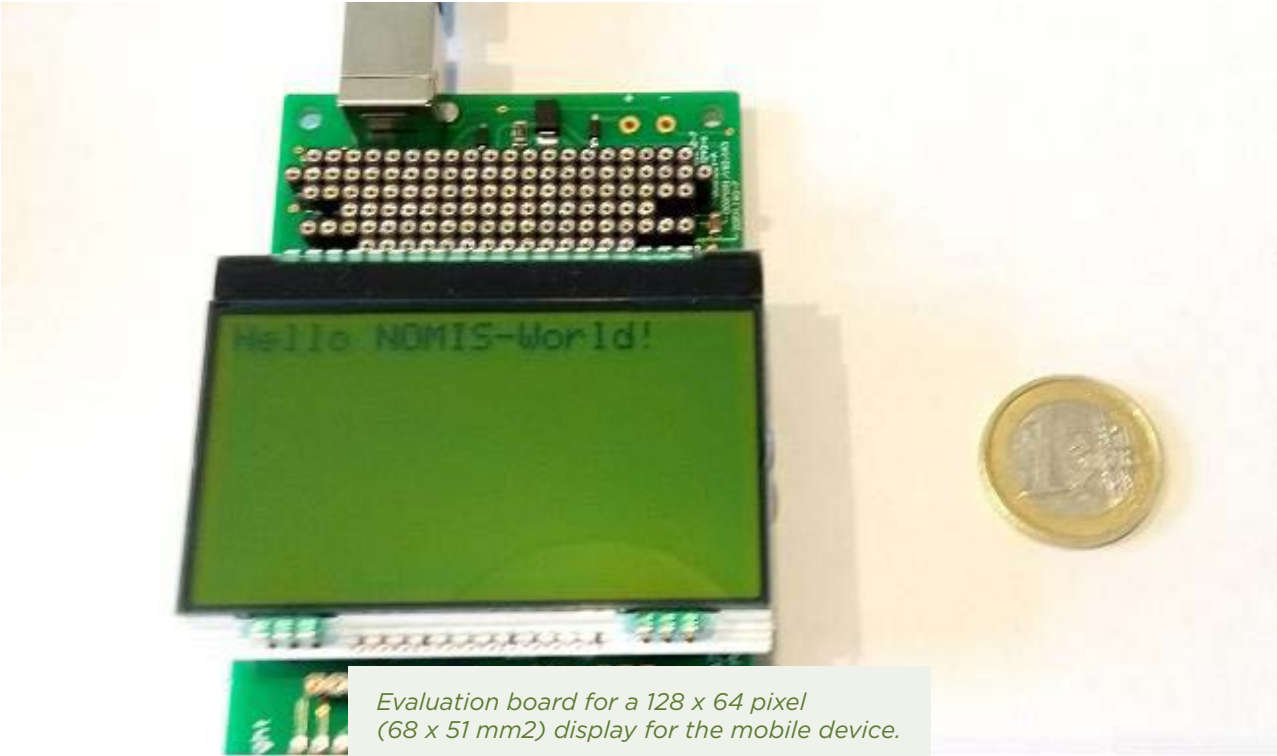
Fabrication of the microfluidic platform and integration with printed electrode arrays

The designs of the printed electrode arrays were drawn in AUTOCAD. Two designs for the arrays were established as an exact decision on the way to interface the electrode array is yet to be decided. The first design can be incorporated using a FPC (Flexible Printed Circuit) connector and the second design is compatible with the Yamaichi connector, which is beneficial for initial testing of the electrode arrays.



The designed electrode arrays were fabricated using metal sputtering on Polyimide (PI) foils and laser patterning to define electrode sites and feedlines. This rapid fabrication method was implemented as a fast-prototyping approach for initial testing before establishing appropriate printing procedures. To isolate feedlines, chemical vapor deposition of parylene C

was used and its removal from electrode sites and pads was done using a combination of laser patterning and O₂ plasma etching. Further tests concerning the stability of the insulation must be conducted and possible considerations are to be taken about whether parylene C is the best material for isolating the feedlines.



cellasys & TU Munich

Mobile device prototype

A workplace with the electronic design automation software Altium was

established. The circuit design process was initiated considering the current semiconductor supply chain crisis. The evaluation of possible display solutions for the mobile device started.

AutoNutri

Onsite multi-ion monitoring system for online nutrient-laden water control in vertical hydroponic systems to minimize environmental impact

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Project Brief

One of the major challenges of cultivation in a hydroponic system with a closed irrigation system is the optimized nutrient regulation due to inaccurate information of composition, although many researchers describe the determination of the concentration of individual ions in solution as the key information for optimized operation. Current practice is the determination of conductivity, pH, redox potential and temperature. The consequence is the limited possibility to adjust nutrients to the needs of individual crops to avoid deficiency or eutrophication. The operators therefore periodically drain and replace the nutrient solutions. The aim of the project is to develop an onsite multi-ion monitoring system for automated online control of nutrient input in vertical hydroculture systems with closed circulation systems based on a feedback-controlled supply of nutrients. The monitoring system enables the effective use of nutrients for optimal plant growth by targeted regeneration of nutrient solution and thus contributes to a reduction in water pollution due to premature nutrient disposal into the environment. Nutrient monitoring is based on the direct potentiometric determination of relevant ions using ion-selective sensors. The choice of ions is characteristic of the growth of the selected crops. The sensors are integrated into a microfluidic system, which enables automated sample collection and adjustment of the measurement matrix. Calibration and data acquisition/processing are carried out using "Machine Learning (ML)" algorithms developed in the project to compensate for non-linear effects due to ion interference/cross-sensitivity and electrode/temperature drift. Prototypes will be provided to end users in India for beta testing.

Progress made/achieved

Some of the main objectives of the project:

- The development of an on-site multi-ion monitoring system OMIS (as Lab Demonstrator) for automated measurement of macro and key micro-nutrient concentration in vertical hydroponic nutrient solution systems.
- The development of a feedback-controlled release system of the key nutrients in a closed irrigation hydroponic system.
- Combining the onsite multi-ion monitoring system for the measurement of nutrient concentration with the feedback-controlled release system for the key nutrients in order to build a prototype of a microcontroller based online monitoring system for automated control and release of nutrients in relevant vertical hydroponic systems.
- Validation of the prototype in a hydroponics system for selected crops as well as beta testing by end users in India.

One of the most critical objectives of this project is to ensure that the system is compatible with crops that are commercially important in terms of consumption, essential oil production and medicinal properties. With respect to this, consortium have selected Lettuce (*Lactuca sativa* var. *crispa* 'Lollo Rossa'), Brahmi (*Bacopa monnieri*), Thyme (*Thymus Bulgaria*), Stevia (*Stevia rebaudiana*) & Basil (*Ocimum basilicum*) as model crops for this project.



Basil
(*Ocimum Basilicum*)



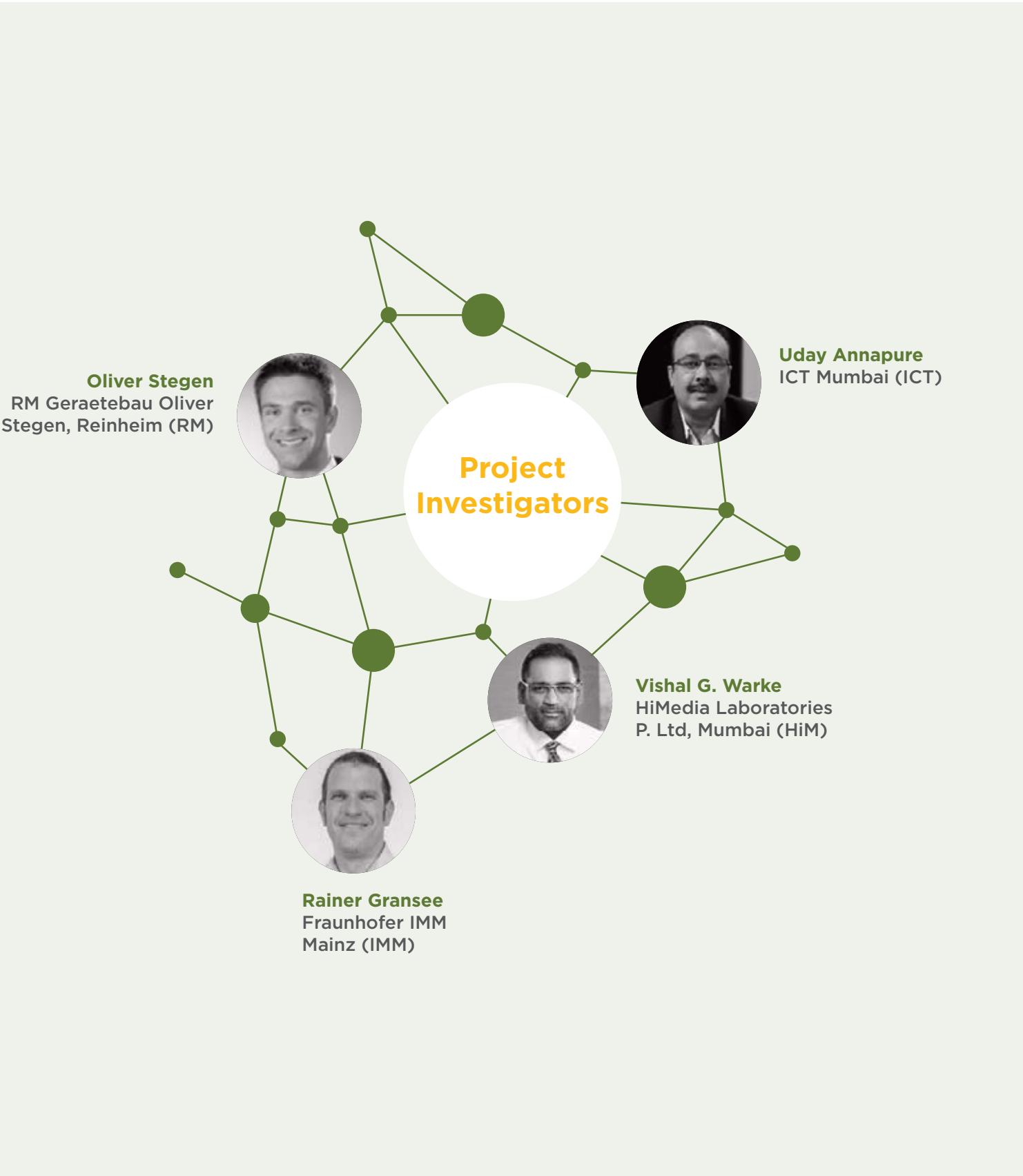
Thyme
(*Thymus bulgaria*)



Lettuce (*Lactuca sativa*
var. *crispa* 'Lollo rossa')



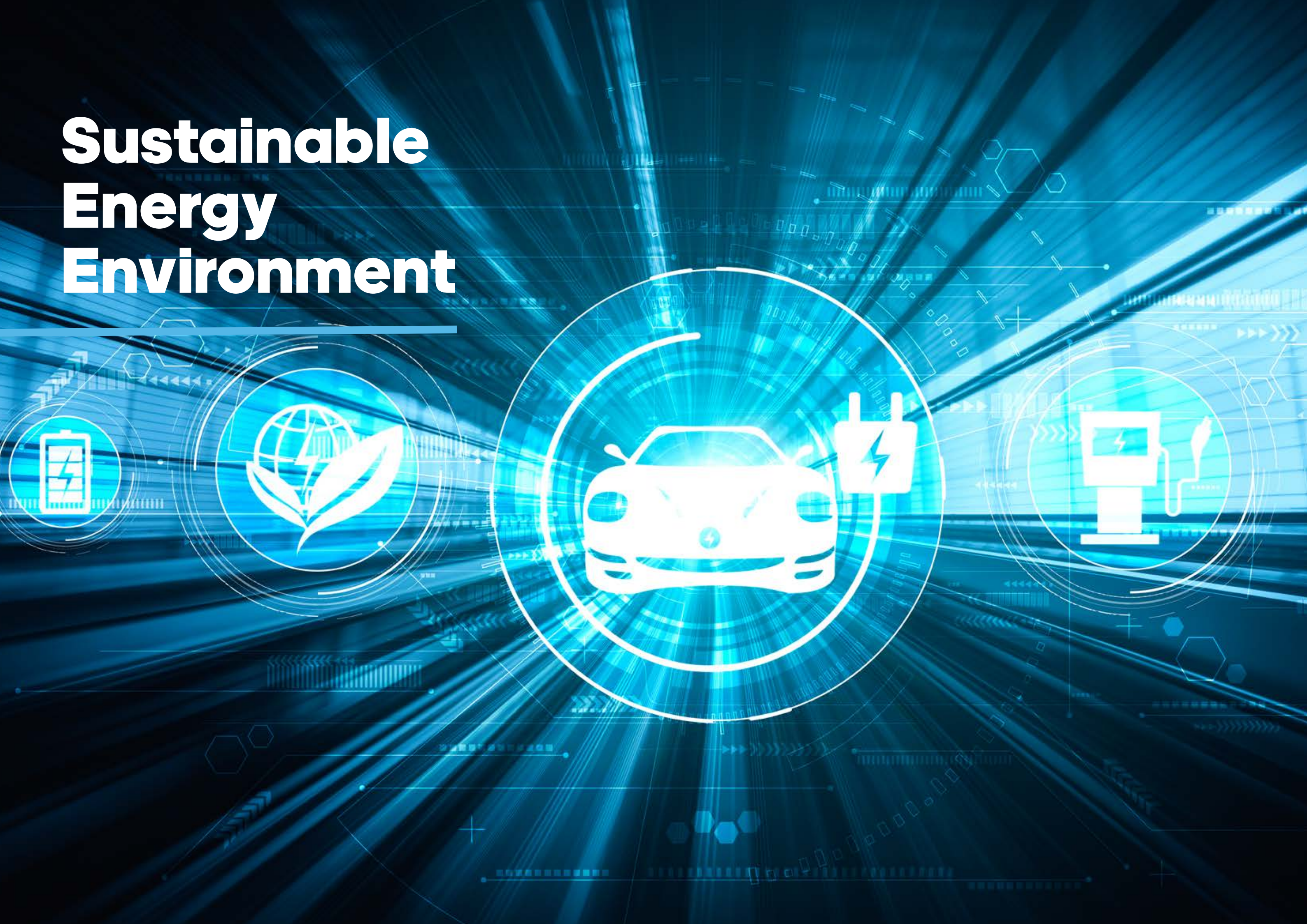
Stevia
(*Stevia rebaudiana*)



Salient Research Achievements

- Assay Procedure for 2 Crops for Nutrient Release in Hydroponic system has been developed
- Lab Demonstrator: Multi-ion detection of 4 key ions in the concentration range has been standardized
- Hydroponics system for 2 crops for testing and validation of prototypes has been set up.
- The model plants for this project namely Lettuce (*Lactuca sativa var. crispa 'Lollo Rossa'*), Brahmi (*Bacopa monnieri*), Thyme (*Thymus Bulgaria*), Stevia (*Stevia Rebaudiana*) & Basil (*Ocimum basilicum*) have been successfully grown and maintained hydroponically at Igatpuri.
- Climate Tests of Electronic Components, Sensors, and Online Measuring System (Test passed, parameters defined)

Sustainable Energy Environment



CO₂BioFeed

CO₂ and Biomass as feedstock for the production of fuels and chemical intermediates

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Project Brief

Catalytic processes that are ecologically & economically advantageous form the base of sustainable value chains in the industry. However, fossil resources are currently used as the primary raw materials in the production of fuels and in the chemical industries. In the CO₂BioFeed project, a consortium of academic institutions and industry partners from India and Germany are collaborating to use Carbon dioxide (CO₂) and biomass as sustainable feedstock to produce high value chemical intermediates such as epoxides and acrylates.

CO₂ plays an important role as a soft oxidizing agent for the epoxidation of short-chain alkenes and other highly valuable follow-up products. It can be also used as a carboxylating agent to produce acrylic/methacrylic acid. Carbon monoxide (CO), obtained as a renewable by-product can be utilized in other industry-relevant production processes. Furthermore, a key process in the industrial value chain to produce a basic chemical containing only carbon from sustainable sources will be compared via a Life Cycle Assessment (LCA). The main goal of the project is to scale-up the process to industrial scopes, confirm the performance of the newly developed catalysts under industrial conditions and assess the cost benefits and environmental impact of the processes.

Progress made/achieved

Indian Association for the Cultivation of Science (IACS)/IIT(ISM), Dhanbad/ Reliance Industries Ltd. (RIL)

The work on epoxidation of propylene and ethylene has been initiated in India. Functional metal organic frameworks (MOFs) (Cr-MIL-101, Fe-MIL-101) have been synthesized through solvothermal crystallization in autoclave under refluxing conditions. These highly porous support materials were impregnated with reactive Ru and Ag nanoparticles (NPs) through wet impregnation. The catalyst was sent to Germany for evaluating ethylene epoxidation using CO₂. The Indian colleagues at the Indian Association for the Cultivation of Science (IACS), Kolkata, IIT (ISM) Dhanbad introduced some new innovative catalyst systems based on their amine surface-modified SBA-15 mesoporous materials and TUD-1 materials.

For NiO@SBA-15 nanocomposite materials with Ca. 13 % Ni (II) loading a high BET surface area of 409 m²/g and weak surface acidity were determined (IACS). The catalytic activity of NiO@SBA-15 (Nickel oxide@Santa Barbara amorphous-15) was tested at IIT (ISM). Several catalysts were sent to Germany for evaluating ethylene epoxidation using CO₂. They also developed and characterized mesoporous TaPO₄ catalyst for synthesizing acrolein and glycerol carbonate from glycerol.



RIL's Gas Reactor set up (to be integrated with GC)

Reliance Industries Ltd. (RIL) developed various mixed metal oxide and supported metal oxide catalysts. The performance evaluations for various carboxylation and glycerol conversions are being evaluated at IACS Kolkata. Online GC installations are in progress. The data is generated to serve as input for process simulation. The safety concept for the laboratory tests was developed and secured.

The Indian colleagues at the Indian Association for the Cultivation of Science (IACS), Kolkata and IIT (ISM) Dhanbad introduced some new innovative catalyst systems based on their amine surface-modified SBA-15 mesoporous materials and TUD-1 materials.



Ruhr-Universität Bochum (RUB). Process simulation was initiated and CO₂-activation & adsorption of atomic oxygen on the catalyst surface were explored with RUB made ceria and indium oxide catalysts to derive process simulation data and identify the process window for operating the high-temperature mini plant. For further process validation and development, an online gas chromatograph was received and integrated for analytical purposes together with the experimental Berty-Reactor into an existing setup at RUB.

As part of the process development, initially, the hydrogenation activity of the catalyst was investigated and later catalysts from IACS/ISM/RIL and RUB were compared. The initial functional MOF catalysts (Cr-MIL-101, Fe-MIL-101) impregnated with nanoparticles (Ru and Ag) of the Indian partners were not sufficiently stable at the higher reaction temperatures. However, the metal nanoparticle modified SBA15 and TUD-1 catalysts showed promising results at RUB in reactions activating CO₂ and producing valuable synthesis gas. Fe, Ag@SBA-15 nanocomposite materials received at the end of 2021 have shown promising reactivity about reverse water gas shift (RWGS) and epoxide formation. The catalysts were characterised by BET and XRD measurements.

Further investigations of the Fe, Ag@SBA-15 catalysts in batch operation for the epoxidation of styrene were promising.

RWE Power focused on the safety concept necessary for any test runs on the pilot plant scale with RIL and RUB. The most suitable site for the respective reaction as well as safety, legal and technological limitations of the sites and materials needed were evaluated. After involving experts of safety technology (Rembe GmbH), a safety concept for the laboratory tests was developed. The results of the safety concept and process development at RUB lead to a re-evaluation at RWE, to decide on which pilot plant reactors could be used for the project.

Parr Germany. Mini-Plant constructed at Parr considering the inputs of the consortium was engineered into a novel high-temperature Berty-Reactor and delivered to RUB. The process development carried out at RUB took place in close consultation with the partners and different modes of operation (continuous and batch) and the influence of different process parameters (pressure, residence time, stirrer speed, etc.) on the adsorption behaviour of the catalyst were investigated.



Publications

- *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, 11882-11889.
- *Selective N-formylation of amines catalysed by Ag NPs festooned over amine functionalized SBA-15 utilizing CO₂ as C1 source.* Sayantan Chongdar, Sudip Bhattacharjee, Shiyana Azad, Rajaram Bal and Asim Bhaumik*, *Molecular Catalysis* 2021, 516, 111978.
- *Nickel Nanoparticles Immobilized over Mesoporous SBA-15 for Efficient Carbonylative Coupling Reactions Utilizing CO₂: A Spotlight.* S. Chongdar, S. Bhattacharjee, Shiyana Azad, Surajit Samui, Saikat Dutta, Rajaram Bal and Asim Bhaumik*, *ACS Applied Materials & Interfaces* 2021, 13, 40157-4017
- *Soft templating route for the synthesis of mesoporous tantalum phosphates and their catalytic activity in glycerol dehydration and carbonylation reactions.* Kushanava Bhauduri, Anindya Ghosh, Aline Auroux, Sauvik Chatterjee, Asim Bhaumik and Biswajit Chowdhury*, *Molecular Catalysis* 2022, 518, 112074.
- *Synthesis of cyclic carbonates of different epoxides using CO₂ as a C1 building block over Ag/TUD-1 mesoporous silica catalyst: A solvent free approach.* Kumer Saurav Keshri, Sudip Bhattacharjee, Aniruddha Singha, Asim Bhaumik*, Biswajit Chowdhury*, *Molecular Catalysis* 2022, 522, 112234
- *Hydrogenation and Hydrogenolysis with Ruthenium Catalysts and Application to Biomass Conversion.* Thomas E. Müller*, *InTech Open*, 2021, DOI 10.5772/intechopen.97034
- *T. E. Müller*, CO₂BioFeed: Kohlenwasserstoffe im Kreislauf halten, Innovationsradar zur Ressourcenwende, Kompetenznetzwerk Umweltwirtschaft. NRW, 2021, 32, online available at https://www.knuw.nrw/fileadmin/public/Redaktion/Dokumente/Publikationen/Innovationsradare/2021/Wachs_tumskern_CO2_als_Rohstoff_fuer_die_Kunststoffindustrie.pdf.*

Papers published in conference proceedings, popular journals etc.

Energy transition and the potential of hydrogen

Thomas Ernst Müller*

Jahrestreffen Hochdruckverfahrenstechnik 2021 - HDVT

Lecture presented on 16.3.2021

Energy Storage Systems for the Supply of the Process Industry with Renewable Energy

Steffen Schneider, Thomas Ernst Müller*

DGMK/ÖGEW Frühjahrstagung 2021

Lecture presented on 21.4.2021

Power-to-X: New Raw Materials for a Climate-Neutral Chemical Industry

Thomas Ernst Müller*

18th European Meeting on Supercritical Fluids - EMSF 2021, Session 13: Green Chemistry 3

Lecture presented on 5.5.2021

Power-to-X Technologies, Part of a Sustainable Industrial Ecosystem

Thomas Ernst Müller*

18th International Conference on Carbon Dioxide Utilization - ICCDU 2021

Lecture presented on 19.7.2021

PhD/Master thesis supervised

1.

Master Thesis by
B.Sc. Kendra
Bittner
completed at
(RUB) Bochum,
17.06.21

2.

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

3.

PhD thesis of
Mr. Kumer Saurav
Keshri, Kushanava
Bhaduri, Anindya
Ghosh (supported
by institute) to be
submitted at IIT
(ISM) Dhanbad

SELBA

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

Project Brief

With the development of safe and cost-effective high energy density all solid-state lithium batteries, we can realize the dream of sustainable road transport system. The research on such systems is carried out mainly due to two reasons: 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 and 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, they are 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.

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Progress made/achieved

Following milestones have been achieved towards developing solid electrolytes for all solid state batteries.

- Optimized experimental conditions for the synthesis of Li₇La₃Zr₂O₁₂ (LLZO)
- Protocols for the bulk production of LLZO
- Experimental conditions for the synthesis of Ta doped LLZO
- Optimized experimental conditions for the synthesis of multi-elements doped LLZO.
- Optimized experimental conditions for polymer composite solid electrolyte
- Optimized experimental conditions for additive based solid electrolyte
- Interfacial modification - Use of a binder and subsequent sintering at high temperature



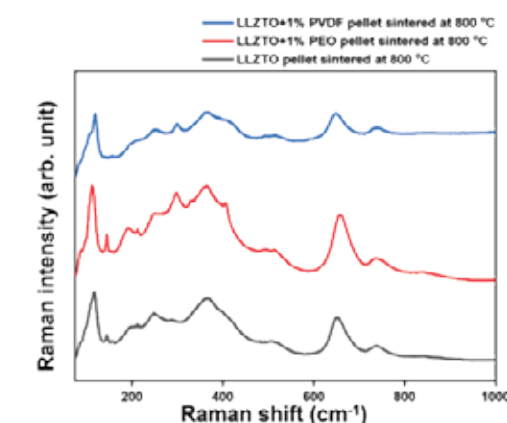
Polymer sheet dimensions (length x width x thickness): 10 cm x 6 cm x 100 μm



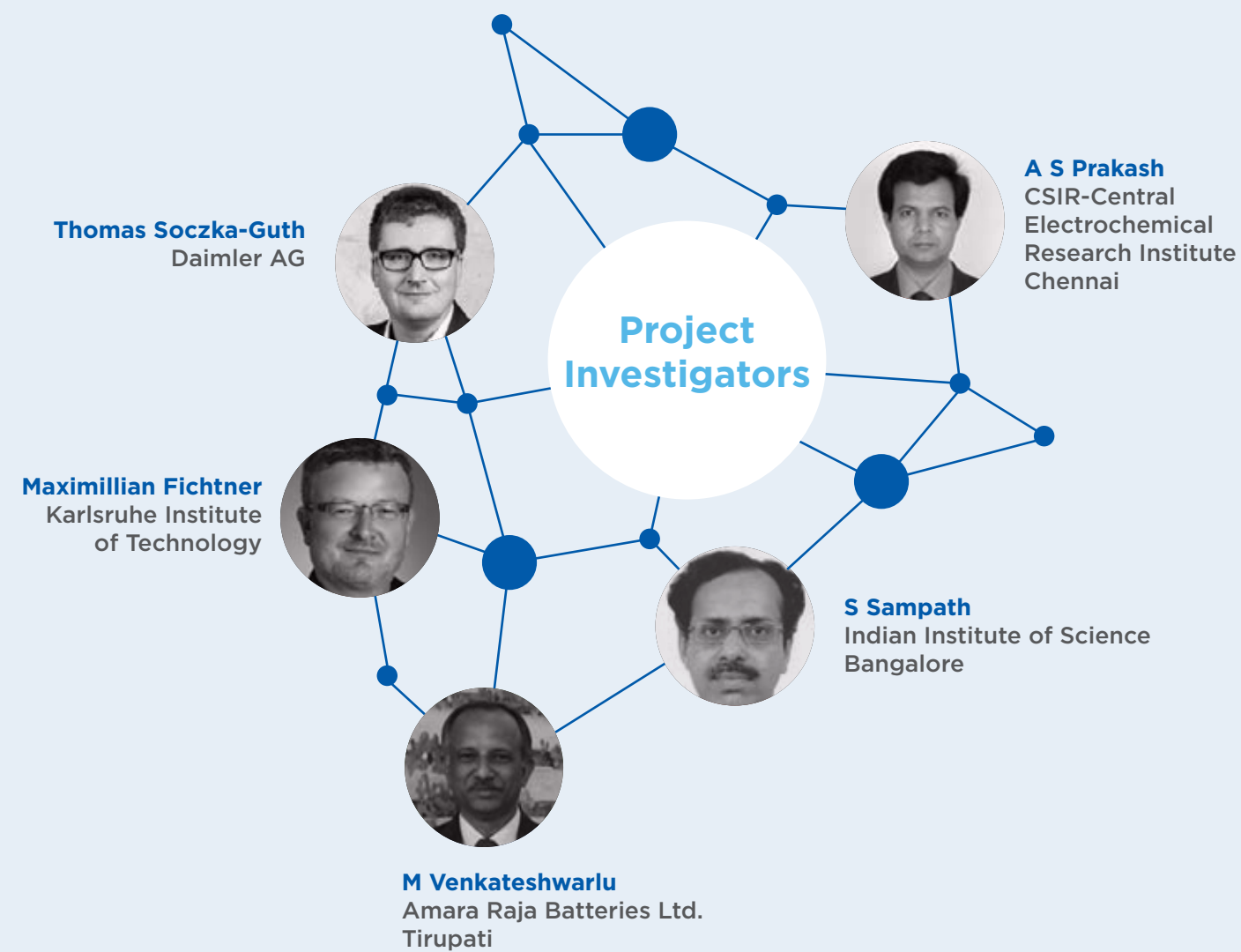
Large area LLZO films

Salient Research Achievements

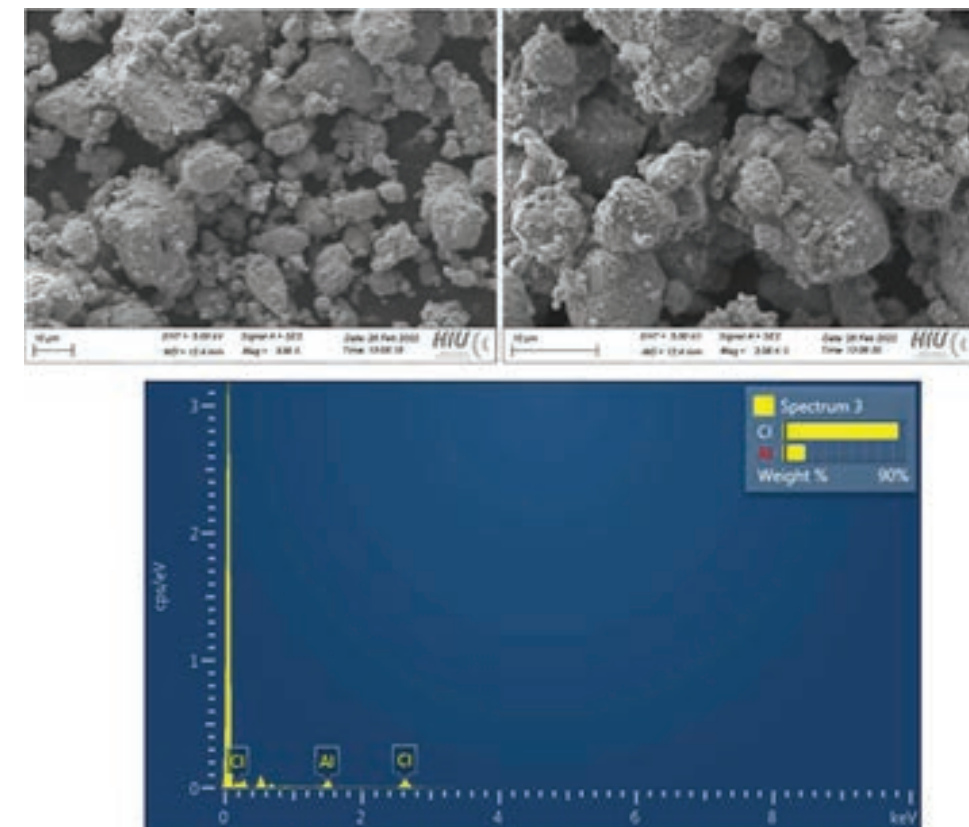
- Synthesis and optimization of garnet type solid electrolyte and new phases with high ionic conductivity (10⁻⁴ S/cm).
- Different methods of preparation resulting in reduction of temperature for synthesis has been achieved.
- Following extensive physicochemical characterization using spectroscopy and preliminary microscopy, the electrode fabrication of various lithium ion conducting electrolytes has been optimized. Nano materials based NMC (Lithium-Nickel-Manganese-Cobalt-Oxide) Cathode with high density has been made for further studies.
- Thin film coating of a surface layer of an oxide by magnetron sputtering carried out to reduce the interfacial resistance across NMC cathode and characterization of interface layer has been carried out.



Raman spectra of LLZTO, LLZTO+1%PVDF and 1% PEO pellets sintered at 800 °C.



- Electrochemical polarization studies using coin cells has been performed and excellent stability is observed.
- Preliminary studies on full cell with Li metal – solid electrolyte – appropriate cathode has been carried out.
- Prepared large area LLZTO films (2cm length X 2cm width X 100 μm thickness) and polymer composite solid electrolytes (10cm length X cm width X 100 μm thickness) with high ionic conductivity has been synthesized for further fabrication of pouch cells.



Different magnified SEM images and EDS mapping of the LiAlCl_4

HERCET

Development and validation of a cost-effective hybrid electric drive solution for small two-wheelers for reducing CO₂ emission

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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 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

IIT Madras (IITM)

Develop and validate an engine simulation model; Develop a CVT model, integrate with the engine (performance and emissions) and preliminary vehicle model and validate; Integrate the models and implement different hybrid topologies and combinations of subsystem components in the mode.

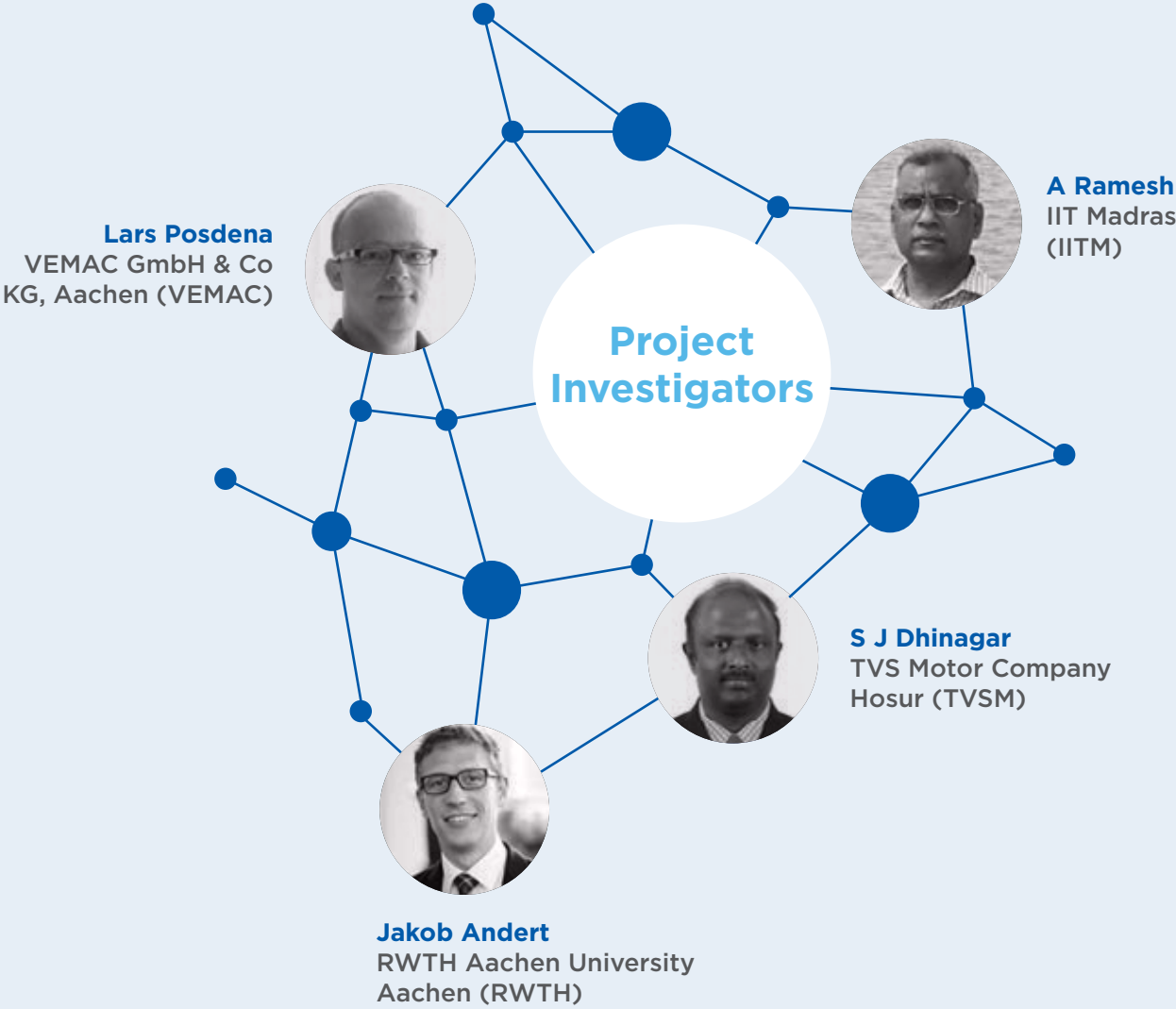
The conventional vehicle powertrain including the engine and the CVT (Continuously Variable Transmission) was modelled and validated with test measurements. A steady state engine test bench has been created using the engine provided by TVS Motors (TVSM) with necessary instrumentation for performance, combustion and emissions. The engine was tested at 70 different steady state speed-load points to characterize the same. The Three Way Catalytic (TWC) converter efficiency was calculated by measuring the emissions at engine-out and tail pipe locations at about 30 steady state points.

With the transient vehicle test measurement, the entire conventional powertrain model was validated



Steady state engine test setup at IITM

Maps of these measurements were used for the simulation model. A transient engine-out emission model was developed based on Artificial Neural Network (ANN). Training the ANN model requires transient emission data. Hence, a few slow transient emission measurements were done in steady state test bench in IITM. For validation of the entire powertrain model and measuring the CVT efficiency, steady and transient tests were conducted on the vehicle on a chassis dynamometer at TVSM. The vehicle was specially instrumented for this measurement. With the transient vehicle test measurement, the entire conventional powertrain model was validated. The developed engine and CVT models were presented and handed over to RWTH to perform drive-cycle simulations and compare all the four hybrid powertrain topologies chosen at the end of first phase of the project.



Vehicle test bench at TVSM

TVS Motor Company, Hosur (TVSM)

Evaluate different hybrid controller architectures and methods of integration with the engine controller; Evaluation with respect to cost, package size, driving distance and emissions

TVSM supported IITM team in conducting test for verification of the CVT model and

collection of emission test data (2nd & 3rd milestones). TVSM is supporting the 5th milestone with respect to the feasibility of component integration & development. Work related to the 7th milestone is under progress.

RWTH Aachen University, Aachen (RWTH)

Develop and validate EM and Vehicle models

For a profound system simulation validated components models are necessary. The map-based electric machine model of a suitable 48 V machine for a scooter application was already introduced last report. Meanwhile, the model was fine tuned to fit the measurements at the test bench. Moreover, a Vehicle model has been developed and parameterized based on technical data provided by the project partner TVSM and IIT Madras. The model structure is depicted in the Figure "Vehicle Model Structure".

VEMAC GmbH & Co. KG

The new proto vehicle controller is ready for commissioning on the upcoming next demonstration vehicle. Since all new controller functions are already integrated into the actual used development system / OSEK as part of the continuous integration process, the transition to the new controller type will go smoothly.

Salient Research Achievements

- Fifteen different hybrid topologies were initially conceived and then discussed in detail by all the partners. Four of these hybrid topologies were finally selected for further evaluation by considering various aspects like drivability, efficiency, economy, safety and packaging. The scooter platform and the engine that will be used were taken as inputs. It was then decided to evaluate these topologies through simulations so that the one/s that can be developed into prototype/s can be selected.
- TVSM provided two vehicles one for IITM and the other for RWTH. Spares and technical support and additional engines were also supplied to IIT Madras as needed.
- A Physics based model of the CVT was also parallel developed at IIT Madras and validated using the measured data at TVS Motors. Efficiency of the CVT obtained from TVSM was taken as a map of speed and torque.
- Another vehicle was evaluated by RWTH. Vehicle tests were done on their test track to assess the different components of driving resistance.

PhD/Master thesis supervised

1.

PhD Thesis
"Experimental and simulation studies to reduce CO₂ emissions and enhance performance of a hybrid electric two-wheeler"

Student:
Pradeev E

2.

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

3.

Master Thesis
Hybrid Powertrain Modelling & Control for a Two-Wheeler Application"

Student:
Abhiram Shenai

Publications

Mathivanan, A., Elango, P., Kakani, R., Das, H. et al., "Model Based Evaluation of Parallel Hybrid Concepts for a Scooter for Reduced Fuel Consumption and Emissions," SAE Technical Paper 2022-01-0665, 2022, <https://doi.org/10.4271/2022-01-0665>.



Water Technology

DEMO-Multi-WAP

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

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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. 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%). This will be realized 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, further investigation is being carried out to produce stable biofunctionalized plasma-treated and silanized fibres (Institut für Oberflächentechnik (IOT) (TU Braunschweig) 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 (small and medium enterprise), startups in incubation and 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".

Progress made/achieved

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 fibres using HF (hydrogen fluoride) 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 as per World Health Organisations recommendations for pathogen levels in drinking water, the state-of-the-art techniques for pathogen detection and their limitations was carried out. The Project partners 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 the discharge uniformity and thermal stability of a reactor is in progress. The principal ability to use a low-cost simple HV-generator was approved. Work on the safety unit development and process parameters optimization are in progress. In this period

of the report at LIONEX, a first 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 are 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 antibody immobilization was done at LIONEX in the label free protocol on the octet platform using different buffers and concentrations.

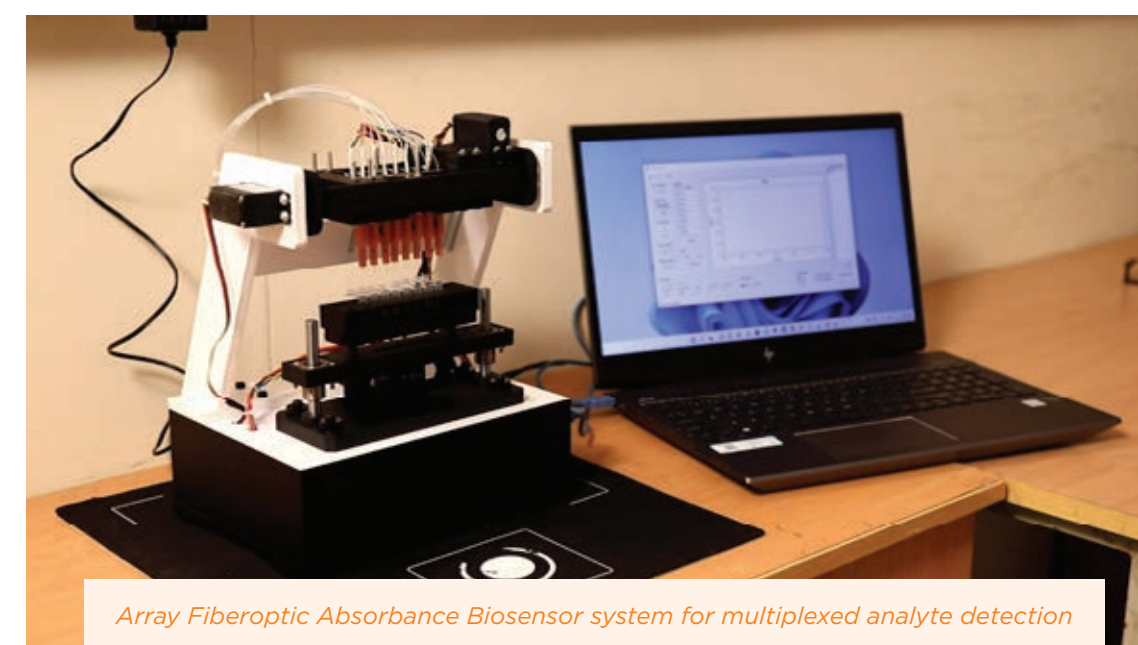
At IOT the new reactor design was developed for simultaneous plasma treatment and silanization of 8 U-bent probes, mounted into a cartridge, and a model was built. Work on the discharge uniformity and thermal stability of a reactor is in progress.



Progress made/achieved

IIT Madras has been working on the development of technologies for U-bent fiber probe fabrication handling, and Array Fiberoptic Absorbance Biosensor (ArFAB) for multiplexed analyte detection. High-capacity fiber probe fabrication machine (50 no/hr to 250 no/day) was developed which can be reach TLR7. Fiber optic probe cartridge and Fiber optic coupling mechanism were successfully developed at the status of TRL 6. ChemBioSens Pvt Ltd. did market assessment for the proposed problem of multiplexed pathogen detection system. As of now, work on verification and identification of the potential customer base for this technology is in progress. At IOT, three different designs of reactor for simultaneous plasma-treatment and silanization of 8 U-bent probes, mounted into a cartridge, were developed. After models building and testing the conveyor-type reactor was selected for the further development and a working prototype was built. Test runs of the built reactor prototype show good discharge uniformity and thermal stability of the

reactor. Using of technical-purity argon gas (Ar 4.6) as a plasma-forming gas and as silanization reagent carrier shows suitable results comparing to high-purity argon gas (Ar 6.0). It can decrease expenses in industrial application of the technology. In this period of report at LIONEX, Semi-final drafts of a Failure Mode and Effects Analysis (FMEA) and Risk Analysis were prepared according to DIN EN ISO 14971 and will be finalized after the detailed system and interface specifications released through WP1+WP2. The semi-final PDP- related files Drafts were prepared. More batches were produced of M. bovis and M. tuberculosis LAM and lipoglycans. Started developing new and novel method for lipoarabinomannan (LAM) purification and QC using unique platform. Several batches of quality-controlled anti-LAM antibodies were produced, with KD around 10^{-8} - 10^{-9} . The optimization of antibodies immobilization done at LIONEX in the label free protocol on octet platform using different buffers and concentration.



Array Fiberoptic Absorbance Biosensor system for multiplexed analyte detection

Salient Research Achievements

IIT Madras has been working on the development of technologies for U-bent fiber probe fabrication handling, and Array Fiberoptic Absorbance Biosensor (ArFAB)

for multiplexed analyte detection. The following are the technologies being developed and their TRL status:

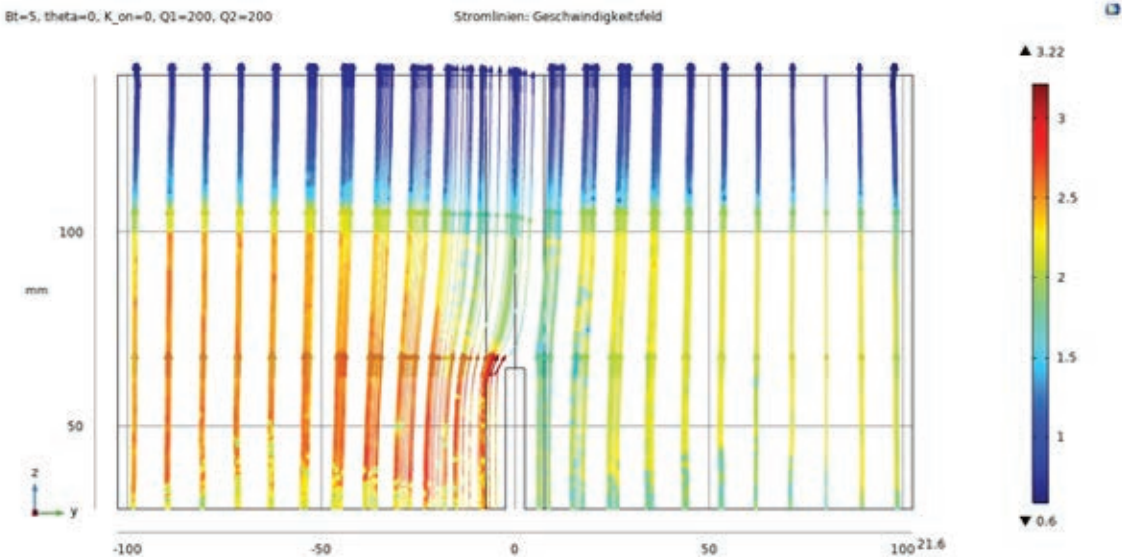
Technology	TRL status
High-capacity fiber probe fabrication machine (50 no/hr to 250 no/day)	TRL 7
Fiber optic probe cartridge	TRL 6
Fiber optic coupling mechanism	TRL 6
Array Fiberoptic Absorbance Biosensor (ArFAB)	TRL 4



U bend probes with paper cartridge placed on the cartridge holder compatible with 96 well plates to functionalize

- Three different designs of reactor for simultaneous plasma-treatment and silanization of 8 U- bent probes, mounted into a cartridge, were developed. After models building and testing the conveyor-type reactor was selected for the further development and a working prototype was built.
- Test runs of the built reactor prototype show good discharge uniformity and thermal stability of the reactor.
- Treatment parameters were optimized both for plasma-pretreatment part and for gas-phase silanization part.
- Middle-cost HV generator (Information Unlimited, USA) was mounted into dielectric compartment and equipped with

- safety switch to work with the standard research plasma- box.
- Using of technical-purity argon gas (Ar 4.6) as a plasma-forming gas and as silanization reagent carrier shows suitable results comparing to high-purity argon gas (Ar 6.0). It can decrease expenses in industrial application of the technology.
- More batches were produced of M. bovis and M. tuberculosis LAM and lipoglycans.
- Started developing new and novel method for LAM purification and Quality Control (QC) using unique platform. Several batches of quality-controlled anti-LAM antibodies were produced, with Kilo Dalton around 10^{-8} - 10^{-9}



Gas flow lines (simulation) for equal linear gas velocities and different temperature - left compartment hot (80 °C) and right compartment at ambient (20 °C) temperature.

IDC-Water

Integrated diagnostics of contaminants in water supply and management system

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Project Brief

The project aims to develop a system for monitoring water quality in terms of specific bacterial cell/DNA and pharmaceutical residues. The system shall consist of the following components: (1) an inline water sample collection & enrichment compartment, (2) a system of microfluidic cartridges for bacteria cell capture, culture, amplification, and detection in a short time, (3) a system of microfluidic cartridges to capture and detection pharmaceutical residues in a short time, (4) an integrated board that hosts all the compartments 1-3, reagent supply units, detection units and performs automated diagnostic tasks and (5) a software framework to operate the integrated system, analyse the data collected over time and provide an appropriate early warning. The system shall be designed in such a way that it can be installed in the water supply & distribution network, water treatment plant settings and in building infrastructure settings for remote monitoring. (1)-(4) together shall form a sub-system which will allow samples from its cell/DNA cartridge to be collected and loaded into a portable micro-PCR (polymerase chain reaction) for offline diagnostics. Two different types of microfluidic cartridges will also be integrated into the system. One will detect bacterial cells and DNA by taking advantage of cell counting and target DNA detection in an amplified manner on nanomaterial assay and alternatively with offline integrated micro-PCR. The other one will detect molecules of selected pharmaceuticals, which are emerging to be harmful, on a combined immunoaffinity column using antibodies, extracted compounds being eluted into a microfluidic detection system. The target specification for detection of the pathogen would be 1 CFU/100 ml and nanomolar concentration of target DNA detection within an hour. Targets for detecting pharmaceuticals will be a concentration of 100 ng/L and within a measurement time cycle of 10 minutes.

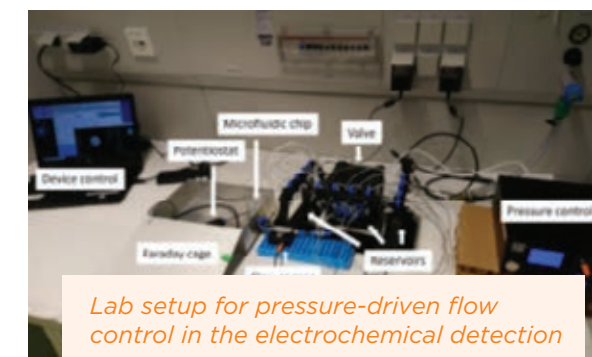
Progress made/achieved

A detailed product requirement specification document has been developed jointly by all partners.

sifin & BAM

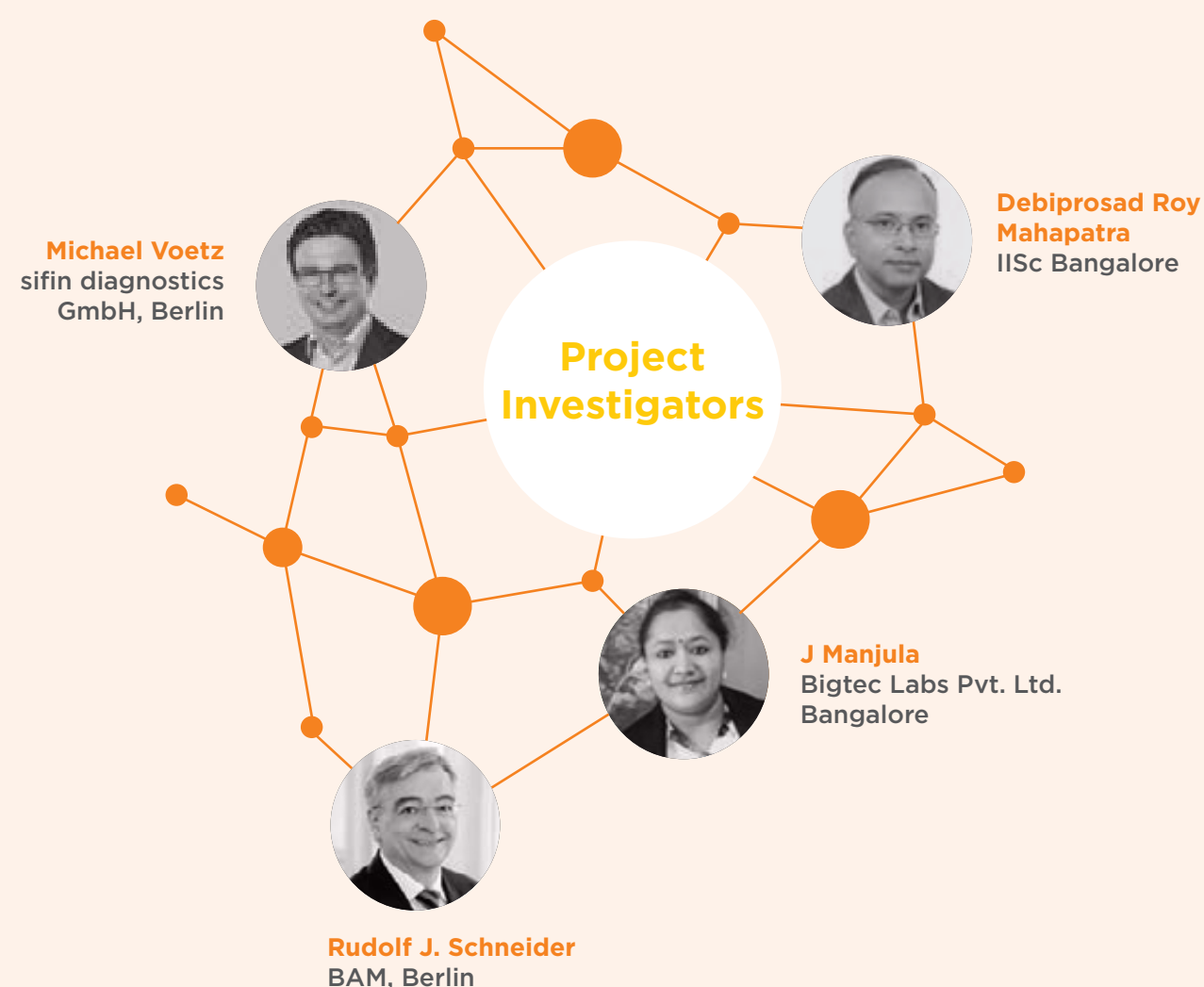
- Two independent monoclonal anti-diclofenac antibodies were produced, purified, and pre-characterized in ELISA formats by sifin. Diclofenac protein conjugates have been synthesized by BAM. The antibodies have been characterized for affinity and cross-reactivity in several immunoassay formats (BAM). Antibody F01G21 is the most suitable and is now being produced by sifin.
- Immunoaffinity extraction via antibodies immobilised on magnetic beads has been conceived and tested, binding of diclofenac to magnetic beads coated with monoclonal anti diclofenac antibodies has been established. The miniaturization for the use in a mesofluidic devices still is process of development by sifin.
- Monoclonal anti amoxicillin antibodies were procured by sifin. Protein conjugates required for establishing an ELISA were proved to be dysfunctional. BAM tested new amoxicillin conjugates. The combination of AMX-HSA and Squarix resulted in an ELISA test with a satisfactory detection limit, yet it was sensitive to the open-ring form of amoxicillin. The production of amoxicillin will be studied in the final stage of the project
- Comprehensive studies were carried out to develop an optimized homogenous DCF assay based on luciferase complementation (sifin). Test results revealed that the sensitivity for the detection of diclofenac is not sufficient for the envisaged field application (sifin).

- An approach to performing assays via antibodies immobilized on magnetic beads (size ca. 1 micron) was extended. For immobilization of the antibodies on magnetic beads, a chemical approach of cross-linking amino-functionalized (commercial) beads with amino groups in lysine residues of the antibodies by glutaraldehyde was initially chosen and modified later (BAM).



Indian Institute of Science (IISc), Bangalore

- Cell culture cartridge has been designed and improvised to integrate separate fluidic lines for reagents avoiding any sort of contamination and false +/- results. These were detected with a culture of 1CFU/10mL of E. coli using the optical method and electrochemical impedance method.
- 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. Subsequently, the general condition of the sample in terms of pH, TDS, temperature, and turbidity was monitored.



- Optical spectroscopy techniques with detection units were established and tested for the detection of cell growth in the cartridge. It was established that a reduction in sample volume in the detection zone to microfluidic-like conditions could significantly eliminate the culture lag phase and an increase in cell count with high sensitivity is possible to detect earlier than what is existing standard. In the integrated board, the technique is further refined for specific wavelengths. Various product development milestones have been followed, and product design, fabrication, unit testing have been carried out.

Bigtec

16S rRNA primers & probes have been designed and tested by Bigtec for the detection of 16S rRNA gene to do the preliminary screening of total bacteria present in contaminated water samples using a portable micro-PCR device. Further, they were tested for the detection and characterization of Shigella, Salmonella, and STEC (Shiga toxic E. coli).

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

- Alexander Ecke, Tanja Westphalen, Anika Retzmann, Rudolf J. Schneider, "Hydrolysis of amoxicillin in different types of water-Journals of Hazardous Materials (in submission)"- 2022*
- Alexander Ecke, Tanja Westphalen, Jane Hornung, Michael Voetz, Rudolf J. Schneider, "A rapid magnetic bead-based immunoassay for sensitive determination of diclofenac"-Analytical and Bioanalytical Chemistry 2022, 414(4) 1563-1573-2022*
- Alexander Ecke and Rudolf J. Schneider, "Pitfalls in the Immunochemical Determination of β -Lactam Antibiotics in Water"-Antibiotics 2021, 10, 298 - 2022*
- 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"-Biomedical Microdevices 2021, 23:36-2022*

Patents granted

D. Roy Mahapatra, Mishra M., Chakraborty N., Das S., Vasireddi R., Hegde G.M., Konnur M.C., Nagraj S.A., Umesh A., Nair C.B. Devices and methods for rapid extraction, screening and detection of biomolecules Indian Patent Application No. 5812/CHE/2013 dated December 13, 2013, IPO Publication No. 32/2015, 2015/08/07. Patent No. 377526, Grant Date: 22 Sept 2021

CleanWater

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

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 a 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 can 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). Within the project a design suitable for the innovative material will be developed. 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 is developed.

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Progress made/achieved

IIT Madras

A concrete matrix has been developed to address the need for a larger aggregate size for TRC, the 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 Institut für Textiltechnik of RWTH Aachen University (ITA) were assessed for their tensile capacities. Uncoated textiles from ITA were coated with styrene-butadiene rubber (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. The test results were shared for incorporation in numerical models. Matrix and composite surface coatings were examined in acidic attack tests to increase the durability of the WTPs. First full scale demonstrators for both versions (rectangular and circular) were cast in laboratory facilities. Site visits were conducted to finalize the installation locations.

CSIR-SERC

Structural analysis, design and finite element modelling of baffle TRC WTP unit were carried out. Based on the investigations, 40mm thick TRC panels with 3 layers of textile reinforcement are

recommended for constructing baffle TRC WTP. A novel fabrication method was developed for the fabrication of rectangular as well as circular/cylindrical TRC WTP modular units. The method was successfully upscaled and demonstrated for the fabrication of full-scale dimensions of TRC WTP modular unit. A jointing method was designed for stacking TRC segments to achieve full height for TRC WTP unit. Experimental investigations were carried out on the prototype TRC WTP rectangular unit and the response behaviour specific to cracking, ultimate load and full failure were captured.

Investigations were also carried out to determine the joint efficiency and leakproof nature and both were found to be satisfactory. More investigations are ongoing with the circular segments of the prototype TRC unit. Full scale demonstrators of rectangular and circular types were fabricated at CSIR-SERC for further investigations towards qualification for site implementation.



Experimental investigations on prototype unit at CSIR-SERC



*Meeting of Indian Consortium Partners
at CSIR-SERC, April 2022*

Raina Industries

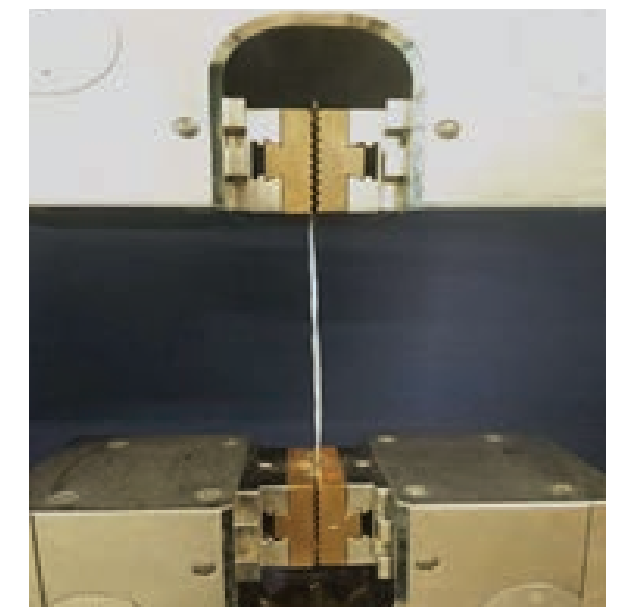
For the development of a transport concept, the limiting factors (including availability, size and maximum load weights) of the means of transport were defined. The maximum dimensions for transportation were derived from the design of the equipment including the lengths as well as the weight dimensions. 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 the placement of textiles and creation of small mock curvilinear samples replicating the wall thickness of the STP Plants. Design of the components is currently transferred to mould designs. Compromises were made between the highest technological efficiency and economic production. Two business models were developed, one targeting customers close by, the other targeting customers at a further distance. Locations for on-site implementation of the first systems were visited.

Institut für Textiltechnik of RWTH Aachen University (ITA)

Tensile tests were performed on high-performance fibre materials commonly used for 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 roving with finesses below 1200 tex and above 4800 tex, as well as 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). The first quantity of textile was sent in coated condition to the Indian partners to perform composite and textile comparative tests. After feedback from the partners, further textile was sent to perform structural component tests. Further coating materials were tested to improve understanding regarding the effects of varying environmental conditions on material behaviour. 350m² of textile reinforcement is in the progress to be shipped to the Indian industrial partner for fabrication of the demonstrator.



Textile testing at ITA, Aachen



Sample Preparation at ITA

Hentzschel

Based on typical small sewage treatment plants made of (steel) concrete, as they are currently sold, a cylindrical design of small sewage treatment plants made of textile concrete was derived. The classical production process was discussed with the Indian industrial partner Raina Ind. The transport and installation process as well as the resulting requirements for the tank were defined for the classic small wastewater treatment plant. The plant was dimensioned based on the expected wastewater volume. Instructions and concepts for the procedure and implementation of functional testing after implementation and over the service life of the plant - also beyond the duration of the project - were prepared and discussed with the partners.

The classical production process was discussed with the Indian industrial partner Raina Ind. The transport and installation process as well as the resulting requirements for the tank were defined for the classic small wastewater treatment plant. The plant was dimensioned based on the expected wastewater volume.

Publications

- *Smitha Gopinath, Shankar S, Farvaze Ahmed AK, Kira Heins, Gözdem Dittel, Thomas Gries, A Macro Modelling Based FEA Methodology for Realization of Textile Reinforced Concrete Rectangular and Cylindrical Shaped Tanks, Journal of The Institution of Engineers (India): Series A.*

Talks with reference to CleanWater

Kira Heins, Gözdem Dittel, Komathi Murugan, Mohit Raina, Smitha Gopinath, Oliver Hentzschel, Sachin Paul, Ravindra Gettu, Thomas Gries - Modular Lightweight Wastewater Treatment Plants made of Textile Reinforced Concrete Means to Reliable Wastewater Treatment in Rural Areas. 75th Rilem Annual Week & International Conference on Advances in Sustainable Construction Materials and Structures, Mérida, Yucatán, Mexico, 30.08.2021-03.09.2021

Full paper submitted for publication in proceedings

- Kira Heins, Gözdem Dittel, Martin Scheurer, Magdalena Kimm, Thomas Gries Contribution of technical textiles to sustainable water management.
- First International Conference on Circular Economy for Sustainable Water Management Online Format, 23.03.2022-25.03.2022

PhD/Master thesis supervised

Mr. Srikrishna B, "Experimental and Numerical Investigations on the Behaviour of Textile Reinforced Concrete Rectangular and Cylindrical Segments", Completion in July 2022 under the supervision of Dr. Smitha Gopinath

Smart Cities



ECO-WET

Efficient coupling of water and energy technologies for smart sustainable cities

Project Brief

Smart cities are envisioned to efficiently use the two most critical resources: Water & 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. Water management and energy efficiency are complementary to each other. On one hand, electricity from 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.

The coupling of cross-commodity infrastructure and integration of energy storage is a challenge for smart cities. With respect to ICT (Information & Communication Technology), 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.

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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 smart sustainable cities. The core scientific research is to enhance the overall efficiency by coupling these most essential infrastructures, through advanced ICT and intelligent computational framework.



Progress made/achieved

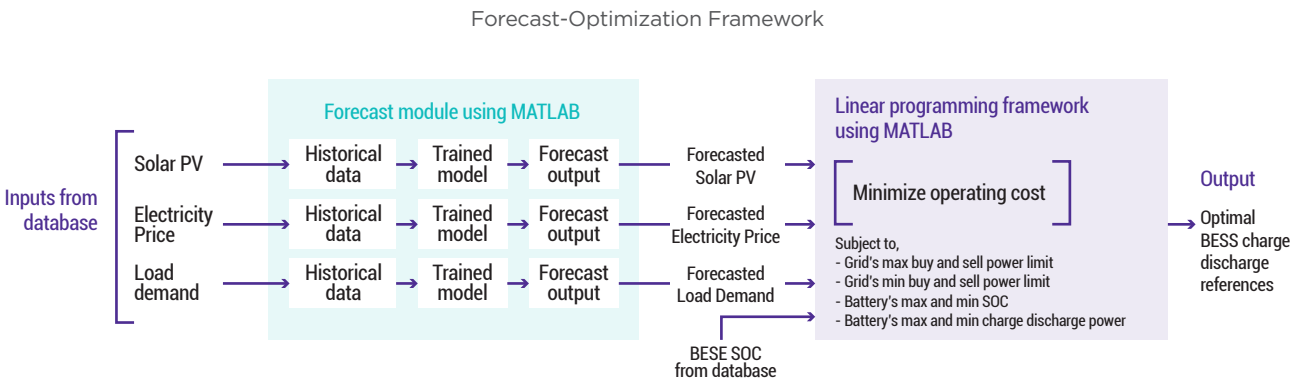
Following Milestones were achieved:

- Use case specification and requirements
- Software architecture and communication design
- Hardware procurement/details and specifications
- Optimization, decision making algorithm for optimal integration of distributed energy resources and battery management in a simulation environment
- Assessment of the software, optimization techniques, performance of testbed and storage

The software forecasting optimization framework will be the heart of the project where a day ahead forecasting module will forecast solar PV output power, electricity price, load demand and is given as input to optimization framework to obtain the optimal Battery Energy Storage System (BESS) charging and discharging references. The forecast optimization framework will be implemented at each use case levels at both STP and WTP. The basic flow of forecasting optimization framework is shown in the figure below.

The proposed energy management algorithm was developed and can be readily applied for solving the energy management problem at use case levels. The algorithm is developed in such a way that it can be extended for solving energy management of any additional use cases identified during future course. The entire forecast optimization framework is developed in python programming language as to implement it in Raspberry Pi with ease. The forecast optimization framework will be integrated to fortiss's iEMS software and will be deployed at workstations at STP and WTP. Consortium have carried out research and achieved the level of TRL 6 & TRL 7 and are working on TRL 8 (Actual system completeness and flight qualified through test and demonstration).





Publications

K. Srivastava, A. N. Tiwari and S. N. Singh, "Harmonic/Interharmonic Estimation: Key Issues and Challenges," 2021 IEEE 6th International Conference on Computing, Communication and Automation (ICCCA), 2021, pp. 842853, doi: 10.1109/ICCCA52192.2021.9666331.

PhD/Master thesis supervised

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.

Smart & Wise

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

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Project Brief

The project contributes to improvements of planning procedures for sustainable water and wastewater systems in Indian and German cities. Innovative infrastructure planning processes, methods and tools were developed on following action fields: (i) Water supply and water reuse, (ii) Storm water management, (iii) Sewerage systems, (iv) Heavy rain including urban flooding and (v) Decentralized resource orientated sewage treatment. Flowcharts show in which infrastructure planning step the developed tools can be used effectively and how the above and further action fields, e.g. smart city planning, are linked in this integrated approach. In pilot cases in India and Germany the new planning tools and smart measures were applied. Country specific conditions as well as common practice and new planning requirements were considered. Trainings, planning tools and services are provided for planners and decision makers.

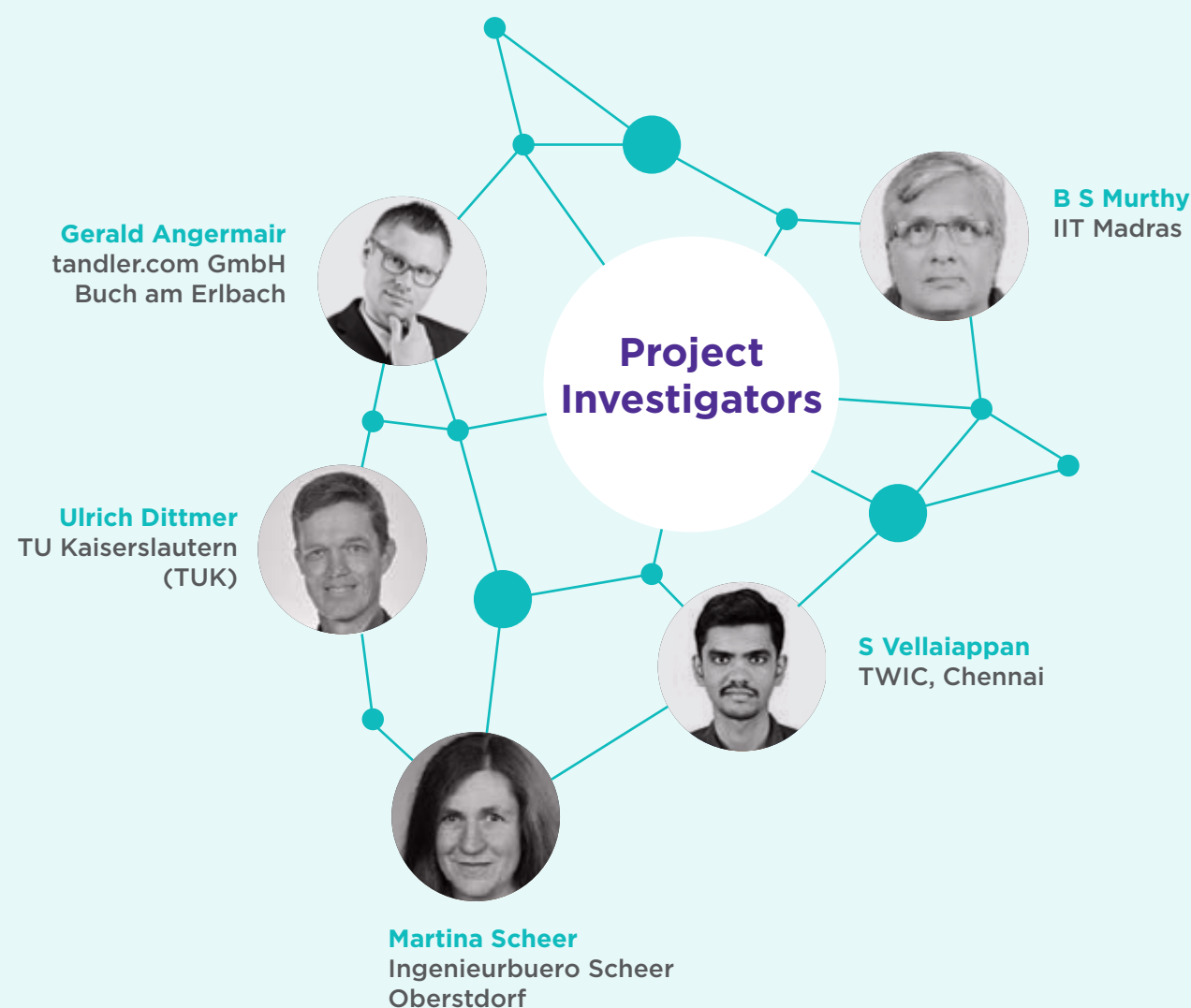
Progress made/achieved

The Indian project partners IIT Madras and Tamil Nadu Water Investment Company Limited, as well as the German partners Technische Universität Kaiserslautern (University of Kaiserslautern), Ingenieurbuero Scheer (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 and wastewater infrastructure systems. Research on advanced level involves integration of decentralized 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 are demonstrated on pilot areas in India and Germany. Country specific conditions in the pilot and example cases, e.g. local climate conditions, population density or existing infrastructure, require robust systems under changing circumstances. The bilateral team together with local stakeholders identifies smart WIS solutions to be integrated in smart city planning. Project results are disseminated and utilized as planning services for local planners and decision makers.

The project team has developed flow charts for a systematic guidance on urban water infrastructure planning. The focus is on five specific action fields: (i) Water Supply and Water Reuse, (ii) Storm water

management, (iii) Sewerage systems, (iv) Heavy rain and flood protection and (v) Resource orientated sewage treatment. The use of the flowcharts and corresponding manuals leads the planner through an integrated planning procedure up to a smart planning result. Integrated means identification of linkages between different action fields, e.g. water supply, sewerage, rain water, and consideration in the planning process. The flowcharts illustrate which methods can be used to get a smart planning result. Smart in this project means not only the use of smart planning methods, e.g. optimization, but also the integration of sustainable measures in the infrastructure systems. The flowcharts show which measures are considered, which planning methods and tools are available, in which planning step they can be used and which action fields they affect.

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 and wastewater infrastructure systems.



Further development of planning methods and tools is carried out by applying them to pilot areas in India (Kurichi in Coimbatore city) and Germany (Ochsenhausen, Kempten). All project partners are involved in the development of flow charts. This has helped to identify, to develop or adapt several tools (as in a tool box) which aid in the planning processes. These tools are available in the form of: (i) computer codes for solving specific optimization problems; (ii) enhancements to existing ++SYSTEMS software, (iii) excel computation sheets; (iv) external available tools and (v) manuals which give guidelines. Academic partners IIT Madras and Technische Universität Kaiserslautern carried out the necessary research and developed computer codes to demonstrate the new methodologies. The industry partner tandler.com focused on adapting and extending the capabilities of ++SYSTEMS software for planning. One of the major contributions is the development of software within ++SYSTEMS framework for planning the network routing for water supply, sewerage and storm water drainage systems. Industry partners Engineering Office Scheer and Tamil Nadu Water Investment Company provided pilot case data for the use by all partners, developed planning approaches and apply the tools in the pilot areas in India and Germany.



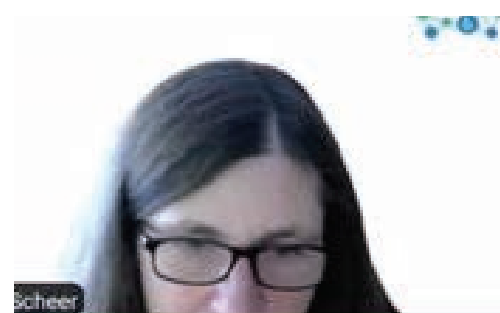
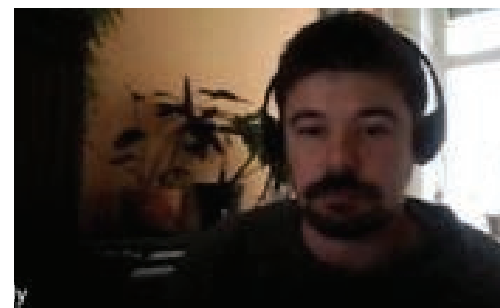
Sewerage network in IIT Madras - Picture Courtesy - DOI: 10.3390/w13152004

Salient Research Achievements

- FFlowcharts: Findings from the application of flowcharts for sustainable stormwater management and feedback from stakeholders were incorporated. After the Proof-of-Concept was completed, the results were discussed with the scientific community. Based on the results, a manual was created. Work on the Resource Oriented Wastewater Treatment flowchart has been completed.
- IITM and TUK completed and proof-tested the method and MATLAB® code for design of new sewerage systems with on-site grey water recycling (initiated in 2020). Details have been provided earlier. The approach is currently being tested for Indian and German pilot cases. IBS worked out and provided suitable data of pilot case Ochsenhausen.
- IITM and TUK developed method and MATLAB® code for integrated design of new water supply scheme along with new sewerage systems inclusive of on-site grey water treatment and recycling. This tool not only finds the optimal sizes of pipes in water and supply and sewerage systems but also the amount of grey water to be treated at each site.
- IITM and TUK completed the work on Key performance indicators for water supply. Work on this topic which was initiated in 2020 was completed by June 2021.

- DMA Creation Tool for Water supply Distribution network (Indian pilot): With the Data sup-port from TWIC for the Water supply distribution network of Pilot – Area Kurichi , IITM has tested and carried out the design of the DMAs based on the clustering of nodes in the water network with reference to the graph theory concept. The results and learnings of the DMA creation tool for the pilot case area in the form of Net-work drawings & network models and results of this tool were documented in form of output reports to ensure that the learnings can be used for planning of other similar projects.
- Urban Water balance: TWIC with help from TUK and IITM has carried out the Urban water balance of Coimbatore pilot area and arrived at the urban infrastructure gaps. As part of this task, assumptions were made on the future population growth in next 5 years, 15 years and 30 years and accordingly the urban water demand and used water generation quantity was estimated. The gaps were assessed in order to recommend actions and for future planning of 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 and wastewater infrastructure systems.



Publications

- Dev, A.; Dilly, T. C.; Bakhshipour, A. E.; Dittmer, U.; Bhallamudi, S. M. (2021): *Optimal Implementation of Wastewater Reuse in Existing Sewerage Systems to Improve Resilience and Sustainability in Water Supply Systems. In: Water 13 (15), S. 2004. DOI: 10.3390/w13152004.*
- Dilly, T. C.; Sedki, K.; Dittmer, U.; Scheer, M. (2021): *Mit Regenwasser nachhaltig umgehen. Erprobung eines ganzheitlichen Planungsansatzes zur Förderung einer wassersensiblen Stadtentwicklung. In: Transforming Cities (3 - Zu viel oder zu wenig Wasser? Strategien für ein nachhaltiges Wasserressourcenmanagement), S. 62–67.*
- Dilly, T. C.; Dittmer, U.; Bhallamudi, S. M.; Scheer, M.; Vellaiappan, S. (2021): *Wise Planning Processes for the Water Infrastructure in Smart Cities in India and Germany. IWA Digital World Water Congress. IWA the international water association, 24.05.2021.*

PhD/Master thesis supervised

1. M. Tech Thesis of Adwait Bharade (completed in June 2021). "Integrated planning and design of water supply and sewerage systems".
2. M. Tech Thesis of Dinesh Borse (completed in June 2021). "Key performance indicators for planning and design of water infrastructure".
3. M. Tech Thesis of Subhashish Jena (completed in June 2021). Condition assessment of existing water supply networks.

Advanced Manufacturing/ Materials



PPAM

Metal powder production for additive manufacturing

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 strongly depend on the uniformity of size and consistency of the powder particles. PPAM 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 operation 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.

Contact Details

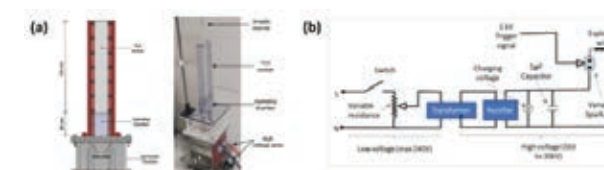
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Progress made/achieved

IISc Bangalore

The shock tube setup and supersonic flow wind tunnel have been fabricated for carrying out shock droplet interaction experiments. Geometrical parameters & electrical circuit design of the shock tube are shown in Figure. For carrying out the shock droplet interaction experiments, the droplet was injected from the top of the shock tube using a droplet dispenser, and a shock wave was generated by the wire explosion in the exploding chamber. Timings of droplet injection, shock wave generation and triggering of the camera were synchronized using a digital delay generator. The interaction of the shock wave with a droplet is studied using high-speed shadowgraphy and Schlieren techniques which are later used for visualising droplet breakup and short structures during the interactions. Another experiment was performed with a supersonic flow wind tunnel to study the droplet interactions with an oblique shock.



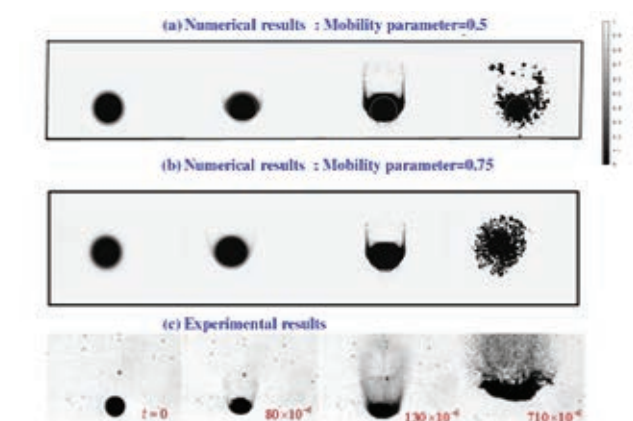
(a) Geometrical parameters & (b) electrical circuit design of the shock tube experiment at IISc Bangalore



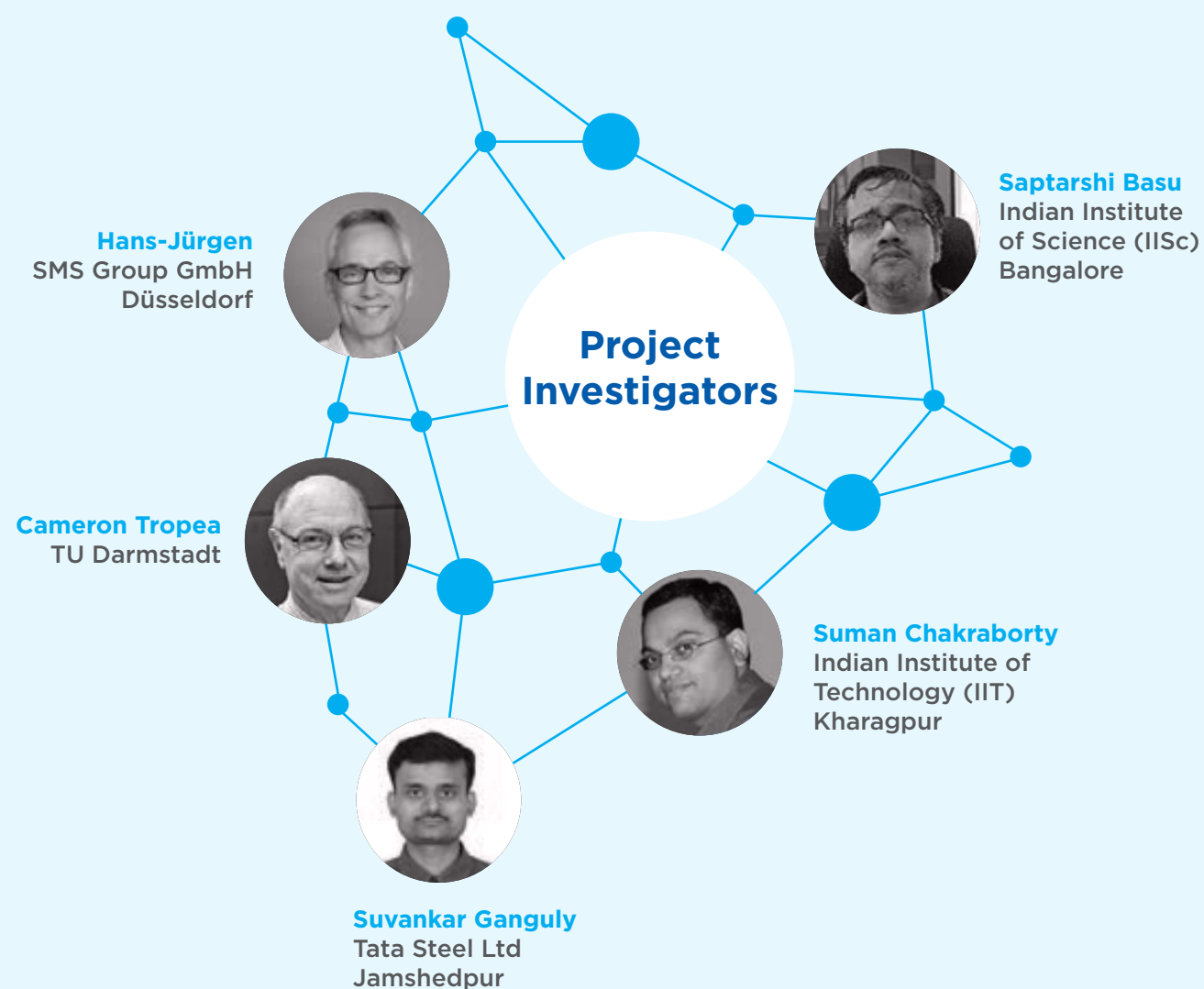
Supersonic flow wind tunnel installed at IISc Bangalore

IIT Kharagpur

Partners at IIT Kharagpur studied the interaction between the droplet and shock wave. During the interaction, regular reflection occurs as long as the angle of incidence is above a certain critical value, the so-called detachment angle. When the angle of incidence becomes less than the detachment angle, a transition from regular to Mach reflection takes place. Until the onset of the sheet thinning type of breakup of the water droplet, diffraction of the shock wave is identical to a solid cylindrical case. The numerical experimental results generated at IISc Bangalore on breakup characteristics of droplets at higher value were further compared and stimulated for different mobility parameter. Two sets of simulations were 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.



Comparison between experimental & numerical results for different mobility parameters



Tata Steel Ltd.

Partners at Tata Steel have examined the dynamic, shear and bulk properties of the metal powder along with their shape, size and texture of the individual particles at higher magnification scales from SEM images. Furthermore, the metal powder was used to fabricate ASTM standard dog bone specimen for

mechanical testing. The printing of the specimen was done through the Selective Laser Melting (SLM) process. The future work includes the following tests to be performed: Mechanical tests: Compression test, DIC and Powder characterization: Density, Flowability, Cohesiveness, Porosity, Powder morphology.



3D Printed Dog specimen from metal power

TU Darmstadt

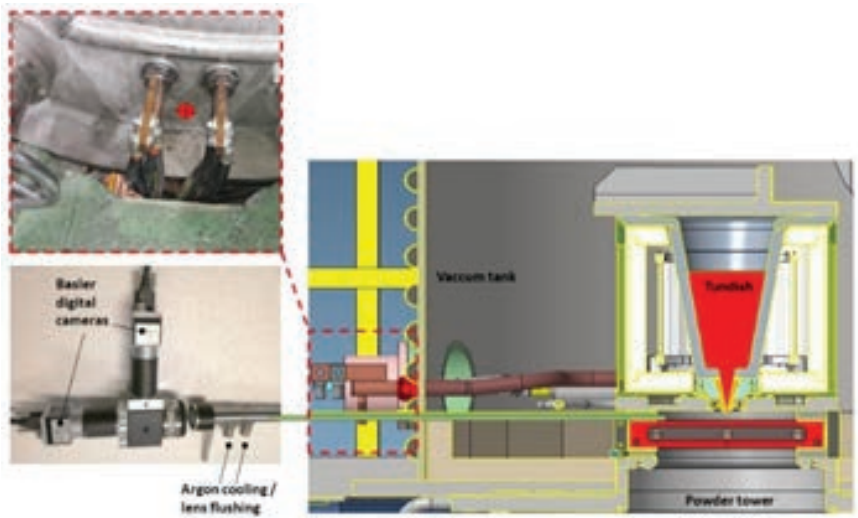
An experimental study for process characteristics of the close-coupled atomizer setup had been conducted by partners at TU Darmstadt. A strong focus has been put on investigating the atomization result by performing and evaluating phase Doppler measurements of local particle size and velocity distributions within the spray. Due to the extreme process conditions, i.e., small time and length scales, it was found to be a difficult task. Henceforth, 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 MATLAB.

Generic experiments, numerical simulations and pilot plant operation are used in combination to develop validated, predictive capabilities and design guidelines for full-scale facilities.

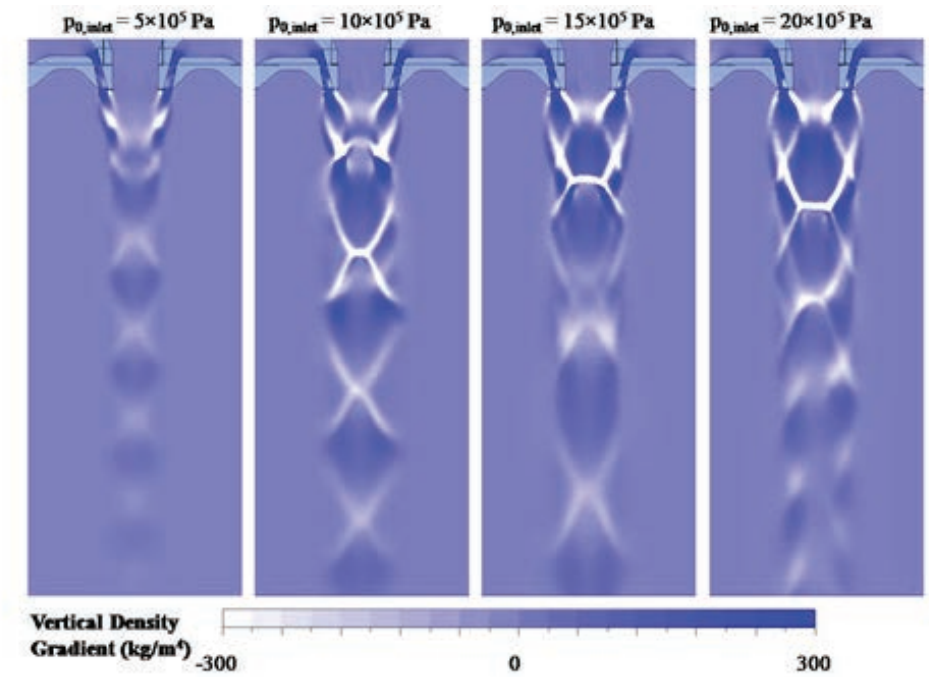
SMS Group GmbH

Partner group at SMS Group developed a model for atomization process to improve the stability of the OpenFOAM solver. The model developed so far is a Euler-Euler-Lagrangian model consisting of two sub-models. Euler-Euler approach coupling the liquid and gaseous phase and a Lagrangian approach, which calculates the droplet diameter distribution in a post-processing manner. In both models, a distinction is made between two different breakup modes, that is the bag and multimode breakup at Weber numbers and the shear or boundary breakup for Weber numbers larger than 80. In order to check if an

axisymmetric assumption can be applied to the computational domain of the atomizer, different simulations were compared, on the one hand with a full 3D mesh and on the other hand with an axisymmetric mesh. In order to visualize the atomization process in the primary atomization zone beneath the nozzles, an endoscopic high-speed digital camera has been delivered by PYROOPTIC, Denmark. To investigate strength-ductility properties of additively manufactured structured parts initial investigations have been carried out further with a charge of 1.4404 steel powder produced on the production plant.



Endoscopic high-speed digital camera from PYROOPTIC, Denmark



Variation of the vertical density gradient in the atomizer for different values of the inlet pressure

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 (Accepted).

PhD/Master thesis supervised

<p>1.</p> <p>Apell, N. (2019)</p> <p>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.</p>	<p>2.</p> <p>Wilkens, Y. (2019)</p> <p>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.</p>	<p>3.</p> <p>Schrimpl, T. (2021)</p> <p>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)</p>
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TransLearn

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

Project Brief

Industry 4.0 will be driven by two basic technologies: AI and Robotics. The combination of both enables robots to learn skills and tasks without explicitly programming them. Learning & 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.

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Progress made/achieved

In accordance with the project proposal, the consortium started with an extensive requirement analysis considering both the industrial and the academic perspective. Given that all project partners share the goal of using modern learning methods to foster a sustainable and resource-saving economy, automatic waste segregation was identified as a promising demonstration scenario for TransLearn. For efficient separation of recyclables, a robot must be able to generate fast and adaptive movements while carrying out optimized grasps. The novel techniques developed in the TransLearn project enables these skills can be efficiently acquired using reinforcement learning.

To enable high throughput for an automated waste separation system, fast robot movements are essential. Learning fast robot motions without special considerations is likely to damage the robot due to self-collisions or by exceeding the operating range of its joints. In order to address this issue, special focus was laid on investigating and developing methods to enable safe exploration of the environment. 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 regards to 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.

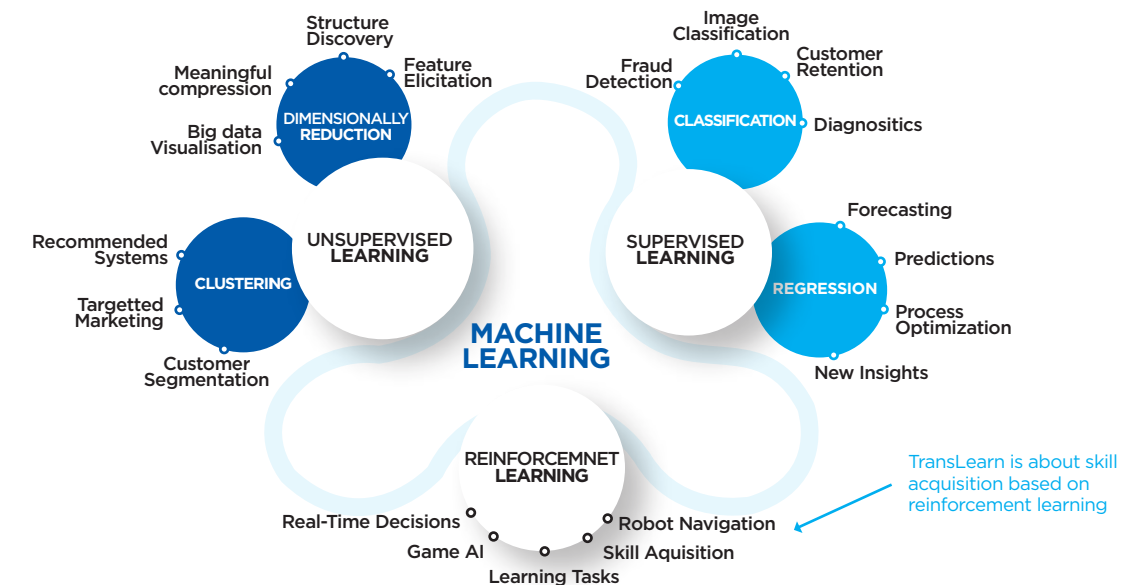
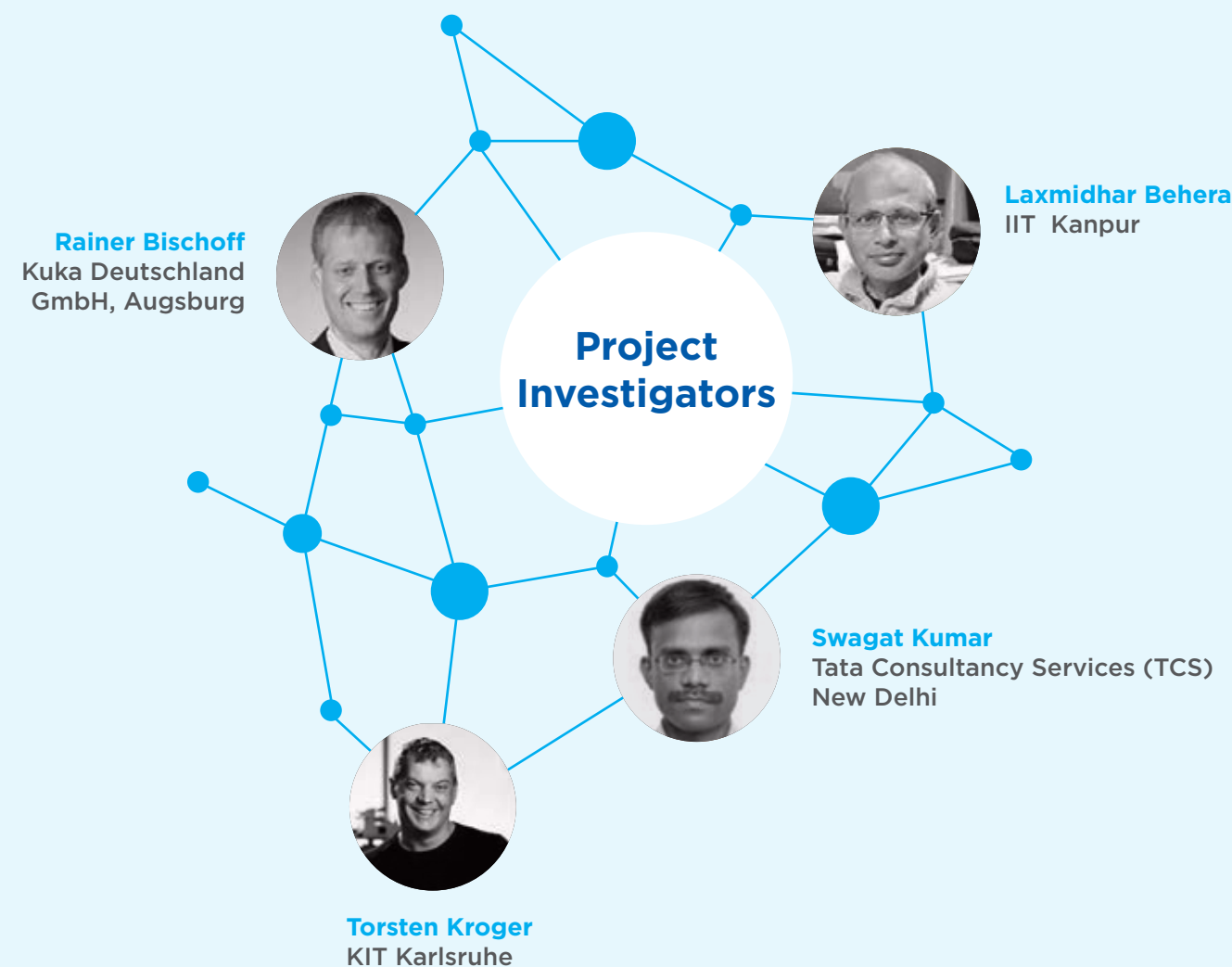


Motion adjustments based on sensory feedback

Salient Research Achievements

WP6 Transfer Learning

In the field of transfer learning, the major focus is on the successful transfer of learning grasping in simulation and then transferring this knowledge to the real world. Regarding this, project partners 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 successful transfer domain randomization on the color image and add noise to the depth image is performed. Additionally, the position of the CAD objects help to 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. E.g. 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.



Classifying the research in the TransLearn project

source: <https://www.cognub.com/index.php/cognitive-platform/>

WP7 Learning in the physical world

With respect to WP7, the project partners have implemented the learning and the control algorithms in a way that allows training with both simulated and real robots. A skill learning framework for acquisition of novel skills from human demonstrations has been developed at IITK. The framework combines dynamic movement primitives with techniques stemming from optimal control. For the grasping design approach, a new approach has been proposed and as follows: Instead of estimating the exact CAD model of the target objects, we aim to approximate the target objects with simple shape primitives like cuboidal or cylindrical shapes. One of the main advantages of approximating the objects with shape primitives is that the final grasp pose can be calculated analytically. Further, to cover the wide range of the objects, the dimensions and orientations of the shape primitives should be estimated at runtime. In general, principal component analysis (PCA) is used for obtaining minimum area rectangle by computing principal-axis (min and max variance) from a set of data points. However, the resulted axis does not guarantee a minimum area rectangle. This encourages us to develop a technique to compute a pair of orthogonal vectors, such that the rectangle formed by the pair should have a minimum area.



Collision-free target point reaching

Publications

- **Jonas Kiemel, Torsten Kröger:** *Learning Robot Trajectories subject to Kinematic Joint Constraints, IEEE International Conference on Robotics Automation (ICRA), Xi'an, 2021*
- **Anuj Nandanwar, Vibhu Kumar Tripathi, Laxmidhar Behera.** *Fault-Tolerant Control of Multi-Robotics System using Variable Gain Super Twisting Sliding Mode Control in Cyber-Physical Framework. In 2021 IEEE/ASME International Conference on Advanced Intelligent Mechatronics (AIM) 2021 Jul 12 (pp. 1147-1152).*
- **Anuj Nandanwar, Narendra Kumar Dhar, Laxmidhar Behera, Sahied Nahavandi, Rajesh Sinha.** *A Discrete-Time Event-Driven Near-Optimal Second-Order SMC for Multi-robotic System Formation Prone to Network Uncertainties. IEEE Transactions on Neural Networks and Learning Systems. 2021 Dec 31.*
- **Mohit Vohra, Laxmidhar Behera,** *Robot learning by Single Shot Imitation for Manipulation Tasks, IEEE International Joint Conference on Neural Network, 2022.*

Steel4LTC

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

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 lightweight design. The springs which are currently used may not be able to withstand the high stress. Hence, there is a 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 can be achieved by suitable alloying strategies, fabrication technologies and heat treatments. This consortium aims to develop 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).

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University of Hyderabad (UoH)

Experimental based hypothesis of LTC (low temperature controlling) mechanism & substantiation of hypothesis by extensive mechanical testing and microstructural characterisation.

The stability of Retained Austenite (RA) is essential and there are several factors governing the stability of RA. The RA stability can be classified into thermal stability and mechanical stability, which can be affected by intrinsic and extrinsic factors. The extrinsic factors are those applied by adjacent grains, involving the stress/strain partitioning, strength of the matrix, stress state, grain orientation and strain rate. In contrast, the intrinsic factors are related to the austenite grain domain defined by its grain boundaries, including interstitial/substitutional atoms (chemical composition), dislocations and grain boundaries (grain size/morphology). Having a RA with different volume fractions and morphologies can help understand how these factors directly affect the rate controlling mechanisms in LTC. With this idea, UoH has proposed martempered heat treatments for SAE 9254 steel which helps in varying the percentage, morphology, stress state, dislocations and so forth, covering almost all the intrinsic and extrinsic factors governing the stability of RA.

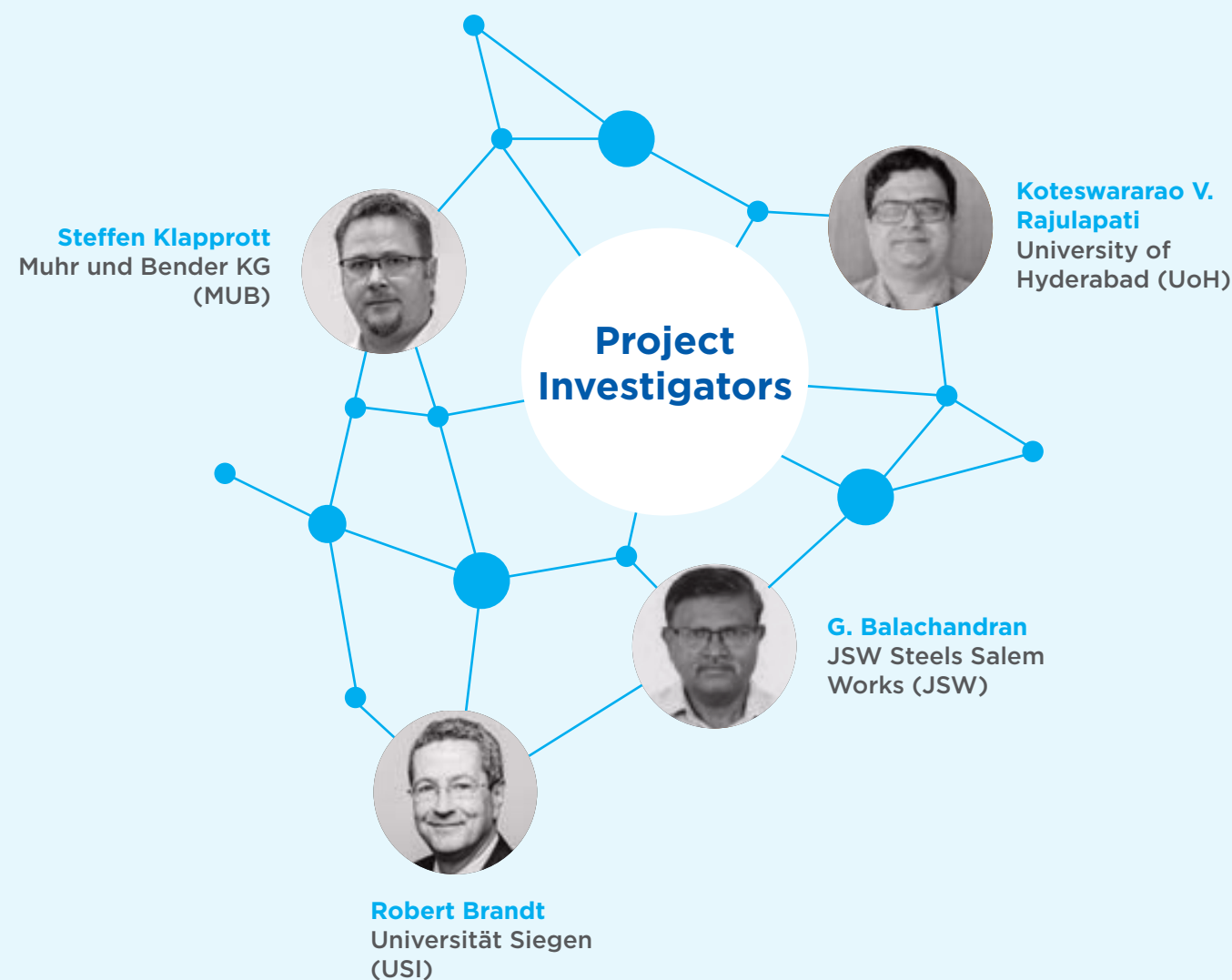


Industrial partners meeting at JSW Steels Salem Works, Salem. From left to right: Mr. Hessland, Mr. Gobinath, Dr. Manjini

JSW Steels Salem (JSW)

Profound proposal of steel grade and heat treatment.

The work of academic partners strengthens the assumption that RA in HSS to be the sole contributor to LTC. Accordingly, the consortium proposed alloying addition of “Nb (Niobium)” to SAE 9254 to reduce the RA in HSS. Accordingly, JSW made laboratory-scale melting of 3 compositions. i.e., adding 0.04, 0.06 and 0.1% Nb to SAE 9254 followed by optimising heat treatment of parameters. Subsequently, RA quantity in the new compositions will be determined by academic partners. Besides, JSW is planning to melt a new composition by alloying with “Al” to suppress RA quantity by forming martensite and ferritic steel.



Universität Siegen (USI)

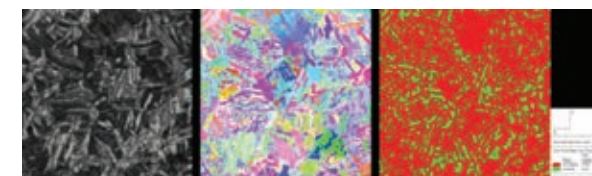
Experimental based hypothesis of LTC controlling mechanism.

Although, Nabarro has proposed an exhaustion creep model (ECM) to explain the LTC behaviour in single phase materials, the model is not applicable to multi-phase high strength steels (HSS). Based on critical evaluation of HSS microstructure and literature review, USI has reworked Nabarro's ECM.

Mubea Fahrwerksfedern GmbH (MUB)

Profound proposal of steel grade and heat treatment

Since metastable RA in HSS is assumed to be the sole contributor to LTC. MUB is focused on optimising the in-house heat treatment technology parameters to tailor the austenite the RA quantity, size, and morphology in HSS with the support of USI.



Electron Backscatter Diffraction of martempered sample quenched at 250C

Publications

- *M. Muench, R. Brandt, N. Remalli, "A verification of Mechanism Based Theories for Low Temperature Creep of High Strength Steel," Ilmenauer Federntag 2021, Ilmenau, Germany on 7th October 2021.*

PhD/Master thesis supervised

1. Prof. Robert Brandt, USI is supervising a PhD thesis within the frame of this project. One Master thesis completed.
2. 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.

LABELONIK

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

Project Brief

The project aims to establish a test production line for printed electronic labels by roll-to-roll gravure printing. The label shall comprise 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 a magnetic field to be detected by the Hall sensor of the smartphone). The resistive sensor can detect a change in temperature or humidity or damage to 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 in circuit design, functional inks, organic transistors and roll-to-roll gravure printing to one platform to guarantee the success of the project.

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Progress made/achieved

Saralon GmbH (SAR)

SAR has developed and optimized temperature sensors and humidity sensor inks. The inks are screen printable and are also suitable for gravure printing. The screen-printed sensors show an increase in resistance with increasing temperature/humidity. These two inks were launched in the LOPEC (Large-area, Organic & Printed Electronics Convention) exhibition in Munich (21-23 March 2022). They are currently available at SAR's website: <https://www.saralon.com/en/inks/>. With a printed humidity sensor, SAR has printed a device that can communicate with a smartphone using an NFC (Near-field communication) chip. From a commercial point of view, they have developed many innovative inks like highly conducting silver ink and cost-effective copper-based ink during the LABELONIK project. During the project extension period, SAR will use the n-type semiconductor developed by IISER to print the rectifier and transistors.



NFC readable humidity sensor from Saralon GmbH

TU Dresden (TUD)

TUD designed a circuit for the NFC label & an Android app for the interaction of smartphones with the NFC label. All circuits were designed using PMOS transistors, diodes, capacitors, planar antennas that are already or are expected to become available in printed organic technology.

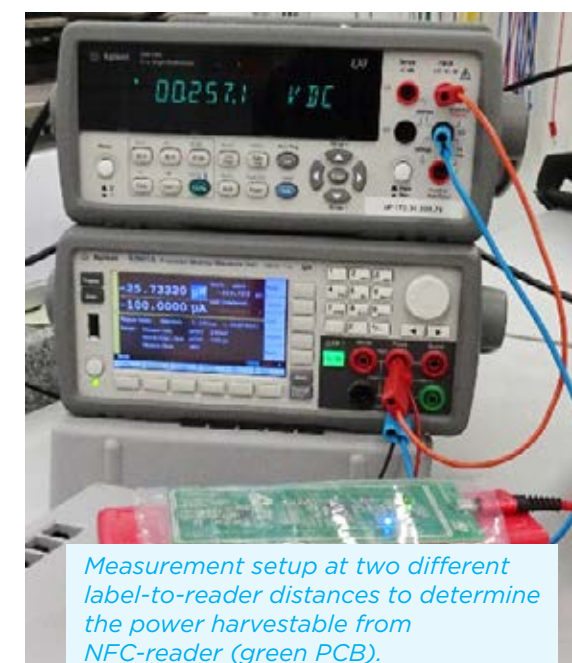
Earlier investigations have shown that NFC power harvested wirelessly from the NFC reader integrated into the smartphone was not sufficient to generate a magnetic field in the label strong enough for the Hall sensor of the phone to pick up. Hence a standalone NFC reader, green printed circuit board and PCB were used. The yellow boards in the circuit are the Planar antenna & rectifier used to harvest energy. As previously shown in the project, 25 mA is insufficient to achieve the signal-to-noise ratio (SNR) required for reliable label-to-smartphone communication. The integrated Label's system design was later modified to include a battery as a power source for the oscillator and transmission coil to mitigate the risk associated with this.



Cost-effective and sustainable printed copper ink from Saralon GmbH



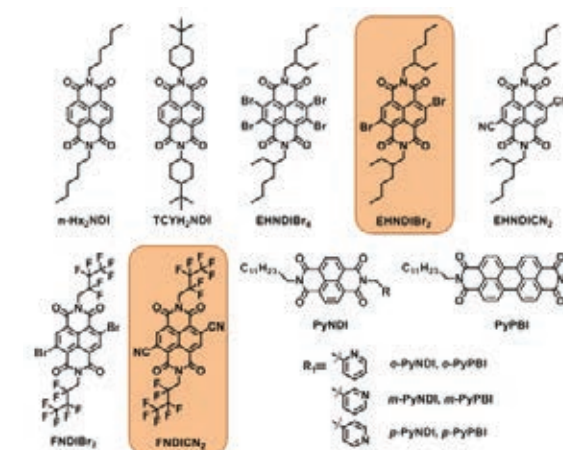
As the smartphone is relative to the Earth's magnetic field, any movement of it causes the measured magnetic field to change notably. The magnetic field strength of the signal transmitted by the Labelonik-NFC-label is only in the same order as the strength of the Earth's magnetic field, it is not possible to detect the signal transmitted by the tag, while it is moving. To improve the signal-to-noise ratio, the Android app has been extended with the ability to evaluate the smartphone's gyroscopes. Based on these acceleration measurements any phone movement detected is filtered out negating the effects of a changing earth's magnetic field.



The Labelonik Android app has been designed using Android Studio and Kotlin. It can poll the hall sensor (magnetic compass) of most smartphones at a rate of 50 Hz. Since the smartphone's magnetic sensor and NFC-reader antenna are located close together, the centres of the antenna used for harvesting power from NFC and the magnetic transmission coil must be close. Consequently, a second coil on the backside of the test board could be used for

transmitting magnetically or an outer coil surrounding an inner coil could be used. Together with the developed Android app, Labelonik demonstrated the magnetic transmission from an active NFC-label to a smartphone using its hall sensor (magnetic compass). The transmission was triggered by the NFC-reader of the phone.

Labelonik demonstrated the magnetic transmission from an active NFC-label to a smartphone using its hall sensor (magnetic compass). The transmission was triggered by the NFC-reader of the phone.



IISER Kolkata

High carrier mobility, ambient stability and solution processibility of n-type semiconductors are attributes of prime significance in this project. With this objective in mind, the following molecules were synthesized. The design focused on optimizing the substitution at the imide N atoms and the organic core to achieve the best results. The large polarizability of Br and CN groups in the core position results in good solubility and solution processibility. Electron-withdrawing nature of these groups lowers the Lowest Unoccupied Molecular Orbital (LUMO) and in turn, improves charge injection and affords high ambient stability. Finally, the fluorocarbon chains are known to improve surface crystallization and ordering in the solution processed thin films.

The design focused on optimizing the substitution at the imide N atoms and the organic core to achieve the best results.

Holographic Security Marking Systems (HSMS)

HSMS have started its 8-colour gravure machine and undertook some printing trials of moisture sensor inks. The inks were supplied by SAL. Initial trials were promising but there is variability in resistance. With the New tooling that is being developed more consistent readings with the new trials are expected.



Gravure printed humidity sensor

Publications

- *S. Datta, D. Chaudhuri, Reversible Supramolecular Polymorphism in Solution and Solid Matrix by Manipulating Sidegroup Conformation, Angew. Chem. Int. Ed. DOI: 10.1002/anie.202201956, 2022.*
- *S. Samanta, P. Raval, G. N. M. Reddy, D. Chaudhuri, Cooperative Self-Assembly Driven by Multiple Noncovalent Interactions: Investigating Molecular Origin and Reassessing Characterization, ACS Central Sci., 2021, 7, 1371.*
- *T. Ghosh, M. Mondal, R. K. Vijayaraghavan*, Minute torsional reorganization elicited large visible range fluorescence gain in terphenyl derived Crystals, Mater. Chem. Front, 2022, 6,297.*
- *B. K. Barman, Manas Khatua, Bappaditya Goswami, Subhas Samanta*, Ratheesh K. Vijayaraghavan* Irreversible resistive state switching in devices with homoleptic Cobalt(II) complex active layer, Chem. Asian. J., 2021, 16, 1545.*
- *B. K. Barman, N. G. Ghosh, I. Giri, C. Kumar, S. S. Zade,* Ratheesh K. Vijayaraghavan*, Incorporating redox active entity to attain electrical bistability in a polymer semiconductor Nanoscale, 2021, 13, 6759.*
- *K. J. Kalita, I. Giri, R. K. Vijayaraghavan*, Influence of non-covalent interactions in dictating the polarity and mobility of charge carriers in a series of crystalline NDIs: a computational case study, RSC Adv, 2021, 11,33703.*

Patents filed

- "Ambient Stable Bipolar Non-Volatile Resistive Memory Device" - Inventors: Ratheesh K. Vijayaraghavan, Biswajit K. Barman, Debansu Chaudhuri, Soumik Sao, Triza Pal. Filed for Indian Patent
- "Semiconductor for ambient stable organic field-effect transistors" - Inventors: Ratheesh K. Vijayaraghavan, Debansu Chaudhuri, Sagar Biswas, Indrajit Giri. Filed for Indian Patent

Biomedical Technology



SIBAC

Next Generation of corneal imaging and analytics – From Lab to Market

Project Brief

Over the years, refractive surgeries like LASIK, SMILE, PRK, RLE have been most opted by people to get rid of eyeglasses or contact lenses. But it also comes with the risk of postoperative complications of the cornea. It is well known that the biomechanical response of the cornea plays a significant role in refractive outcomes. If the collagen in the cornea degenerates, it will lead to steepening of the cornea which can further cause visual impairment. Post-refractive surgery ectasia is one such rare condition which results from refractive surgery characterized by an abnormal change in corneal refraction and vision loss due to cornea steepening after surgery. Thus, the knowledge of the biomechanical properties of the cornea is important in disease diagnosis, treatment planning and monitoring of treatment outcomes.

There are several techniques which are being investigated to quantify the in-vivo corneal biomechanics, but none have been translated to the clinic so far. To explore these issues and find a plausible solution, SIBAC Project: Next-generation dynamic Scheimpflug imaging and biomechanical analytics for in vivo quantification of corneal viscoelasticity under the flagship programme of IGSTC “2+2 Projects” was initiated. Phase 2 of the project is partnered by Dr Abhijit Sinha Roy, Narayana Nethralaya Foundation, Bangalore and Mr Sven Reisdorf, OCULUS Optikgeräte GmbH, Dresden. The project intends to provide a comprehensive package to investigate the accurate biomechanical outcomes after refractive surgery and corneal crosslinking by coupling corneal tomography with high-speed dynamic Scheimpflug imaging.

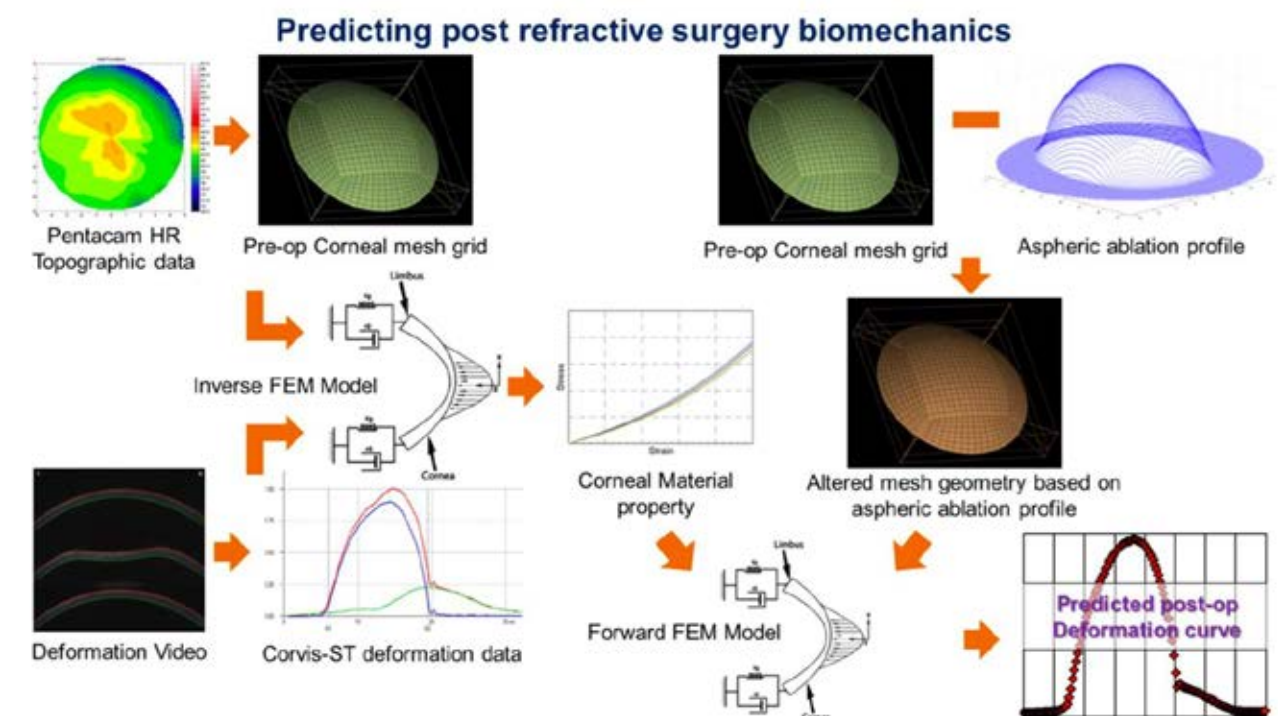
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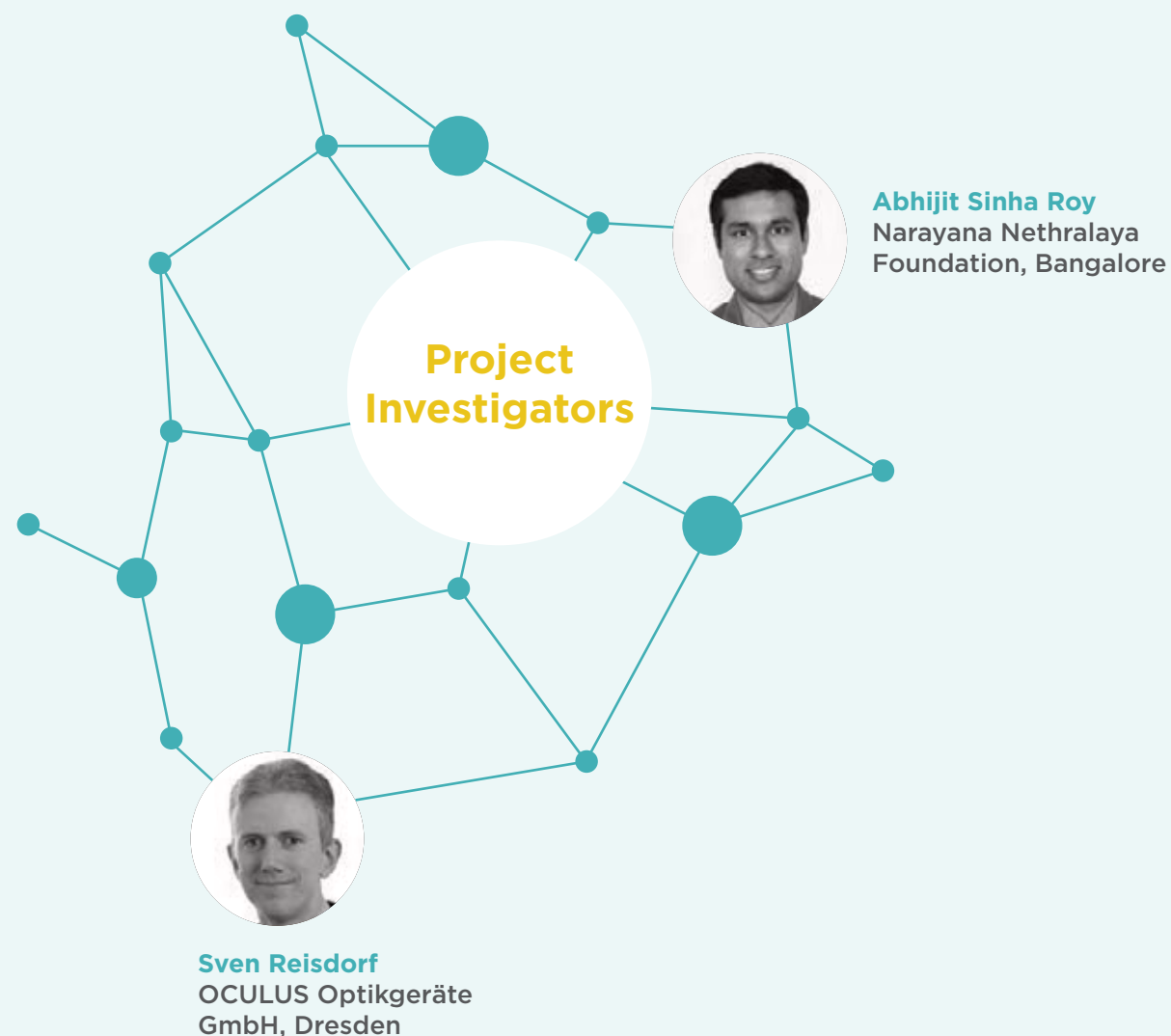
Progress made/achieved

One of the major achievements of this project is the development of the software called “AcuSimX,” an inverse finite element tool for post-refractive surgery biomechanics prediction. It is the world’s first advanced biomechanical simulation software which allows to

predict biomechanical outcomes after refractive surgery and estimate the risk of corneal ectasia. This tool shall aid surgeons in simulating the surgery before the actual surgery has been conducted which shall further help mitigate the risks associated with it.

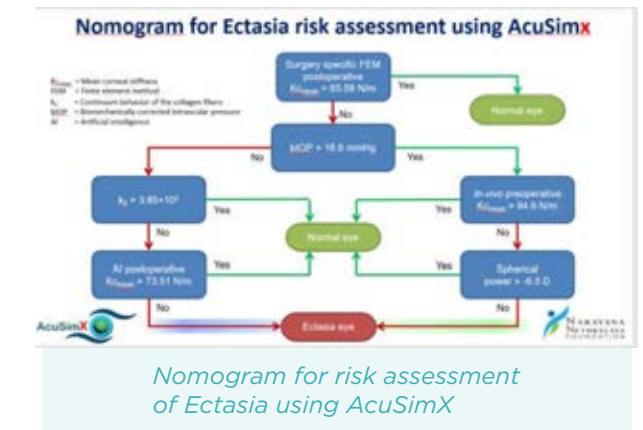


Schematic of software tool predicting post-refractive surgery biomechanics



AcuSimX is designed to accept data directly from the Corvis ST and the Pentacam devices made by German ophthalmic instrument developer OCULUS. In LASIK, preoperative Pentacam and Corvis measurements are processed to perform an inverse finite element solution which determines the biomechanical properties of the cornea. These properties along with the postoperative geometric mesh produced using refractive errors present in the patient's eye are used to generate a simulation report which can be later exported as a pdf and shared with the patient and surgeon. This entire process of finite mesh generation, biomechanical simulation and AI driven population comparison are automatically performed by the AcuSimX without any proprietary tools. Similar reports are also generated for SMILE, PRK and glaucoma simulations making AcuSimX, standalone software to put the power of simulations in the hands of clinicians.

Recently, project partners have made a new advancement by producing a Nomogram to predict corneal ectasia using the outcomes of AcuSimX software. The Nomogram is a tree of parameters which helps the clinicians to identify the risks involved in the cornea. This new development shall be installed in the upcoming versions of AcuSimX.



Currently, AcuSimX is available for installation at the customer sites of OCULUS Optikgerate GmbH, Germany. In the first phase, AcuSimX is being made available to Asian customers via OCULUS Optikgerate GmbH, Asia. As a next step, OCULUS Optikgerate GmbH, Asia has taken over sales and marketing of the software in South-East Asia.

Sound4All

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

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Project Brief

Hearing impairment is one of the most common forms of disability in countries like India. In rural areas, children are prone to this due to malnutrition and inadequate medical facilities. In urban areas, the population is continuously exposed to high levels of noise, particularly in their work environments (e.g., in factories or construction sites). However, with regular screening hearing impairment may be detected early and treated. The screening of newborns for hearing loss is slowly gaining momentum in India but monitoring of children and adults regularly is almost non-prevalent. This is because the currently available screening equipment is expensive and there is a shortage of specialists to operate that equipment. Therefore, this project aims to completely re-engineer a screening device in such a way that it (i) significantly brings down the cost, and (ii) enables it to be used by laypersons in the same manner that we use blood pressure monitors or thermometers. The more widespread availability of low-cost screening devices will enable their usage in schools, small healthcare centres, factories & construction sites. This shall help with the early detection of hearing impairment thereby significantly improving their chances of recovery or preventing further deterioration. To make them cost-effective, the newly designed devices will require a completely different hardware and software architecture, without compromising the quality of the screening. Developing such architectures and evaluating them are the main scientific goals of this project. The consortium shall rely on two main techniques: (i) offload the involved signal processing algorithms onto a mobile phone, and (ii) usage of available off-the-shelf components instead of using expensive and specialized probes, as is the case in existing screening equipment. The measurement distortions introduced by it will be corrected using suitable signal processing algorithms. Since the usage and penetration of mobile phones even in rural areas in India is relatively high, designs based on such solutions will bring down the manufacturing cost.

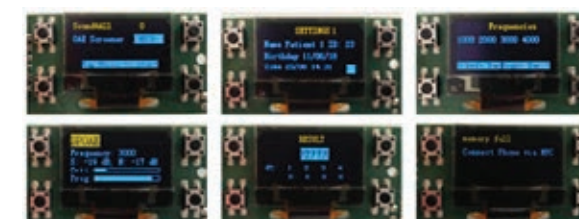
In the consortium aimed to make a cost-effective hearing screening device based on off-the-shelf components. Rapid prototyping techniques have helped them to explore many variants of ear probes. Further investigations on the usage of smartphones for hearing screening proved to be helpful. They developed promising prototypes for an ear probe and a small standalone device.

Phase 2 is being 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 would like to proceed with improving the user experience with sensor data gathered outside the ear probe.

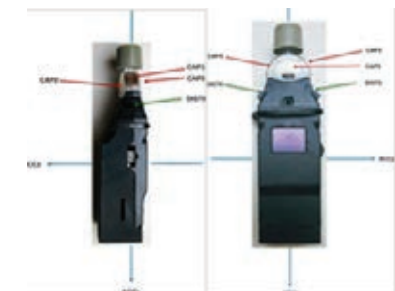
Progress made/achieved

TU Munich (TUM) & PATH Medical

TUM & PATH Medical have started working on the Android-based smartphone app that serves as an interface for patients, test data management and configuring the standalone device. The operator can set the parameters of the OAE (Otoacoustic Emission) measurements and enter patient data on the smartphone and transfer it to the device. After the measurement is completed, the results can be transferred back to the smartphone.

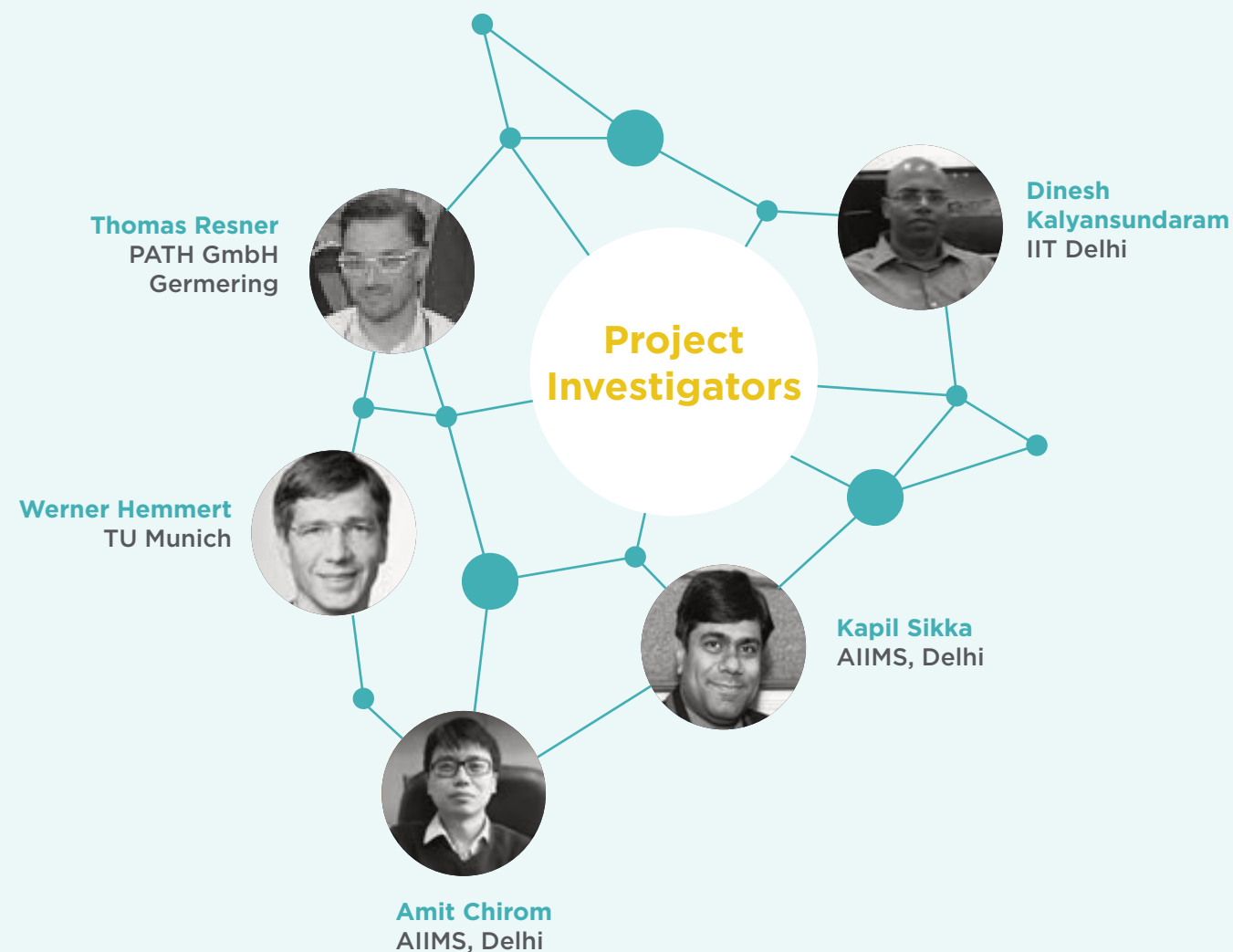


User Interface on the standalone device



Photographs of the S4A standalone OAE device with the position of the four capacitive sensors (CAPO-3), the two distance sensors (DISTO-1) and the acceleration sensors (ACC x,y,z).

The Sound4All (S4A) standalone OAE (Otoacoustic Emission) device has two distance sensors and four capacitive sensors built in close to the tip where the device touches the earlobe during an OAE measurement. Capacitive sensor values change when human body parts come closer. The relative changes in the value of opposite sensors would differ while insertion into the ear due to the asymmetry in the shape of the human ear. This difference can be exploited to detect whether the device was inserted in the left or right ear. With distance sensors, detection was possible in 100% of the cases. However, with two sensors the detection was only possible when the orientation of the device (display) was horizontal and with the four capacitive sensors, the detection was possible with the display horizontal or vertical, but the accuracy was only 75% with a simple algorithm. i.e., a left-right detection with distance sensors is possible with high accuracy if the orientation of the device is controlled, as in the case of acceleration sensors.

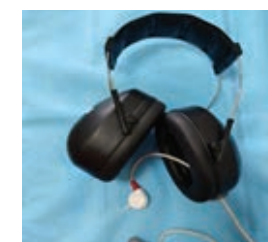


TU Munich (TUM)

TEOAE (Transitory evoked otoacoustic emission) – detection algorithm tested with chirps.

On the S4A standalone device, an unparametrized statistical detection algorithm based on the work of Giebel, 2001 has been used. The basic concept is level-weighted averaging over several successive single measurements and normalization of an analysis window to a defined standard deviation. Assuming the data to be gaussian, outliers are detected as OAEs. This concept was tested with clicks and fast chirps on the Path Medical Sentiero device on one normal hearing subject. As a reference, every measurement was done in a cylindrical control volume. The results suggest that chirps can be an appropriate alternative to clicks, which has advantages for example when the peak sound pressure of the loudspeakers is limited.

Giebel, A. (2001). Applying signal statistical analysis to TEOAE measurements. Scandinavian Audiology. Supplementum, 52, 130-132. <https://doi.org/10.1080/010503901300007308>



The re-engineered probe with the muff

All India Institute of Medical Sciences (AIIMS) & IIT Delhi

Probe comparison study conducted by AIIMS

A comparison study to investigate the performance of PATH Medical's EPDP (Electric Potential Difference Probes) and EPLT probe was performed. EPDP probe is currently being used in the Sound4All device. The efficiency of the EPLT probe design was assessed. A total of twenty-five DPOAE (distortion product otoacoustic emission) and TEOAE measurements were obtained using both probes. Factors such as test results, time taken to record and recording comfort of measurements using both the probes were noted.

Neonatal hearing screening program conducted by AIIMS

In conjunction with the Department of Paediatrics, the universal neonatal hearing screening program using commercially available screening devices was initiated. Experience with Otoacoustic Emission measurement using both the Transient Evoked Otoacoustic Emissions (TEOAE) and Distortion Product Otoacoustic Emissions (DPOAE) in a larger population was broadened. A total of twelve hundred neonates have been screened using DPOAE/TEOAE and Automated Auditory Brainstem Responses (AABR). The program has been running for eight months and achieved 95% coverage. The test protocol has been designed to prioritize the high sensitivity of the program. The hands-on experience in how the OAE and AABR measurements can be recorded and how various factors such as probe placement and ambient noise can affect the testing in various settings such as the intensive care units and the wards have been acquired. Re-screening and diagnostic evaluation of patients who fail initial hearing screening is also being carried out using appropriate test battery.



Revised prototype with integrated sensors and smaller housing



Assembled probe with injection moulded parts design-I

Publications

- *Abstract submitted to Indian Speech & Hearing Association Conference 2022. Title is "Effect of Earmuff on Distortion Product Otoacoustic emissions in the presence of Noise".*

MIDARDI-D2P

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

Project Brief

Diabetic foot ulcers (DFU) are often associated with type 2 diabetes and are therefore still 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 is 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 toward a system prototype. Aspects addressed include storage stability, cost and the 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.

The project team have standardized an isothermal amplification method to incorporate in the point of care device being developed.

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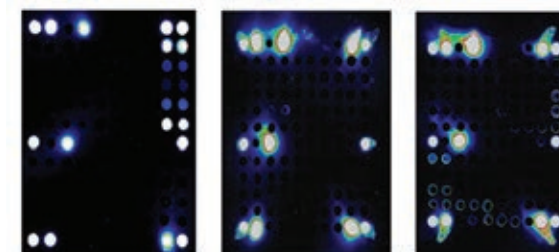
Frank.Bier@izi-bb.fraunhofer.de
j.nestler@biflow-systems.com

Isothermal amplification methods are a streamlined, exponential way of identifying the target nucleic acid sequences, without the need for an external thermal cyclers. The independence from a thermal cyclers enables the device to be used in any healthcare setting without reliance on external machinery or specially trained personnel. Loop-mediated isothermal amplification (LAMP) enables rapid amplification of DNA with high specificity and efficiency.

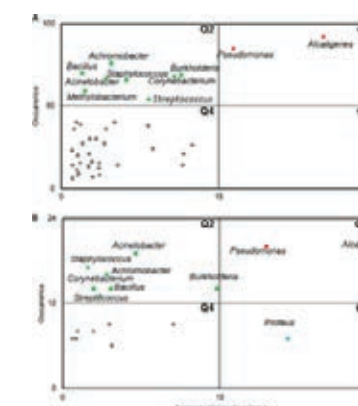
Progress made/achieved

Manipal School of Life Sciences (MAHE)

Isothermal amplification methods such as LAMP, SDA (Strand Displacement Amplification), HDA (Helicase Dependent Amplification) were streamlined to identify the target nuclei acid sequences with high specificity and efficiency. Two strains each of *Staphylococcus aureus*, *Proteus mirabilis* and *Acinetobacter baumannii* and one strain each of *Pseudomonas aeruginosa*, *Escherichia coli*, *Streptococcus mutans* and *Enterococcus* spp were analyzed in LAMP assays. Further, hybridizations were carried out onto microarray slides with probes aimed at accurate identification of *S.aureus*, *A.baumannii* and *S. mutans*.



Hybridization of labeled LAMP product of *S.aureus*, *A.baumannii* and *S. mutans* onto array



A) Dominant microbes among diabetic wound samples. (B) Dominant microbes among nondiabetic wound samples

Achira Labs

A custom sample preparation module has been designed to isolate bacterial DNA from the DFU swab samples. The module is currently being evaluated with actual samples and efficacy data will be presented in the next report. It will be later useful for comparing the efficiency of DNA elution and lab standard technologies.

BiFlow Systems GmbH

Different species were detected by on-cartridge hybridization and automatically detected by a specifically developed spot-recognition software. That software also allows for correctly identifying single nucleotide polymorphisms (SNPs) used for both correct species identification and the detection of some resistances. RPA was established based on primer sequences provided by Fraunhofer IZI-BB. On-cartridge experiments were first carried out on a standard cartridge which was modified to run the required protocol. In order to implement more of the workflow into the microfluidic device, the amplification has been carried out on the BiFlow cartridge.



Publications

- Jnana A, Muthuraman V, Varghese VK, Chakrabarty S, Murali TS, Ramachandra L, Shenoy KR, Rodrigues GS, Prasad SS, Dendukuri D, Morschhauser A, Nestler J, Peter H, Bier F, Satyamoorthy K. (2020). Microbial Community Distribution and Core Microbiome in Successive Wound Grades of Individuals with Diabetic Foot Ulcers. *Applied and Environmental Microbiology*, 86: e02608-19.
- Prasad ASB, Shruptha P, Prabhu V, Srujan C, Nayak UY, Anuradha CKR, Ramachandra L, Keerthana P, Joshi MB, Murali TS. Satyamoorthy K. 2020. *Pseudomonas aeruginosa* virulence proteins pseudolysin and protease IV impede cutaneous wound healing. *Laboratory Investigation* 100, 1532-1550.
- Warriar A, Mazumder N, Prabhu S, Satyamoorthy K, Murali TS. 2021. Photodynamic therapy to control microbial biofilms. *Photodiagnosis and Photodynamic Therapy* 33, 102090.
- Warriar A, Satyamoorthy K, Murali TS. 2021. Quorum-sensing regulation of virulence factors in bacterial biofilm. *Future Microbiology* 16, 1003-1021.
- Nayak N, Satyamoorthy K, Murali TS. 2021. Next-Generation Sequencing technology for diagnosis of microbial infections in chronic wounds. *Journal of Wound Care Accepted*

Papers published in conference proceedings, popular journals

Murali TS, Jnana A, Ramachandra L, Prasad SS, Dendukuri D, Morschhauser A, Nestler J, Peter H, Satyamoorthy K. 2021. Poster presentation - Analysis of major bacterial genera in diabetic foot ulcers of different wound severities based on NGS at the Annual Meeting of the Society of Biological Chemists (India), Amity University, Haryana, India, December 16-19, 2021.

PhD/Master thesis supervised

1. Chinmayi M. 2022. Development of LAMP assays for simple and rapid detection of bacterial pathogens. MSc dissertation submitted to Manipal Academy of Higher Education.
2. Vanshika K. 2022. Development of LAMP assays for simple and rapid detection of antibiotic resistance markers in bacterial pathogens. MSc dissertation submitted to Manipal Academy of Higher Education.

Waste Management

REDUCE
REUSE
RECYCLE



Pyrasol

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

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Project Brief

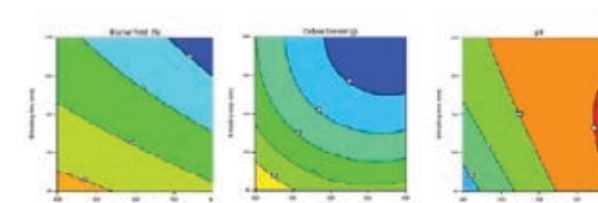
Collection, treatment, and disposal systems of urban wastes in Indian Smart Cities as well as in other urban centers have to be managed and organized with an integrated and interactive approach. Through this PYRASOL project, simple and robust processing technologies for urban organic waste will be combined 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 transforming 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 the pyrolysis process 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 targeted exchange and training schedules are elaborated.

Progress made/achieved

CSIR-CLRI, Chennai, India

Optimization of pyrolysis conditions using RSM tool

For optimization of pyrolysis conditions of fibrous organic waste i.e. Banana Peduncle (BP), Response Surface Methodology (RSM) using Central Composite Design (CCD) has been carried out using Minitab software (version 21). Experimental investigations were carried out under different conditions, i.e., pyrolytic temperature (PT), holding time (HT) and heating rate (HR). The design Minitab software generated a total of 20 experimental conditions with different factor combinations (PT, HT and HR). The responses are biochar yield (%), carbon content (g) and pH of the biochar. Based on the experiments carried out, the responses obtained were analyzed in Minitab software to generate 2D graphs showing the reactions at different levels of independent factors. In addition, variance analysis by ANOVA was used to analyze the experimental responses.



Graph indicating pH with factors pyrolytic temperature (PT), Holding time (HT) and Heating rate (HR)

Ramky, Hyderabad, India

Pilot plant site development and soil test for construction

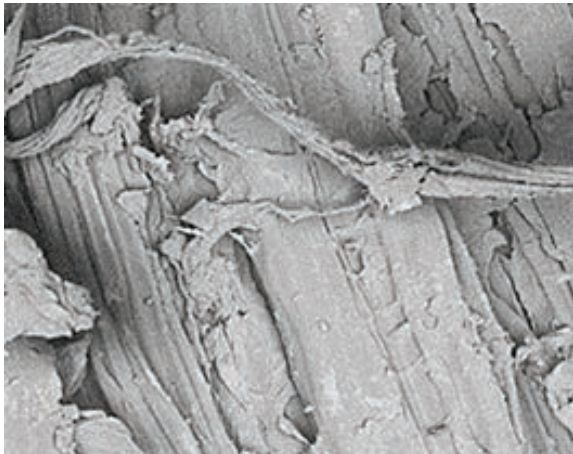
The technical team of Ramky already visited the pilot plant site several times during the reporting period and developed the site for base foundation and subsequent construction. Soil samples are taken and tested for the required parameters for the civil construction of the solar updraft dryer.

Structural design of solar updraft dryer & BoQ preparation

The structural design for the solar updraft dryer has been completed with the help of ISAH and CLRI. The finalized drawing has been submitted and approval has been obtained from CLRI. Based on the approved drawings the bill of quantities (BoQ) has arrived for finalization of the tender. Similarly, the quotations from the competitive vendors have been requested and are under finalization.



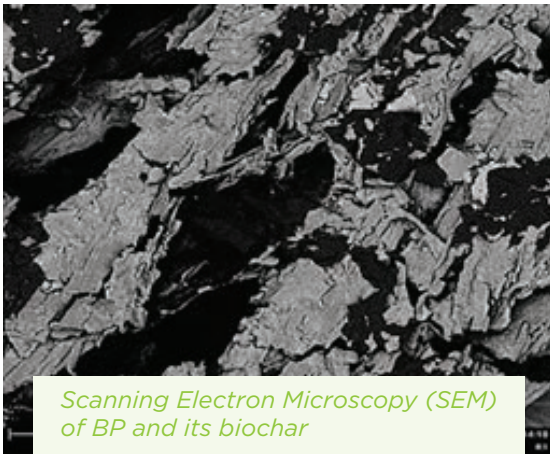
Visit of Mr. Madhan, Director IGSTC to Pilot plants at CLRI on 29.09.2021



Institute for Urban Water Management and Waste Management (ISAH), Leibniz Universität Hannover, Germany

Kinetics and thermodynamic analysis of pyrolysis

The pyrolysis of organic wastes is kinetically complex and hence it requires detailed investigation. For this, ISAH has conducted an investigation and comparison of the pyrolysis mechanisms for three different PYRASOL feedstocks - banana peduncle (BP), sewage sludge (SS), and anaerobic digestate (AD)- during the reporting period. The main purposes of this study are to determine the different pyrolysis stages including secondary tar cracking reactions, their associated gas/volatile emissions & heat flow, kinetic triplets and reaction thermodynamics using linear and non-linear isoconversional methods.



Scanning Electron Microscopy (SEM) of BP and its biochar

ISAH has conducted an investigation and comparison of the pyrolysis mechanisms for three different PYRASOL feedstocks - banana peduncle (BP), sewage sludge (SS), and anaerobic digestate (AD)- during the reporting period.

Development Life Cycle Assessment (LCA) model of the complete system

An LCA model of the PYRASOL process is created with the help of the life cycle assessment software Umberto® LCA+ to be able to evaluate the system ecologically. The software Umberto LCA+® enables life cycle assessments, material flow analyses and cost structures to be realized and visually processed in a single model (Sankey diagram, network plan view). Umberto LCA+ also offers the user a choice of databases (Ecoinvent, GaBi, EstiMol), which allow to obtain ISO standardized (ISO 14044, ISO 14064 and ISO 14025) results. Umberto LCA+® is also characterized by an application-oriented programming and input structure, which makes it easy for the user to run intuitively.

Biomacon GmbH, Rehburg, Germany

Operation manual and the configuration of the commissioning process

A detailed operational manual and guides are prepared and sent to CLRI for supporting the initial operation and commissioning. An additional chapter in the operation manual was created to explain in detail the handling of the touch panel and the configuration for the commissioning process.

Publications

- *SMART city concepts for treatment of and resource recovery from municipal organic wastes: Experiences from IGSTC 2+2 projects (presented in the 12th Hanseatic India Colloquium on Solid Waste Management in Hamburg on 07.04.2022, submitted for publication as a book chapter of the conference proceedings on 29.04.2022)*
- *Urban organic waste management through combined biochemical and thermochemical processes: Material flow analysis (MFA) including mass, energy and carbon layers using STAN2 software*
- *“Production and characterisation of biochar from Sugarcane bagasse and tender coconut wastes” Nishanthi R, Sathish G, Nivethitha B. S., Geethakarathi A., M. Mondal, Dirk Weichgrebe and Srinivasan S. V*, Accepted & presented in the International Conference on Advances in Sustainable Research for Energy and Environmental Management (ASREEM-2021) organized by the Department of Chemical Engineering, Institute of Technology, Surat (India) on August 06 – 08, 2021.*

PhD/Master thesis

1. Master Thesis - Marianne Pichler “Comparative evaluation of electricity and cooling recovery processes for the use of low-temperature energy from the pyrolysis of waste biomass”: 01.12.2020 – 01.06.2021
2. Master Thesis-Kara Rahmi “Life cycle assessment (LCA) of the conversion of urban organic wastes through combined biochemical and thermo-chemical processes”: 24.05.2021 – 24.11.2021
3. Master Thesis-Reejula Roy “Material Flow Analysis (MFA) of the conversion of urban organic wastes through combined biochemical and thermochemical processes”: 15.09.2021 – 15.03.2022
4. Research Project-Paul Jübner “Thermodynamic analysis of biomass pyrolysis process”:15.01.2021 – 15.07.2021
5. Research Project-Jacqueline Schwingel “Heat transport model for solar drying of organic residues”:21.01.2021 – 21.07.2021

Bio-CuInGe

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

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Project Brief

Germanium (Ge) and Indium (In) are important elements for 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 challenge for Cu smelters. This project proposes to develop environmentally 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

IIT Delhi

- 1) Leaching of Hindustan Zinc Limited (HZL), Hindustan Computers Limited (HCL) and Lakshmi Life Sciences (LLS) samples are completed
- 2) SX process for HZL and LLS samples is almost completed
- 3) Complexation of Ge with Desferrioxamine B (DFOB) is optimized and result will be reported in the next report
- 4) Work on the complete flow sheet of HZL, HCL and LLS sample is being carried out

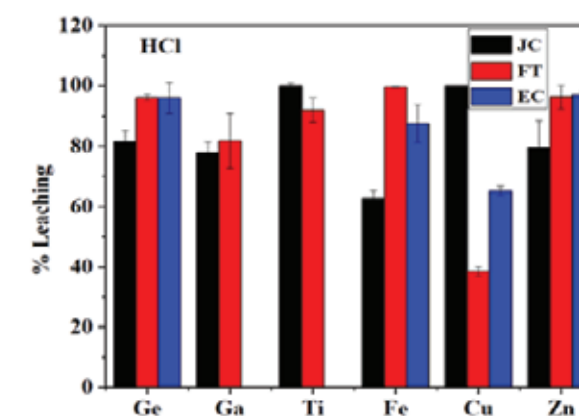
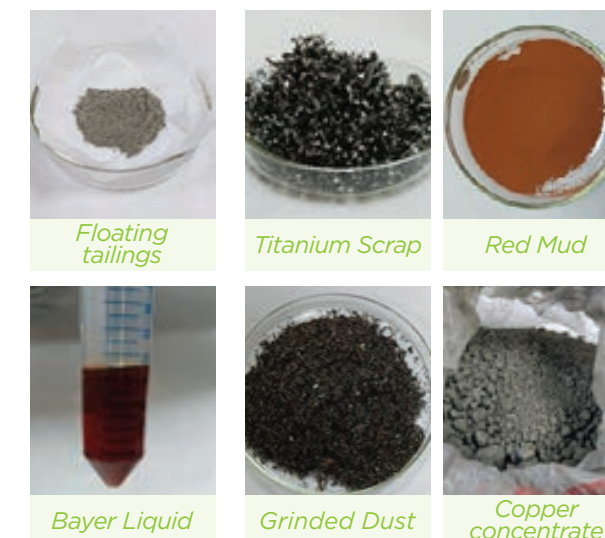


Figure: Effect of HCL concentration

Lakshmi Life Sciences (LLS)

LLS also supported in making contacts with Indian Titanium (Ti) recycling company. They also shipped more samples for leaching tests. Soon, the Cu solution will be sent to them for conversion to rods



Helmholtz-Zentrum Dresden-Rossendorf (HZDR)

- Material Liberation Analysis were done 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 were performed
- Further investigations of the peptides were performed using Mass Spectrometry.



Site visit at Helmholtz-Zentrum Dresden-Rossendorf (HZDR)



Publications

- *Pollmann, K. Lederer, F. "Biotechnology: new tools for recycling"; Lecture, graduate course "Urban mining", 09.04.2021, Vancouver, Canada (online)*
- *Pollmann, K.;" New concepts for recovery of metals from wastes using biological means", oral presentation at ACS Spring 2022, 20.-24.03.2022, San Diego, CA, USA (online)*
- *Matys, Sabine "Biotechnological processes for the treatment of mining residues, oral presentation, rECOMine workshop, 07.04.2022, Freiberg, Germany Phage Display Derived Phage Clones and Peptides for the Recovery of Valuable Metal Ions from Low Concentrated Water Streams, 1. International Conference on Metal Binding Peptides, Nancy, France, postponed to July 2022*

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.

PhD/Master thesis supervised

1. HZDR: Supervision of 3 Erasmus students from Italy; parts of their internship were related to the Bio-CuInGe project.
2. Subtasks of the project were worked on by students of the Zittau University of Applied Sciences during the reporting period.
3. From 01.10.2019 – 15.12.2020 Mrs. Priyanka Dubey performed her DAAD project "Extraction of Critical Metals (Cu, In, and Ge) from Industrial wastes" at the HZDR.

Workshops



Indo-German Virtual Workshop on Artificial Intelligence

During the inter-governmental consultations between Germany and India in November 2019, it was decided to strengthen and enhance the cooperation in the field of artificial intelligence.

6 – 7 September 2021

In the past years, AI has generated intense interest in science and business as well as in almost all fields of daily life. Due to its tremendous impact, it is important to discuss and evaluate opportunities and challenges for science, industry, and society also in the international context. Hence, during the inter-governmental consultations between Germany and India in November 2019, it was decided to strengthen and enhance the cooperation in the field of artificial intelligence.

This workshop was the first visible effort initiated by the German Federal Ministry of Education and Research (BMBF) together with the Department of Science and Technology (DST) of Ministry of Science and Technology, India organised by Indo-German Science & Technology Centre (IGSTC). The aim was to bring scientific experts together, enlarge networks and identify fields of mutual interest for future collaboration.



Participants of AI workshop

The workshop was held over two days on a virtual platform. The workshop was coordinated on the Indian side by Dr. P. V. Lalitha and on the German side by Ms Dörte Merk. The first day commenced with an inaugural session with initiation by Rajachandran Madhan, IGSTC; Welcome by S K Varshney, DST; Opening remarks by Kathrin Meyer; Address by Prof Ina Schieferdecker, BMBF; and by K R Murali Mohan, DST. This was followed by a plenary lecture by Rupak Majumdar, Max Planck Institute for Software systems, Kaiserslautern on the Topic: Explainable and Responsible AI. Subsequently, five parallel sessions were held on the following topics:

- AI for Sustainability
- Trustworthy AI
- AI for Healthcare
- Mathematical Foundations of AI/ML
- Autonomous Robotics

The second day commenced with a plenary lecture by Subhasis Chaudhuri, Director, IIT Bombay on the topic: What constitutes features in pattern recognition problems. This was followed by five parallel sessions on the before mentioned five topics. The concluding session featured presentation of summaries of deliberations in the five sessions followed by a presentation of recommendations and vote of thanks.

Each Session had 12 experts, six from India and six from Germany and was also attended by special invitees from the Government, academia, industry, and startups.

Session summaries of the five sessions are provided as separate documents.

The following themes and subthemes were identified for possible future collaborations between India and Germany as also for preparing a call for proposals for a forthcoming IGSTC's 2+2 call.

Themes and Subthemes

Theme 1: AI/ML in Sustainability

- AI assisted understanding of extreme weather events
- Infrastructure planning: urban planning for flash floods; planning for mountainous regions and national parks; rural/agricultural land use planning; Bridging synoptic scale patterns in data/models to small scale, local extreme weather events which can damage infrastructure

Theme 2: Trustworthy AI

Foundations for Safe AI: Responsible and Ethical AI; AI for Social Decision Making; Privacy Preserving Robust ML; Integrating Symbolic and ML Methods; AI interacting with Physical World, Explainable AI/ML.

- Foundations for Safe AI: Responsible and Ethical AI; AI for Social Decision Making; Privacy Preserving Robust ML; Integrating Symbolic and ML Methods; AI interacting with Physical World, Explainable AI/ML.

- Practice for Safe AI systems: Systems Engineering based Trustworthy AI; Resource Constrained Robust AI; Certifiable and Auditable AI for Safety and Security Critical Applications; Integrating AI/ML with High-fidelity Domain; Human Simulation Models for end-to-end Applications.

Theme 3: AI for Healthcare

- AI for Healthcare of the Mind;
- Affordable AIML Technologies for Healthcare
- Creating Better Populations (Epidemiological Models and Public Health)
- Explainable AIML Models for Healthcare

Theme 4: Mathematical Foundations of AIML

- Optimisation, particularly in the context of training large ML models or deep networks
- Causality and its implication in robust, fair, explainable ML and domain adaptation.

Theme 5: Autonomous Robotics

- Autonomous navigation/assistance
- Robot Manipulation
- Robotic Paramedic (Moonshot)

The following modes of collaboration were proposed by the experts.

Modes of Collaboration

Collaborations which foster joint solutions of these challenges can follow more classical and established schemes. In addition, novel formats could facilitate a long-lasting impact. The following forms of collaborations were judged as optimal ones:

Established formats

- Short-Medium Term Projects
- Mobility, Joint / Tandem PhD, Post-Doc – Faculty, Student, Researchers
- Industry Collaborations (1+1 or 2+2 Model)
- Large Multi-Institutional Projects with long-term goals

Novel formats

- Long Term Multi-Institutional Academic Collaboration (Integrated Indo- German Grad School)
- Umbrella Indo-German Industry-Academia Consortium Model for Long-Term Engagement
- Entrepreneur / Startup driven R&D for new Deployment Ideas

High-performance metallic materials for energy storage and power generation (MATAPP-2021)

Development of advanced ultra-supercritical power plant technologies is being handled on mission mode in India. In this context, specialty steels and superalloys are being developed and evaluated in both in India and Germany.

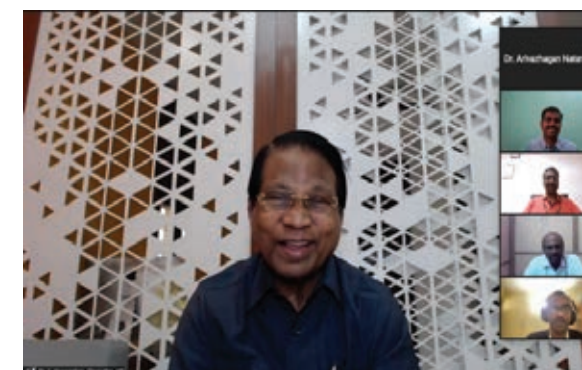
22-23 April 2021

Indo-German bilateral workshop on High-performance Metallic Materials for Energy Storage and Power Generation (MATAPP-2021) was jointly organised by Vellore Institute of Technology (VIT) & FZ Jülich on 22-23 April 2021. The workshop coordinators were Dr M. Manikandan, VIT and Dr Bernd Kuhn, FZ Jülich GmbH.

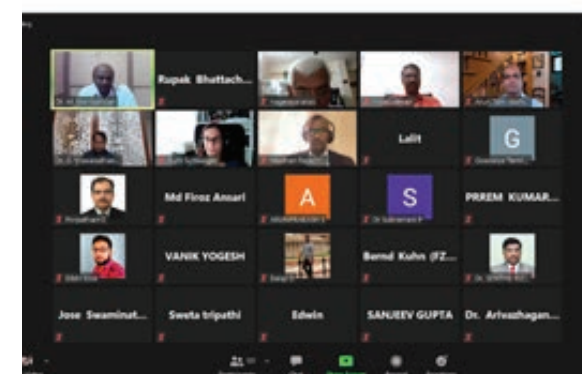
While fossil fuel based power plants are being phased out, some avenues are still being explored to increase the efficiency of thermal power plants and reduce the emissions of polluting species. Development of advanced ultra-supercritical power plant technologies is being handled on mission mode in India. In this context, specialty steels and superalloys are being developed and evaluated in both in India and Germany. Solar power generation is the most important type of renewable energy, receiving serious attention in both nations. Here again Concentrated Solar Power (CSP) based power generation has several advantages over the photovoltaic approach. Thermal energy storage systems become important in this context and special steels and superalloys resistant to Phase Change Materials (PCM) need to be developed. The Workshop covered special metallic materials required for advanced versions of thermal power plants and energy storage systems for CSP technology.



Mr Madhan addressing Inaugural session



Dr G. Viswanathan, Chancellor, VIT delivering Presidential Address



The Workshop created an excellent platform for interaction among experts from around the globe on current status and directions / thrust areas for future in the field of special steels and superalloys for advanced thermal, concentrating solar power and heat storage plants. Close to 250 delegates from all over the globe participated in the Workshop. Dr Ruth Schwaiger, Director at the Institute of Energy and Climate Research, FZ Jülich, Germany, was the Guest of honour. Mr Madhan addressed the inaugural session and briefed about the various programmes initiated by IGSTC to enhance R&D partnership between India & Germany. He also urged the participants to find innovative solutions for renewable energy.



Dr Bernd Kuhn, FZ Jülich; Dr G. Sivakumar, ARCI, Hyderabad; Dr Torsten Fischer, FZ Jülich; Dr Hongcai Wang, Ruhr-University Bochum, Dr S K Jha, Chairman and Managing Director, MIDHANI, Hyderabad were some of the eminent speakers who delivered talks during this two day workshop. The workshop deliberations resulted in forging an academia-industry partnership to take stock of latest development and strategies to be adapted with reference materials for advanced thermal power plants and thermal storage systems based on concentrated solar power.



First Call of IGSTC Industrial Fellowship

A Glimpse

The fellowship is tailored for PhD students/researchers in S&T with appreciable track record and aptitude for applied research and technology development.

The IGSTC-Industrial Fellowship was launched by Prof. Ashutosh Sharma, the then Secretary of the Department of Science & Technology, Government of India on the occasion of IGSTC's 11th Foundation Day on 14th June 2021. The fellowship is tailored for PhD students/researchers in S&T with appreciable track record and aptitude for applied research and technology development. It is designed to encourage young researchers from an early stage of their career to experience an industrial exposure in a German setup.

The fellowship is provided at two levels.

- 1. PhD Industrial Exposure Fellowship (PIEF): Young researchers who have completed one year of their PhD course in Science/Engineering from India within an age limit of 30 years are eligible. The duration of the fellowship is up to 6 months.
- Post-Doctoral Industrial Fellowship (PDIF): Fresh PhDs in Science/Engineering with an age limit of 35 years (and within 3 years of completion of PhDs from Indian universities/institutes) are eligible. The duration of the fellowship is up to 12 months.

After an overwhelming inflow of applications and their successful evaluations, the result of IGSTC-Industrial fellowship was announced on 21 December 2021. A total of 20 candidates were selected for this prestigious fellowship.

The following are the brief profiles of 20 successful candidates for PDIF & PIEF awardees.



Post-Doctoral Industrial Fellowship (PDIF) Awardees



Dr. Tauheed Mohammad, IISc Bangalore

Host: AMO GmbH, Aachen

Area of Work: Integrated Perovskite on-Chip Laser. He intends to combine Perovskite Nanocrystals and quasi 2-D perovskites with silicon nitride to integrate first order distributed feedback grating resonators or ring resonators in order to produce on-chip lasers.



Dr. Bharathi Priya C, CSIR - SERC, Chennai

Host: Fraunhofer LBF, Darmstadt

Area of Work: Adaptive torsional vibration isolators using Magneto-rheological elastomer (MRE). She intends to develop a prototype adaptive torsional vibration isolator (ATVI) using Magneto-rheological elastomer (MRE), whose dynamic properties can be controlled in real-time using magnetic field.



Dr. Raviraj Verma, IIT Madras

Host: Fraunhofer IAPT, Hamburg

Area of Work: Design and Development of Aerospace Structural Part Manufactured through Laser+Wire Based Directed Energy Deposition Technique. He intends to use additive manufacturing (AM) techniques to improve buy-to-fly ratio, lead-time, and structural integrity of aerospace components (like satellite bracket, aeroengine stators, etc.)



Dr. Navaneethakrishna Makaram, IIT Madras

Host: Mentalab GmbH, Munich

Area of Work: SmarTaTSS: Tattoo Sensors for Smart Sleep Monitoring. He aims to design and develop a tattoo sensor for the continuous monitoring of the respiratory rate for sleep quality assessment.



Dr. Govind Narayan Sahu, IIT Kanpur

Host: Fraunhofer IWU, Chemnitz

Area of Work: Digital twin for machining with structure integrated active damper. He aims to integrate active damping model of metal cutting vibrations in the digital twin of machining process and improve machining performance.

**Dr. Keerthana M**, CSIR-SERC, Chennai**Host:** Fraunhofer IWES Oldenburg

Area of Work: An improved framework for assessment of loads on multi-megawatt wind turbines under yawed flow in Fraunhofer Institute for Wind Energy Systems. She intends to aims to use high fidelity tools such as Computational Fluid Dynamics (CFD) with Actuator Line Model (ALM) to calibrate the correction models adopted in conjunction with BEM.

**Dr. Neeraj Paul**, IIT Madras**Host:** Fraunhofer IWES, Oldenburg

Area of Work: Development of a low-order acoustic propagation model for new-generation wind turbines operating above the atmospheric boundary layer. The objective of the work is development of a low-order acoustic propagation model for Wind Turbine Generators (WTG) higher than 260m and its verification with measured data.

**Dr. Balram Singh****Host:** DendroPharm, Berlin

Area of Work: Through his project "NANOpain" he seeks to treat inflammation with novel dendritic nano-drugs without the addictive, potential for a better quality of life for patients with post-operative pain, cancer and chronic pain.

**Dr. Sanasam Vipej Devi**, NIT Mizoram**Host:** KoRoH GmbH, Karlsruhe

Area of Work: Capacity of joints made of high strength steel tubular section. A method for the numerical determination of the design resistance of punching shear will be made available which can be used later for numerical parameter studies parameter studies.

**Dr. Manjunath Mulimani**, Manipal Institute of Technology**Host:** FAIR GmbH, Darmstadt

Area of Work: Machine Learning. He intends to use novel Machine Learning (ML) and Deep Learning (DL) algorithms to distinguish particles of interest (signal) from other particles (background) produced in large energy particle colliders.

PhD Industrial Exposure Fellowship (PIEF) Awardees

**Devika Vikraman**, Rajiv Gandhi Centre for Biotechnology Thiruvananthapuram**Host:** Nanion Technologies GmbH, Munich

Area of Work: Nanobiotechnology. She intends to study conformational dynamics of CymA by site specific chemical modification in electrophysiology.

**Yugandhara Bhosale**, IIT Bombay**Host:** Airbus, Munich

Area of Work: Large Hybrid Drones. She intends to enhance her technical skills and introduce herself to industrial research to great extent at Weslax in Large Hybrid Drones.

**Sheena**, CSIR-NCL, Pune**Host:** BASF, Germany

Area of Work: Application of Machine Learning along with first principal methods to study industrially relevant reactions. She aims to combine experiments and theoretical computation-based methods with tools like ML that can greatly aid in bringing down the exploration space for computation.

**Ashish Sengar**, IIT Delhi**Host:** Fraunhofer IGB, Stuttgart

Area of Work: Wastewater treatment: Remediation of micro pollutants present in wastewater. He intends to assess different innovative techniques for the remediation of trace pollutants present in effluent of wastewater treatment plants.

**Renuka Sahu**, IISc Bengaluru**Host:** Airbus, Munich

Area of Work: Nanocomposites. She aims to create a sustainable & mechanically competent alternative using Nanocomposite to presently used fibre sizing, which will help to combat environmental degradation due to aerospace industry, making structures more sustainable.

**Yamini Mittal**, CSIR-IMMT Bhubaneswar**Host:** Janisch & Schulz mbH Münzenberg-Gambach

Area of Work: Field scale planning, building and operation of Constructed wetlands (CWs) for municipal wastewater treatment. She intends to learn the planning and construction of CWs at field scale from renowned Janisch and Schulz, Germany in order to augment her skills towards development of CWs in India.

**Sadbhawna**, IIT Jammu**Host:** K|Lens GmbH, Saarbrücken

Area of Work: Video Super Resolution (VSR) using Deep Learning. She wishes to develop a VSR algorithm for real-life videos via a deep convolutional neural network that should up-sample each image by a factor of two in each dimension.

**Aarushi**, CSIR-CSIO, Chandigarh**Host:** RWE Power AG, Essen

Area of Work: CO₂ Bio feed. She intends to work on CO₂ and biomass as feedstock for the production of fuels and chemical intermediates.

**Rinku Kumar Prajapat**, IIT Roorkee**Host:** FAIR GmbH, Darmstadt

Area of Work: Operation of a large-scale facility like the FRS for exotic isotope production in thick target (16g/cm²). He intends to use fragment separator (FRS) to produce exotic isotopes using Heavy-ion and exotic beam experiments.

**Peruswamula Veeravenkata Harish**, IIT Bombay**Host:** BASF SE, Ludwigshafen

Area of Work: Synergetic utilization of quantum chemistry and machine learning approaches to accelerate catalyst design. He is interested in understanding and applying catalysis for energy applications from an industrial perspective and machine learning.

Women Involvement in Science and Engineering Research (WISER)

Women Involvement in Science and Engineering Research (WISER) invites applications from Women researchers in India/Germany to be a part of an ongoing project in partnering countries in science and engineering.

Salient Features

Eligibility

- Women holding a regular/long term research position in academia or research institutes/industry

Tenure

- 3 years

Research stays

- 1 month/year with fellowship in host country

Age limit

- No age limit (preference to early/mid-career researchers)

Financial Assistance

Indian Awardee

- Up to ₹ 39 lakh
- Grant includes support for research staff, consumable, contingency, travel and per diem (€ 2300) in Germany

German Awardee

- Up to € 48000
- Grant includes support for consumable, contingency, travel and per diem (€ 2300) in India

- **Facilitate lateral entry for women in ongoing S & T projects**
- **Create avenues for long-term Indo-German research collaboration**
- **Capacity building and networking**
- **Open to all areas of STEM**

**Application Accepted
throughout the Year**

To Apply
www.igstc.org

Queries
wiser@igstc.org



Paired Early Career Fellowship for Applied Research (PECFAR)

Paired Early Career Fellowship For Applied Research (PECFAR) invites applications to facilitate exchange of early career Indian and German researchers. The Programme supports short duration visit to explore, connect and network for research collaboration in Science, Technology, Engineering and Mathematics (STEM).

Salient Features

Eligibility

- Early career researchers holding regular positions in academic/research institutions/industry or holding long-term nationally recognized fellowship.
- Minimum Qualification: Masters in Science/Bachelors degree in engineering (4 years)
- Applications are to be submitted jointly by the Indian and German researchers.
- Age Limit: 35 years

Tenure

- Up to 2 months

Financial assistance

- Fellowship: € 2300/month.
- Single round trip economy class airfare including visa fees and medical/travel insurances approximately ₹ 1 lakh (for Indian awardee) and € 1500 (for German awardee).

- **Create avenues for two-way exchange of young researchers in pairs**
- **Support for research stay in India/Germany**
- **Explore the Indo-German research landscape on entrepreneurship, joint research and innovation**
- **Build future partnerships with complementary expertise.**

**Application Submission:
1 February–31 March Every Year**

To Apply
www.igstc.org

Queries
pecfar@igstc.org



Small Immediate Need Grants (SING)

Small Immediate Need Grants (SING) invites proposals towards joint initiatives that require modest funding and has the potential to embark on Indo-German collaboration.

Salient Features

Who can apply?

- Individuals or groups from industry/academic/research institutions
- Members/participants of the IGSTC programs including workshops
- Engineering Academic Research (EAR) community from ongoing inter-institutional MoUs between India and Germany
- Personnel from the industry with specific requirements towards applied research/technology development/entrepreneurship

Age Limit

- Preferably below 55 years

Funding Support

- Up to ₹ 9 lakhs (€ 10000) per proposal

- **Quick assistance to kick off ad-hoc opportunities**
- **Seed funding to create new avenues for long term collaboration**
- **Support for capacity building and networking**
- **Single window approach with fast-track processing and low turnaround time**

Applications are accepted throughout the year

To Apply
www.igstc.org

Queries
sing@igstc.org



IGSTC-CONNECT Plus Fellow

A Glimpse

The results also reveal that at a current density of 0.8 A/cm², the system efficiency increases from 61.35% to 63.01% as the PEMFC temperature increases from 65°C to 80°C.

Experimental Studies on Unitized Reversible Fuel cell

IGSTC supported short term visit of Prof Satya Sekhar to the host Otto-von Guericke -University Magdeburg under IGSTC-CONNECT Plus programme. The Programme is aimed at boosting Indo-German networking and long term collaboration among the participants of the Indo-German Frontiers of Engineering Symposia (INDOGFOE), which is co-organised by the Department of Science and Technology (DST) and the Alexander von Humboldt Foundation.

With the rising usage of fossil fuels, there is an urgent need to develop new technologies specifically based on renewable energy sources to power the vehicles running on fuel. A fuel cell is an electrochemical cell that is used to convert the chemical energy of a fuel directly to electric power. Therefore, fuel cells possess advantages such as smaller size, high efficiency, silent operation, etc. However, there can be significant variations in the size and power output of the fuel cells depending upon the application.

Prof Sekhar presented his research work and outcome to the fuel cell group, the group working on the thermodynamic study of integrated proton exchange membrane fuel cell with a vapour adsorption refrigeration systems at Otto-von-Guericke University, Magdeburg in the colloquium held on 25 November 2021.

The focus of the work is to estimate the performance of an integrated system comprising of Polymer Exchange Membrane Fuel cell (PEMFC) and vapour adsorption refrigeration system to produce electric output and cooling effect simultaneously. The adsorption system in this study is based on activated carbon and methanol combination. The PEMFC efficiency is generally around 40- 60%, but it can further be improved by incorporating regeneration methods. The effect of operating parameters such as the operating temperature, current density and evaporator temperature on the energy and exergy efficiency of the system is investigated. The study shows a remarkable improvement in the performance of the integrated system compared to PEMFC alone. The results show that the system energy and exergy efficiency decrease as the current density value increases. Maximum system energy and exergy efficiency of 63.01% and 29.88% are achieved. The results also reveal that at a current density of 0.8 A/cm², the system efficiency increases from 61.35% to 63.01% as the PEMFC temperature increases from 65 to 80°C. In addition, maximum energy efficiency of 65.39% was reported at an evaporator temperature of 5°C and a current density of 0.8 A/cm².



Visit to Enercon GmbH
(Wind turbine manufacturer)



Colloquium Presentation & @ Otto von Guericke University Magdeburg



Dr Bhogilla Satya Sekhar

Department of Mechanical Engineering, IIT Jammu

Host Institute

Jun.-Prof.Dr.-Ing. Ines Hauer
Institute of Electrical Energy Systems (IESY)
Chair Electric Power Networks and Renewable Energy Sources,
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