IGSTC
INDO-GERMAN SCIENCE AND TECHNOLOGY CENTRE

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Annual Report 2018-19

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Department of Science & Technology
Government of India

IGSTC
INDO-GERMAN SCIENCE AND TECHNOLOGY CENTRE

Federal Ministry
for Economic Cooperation
and Development

The Indo-German Science & Technology Centre (IGSTC) has been established to facilitate Indo-German R&D 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 in the identification of suitable partners.
5. Facilitate and promote Indo-German collaboration in science and technology 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.

CONTENTS

THE YEAR 2018-19 AT A GLANCE

In the year 2018-19, IGSTC had significant activities and achievements to improve upon and further strengthen the growing Indo-German industrial research partnerships. Several projects under the flagship scheme of 2+2 are being supported through IGSTC in various areas of national priorities for India and Germany. The revamped Open Workshop Call received great momentum and five workshops under it were held in the period and few more are scheduled in the coming months to create platforms for productive interactions among scientists and policymakers of the two countries. A new programme IGSTC-CONNECT Plus in association with Humboldt Foundation was launched to support short-term research stays in India and Germany.

During the year 2018-19, IGSTC supported 22 joint projects in 2+2 mode in emerging areas of (i) sustainable energy (ii) advanced manufacturing (iii) biomedical devices and biotechnology (iv) water & wastewater technologies (v) nanotechnology (vi) embedded system & ICT (vii) energy materials, energy storage and (viii) water biosensors & wastewater technologies. This also includes six new projects from Call 2017 in the overall thematic area "Advanced Manufacturing & New Materials" which started in March 2018 (3 projects to start in the next couple of months). Currently, ongoing IGSTC Projects involve 88 (eighty-eight) project partners from academia and industry from India and Germany with total project investment

FC & GB meetings

(both Indian and German) of estimated INR 125 Crores or 15 million Euros. There are 10 projects already completed. Approximately 500 scientists, researchers, engineers from both countries are networked through this programme.

This period witnessed changes in the Governing Body of IGSTC. Mr Sanjeev Kumar Varshney has taken over as the new Indian Co-Chair of IGSTC. Mr B Anand has taken the charge of Financial Advisor, DST and as a member of the Governing Body. IGSTC welcomes the new Co-Chair and the Member to the IGSTC Governing Body. IGSTC also expresses its gratitude to the departing Co-Chair Dr Arabinda Mitra and Member Mr J. B. Mohapatra for their pivotal guidance to IGSTC over past several years.

The 4th Finance Committee Meeting and 10th Governing Body meeting of IGSTC were held on 22nd-23rd January 2019 in Aachen, Germany. The GB meeting was co-chaired by Mr Sanjeev Kumar Varshney, DST and Dr Lothar Mennicken, BMBF. GB focused holistically on IGSTC 2 + 2 programme, thematic areas for future grant calls, new programmes to be taken up, etc.

Prof Hüttl, Vice president, Helmholtz Association delivering the keynote

Mr Sanjeev Kumar Varshney, Head, IBCD, Department of Science & Technology delivering the keynote

A major workshop, Helmholtz-Indian Platform on Science, Technology, Education and Research (HIPSTER) was organized in February 2019 in Bangalore to create a platform connecting young scientists from the Helmholtz Institutes with Indian counterparts. The workshop was organized by IGSTC on behalf of Department of Science & Technology (DST), Govt. of India and Helmholtz Association, Germany. The key outcome of the workshop is the White Paper in the topics viz. Georisks/Landslides-Marine Biochemistry, Physics of the Atmosphere, Plant Sciences, Epidemiology/Infectious Diseases/Oncology, Renewable Energy, Material Sciences and Artificial Intelligence.

Group photo of participants in HIPSTER workshop

Five workshops under the Open Workshop call of IGSTC in the areas of Intelligent mobility (IIT Kharagpur), Advanced Manufacturing (NML, Jamshedpur), Membrane Technology (CSMCRI, Bhavnagar), Waste Management (AMPRI, Bhopal) and Nanotechnology (IIT Madras) were organized in various parts of India. Around 300 Indian & German scientists, policy officers, young researchers benefitted from the above workshops. Workshops will generate new associations and joint research projects among scientists/technologists between the two countries.

Indo-German Science & Technology Centre and Alexander von Humboldt Foundation (AvH) jointly launched the IGSTC-CONNECT Plus Programme in May 2018. 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. Under this scheme so far, two fellows have been supported.

GB also approved seven projects of Call 2017 recommended by the Joint Scientific Committee.

As per the instructions of the Governing Body, IGSTC initiated a new scheme to extend the funding support to 2 more years for selected 2+2 projects, as they complete the initial term of 3 years (Phase 1). Projects are selected on the basis of their output / results with high potential for commercialisation. During this period, extension (Phase 2) was granted for 3 projects from Call 2014 on the areas of next generation imaging techniques for eye, low-cost hearing aid devices, and portable detection techniques for diabetes based on microfluidic technology.

IGSTC continued shouldering the responsibility of implementation of the DST-Max Planck Programme on behalf of DST. This programme has provided an excellent opportunity to the Indian young scientists to partner with the global leaders at the Max Planck Institutes in Germany through a networked model of cooperation. During this period, IGSTC is implementing 2 Partner Groups and 14 Visiting Fellowships.

Detailed reports on various activities are presented in the following pages.

Joint Scientific Committee of Call 2017

GOVERNING BODY

Sanjeev Kumar Varshney
DST
Indian Co-Chair

Lothar Mennicken
BMBF
German Co-Chair

B Anand
DST

Gerold Heinrichs
DLR-PT

G Padmanabham
ARCI

Stephan Lanzinger
German Embassy

Sandeep Verma
IIT Kanpur

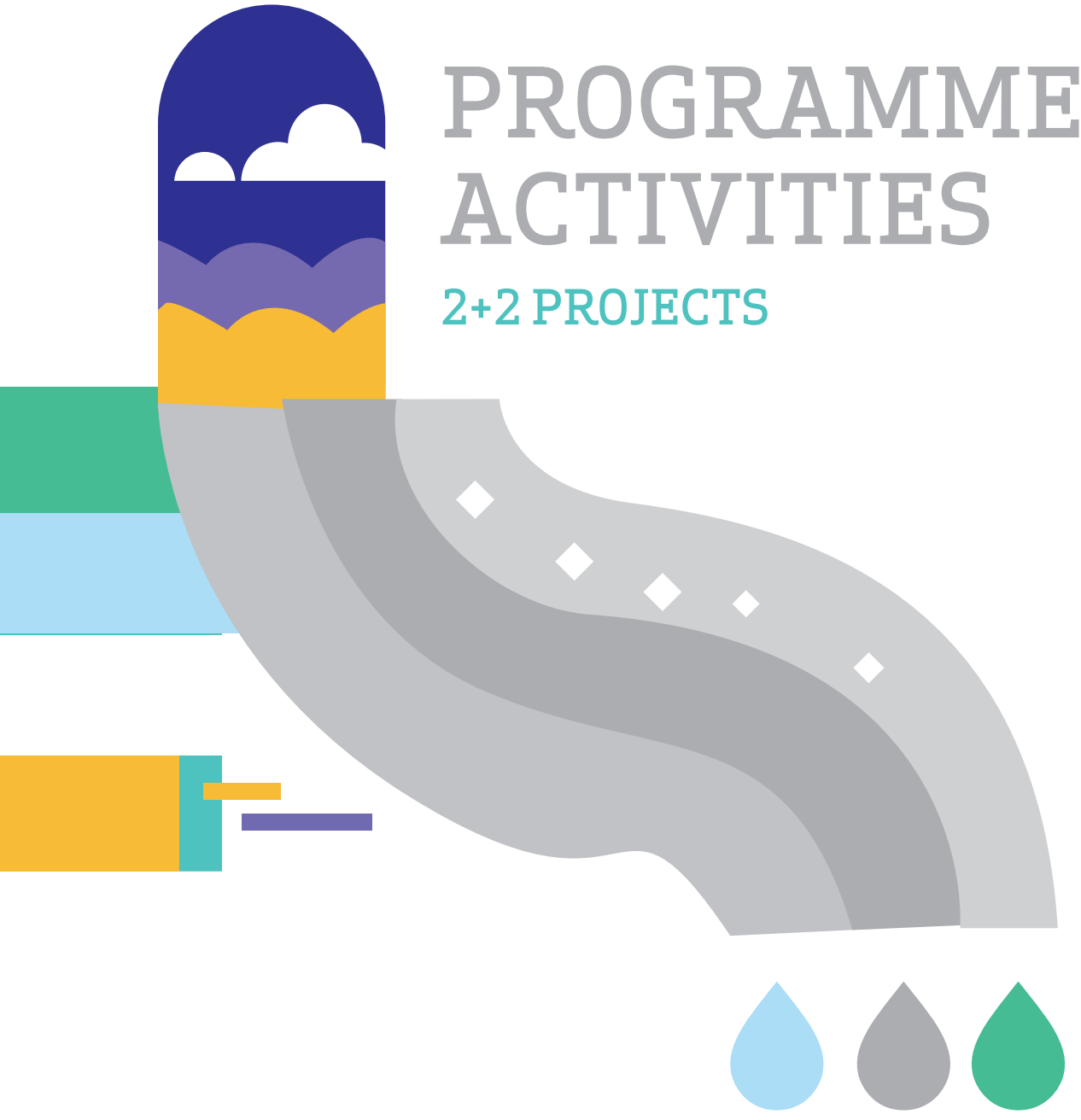
Eberhard Abele TU
Darmstadt

Anjan Das
CII

Clas Neumann
SAP

PROGRAMME ACTIVITIES

2+2 PROJECTS



2+2 PROJECTS CALLS

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

Salient Features of 2+2 Partnership

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

Funding is provided in the form of grants amounting up to ₹ 230 lakhs per project from Indian side and up to € 450000 from German side, for a period of up to three years.

Industry partners are expected to contribute 50% of their eligible cost.

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

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

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


PARTNERS
Min. 4 & Max. 6
India - 1 academic/research institute + 1 industry
Germany - 1 academic/research institute + 1 industry
DURATION
3 years
Extendable up to 2 more years
FUNDING
Indian side - ₹ 230 lakhs
German side - € 450000
THEMATIC AREAS
Energy
Water
Manufacturing
Biotechnology
ICT

SMART CITIES

SMART & WISE

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

B S Murthy
IIT Madras

Ashok Natrajan
Tamil Nadu Water Investment Company Ltd.
Chennai

Theo Schmitt
Heidrun Steinmetz
TU Kaiserslautern

Martina Scheer
Ingenieurbuero Scheer
Oberstdorf

Gerald Angermair
tandler.com GmbH
Buch am Erlbach

Project Summary

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

Figure 1: Smart and reliable WIS for our future cities.

Progress made/achieved

Existing WIS planning methods and tools

A literature research was conducted on existing planning methods and tools for water-wastewater infrastructure planning. German and Indian partners exchanged views on the state of practice and research regarding planning tools in Germany and India. In the course of the development of new planning methods, this step will be continued during the project. Several Detailed Project Reports (DPRS) on earlier water infrastructure planning in India were collected and analysed. Meetings were conducted with officials from TWAD (Tamil Nadu Water Supply and Drainage Board), TUFIDCO (Tamil Nadu Urban Financial and Infrastructure Development Corporation), Coimbatore City Corporation, Coimbatore Smart City Cell and Non-Governmental Organizations in Coimbatore to discuss how the planning is carried out for water infrastructure in India, the lacunae and the difficulties faced by planners. A list was compiled to compare German and Indian planning practices.

WIS measures to improve smart city concepts

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

Project team meeting at IITM on 10.12.2018

Coimbatore field trip

Conditions needed in conventional and smart city planning

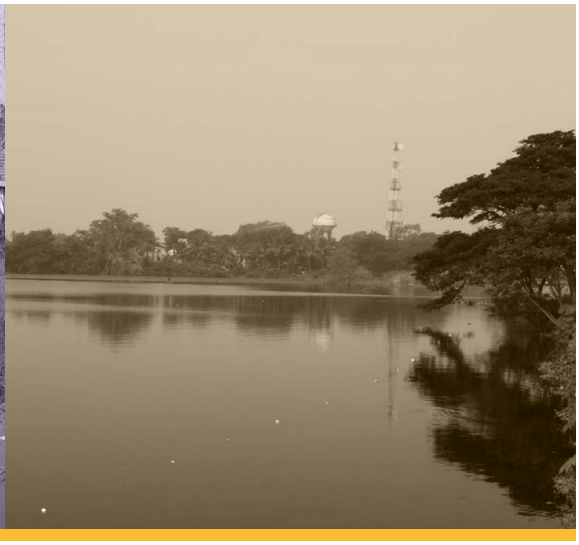
With the help of an in-house questionnaire, a ranking was drawn up which considers conventional, novel and smart water and wastewater infrastructure measures to be considered most important in the project. An in-depth investigation of the measures was started in December. The specific measures that are being considered include (i) rainwater management; (ii) groundwater recharge; (iii) stormwater retention, (iv) reuse and recycling of treated wastewater, (v) dual piping systems, etc. The planning issues with each of these measures are being studied and an attempt is being made to come up with flow charts for planning. With the help of these results, boundary conditions (constraints) for individual measures are to be identified. These flow charts will also help in developing the software tools for planning.

Development of planning & decision-making approaches

The development process to generate planning and decision-making approaches were started. First of all, existing evaluation criteria are summarized by the German partners. These have been checked by the Indian project partners for their applicability in India. A preliminary list of criteria has been identified for evaluating the water infrastructure at conventional; wise and smart and wise levels.

Indian industrial partner (TWIC) has made arrangements for one of their employees to work from Coimbatore to facilitate data collection. It has facilitated collection of secondary data available for (i) new 24x7 water supply project that is planned; (ii) the existing underground sewerage system for the city, (iii) the status of the stormwater drainage system, and (iv) water balance study that was carried out as a part of the smart city project that is being implemented.

City lake - Chennai



Lake pollution

Salient Research Achievements

- Creation of a data requirements list. We used the list to adjust the available data in Germany and India with our needs. 60% of the secondary data collection for Indian Project Area (Coimbatore) has been completed.
- The project team put together the requirements for the cost estimation in India and Germany with the target to verify the portability to each other.
- Commonalities and differences between planning processes in Germany and India have been identified; lacunae in conventional planning process for application to sustainable and smart cities have been identified.
- Creation of a classified list of measures and targets in a smart city in the area's water supply, rainwater management, wastewater and integrated systems.

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ECO-WET

Efficient coupling of water and energy technologies for smart sustainable cities

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Julia Singer
Sonnen GmbH
Wildpoldsried

Project Summary

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

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

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

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

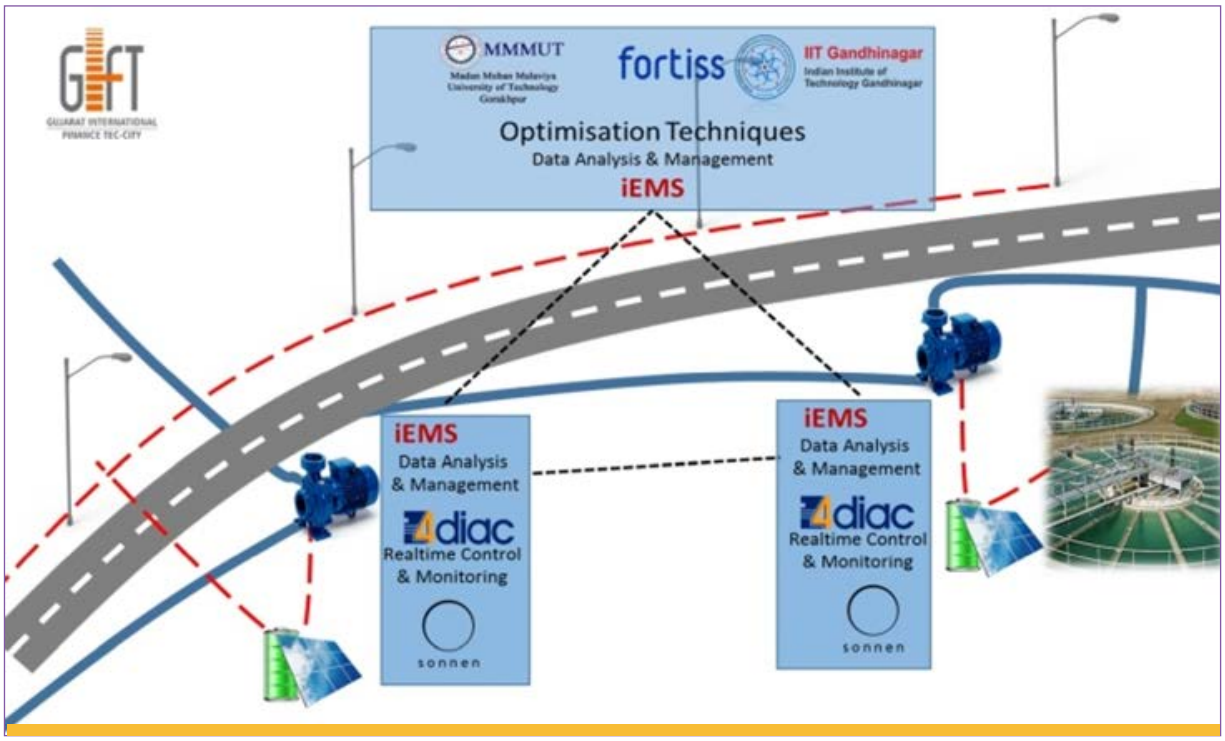

Figure: The Big Picture: Concept of the project

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

Main Objectives

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

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

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

Progress made/achieved

Fortiss GmbH

- Designed appropriate software and system architecture for the test bed system.
- Identified the requirements and use cases for the test bed and the battery system control.
- Prepared software architecture and communication design report and contributed for the report on the use case specification and requirements.
- Interfacing with 4DIAC for real-time controlling of the battery system and other hardware.
- Organized Bi-weekly Telco meetings and set up project collaboration platforms and processes.

IITGN

- Developed optimization framework for optimal integration of distributed energy resources and battery management in a simulation environment.
- Developed forecasted on-site solar PV generation algorithm for improved optimization and decision making.
- Prepared the list of equipment and hardware for procurement.

Sonnen GmbH

- Provided necessary software details for real-time controlling of the battery system
- Executed detailed use case simulation for validation of hardware dimensions and possible additional use cases to be considered
- Developed testbed at Sonnen headquarter, Germany, for hard- and software testing of use cases
- The final definition of battery systems being deployed at GIFT City

- A small modification of battery systems for Indian and project requirements
- Prepared battery system installation information for Indian partners

GIFT City

- Understanding of existing infrastructure to incorporate battery storage and solar PV System.
- Site survey to proceed with battery installation and integration.
- Prepared use-case specification and requirements report.
- Hosted Consortium meeting in January.

MMMUT

- Understanding existing electrical infrastructure for power quality improvement.
- Investigation of various harmonic estimation methods.

Salient Research Achievements

Development of energy management algorithm:

The optimal operation of the battery storage system is essential for efficient energy management when considering intermittent solar PV generation, varying load demand and real-time electricity prices. As a result, in this project we aim to develop and deploy an efficient energy management algorithm which can generate optimal charging and dis-charging references considering solar PV generation, and varying load demand, real-time electricity pricing.

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. Presently, the team is in-process of validating the algorithm at IITGN's Power System & Smart Grid Laboratory. Simultaneously, the developed algorithm will be shared with fortiss GmbH which will be embedded with the existing IEMS software developed by Fortiss GmbH. The modified iEMS with the developed algorithm will be successfully deployed at use-case levels using Raspberry-Pi.

Publications

- Naran Pindoriya, Markus Duchon, Pragya Kirti Gupta, Venkatesh Pampana, S N Singh, Jakob Giza, Bastian Hackenberg, Arvind Kumar Rajput, and Janki Jethi, "Intelligent Hardware-Software Platform for Efficient Coupling of Water-Energy Nexus in Smart Cities: A Conceptual Framework", Mobility IoT 2018 – 5th EAI International Conference on Smart Cities within SmartCity360° Summit, Guimarães, Portugal, 21-23 Nov. 2018.

- Sachin kumar Suthar, Nitish Kumar and Naran M. Pindoriya, "Cost-Effective Energy Management of Grid-Connected PV and BESS: A Case Study", IEEE PES ISGT ASIA 2019, Chengdu, China, 21-24 May 2019. (paper accepted for oral presentation)

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IDC-Water

Integrated diagnostics of contaminants in water supply and management system

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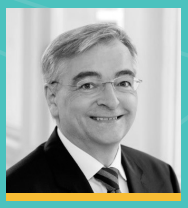

Rudolf J. Schneider
BAM, Berlin

Michael Voetz
Sifin diagnostics GmbH
Berlin

Project Summary

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

Progress made/achieved

Salient research achievements

- Culture of cell lines secreting diclofenac antibodies could be improved by modifying the culture medium (Sifin). Diclofenac protein conjugates have been synthesized in a larger amount for the uses during the course of the project (BAM). The antibodies have been characterized for affinity and cross-reactivity in several immunoassay formats (BAM).
- Binding of diclofenac to magnetic beads coated with monoclonal anti-diclofenac antibodies was established. Appropriate elution conditions could be figured out. Miniaturisation for the use in a meso-fluidic device still needs to be developed (Sifin).
- Monoclonal anti-amoxicillin antibodies could be procured from a university lab (Sifin). Required protein conjugates for establishing an ELISA that was commercially available proved dysfunctional. New amoxicillin conjugates have been synthesized and are undergoing testing in May 2019 (BAM). In case of successful test runs Sifin intends to sign a license agreement for the corresponding antibody-producing cell lines.
- Equipment for testing microfluidics/ electrochemical detection combinations has been assembled and training on potentiostat programming has been undertaken (BAM).
- Cell culture cartridge has been designed by IISc, fabricated and tested with successful results of culture of 1CFU/20ml of E coli detected using optical method and electrochemical method.
- Cell detection methods using fiber-coupled optical spectroscopy and electrical impedance spectroscopy have been studied. The experimental data is currently being analyzed to arrive at the detection technique. Further experiments involving combinatorial effects of the different pathogen will be carried out.
- Water sampling, filtration, storage and integration of cell culture cartridge have been developed by IISc in a preliminary board-level design. This design will be further refined in collaboration with Bigtec to realize the proposed integrated platform hardware.
- A detailed requirement specification document for the water quality

monitoring platform has been developed including national and international standards and recommendations and technology gap analysis.

- Primers and probes have been designed by Bigtec for the detection of 16S rRNA gene to detect total bacteria present in contaminated water samples using portable micro-PCR.
- In addition to this, primers and probes have been designed by Bigtec for the detection of Shigella. PCR has been performed for these designed set of primers to confirm for their specificity with regard to the identification of the respective bacteria. The agarose gel results as well as the melt curve analysis of the PCR amplicons has confirmed that the designed primers are specific to the respective bacteria. Probe related work is yet to begin.

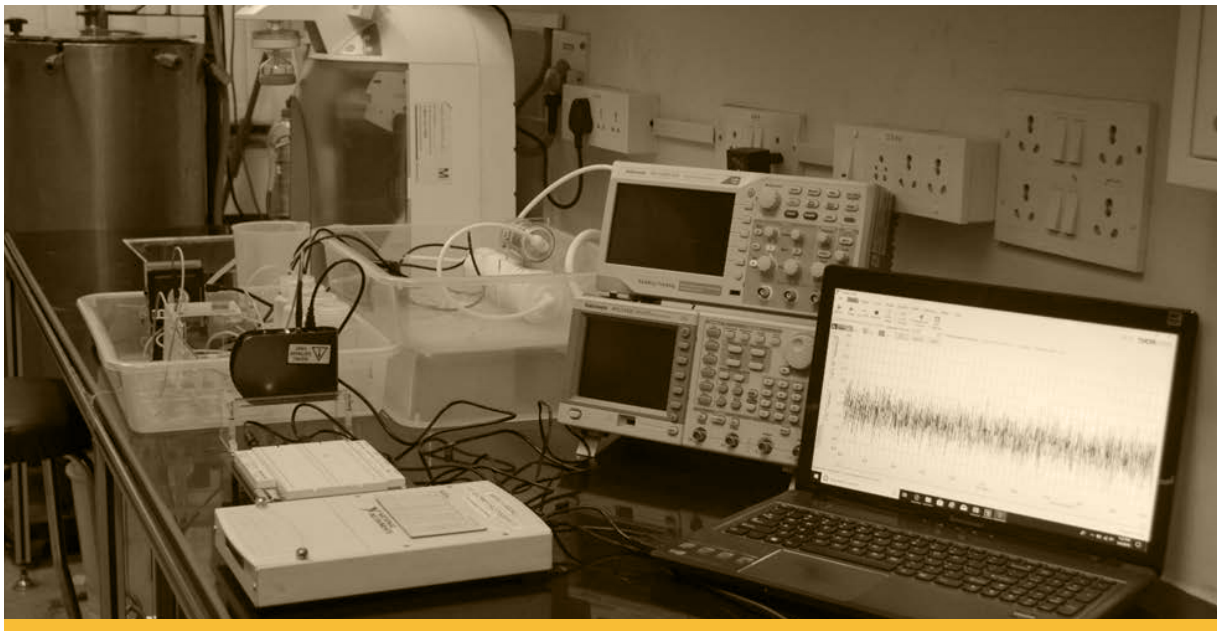

Figure: Lab level prototype test set-up developed for testing of components of the integrated water quality monitoring platform having modular or compartment-based design for automated cell culture, detection cartridge and further provisions for integrating DNA cartridge/PCR sampling scheme and immunoassay integration. Inset shows preliminary prototype layout including water sampling unit, cartridge tray, and a detection unit.

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Bio-CuInGe

Biotechnology for the recovery germanium, indium and copper from industrial copper dust waste

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GEOS
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Project Summary

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

Progress made achieved

Partner 1 (IIT Delhi)

- Collection of 4 samples from Khetri Copper Complex and 3 samples from Laxmi Life Sciences.
- Elemental and mineralogical characterization of the samples by ICP-MS, SEM EDX, and XRD.
- Chemical leaching of samples in 5 types of leaching reagents (Ultrapure water, HCl, HN03, H2S04 and NaOH).

Partner 2 (LLS)

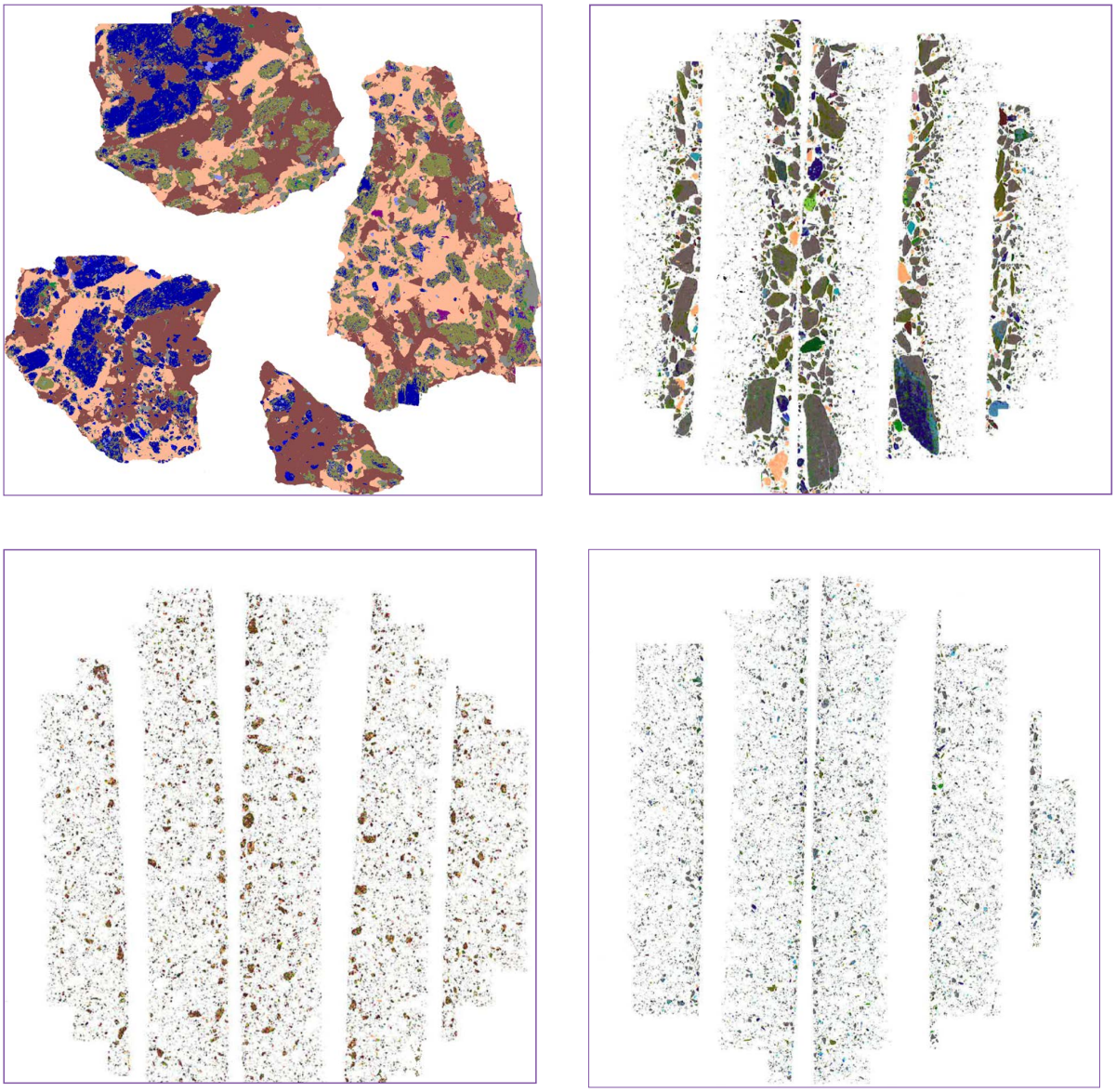
- Providing samples.

Partner 3 (HZDR)

- Receiving of 4 different samples from Indian copper industry (01).
- Chemical and mineralogical characterizations of the received samples by MLA (D2).
- DFF calculations for In and Ge complexation by DFOE and DFOB, the calculation for Ge is planned, Ge complexation has been experimentally demonstrated by HPLC analyses (D5).

Partner 4 (GEOS)

- The conducted work in the reporting period included participation in the kick-off meeting held in New Delhi, India, via skype video call (general/ entire project), and literature search on possible processing options for Ge-containing ores and materials potentially applicable for the current project work (concerning D3, WP2)
- potential processing options found include alkaline digestion followed by water leaching, acid digestion followed by water leaching and leaching with ferric sulfate solution which all will be tested with the available sample material in the next reporting period



Mineral Liberation Analyzer (MLA) mapping of ore sample embedded in epoxy resin

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WATER & WASTE WATER TECHNOLOGY

Multi-WAP

Multiplexed, label-free fiber optic biosensor array system for waterborne pathogen detection

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V I Bishor
ubio Biotechnology
Systems Pvt Ltd, Cochin

Claus-Peter Klages
TU Braunschweig
Braunschweig

Mahavir Singh
Lionex GmbH
Braunschweig

Project Summary

Multi-WAP proposes to develop multiplexed, rapid, accurate, label-free, and real-time method for continuous monitoring the multiple waterborne (faecal) pathogens present in water samples at low cost and high sensitivity (>90%). The main objective of this collaboration is to develop cost-effective fiberoptic biosensor for multiplexed detection of microbial pathogens in water (up to seven waterborne pathogens). With the novel multimarker assay, Multi-WAP will also be the first system capable of detecting of up to 7 or more waterborne pathogens at the same time. In this project, IIT Madras shall be responsible for the development of the fiber optic sensor arrays and optoelectronic instrumentation. The German Research partner (IOT, Braunschweig) is leading the tasks of fiber probes surface modifications. The German industrial partner Lionex taking the lead in producing and selecting the specific antibodies to surface biomarkers of model analytes and for waterborne faecal pathogens. The Indian industrial partner (ubio) shall integrate into the device assembly and evaluate the final lab-device using model and pathogen contaminated water samples (along with Lionex).

Successful implementation of the project is expected to yield the following results:

A portable, optical absorbance-based, ultra-sensitive water pathogens detection device, which can be adapted to other pathogen detection applications.

A removal 'plug & play' cartridge to house the biochip and to provide a secure environment for the analysis.

Optimized analysis protocols for successful pathogen detection.

Progress made/achieved

Technical work done: IITM has made significant progress as per the work packages WP1 and WP5. Except for the task of efficient optical coupling in an array sensor, all the remaining objectives are successfully met. Over the last 6 months, they switched to silica-clad fibers as they are better suited for UV applications. Optoelectronic instrumentation and software for array sensor are developed. However, an important bottleneck of efficient optical coupling of fiber optic probe cartridge to array sensor remains to be solved. Two alternate designs under investigation. Due to this reason, the project is delayed by 6 months. IOT investigated a process sequence for the amino-silanization of U-bent silica fiber optic sensors, consisting of an atmospheric-pressure plasma pre-treatment in an Ar-H_2O gas mixture, and immediate vapor-phase silanization in a flowing gas stream of Ar, saturated with APTMS at room temperature. Both processes were run in the same process chamber, a low-cost dielectric-barrier discharge reactor made from quartz plates. In an immunoassay-based comparison, virtually the same results are achieved with the new vapor-phase procedure on the one hand, and the standard wet-chemical sequence – etching in piranha solution and silanization in solution – on the other. In repeat experiments, it turned out, however, that the new process is still lacking reliability so that additional studies will be required to guarantee process safety and subsequently address the task of designing a prototype for industrial production. ubio starts establishing the protocol for validation of the model antibody and the first set of the final arrays' antibodies from Lionex. ubio performed an independent validation of these antibodies.

In this reporting period Lionex continued the production of the quality-controlled biomarkers for the real arrays. Further batches of quality-controlled anti-LAM antibodies against Mycobacterium avium complex were

produced, with KD around 10^{-8} – 10^{-9} LAM. The model E. coli antibodies were successfully produced. These both antibodies will be used as model analyte for Multi-WAP prototype. New anti-FimH and anti-fliC polyclonal Abs were produced against Salmonella enterica surface biomarkers, with KD 10^{-7}M and 10^{-8}M respectively. New polyclonal Abs were produced with high affinity against Campylobacter jejuni biomarker (KD 10^{-7}M). New anti-Blc polyclonal Abs were produced to be used for detection of Vibrio cholerae, with KD and affinity less than 10^{-8}M. The validation and kinetics measurement of the new antibodies against Shigella dysenteriae, E. coli O_{157}:H_7 and Yersinia enterocolitica are under intensive progress.

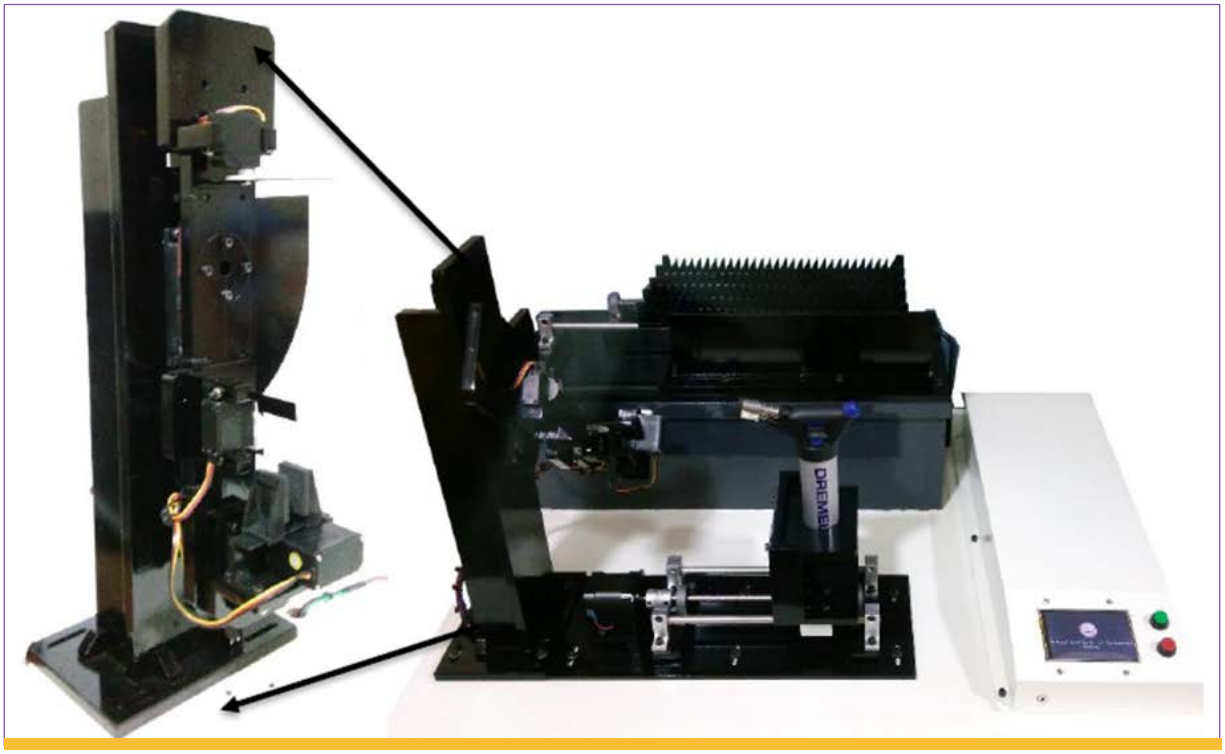


Fig. Automatic Fiber bending machine.

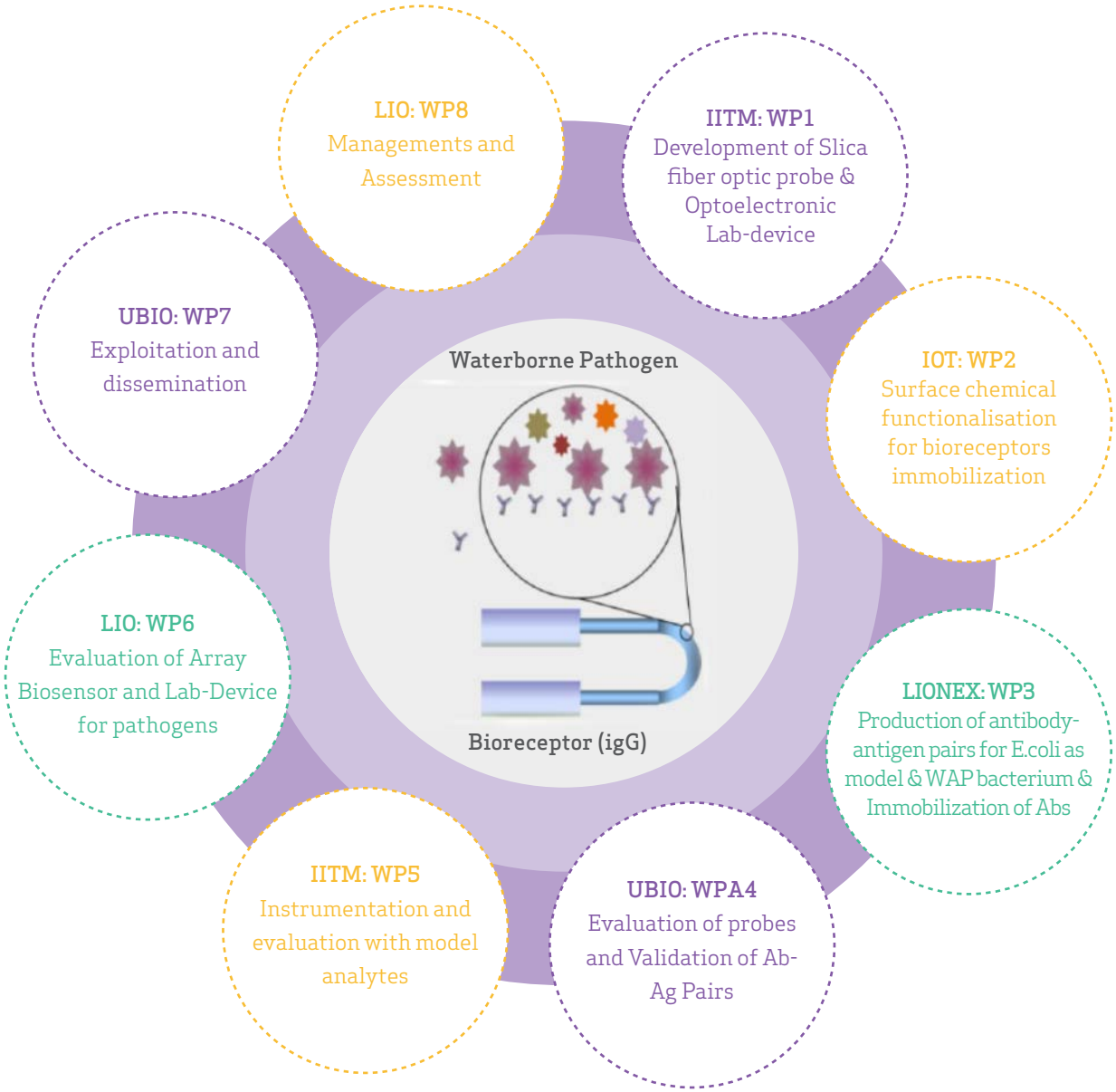
Salient Research Achievements

IIT Madras

- Based on the work done in this project, a U-bent fiberoptic probe fabrication facility for small scale production is set-up at IIT Madras. Optoelectronic instrumentation and a custom-built software are realized for the development of the array sensor. Highly stable UV and visible high-power LED devices are developed. In addition, a point-of-care device and a smart fiber-optic refractometer are being developed for biosensing and chemical sensing applications.

IOT:

- Results obtained in the recent research period show that the concept of gas-phase plasma-based pretreatment and subsequent gas-phase silanization of U-bent silica fiber optic sensors is in principle able to substitute the state-of-the-art wet-chemical process. However, the process stability is still lacking, and more experiments are needed in order to achieve Technology Readiness Level and to design an upscaled version of the reactor. Several possibilities to reduce production costs have been identified and should be investigated (adapted power generator, photometric check of surface functionalization.



Schematic showing the proposed Specific Objectives and the contribution of all Partners

Lionex

- Production of the quality-controlled biomarkers for the real arrays for waterborne pathogen were done successfully.
- Several batches of quality-controlled anti-LAM antibodies were produced, with KD around 10^{-8} – 10^{-9} toward Mycobacterium avium complex LAM. These antibodies will be used also as model analyte for Multi-WAP platform.
- The model E. coli antibodies were successfully produced. These antibodies will be used as model analyte for Multi-WAP platform.
- New anti-FimH polyclonal Abs were produced against Salmonella enterica surface biomarker, with KD 10^{-7} M.
- New anti-fliC polyclonal Abs were produced against Salmonella enterica surface biomarker, with KD 10^{-8} M.
- New anti-FlaA polyclonal Abs were produced against Campylobacter jejuni surface biomarker, with KD 10^{-7} M.
- New anti-Blc polyclonal Abs were produced against Vibrio cholerae surface biomarker, with KD 10^{-8} M.
- The validation, affinity measurement and release of the new antibodies against Shigella dysenteriae, E. coli O_{157}:H_7 and Yersinia enterocolitica under intensive progress.
- ubio performed an independent validation of these Abs.

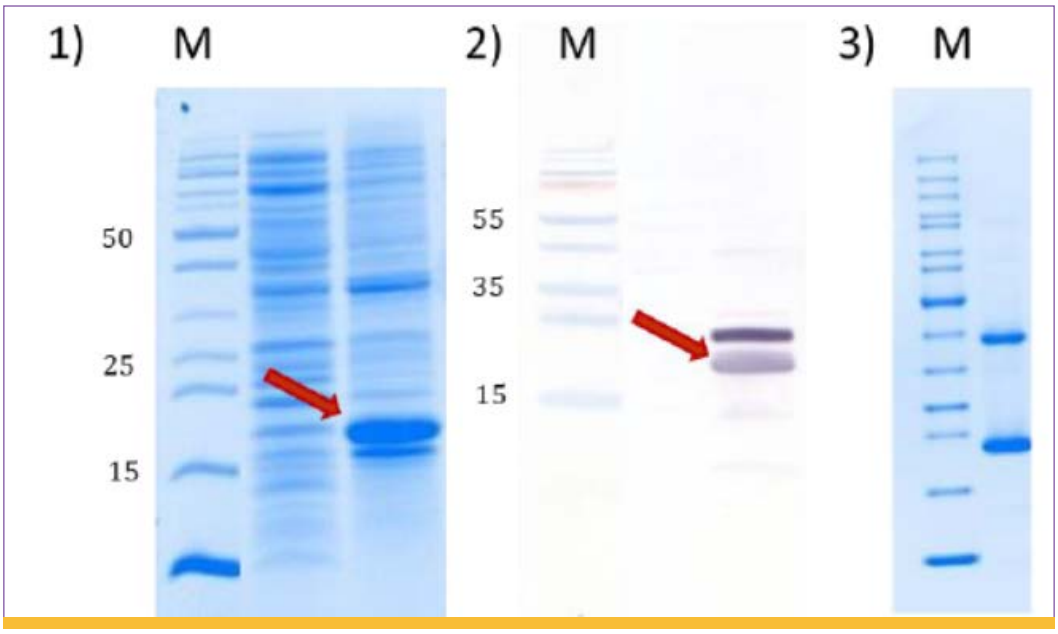


Figure : 1) SDS after the biomass production for recombinant Blc. 2) Western blot from the biomass with anti-His, which gives good reaction. 3) SDS after the after final purification steps. M refer always to marker or ladder.

Publications

1. Plasmonic biosensors for bacterial endotoxin detection on biomimetic C-18 supported fiber optic probes; Hariharan Manoharan, Prasanta Kalita, Shalini Gupta, V.V.R. Sai; Biosensors and Bioelectronics, Volume 129, 2019, pp 79- 86.
2. Graphene oxide coated U-bent plastic optical fiber based chemical sensor for organic solvents. Divagar, M., Gowri, A., John, S., & Sai, V. V. R.; Sensors and Actuators B: Chemical, 2018, 262, 1006-1012.
3. Fiber optic sensor for continuous liquid level monitoring; Allwyn S Rajamani, Divagar M, V V R Sai; Sensors & Actuators A Physical (Under Review)
4. Divagar M, Vitaly Raev, Claus-Peter Klages, V. V. Raghavendra Sai, Integrated atmospheric-pressure plasma pre-treatment and vapor-phase amino-silanization - A comparison with wet-chemical processes for surface functionalization of U-bent fiber optic biosensor – Submitted "Talanta"
5. Divagar. M, and V. V. R. Sai. "Fiber Optic Plasmonic Sandwich Immunosensor: Influence of AuNP Label Size and Concentration." In 2018 IEEE SENSORS, pp. 1-4. IEEE, 2018.
6. Divagar. M and V. V. R. Sai, Influence of core and bend diameter of U-bent POF probes on evanescent wave absorbance sensitivity, Photonics 2018.

Ph.D / Master thesis supervised

1. Master Thesis in Technical University of Braunschweig in cooperation with Lionex Diagnostics & Therapeutics GmbH, Title: Production and Optimization of Biomarkers for the Detection of Waterborne Pathogens, Submitted by: Nora Lambrecht Mat.-Nr. 4679680 Master Program Biology, Braunschweig, January 2018.
2. A PhD student, Ms. Shamlee J is recruited as part of the project at IIT Madras. She is expected to complete her PhD thesis by May 2020 as per the norms of the IIT Madras.

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Fec-Online

Online-indication of pathogen-like pollution in water by fecal pigment (FP) analysis

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Christian Moldaenke
bbe Moldaenke
Schwentinental

Project Summary

A promising alternative for time consuming measurements of pathogens in water is the detection of fecal pigments (FP) as indicator compounds by 2D fluorescence. Pigment analysis is of high efficiency and used for early warning against cyanotoxins in water since a long time. However, while algae pigments can be measured directly, the fecal pigments are of lower fluorescence effect and therefore the sensitivity as well as selectivity of the measurement has to be improved. The project follows the strategy of selective pre-concentration of the analytes, a method which is online practicable and widely used for trace detection of organic contaminants, e.g. using LC-MSMS. Because of the broad peaks of fluorescence, a new calibration software based on multivariate approach is urgent.

The general project outcome is the online-detection of pathogen-like pollution in water. In detail, the outcome of the project is described a follow:

- Understanding of the indicator function of FP against pathogen water pollution based on systematic measurements: The FPs have a significant indicator function against pathogenic water pollution

- Design of a new analytical unit consisting of: automatic sample preparation which is coupled

with a brand new 2D fluorescence sensor. For this device the option of Zn-addition is favored.

- Design of a software package for analysis of the spectra. An intelligent software is the key instrument for using and applying the indicator function of FPs.
- Testing and recommendation for general application of this approach in practice using the new bbe device.

  Potential users of the new technique could be: drinking and wastewater treating companies as well as companies of food production

Progress made/achieved

Partner 1 – TZW

The experiments for method optimization of fluorescence spectroscopic detection of pigments in aquatic environments showed that 10 vol.% ethanol in the sample and the addition of zinc acetate as zinc salt produces the highest fluorescence intensity.

The UV/VIS fluorescence spectrometer Aqualog-UV-800 was used to determine a detection limit of 28 ng/l and a determination limit of 77ng/l for the stercobilin standard. Stercobilin serves as an indicator substance for faecal contamination of the water.

An influence on the measurement results by adsorption of stercobilin on different materials that are

used for sampling (glass and plastic bottles for example) was not found.

The monitoring program with different surface waters and a wastewater treatment plant effluent shows the very good correlation of the faecal pigment fluorescence to enterococci, E. coli and coliform bacteria with a coefficient of determination of 0.75 to 0.86. The limit of determination for the faecal pigments correspond to a bacterial concentration of 2000 coliform bacteria, 350 E. coli or 200 enterococci per 100 ml (see Figures 1 and 2).

The two tested prototypes of the fluorescence onsite devices (sensor) show their suitability in principle, whereby the first prototype cannot distinguish sufficiently between scattered light and faecal pigment fluorescence. With the latest prototype, a better estimate of the bacterial count can be made within eight minutes. Further experiments to reduce the measurement uncertainty, to determine the application limits and the temperature influence in-field measurements are necessary.

According to the current status of the project results, the developed positions (methods and technology) are suitable for the monitoring of surface and bathing waters, but so far not for the monitoring of drinking water.

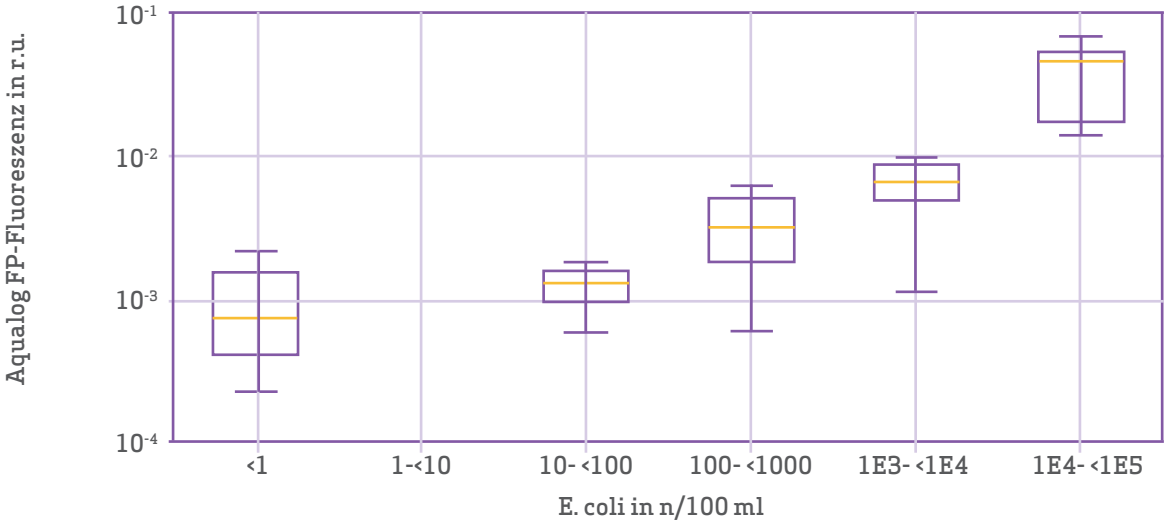

Figure TZW-1: Boxplot of feacal fluorescence in correlation of the E-coli with median (orange line), 75-% 25-% quantile and 95-% convidence interval including outliers (points).

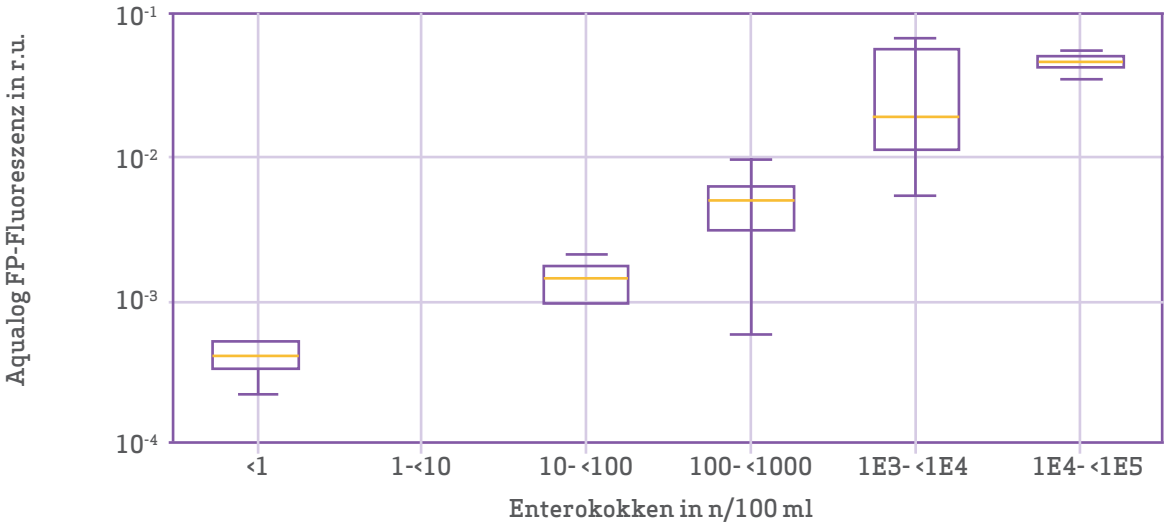

Figure TZW-2: Boxplot of feacal fluorescence in correlation of the enterococci with median (orange line), 75-%-25-% quantile and 95-% convidence interval including outliers (points).

Partner 2 (IITM)

Experiments on Advanced Oxidation Methods for conversion of nonfluorescent Urobilinogen and Stercoblinogen to fluorescent Urobilin and Stercobilin respectively

The conversion of non-fluorescent urobilinogen and stercobilinogen to fluorescent urobilin and stercobilin respectively is expected to increase the detection efficiency of fecal matter in real water samples. Towards this. Experiments were carried out by Mr. Swayam Prakash, PhD student of IIT Madras, at TZW laboratories from 12-05-2018 to 08-08-2018, to find out an appropriate oxidizing agent(s). Chlorine was identified as a better oxidizing agent as compared to H_2O_2 and K_2MnO_4 in pH 7 as well as in pH 9. Fig. IITM-1

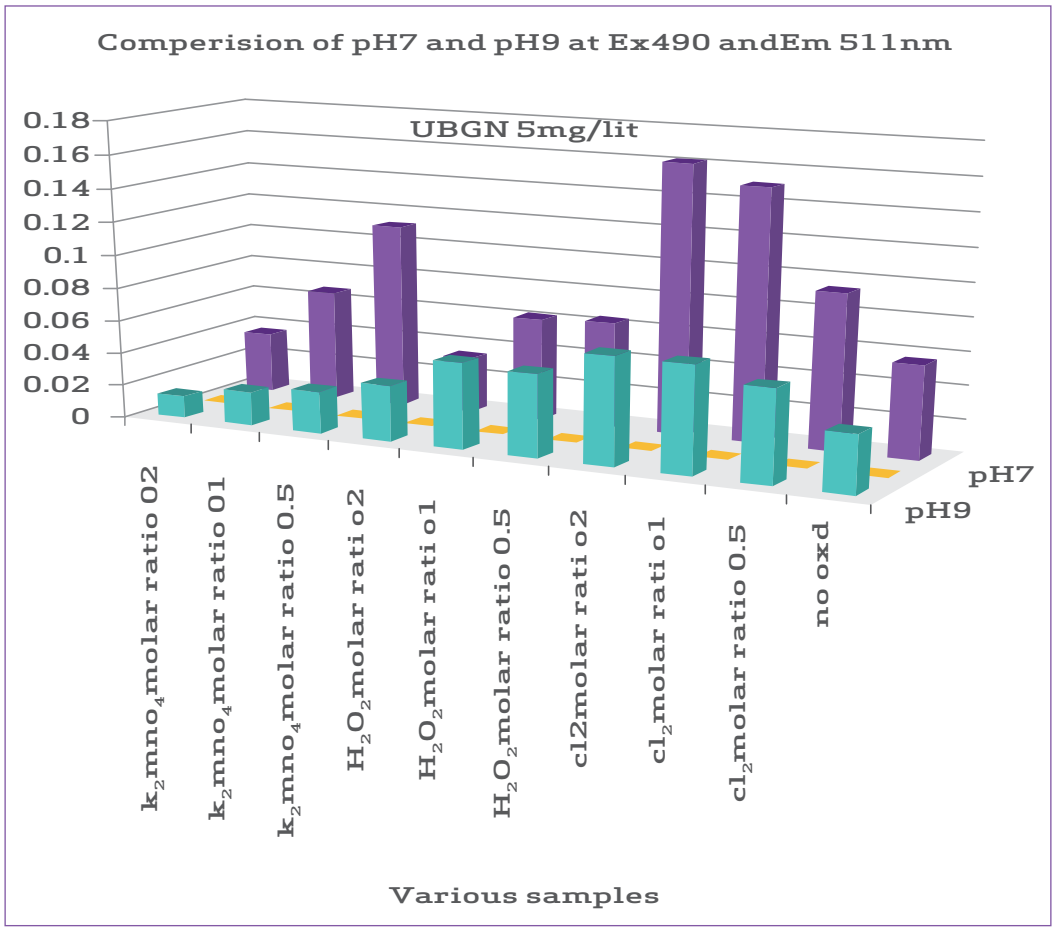

Fig. IITM-1 : Fluorescence Intensity of urobilinogen (UBGN) after oxidation by the various oxidising agent at pH 7 as well as pH 9.

2. Evaluation of the performance of the BBE prototype at IIT Madras:

A BBE prototype instrument was provided by BBE to IITM for testing the performance of the prototype against the standard Aqualog based measurements.

3. Addressing the problem of strong background fluorescence interfering with stercobilin fluorescence:

Towards the analysis of real water samples like raw water prior to treatment, containing significant protein-like and humin-like substances, two major problems were encountered (i) precipitation at pH 10.3 and (ii) interference of humin substance fluorescence with the fluorescence of fecal pigment - Zinc complex, in the wavelength zone of interest [EX (480 ± 5 nm) and EM (510 ± 10 nm)]. It was found that pH 7 is preferable for the samples with appreciable humin and protein-like substances to avoid precipitation problem Calcium Acetate can be additionally used in cocktail to quench the fluorescence of humin like substances and reduce their interference on fecal pigment zinc fluorescence in the measurement zone (EX (480 ± 5 nm) and EM (510 ± 10 nm). Fig. IITM-2

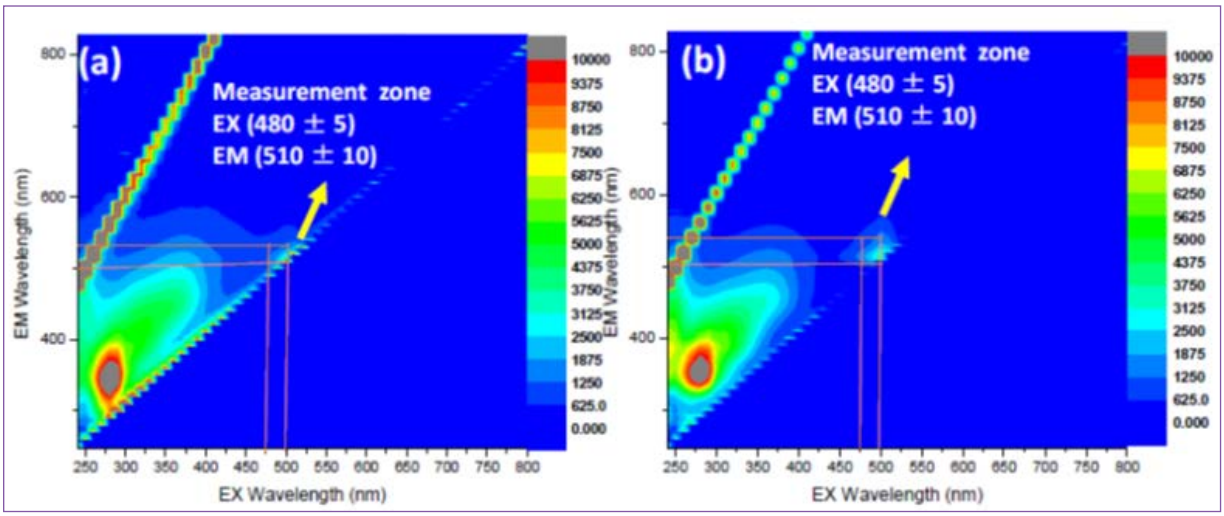

Fig. IITM-2 : EEM signature of (a) Raw water with zinc acetate (10mM) in EtOH 10% of pH 10.3 and (b) Raw water with Zn and Ca Acetate (10mM) in EtOH 10% of pH 10.3

Partner 3 (Spectro)

Adsorption of SB on the surfaces of different materials like (Glass, PET, Quartz) have been done to understand the interference & stability pattern of the faecal pigments. Some more repetitive studies need to be conducted to draw a pattern in this regard.

Partner 4 (bbe)

Based on the demonstrator built in the first project period an instrument for on-site testing was developed. While the first iteration of the instrument still did not meet the necessary detection limit, it was

finally possible to implement some major improvements. The design of the sensor is still based on the principle of the original online-monitor. For the on-site testing, it was altered into a cuvette instrument. This way it is easily possible to derive an online-monitor from the on-site instrument in the future. After the optimization of the sensor for stercobilin, the major component within the group of fecal pigments, the instrument reaches the demanded detection limit and reproducibility.

Figure: Fec-Online demonstrator by bbe Moldaenke GmbH

Salient Research Achievements

1. Stercobilin occurs regularly in µg/L-level in municipal waste waters in Germany and India. In India also river water shows this level.
2. The removal efficiency of FP in wastewater treatment was determined to be very high (approx. 3 log stages (99.8%).
3. A further log stage reduction is determined between the outflow of wastewater and river water, there the FP-concentration was determined about 10 ng/L (Germany).
4. There is a strong linear correlation between FP-concentration (LC-MS), FP-fluorescence and the cell count of Enterococci, E. coli, and Coliforms.
5. Because of its high stability, stercobilin functions as an indicator in case of fecal contamination of water.

6. The sensitivity of fluorescence can be increased up to ng/L-level in case of Zn-addition to 10 % ethanol / 90% water mixture.

7. bbe-designed and manufactured two prototypes of field sensors. The two tested prototypes show their suitability in principle, whereby in case of the first Prototype the impact of scattered light is still too high. A correct estimation of the number of bacteria can be made with the latest prototype within eight minutes.

8. The monitoring program with various surface waters and wastewater treatment plant effluent shows the very good correlation of faecal pigment fluorescence to Enterococci, E. coli and coliform bacteria having a coefficient of determination of 0.75 to 0.86. The limit of quantification for the faecal pigments is equal to a bacteria concentration of 2000 coliforms.

9. For the optimized method with 5 mg/L zinc acetate, the detection limit for stercobilin is 28 ng/l and the determination limit for urobilin is 77 ng/L.

10. With the development of the prototype 3, which is almost ready for series production, fecal impurities can also be measured wherever there is no suitable laboratory for microbiological investigations are in the vicinity, which opens up a large application potential in the developing countries and crisis regions. The detection of harmful concentrations of E. coli in Indian drinking water is possible.

Publications

- E. Daub, Bärbel: Application of 2D fluorescence spectroscopy on faecal pigments in water Characterization of wastewater fluorescence and potential indication of faecal pollution. Master Thesis 2017, TZW and Swedish University of Agricultural Science Uppsala.
- Prakash, S., Wagner, M., Schmidt, W., Imhof, L., Petzoldt, H, Panigrahi, S. K., Mishra, A. K., Fast determination of fecal pigments as indicators for fecal contamination of water. Poster. Jahrestagung der Wasserchemischen Gesellschaft vom 7. bis 9. Mai 2018 in Papenburg.
- Fiona Heiser: Determination of faecal pigments by 2D fluorescence spectroscopy, Master's thesis, TZW and Technical University Dresden, 2019.

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CANDECT

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

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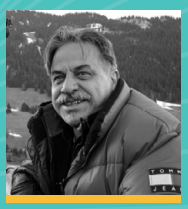

Hansjörg Fader
Fader Umwelttechnik (FAD)
Karlsruhe

Project Summary

Dissolved water contaminants of inorganic (arsenic, chromate, fluoride, uranium, nitrate or strontium) and organic (pesticides, plasticizers, pharmaceuticals, alkylphenols, endocrine disrupters) origin play an important role in drinking water quality and health. Water guideline values are usually in the ppb (µg/L) region, which makes detection difficult. Monitoring of such contaminants is time-consuming and expensive which poses a significant challenge especially for water supplies in rural areas and/or in developing countries, which represents a vast, hugely unexplored and scientifically challenging market. The development of suitable sensor technologies using advanced materials which can be integrated to hand-operated pumps or decentralized water supplies is the subject of this proposal. These materials will interact with pollutants by covalent, supramolecular or ionic interactions and the detection will subsequently take place by excitation and read-out of the colorimetric signal via commonly available devices such as iPhones.

Atomically precise clusters for specific interactions with inorganic and organic contaminants developed by IIT Madras in the detection of heavy metal ions in water at ultra-trace levels will be incorporated in electrospun fibres and porous substrates. This technology will be developed further into a sensor device for arsenic in drinking water. Simultaneously the same technology will be expanded further to address specific challenges of chromate, fluoride, a selected number of pesticides and alkylphenols (for example) for proof of concept.

The key output from this project will be a working prototype of a visual arsenic sensor system based on the atomically precise clusters incorporated in electrospun membranes (nanofibers spun onto porous membranes or clusters immobilized in porous membranes) which will be;

Affordable, at an anticipated cost of $0.1 per test, at the scale of large-scale implementation

Readily adaptable into water treatment and supply technologies worldwide

An immediate improvement to the certainly of the drinking water quality delivered

Progress made/achieved

Partner 1 – IIT Madras

- Luminescent entities like noble metal clusters (Ag_{29}@DPPP) were synthesized.
- Characterization of luminescent clusters was done.
- Photoluminescence characteristics of clusters were checked.
- Influence of arsenic in these luminescent entities was investigated which showed promising results. IIT Madras currently working on enhancing the required interaction among the species.
- Cluster-As interaction in buffer medium which resulted in a decrease in the intensity of cluster luminescence, indicating the possibility of reduction of As(V) to As(III) in the presence of phosphine ligand.
- Hence, the mechanism behind the change in the observed luminescence of the Ag cluster is currently being

studied in detail with techniques like speciation chromatography and X-ray photoelectron spectroscopy (XPS).

- After evaluating multiple methods for the fabrication of cluster-fiber composite, the method to immobilize luminescent materials on nanofibers by electrospinning has been identified.
- Studies have shown that the response of Ag_{29}@DPPP to As(III) in water was inconsistent due to solubility issues. Hence repeatability could not be achieved.
- Incorporation of new phosphine ligands in Ag_{29} clusters were found to be degrading clusters. Hence efforts towards the new cluster system development were started.
- A system of $Ag_{29}(L)_{12}$ – TCEP was developed which can be used for sensing As(III) in water as lipoic acid protected clusters are water-soluble.
- Linear response to As(III) in the sub-ppm regime was observed and it was reproducible.
- $Ag_{29}(L)_{12}$ – TCEP system also showed a response to As(V).
- Studies to understand the interaction between TCEP and arsenic are under progress.

For the development of the arsenic sensitive luminescent system, IIT Madras has been carrying out their interaction in different buffer mediums and controlled conditions, so that maximum sensitivity can be obtained. The selectivity of the system towards arsenic has to be thoroughly investigated.

Partner 2 – KIT Karlsruhe

The KIT team is responsible for electrospinning of fibers once a suitable cluster chemistry is communicated from IIT and then the exhaustive testing of these sensor materials for target pollutants and the potential interference of real water matrices.

- As analytical methodologies were discussed in detail with various experts. While specific columns exist to pretreat As samples to allow selective analysis of As species, a relatively new tool for As analysis has become available and was purchased at KIT. This instrument will be tested for robustness and limitations in terms of interferences, to allow later comparison in terms of cost and quality with the sensors to be developed.
- ICP-MS was anticipated to be accessible through collaborators in Heidelberg for the CANDECT project. Thanks to the infrastructure extension that has since become available a reconditioned inductively coupled plasma mass spectrometry (ICP-MS) could be purchased for this project and a method will be set up for accurate As determination that allows the verification of results obtained with simpler tools.
- Flow field-flow fractionation (FFF) was identified to quantify the extent of As occurring in colloidal form, or associated with organic nanoparticles. Further, liquid chromatography organic carbon detection (LC-OCD) will allow the nature of organic matter associating with As or interfering with the sensing.

These instruments were all received and set up in a temporary laboratory at INE, KIT, which was refurbished to suit such instruments while the IFG-MT laboratories are under construction.

- In terms of electrospinning of the suitable polymer for immobilization of clusters, an electrospinning device was designed and built at KIT with a stage that can print A4 material. This is ready to go for when a person is available and the desired chemistry for fibers is communicated by IIT.

Partner 3 - Inno Nano Research

- Designs available for luminescence-based sensing and readout using mobile attachment were evaluated and approach necessary for the implementation in the present project was identified.
- Various electronic hardware components necessary for the building of mobile attachment were identified. Exact LED excitation source and filters necessary for the attachment will be dependent on the luminescent cluster-nanofiber composite, so final design and integration of components will be decided after completion of the work on sensing element.
- Design for sensor holder was made. The prototype was 3D printed.
- Various components of filter excitation and readout methodology were integrated with the smartphone. An android app was developed for sensor readout using smartphone camera.
- Water samples from various sites in West Bengal India were collected and analyzed using ICPMS to detect Arsenic contamination.
- Water samples from various sites in Nalgonda District, Telangana, India were collected and analyzed using Fluoride ion-selective electrode to detect Fluoride contamination.
- Water samples from various sites in Nallampatti, Erode, India were collected and analyzed using GC-MS to detect Pesticide contamination.
- Water samples from various locations (river) were collected and analyzed using ICPMS to detect Chromium contamination.

Exact LED excitation source and filters necessary for the attachment will be dependent on the luminescent cluster-nanofiber composite; so final design and integration of components will be decided after completion of the work on sensing element.

Partner 4 - Fader Umwelttechnik (FAD)

The GC-MS has been set up, suitable pesticides (relevant in Germany and India) will be identified in consultation with FAD as well as real water sources and compositions identified. The characterization options have been expanded significantly through the availability of FFF, ICP-MS, and LC-OCD.

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WaterChip

DNA Biochip for on-site water pathogen detection including viability and antibiotic resistance testing

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Leibniz Institute of Photonic Technology, Jena

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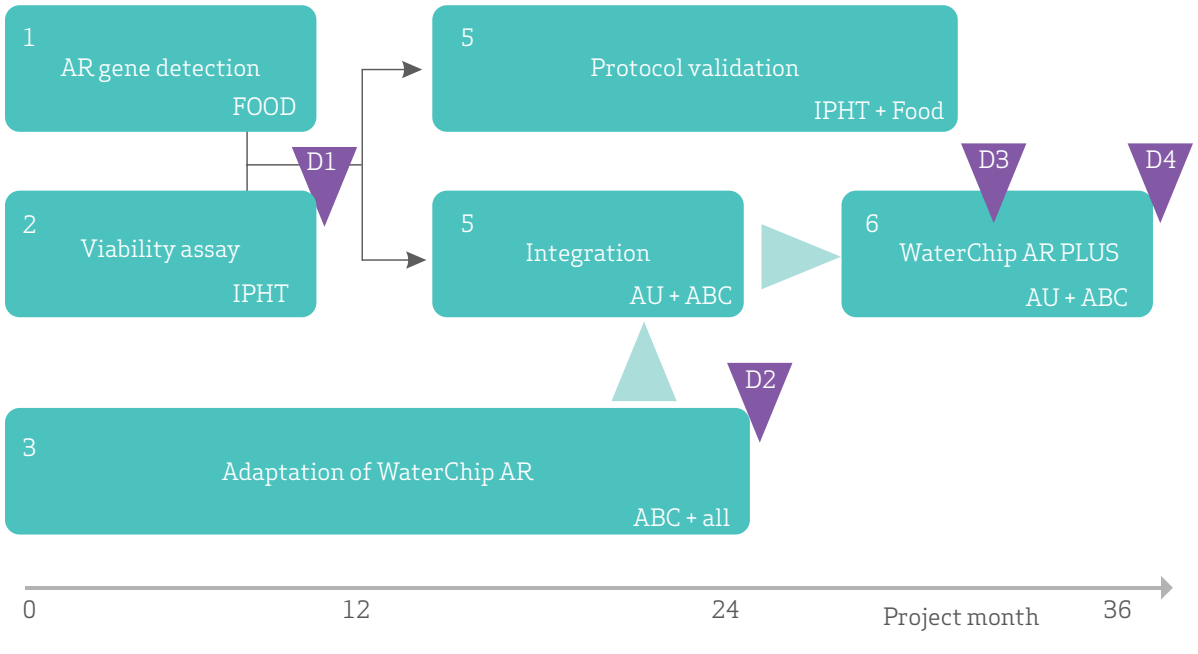
Food GmbH Jena Analytik-Consulting (Food), Jena

Project Summary

The proposal aims at the development and test of a multiplexed chip by adapting an already developed robust and low cost platform for on-site water pathogen detection. Genetic markers associated with at least a dozen waterborne pathogens, indicators, and antibiotic resistance bacteria will be included on the chip including viability testing to be validated with appropriate sensitivity and specificity. The proposed project has three objectives: 1) Provision of waterborne pathogens chips and detection systems, 2) Integration of live vs. dead (viability) protocol on the chip, and 3) field validation, deployment, support and feedback.

In the reported period, a new platform was developed, the Waterchip™, which has a broader application potential and therefore could be used more universally. First chip designs are available for the platform. The selection of target water contaminants and ARGs and protocol optimization has already been completed. LAMP-based amplification has been enhanced with on-site colorimetric detection based on gold nanoparticle assay. Currently, the validation of these assays with regard to quantification is in progress.

The development of parallelized assay based on plasmonic microarray is an extension of the proposal. Here a successfully preparation of this microarray could be demonstrated and published.



Scheme of the work flow in the proposal.

Progress made/achieved

WP3: Provision of Gene-Z platform (ABC Genomics)

D2: Field deployable chips (>100) capable of detecting panel of waterborne pathogens – chip is redesigned and prepared for the novel platform Waterchip™

The work packages were changed after modification and coordination with the project partners. On the one hand, the work was focused on the optimization of the LAMP assays. In addition, a spotter was purchased as a result of the approved project extension, and the fabrication of the plasmonic microarrays for the multiplex assays was started.

LAMP-assays

In the reporting period, the experiments for isothermal amplification in the form of Blue-LAMP were continued in cooperation with the project partner SynLab (formerly FOOD) and were extended by a simple colorimetric assay suitable for on-site use. In addition to Legionella, other water contaminants were also included as model analytes. After the LAMP parameters –provided by project partners - had been extensively tested and optimized in the previous reporting period, the selectivity (Figs. 1 and 2) and sensitivity (Fig. 3) of the method were currently in the focus of attention.

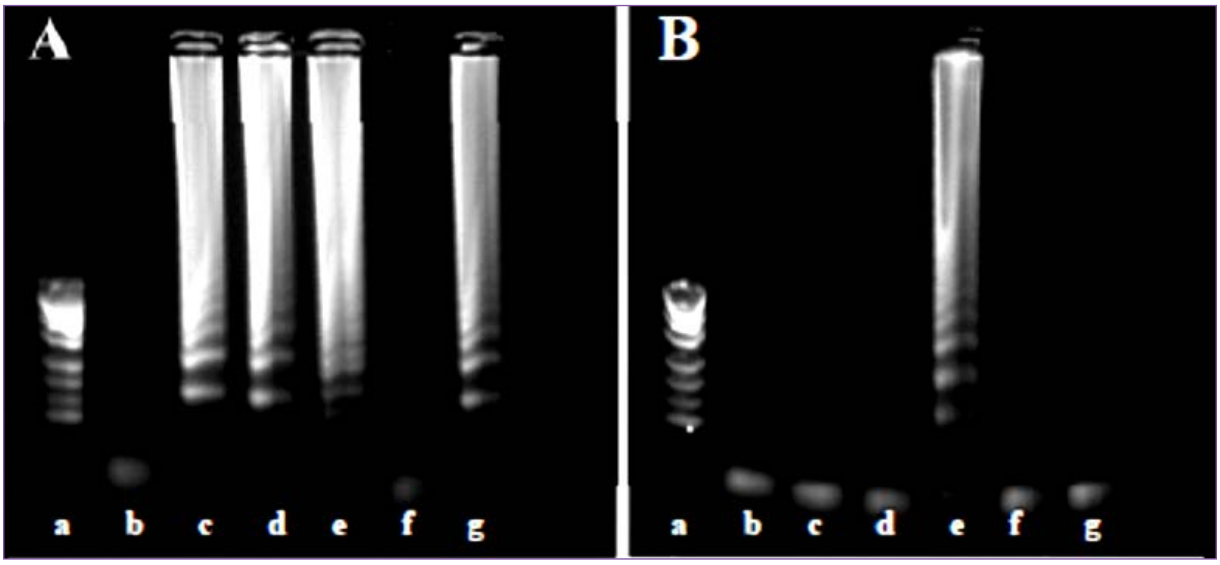


Fig.1 LAMP assay with Waterchip™ platform compatible reaction parameters and additives. Comparison of the primer sets dotA (A) and lepB (B) show a higher selectivity for the second set. Agarose gel of the primer set dotA (A) und lepB (B). a = DNA-ladder, b= negative control, c = L. dumoffi, d = L. feeleii, e = L. bozemanii, f = L. micdadai, g = L. parisiensis.

The sensitivity of the LAMP-based detection was determined for the model water contaminant Legionella (Fig. 3).

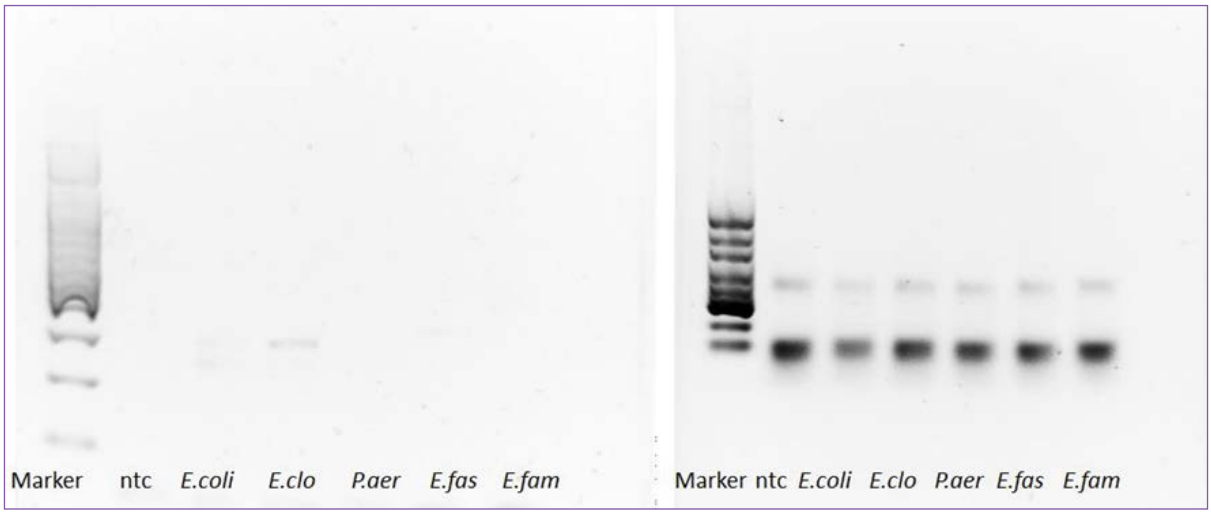


Fig.2 Selectivity of PCR reaction and LAMP assay as comparison for Legionella pneum. with Primerset lepB shows no non-specific amplification.

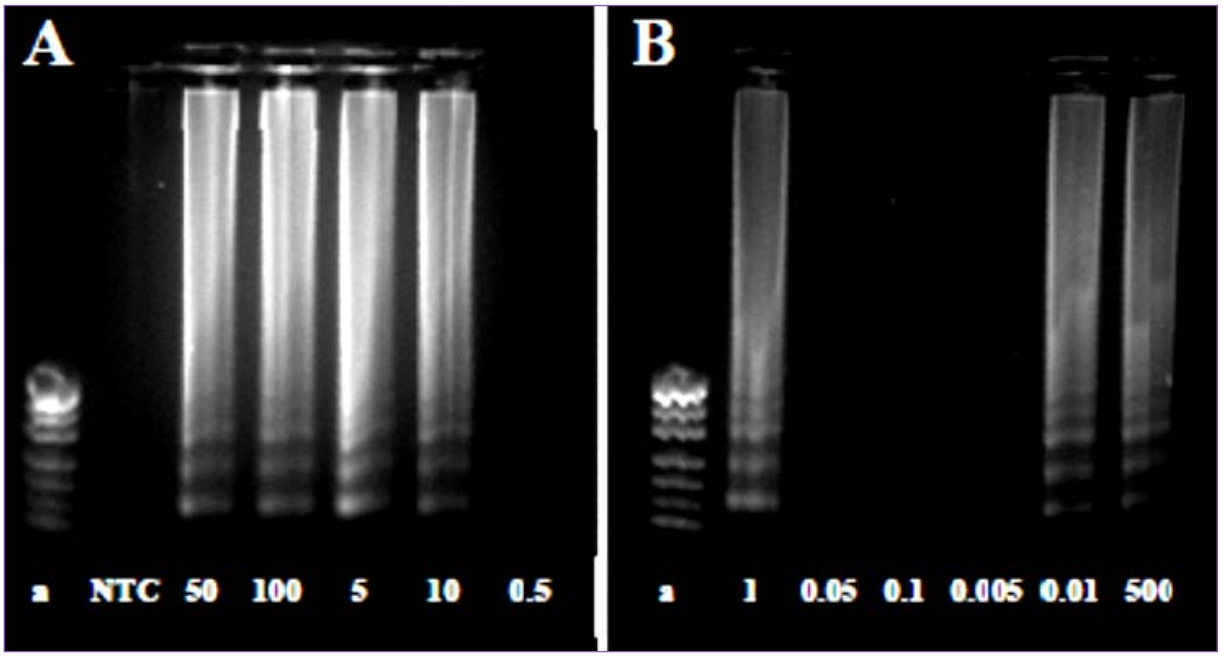


Fig.3 Sensitivity of the LAMP detection (A, B) Agarose gels and evaluation of the LAMP concentration series.

Stock (pg/uL)	Copies	C,(min)
0	0	0
500	100635	1108
100	20127	12.8
50	10063	13.0
10	2012	13.2
5	1006	15.7
1	201	20.5
0.5	100	
0.1	20	
0.05	10	
0.01	2	13.8
0.005	1	

One of the optimization points for the LAMP reaction is an optimal and shortest possible reaction time. A comparison was made with and without the loop primers (Fig. 4). By using the additional loop primers, the amplification time can be reduced by half (- 9.5 minutes).

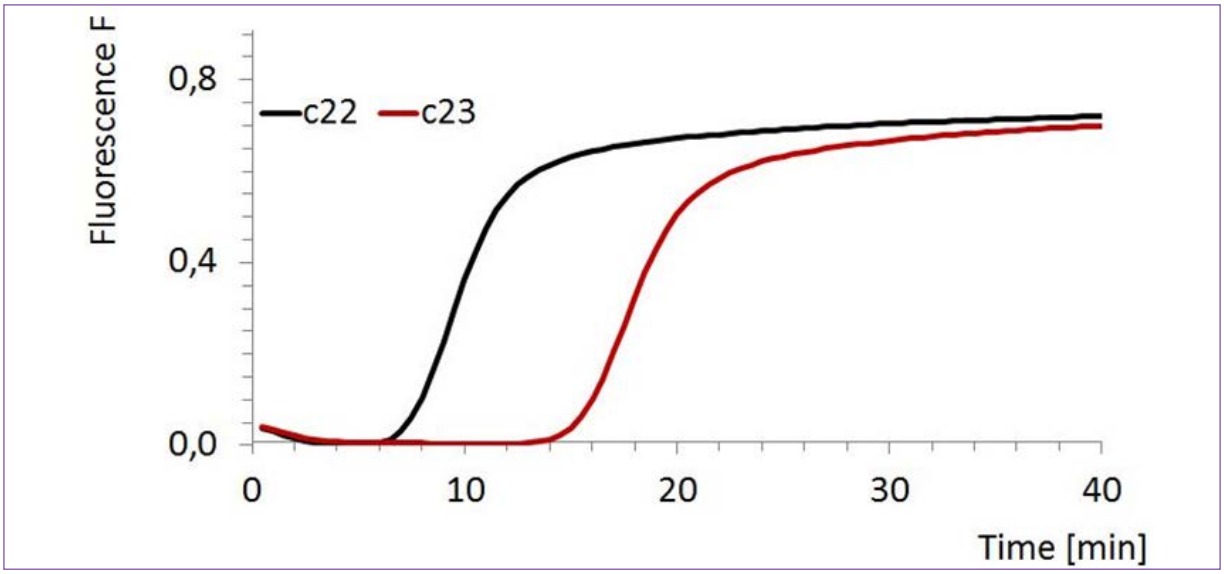


Fig.4 Real-time signal of the LAMP with (c22) and without loop primers (c23). With loop primers, the amplification time can be reduced by half.

As a further development of the LAMP-based detection of water pathogens, the optical detection with fluorescence signal or agarose gels was tested with simple color detection. In the previous reporting period, Blue-LAMP was tested as an alternative. However, there were some problems with reproducible detection of dye color change. Therefore a colorimetric detection was tested. Here, in the absence of the amplificates, destabilization of DNA nanoparticle conjugates occurs and results in aggregation, leading to a color change from red to blue (Fig. 5).

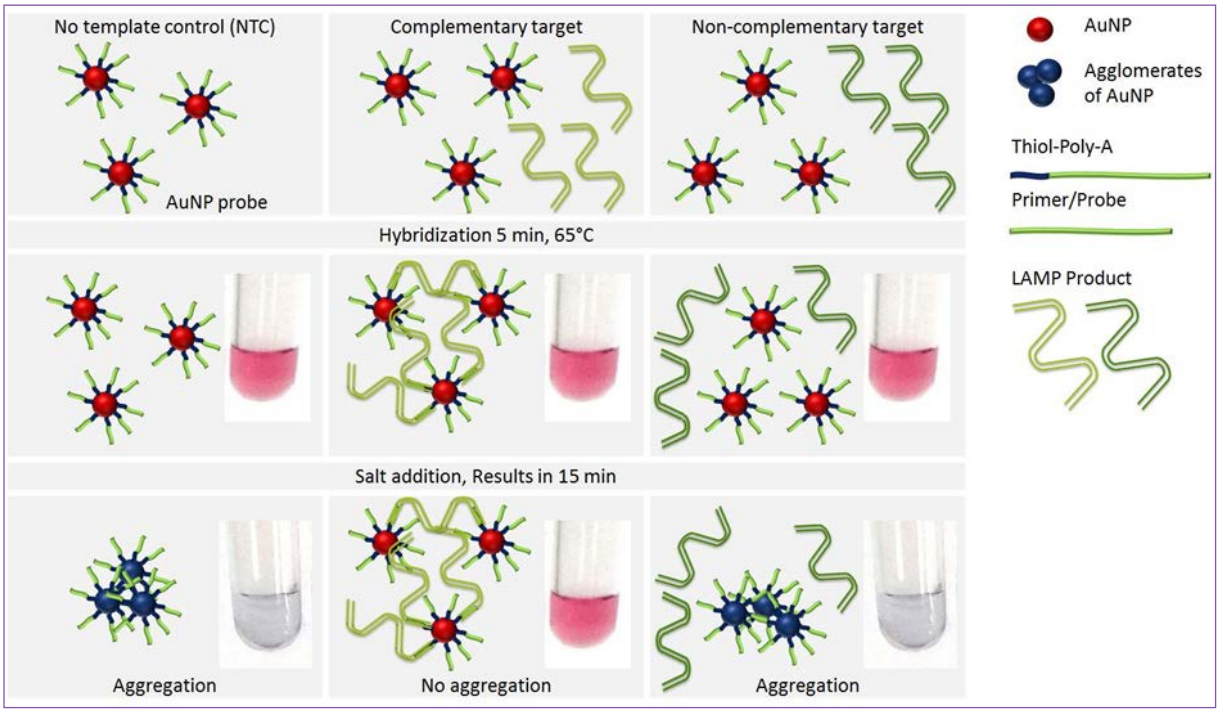


Fig.5 Scheme of the colorimetric assay for the detection of DNA amplification by LAMP.

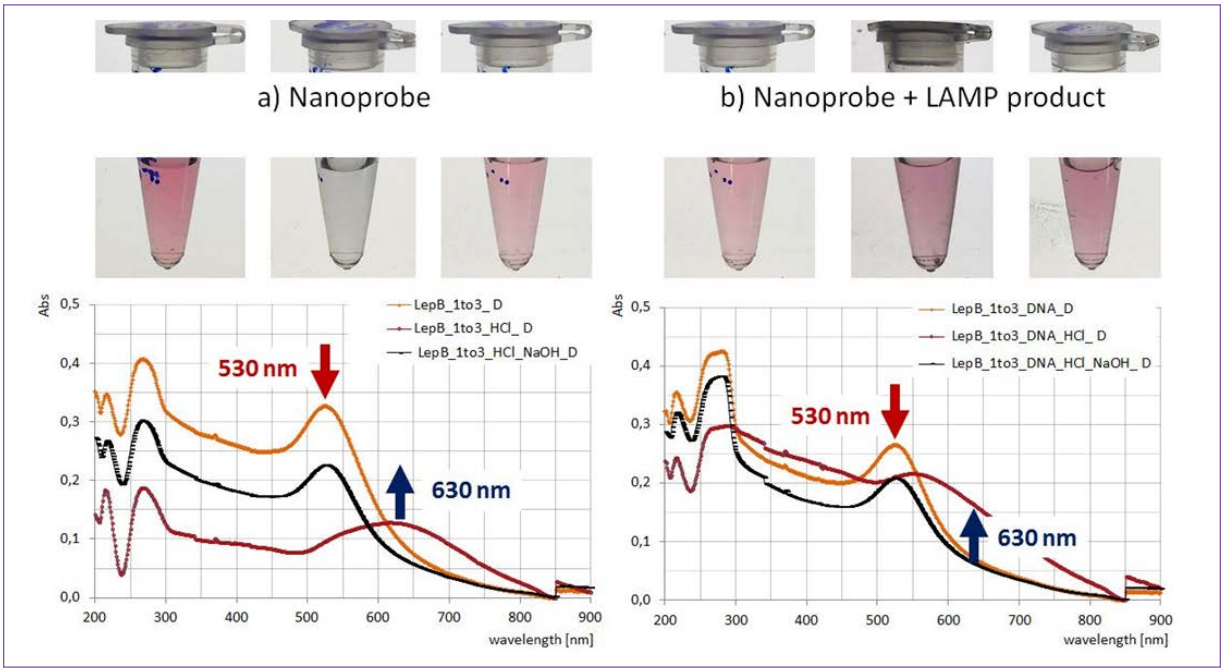


Fig.6 Colorimetric assay for the detection of DNA amplification. In the presence of water pathogens, LAMP generates DNA amplificates which have a stabilizing effect when bound to nanoparticles (primer-nanoparticle conjugates). A color change only occurs with samples without analyte.

The colorimetric assay allows simple discrimination of water pathogens and can be evaluated optically with the naked eye (Fig. 6). This color assay provides optical evidence of successful amplification after 20 minutes reaction time, is inexpensive (no expensive and unstable dyes) and reversible. A determination of the detection limit for the colorimetric assay is under way (Fig. 7).

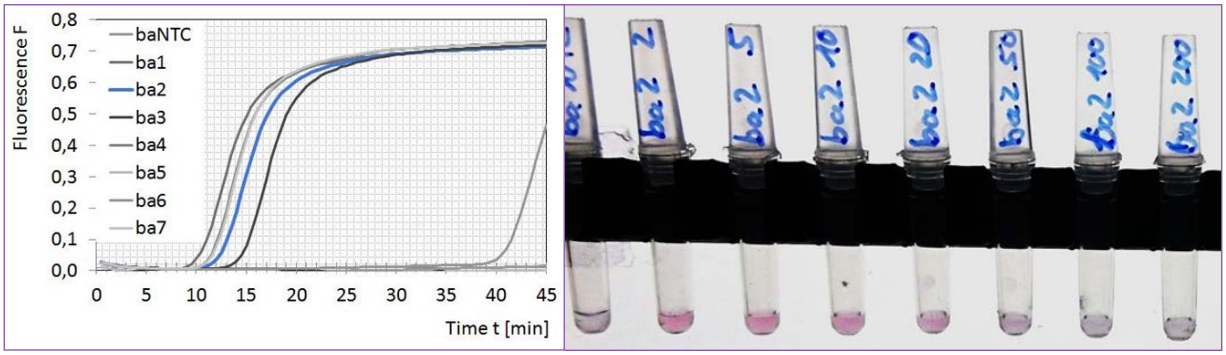


Fig.7 Determination of the sensitivity of the colorimetric assay to detect the DNA of water pathogens. Initial concentration is 1 ng/µl analyte.

Multiplex pathogen detection on microarray

In the second focus of the project, a multiplex pathogen detection by microarray integration was aimed at, which allows more measurements than the Gene-Z platform due to parallel readout. DNA amplificates selectively bind to the capture molecule at nanoparticle spots, this binding is simultaneously optically read out. First experiments with the nano-Plotter™ NP 2.1 (GeSiM GmbH, Radeberg) of the University of Jena were carried out (Fig. 8). The concentration of the nanoparticles used per spot, the spot size and the distance between the spots were optimized. Thanks to the optimum parameter, spots can now be reproducibly produced minimizing the so called "coffee ring effect" (Fig. 9).

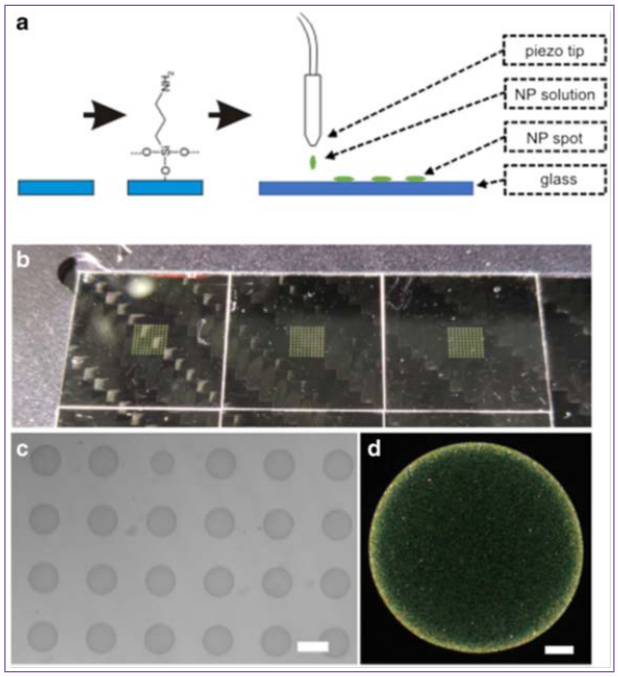


Fig.8 Scheme of the microarray manufacturing and images (b- overview, c – absorption, d – dark field) of the microarray.

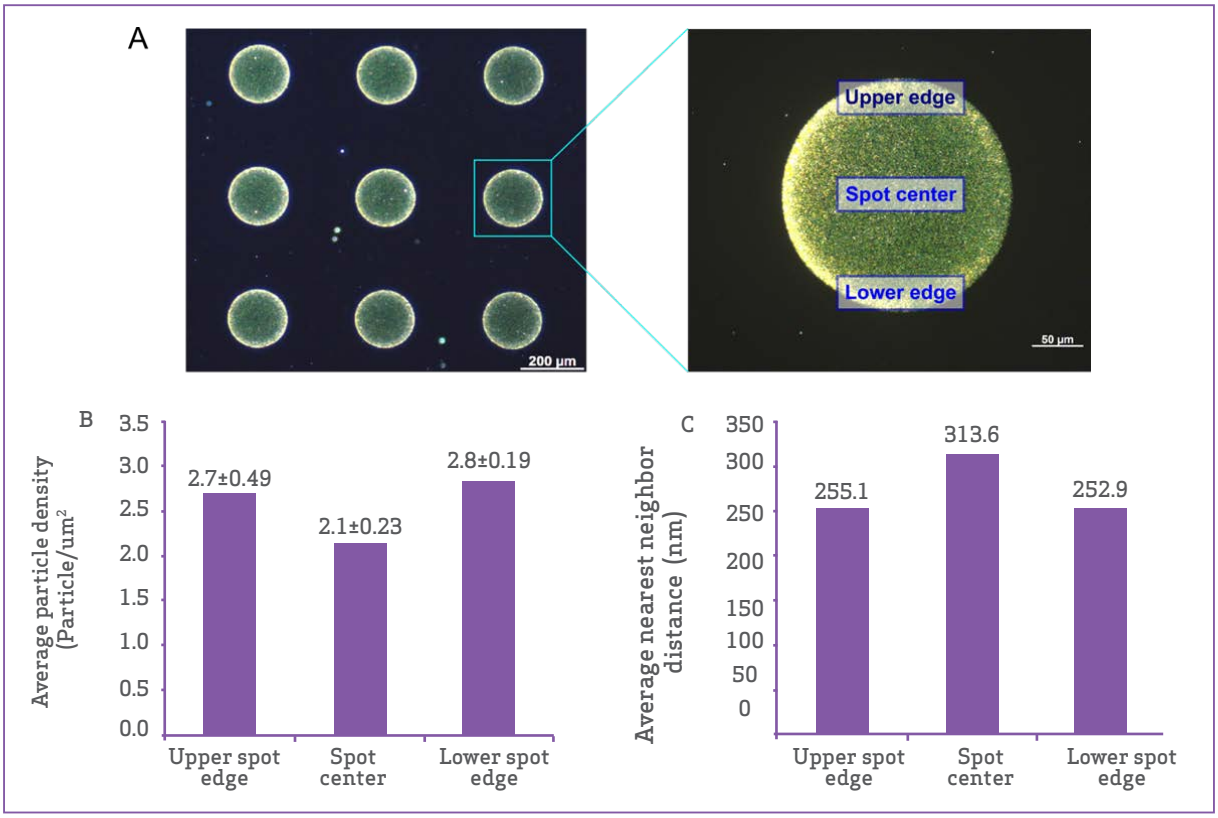


Fig.9 Plasmonic microarray. a) Dark-field image of the microarray. b) Mean nanoparticle density as a function of position within a spot and c) Mean distance of the nanoparticles show a homogeneous distribution.

The mean nanoparticle density within a spot and also the mean particle distances (determined by scanning force microscopic measurements) show a sufficient homogeneity of the spots, which is a prerequisite for good optical properties of the sensors. As a prerequisite for the biofunctionalization of the spots, the positioning accuracy of the spot could also be demonstrated (Fig. 10). The manufacture of the microarray was finally summarized in a publication and has since been successfully published.

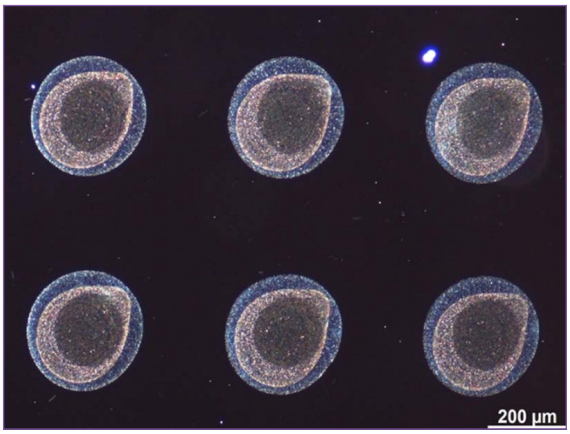


Fig.10 Positioning accuracy of the spotting on plasmon microarray - silver particles (blue) were spotted on previously immobilized gold particles (pink) (both 80 nm in diameter).

The optimized parameters of the microarray production are currently being transferred to the new nano plotter (Fig. 11). The aim is a reproducible production of the new microarrays and the increase of the number of spots in the detector's field of view in order to achieve a significant increase in parallelization. This approach would offer advantages such as faster diagnosis, higher selectivity and sensitivity at lower cost. Simultaneous detection of different water pathogens as well as virulence markers and possibly antibiotic resistance genes in one assay are planned.

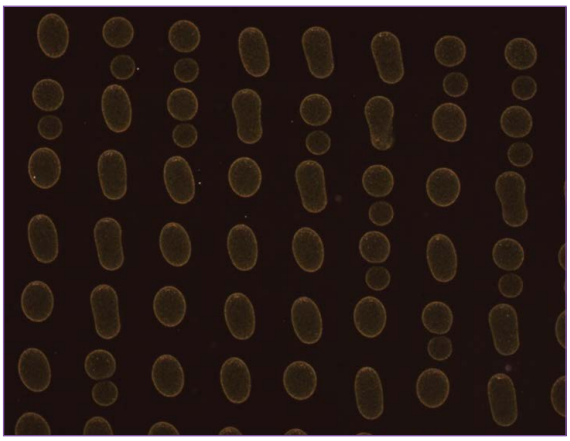


Fig.11 Test with the new nano plotter for the production of plasmon microarrays.

By the partner FOOD/Synlab, the work packages were adjusted accordingly in consultation with the project partners. The focus was on the establishment of LAMP assays for the detection of further antibiotic resistance genes and the testing of these systems with real samples from surface waters. The real samples as well as water samples mixed with bacteria were characterized microbially, concentrated and examined for DNA isolation in the established systems. The DNA samples were also made available to the project partners.

In the period under review, trials were continued to optimize and characterize

the LAMP reactions for E. coli and various antibiotic resistance genes. The investigations had to be continued with a real-time PCR device. The use of the developed detection systems for germs and antibiotic resistance genes for the analysis of real drinking water and process water samples requires a strong concentration of the samples in order to reach microbiologically relevant concentration ranges. Different filtration systems with different filter materials and pore sizes were tested. The concentration of sample quantities between 1 and 3 litres (required for the detection of less than 10 germs per 100 ml drinking water) by means of vacuum filtration led more or less frequently to clogging of the filters, depending on the purity of the water, which necessitated the use of several filters for 1 sample. Pore sizes of 0.2 µm (retention of almost all microorganisms) are less favorable than 0.4 µm (retention of most microorganisms). In classical water microbiology, pore sizes of 0.4 µm are considered sufficient. The subsequent removal of the germs and extraction of the DNA is associated with greater losses with more than 2 filters per batch. Commercial DNA extraction kits provided more constant amounts of DNA compared to manual phenol-chlorophorm extraction and thermal lysis. As a result of the investigations, a protocol for concentration and DNA extraction with high stability and practicability as well as good DNA yield was established (see Fig. 12).

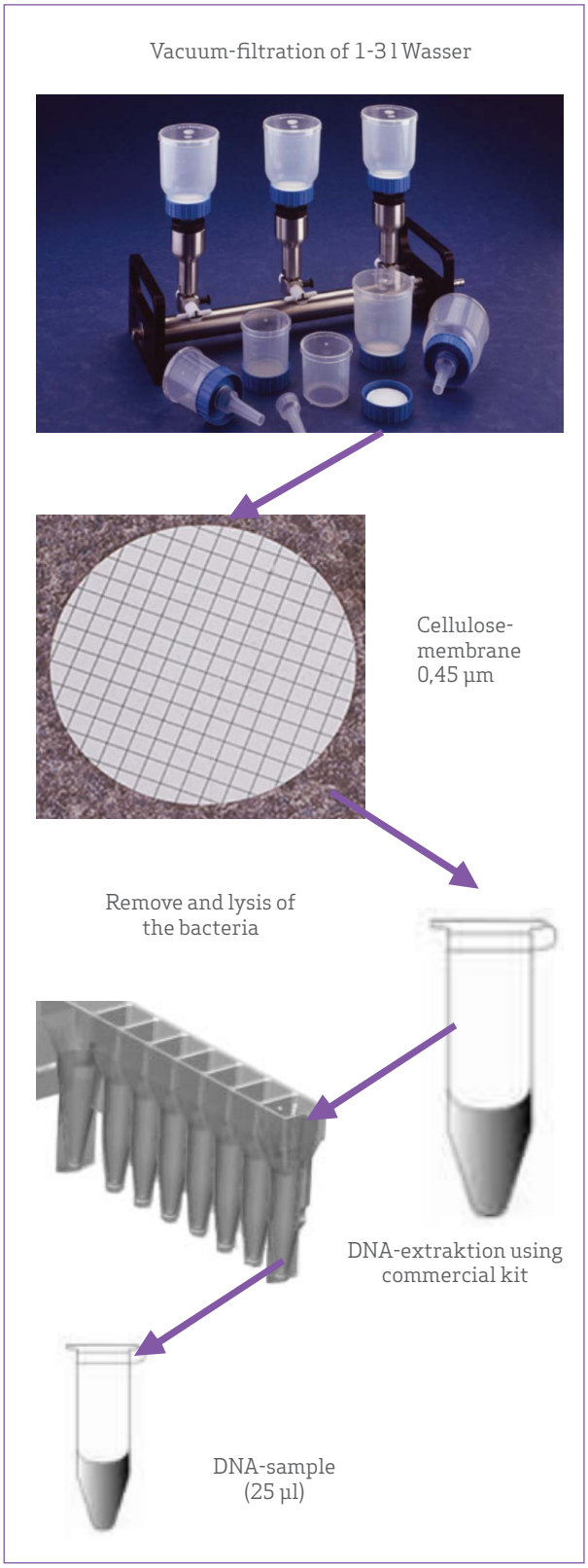


Fig.12 Scheme of the sampling and DNAextraction from real water samples.

To further characterize the detection of E. coli by uidA-LAMP, sensitivity tests were performed with inoculated water samples followed by concentration and DNA extraction. Germ concentrations from 5 CFU/100 ml to 5x106 CFU/100 ml were used (Fig. 2). With the successful detection of 5 CFU/100 ml, a sensitivity was achieved that almost corresponds to the microbiological water tests. However, the reliable detection of 1 CFU/100 ml has not yet been achieved.

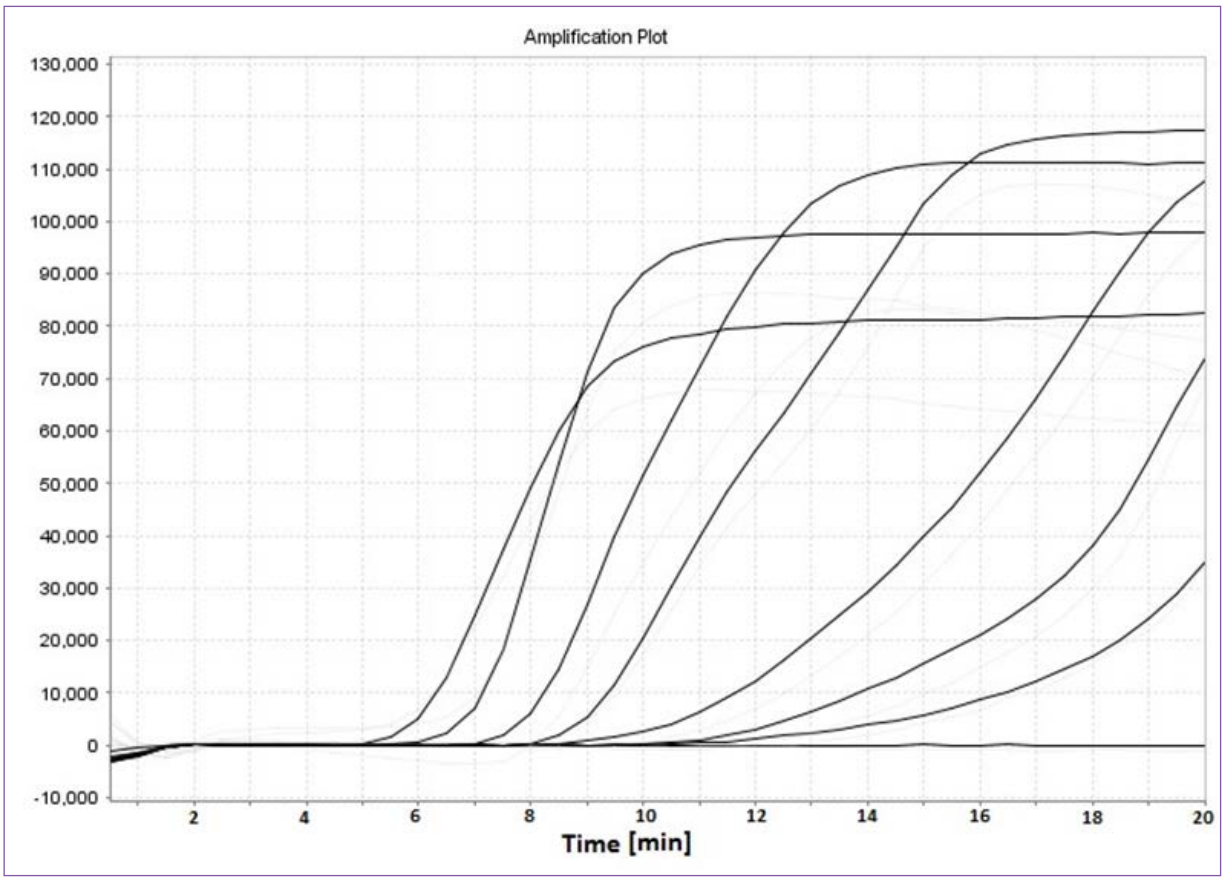


Fig.13 uidA-LAMP of water samples inoculated with E. coli (5 to 5x10^6 KBE/100 ml) after concentration.

Salient Research Achievements

- A set of primers for LAMP for water contaminants and ARGs were tested
- LAMP detection with on-site colorimetric assay
- LAMP protocols for pathogens were tested with real surface water
- Waterchip^{TM} platform was established
- New cartridges were developed and adapted
- Plasmonic microarray for multiplex assays was developed

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- Kosman, J.; Jatschka, J.; Csaki, A.; Fritzsche, W.; Juskowiak, B.; Stranik, O., A New Strategy for Silver Deposition on Au Nanoparticles with the Use of Peroxidase-Mimicking DNAzyme Monitored via a Localized Surface Plasmon Resonance Technique. Sensors 2017, 17, (4), 849.
- Pittner, A.; Wendt, S.; Zopf, D.; Dathe, A.; Grosse, N.; Csáki, A.; Fritzsche, W.; Stranik, O., Fabrication of micro-patterned substrates for plasmonic sensing by piezo-dispensing of colloidal nanoparticles. Analytical and Bioanalytical Chemistry 2019, 411, (8), 1537-1547.
- Reuter et al. "Loop mediated amplification as promising on-site detection approach for Legionella pneumophila and Legionella spp." has been received by Applied Microbiology and Biotechnology.
- Reuter, C. DNA-based Detection of Human Pathogen Water Contaminants, poster at the International Symposium Molecular Plasmonics 2019, May 2019 Jena

Ph.D / Master thesis supervised

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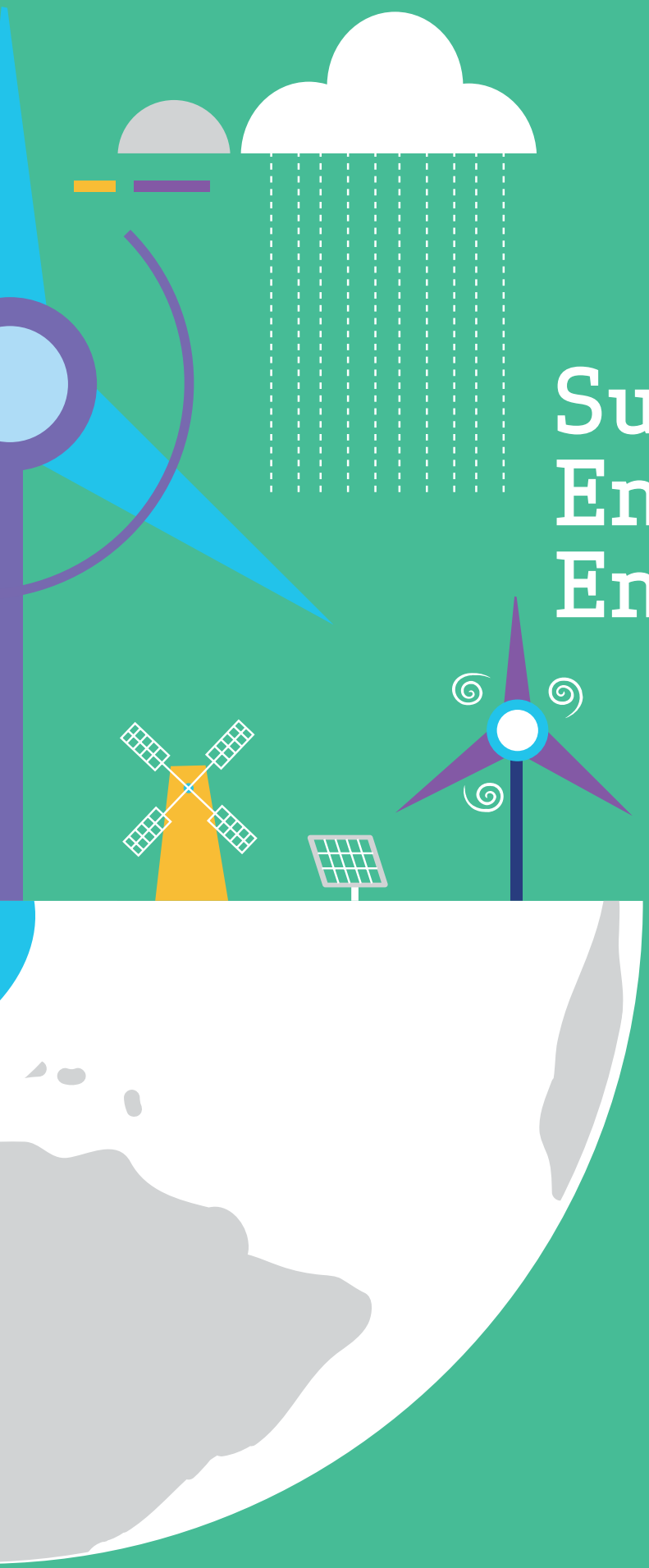

Sustainable Energy/ Environment

LowCostEPS

Low-cost emergency power system based on printed smart supercaps

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Project Summary

Nowadays, in India electrical power is an essential item. To solve the problem of power failures, a standard solution is the installation of a diesel generator supported by a battery stack to provide power in the moment of the blackout. These batteries are costly, the service life is limited, and often they are the most unreliable component in the whole emergency power system (EPS).

To solve this problem, the Indo-German project consortium has the intention to create a new LowCostEPS based on mass-printed smart supercaps for small and medium-sized applications in the power range of 2.5 to 10 kVA. The LowCostEPS should bridge the time of power interruption until the existing diesel generator provides enough power to run a proper energy supply again. The core idea of the proposed project is to use conventional printing methods, such as gravure, offset or flexographic printing, for the production of low-cost supercaps. Conventional printing methods are well-known for their high productivity and cost-effectiveness due to the mass-production possibility.

In the last year of the LowCostEPS project, the performance and long-time electrochemical stability of the supercap components were dramatically improved. With a working materials composition achieved, the partners proceeded

to the mass production of printed supercap. A first supercap module containing 200 individual cells was prepared showing the potential of the chosen setup. Subsequently, Roll-to-Roll flexographic printing and screen-printing techniques were used to print 600 m of supercap substrates. Stencil printing was used to apply electrode layers. Finally, 2400 cells were assembled by hot-laminating with a stencil print electrolyte layer. 12 supercap modules were prepared, where each module contained 200 cells which were interconnected using silver contacts and copper wires.

Progress made/achieved

In the last year, demonstrator-adequate supercap cells were fabricated (M4, M5) and provided as supercap modules to SLN for testing and circuitry development. The target power density of 1 Wh/Kg (D7) is met for the used electrode materials, however, the weight of the additional components lowers the power density to 0.31 Wh/kg.

The long-time chemical and electrochemical stability became the apparently biggest challenge of the project. While the first experiments showed a sufficient performance of the prepared single cells, their long-time stability was only poor. It was found that the chosen electrolyte was incompatible to the silver contact material, which was indispensable for low resistivity and high performance. Replacing the graphite current collector sitting between the silver contact lines and the electrolyte layer by a carbon passivation layer, improved the chemical and performance stability significantly (Figure 1).

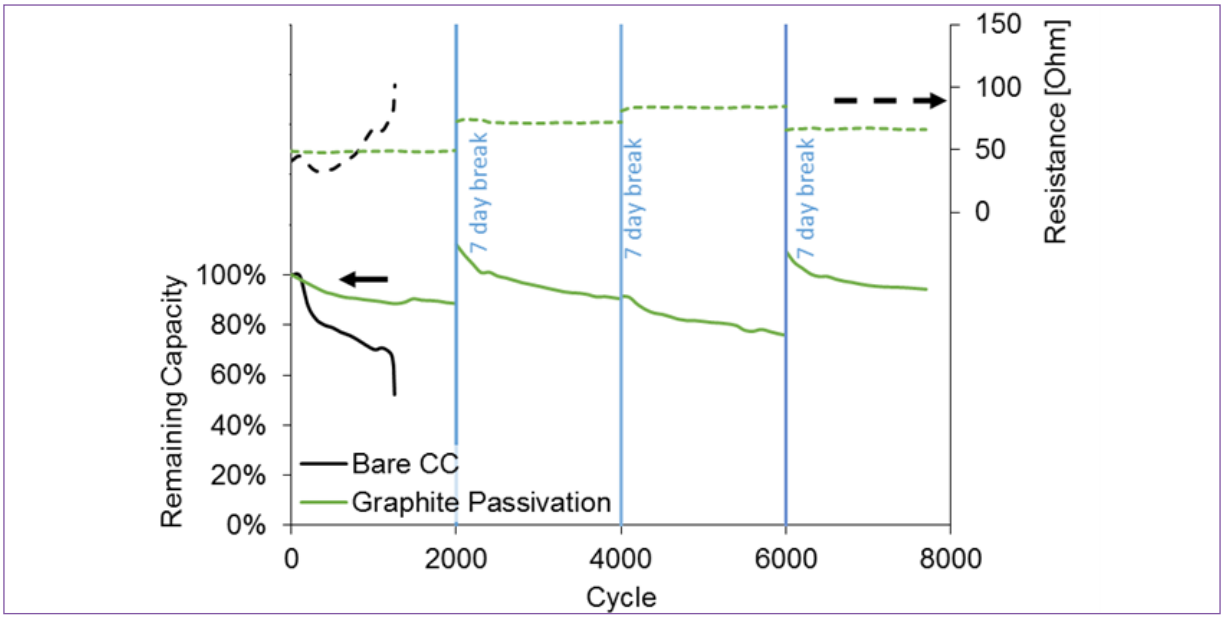

Figure 1: Long-time stability of a protected current collector with graphite passivation layer compared to an unprotected bare current collector. After 2000 charge-discharge cycles, the experiment was stopped for 7 days continuing. Differences between the 2000 cycle sets are also caused by the relative humidity and temperature of the environment.

Furthermore, instead of direct printing the gel electrolyte onto the electrode, the gel electrolyte was print on a PET substrate and subsequently laminated onto the electrodes. This procedure improved the texture of the paper substrate significantly and also lowered the exposure of the substrate to the acidic gel electrolyte ink.

Subsequently, 600 m of supercap current collectors on Grünperga special paper substrate were prepared by roll-to-roll flexographic printing (Figure 2, left) and screen printing techniques. Stencil printing was used to apply electrode layers. In the final step, 2400 supercap cells were assembled by hot-lamination a stencil print electrolyte layer onto the electrodes and hot-laminating two half cells face-to-face to obtain full supercap cells (Figure 2).

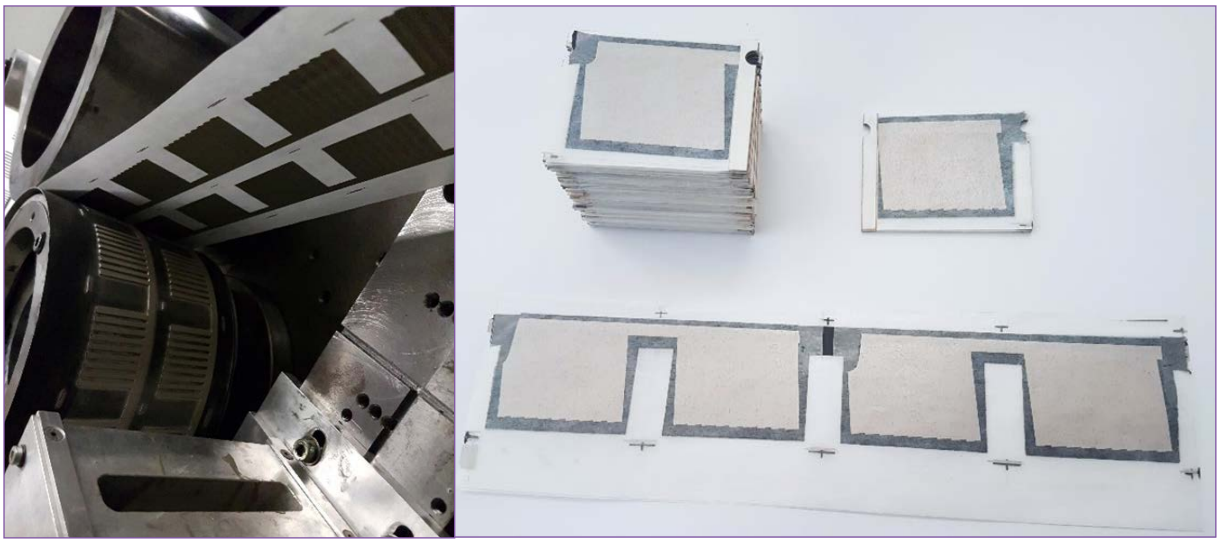

Figure 2: Left: Roll-to-Roll flexographic printing of silver contact and current collector. Right: Cells were assembled by laminating two half cells (bottom), zig-zag folded and stacked (top)

The supercap modules were prepared according to the scheme in Figure 3. The modular assembly of the supercap stack allows tailoring the properties and needed performance of the overall system. 200 single cells were connected in parallel to obtain a module. Each module as individually electrochemically analysed. The modules (Figure 4) have an average capacity of 550 F and a resistance of 0.2 Ohms at 1 A discharging current.

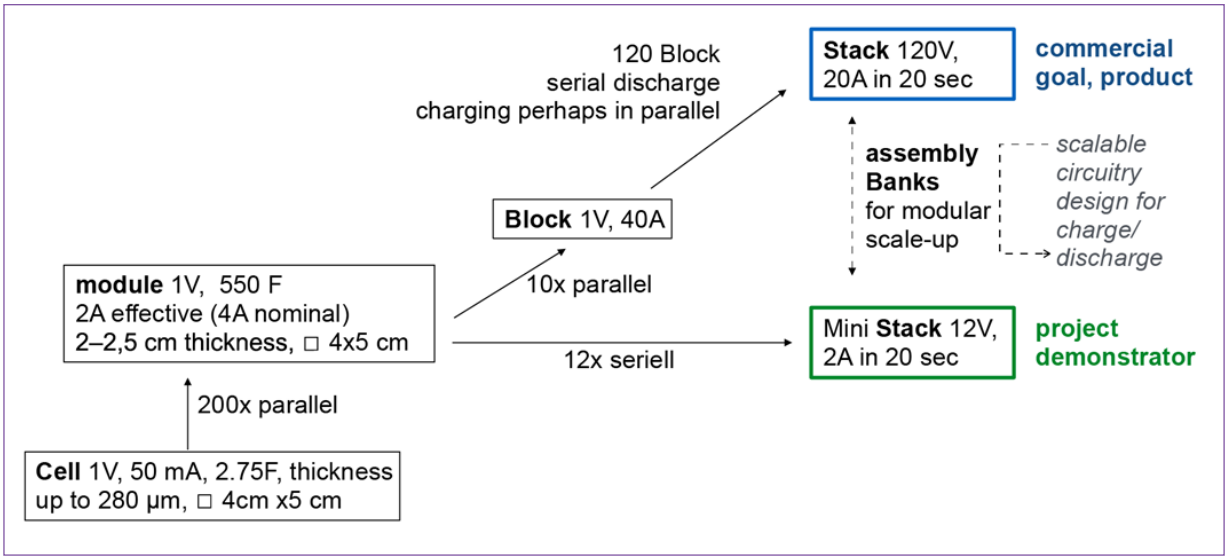

Figure 3: Scheme of the assembly of single cells to supercap stacks. 200 cells are connected in parallel to give a module of 1 V. The moduls are connected either in parallel to give a larger block or in series to achieve the project demonstrator, a 12 V mini stack.

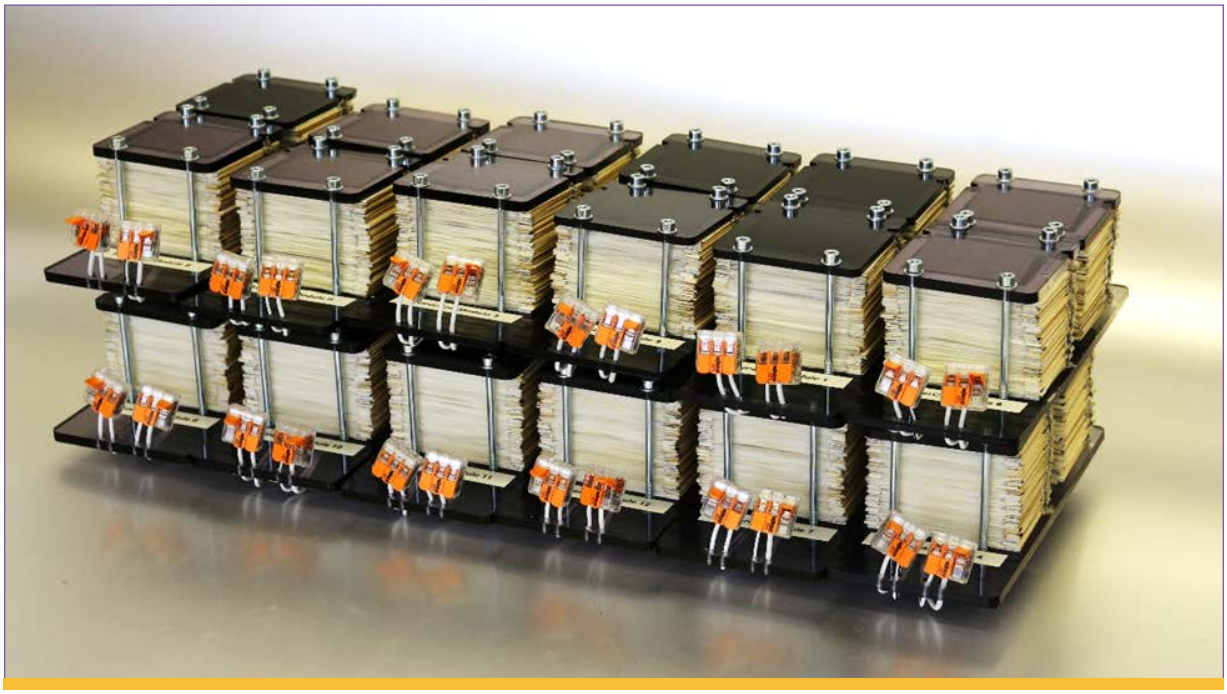

Figure 4: 12 supercap modules were assembled consisting of 2400 single cells with a total capacity of 6600 F.

Publications

- "High-Throughput Template-Free Continuous Flow Synthesis of Polyaniline Nanofibers" Rekha Singh, Karuna Veeramani, Rishab Bajpai, and Anil Kumar, Ind. Eng. Chem. Res., 2019, 58, 5864-5872
- "PANI-Graphene Nanocomposite as an Active Material for Large-Scale Low-Cost Electrochemical Double Layer Capacitors" Thomas Weissbach, Rekha Singh, Tino Zillger, Anil Kumar, and Arved Hübler: ;Oral presentation at the IS&T conference Printing for Fabrication, Dresden, Germany, 2018

Ph.D / Master thesis supervised

- Master thesis – Research of High Conductive Carbon Based Electrodes for Printed Super-Capacitors
- Master thesis – Printed two-phase electrodes for efficient energy storage

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METNETWORK

Nanostructured hybrid transparent network electrodes for large area visibly transparent solar cells

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Project Summary

Semitransparent solar cells could find enormous applications from a window panel to automobile roof top solutions. By definition they require semitransparent active layers and transparent electrodes. The current recipes for realization of a large area technology suffer from process limitations related to deposition of transparent conducting electrodes (TCE) with sufficient transparency and low resistivity. Other issues are related to electrode stability, up-scaling to large areas and flexible substrates. There is also a big demand to replace the expensive indium tin oxide as TCE. Additionally, there is a need to develop printing compatible TCEs which can be applied to any type of surface without the further necessity of welding or soldering. We have demonstrated that micrometer cracks formed in a polymer film can be used as a template to deposit metals and by the lift-off of the polymer template, hybrid metal network TCEs with high transmission and low resistivity can be developed.

To examine the feasibility of printing methods to develop large area TCE metal network

To synthesize the metal network TCE on flexible substrates such as PET or PEN or paper

To test the feasibility of alternative metalation method based on solution processing techniques and/or incorporating graphene

To integrate these TCEs in large-area solar cells suitable for window applications

The uniqueness of this approach is its simplicity and suitability for any kind of metals and their precursors. Since we can control the metal fill factor and the structural width of the metal network by tuning the width of cracks in the polymer film, the conductivity and transmittance of such TCEs can be tuned. In collaboration with the industry partners, the chemistry and the process will be adapted to fulfill the objectives.

The proposed work will provide viable solutions to the pertinent issues related to fabrication of ITO-free TCEs. The application of these electrodes is extendable to other applications such as thermal heaters, sensors, and electrochromic or thermochromic devices. This innovative concept of nanostructured hybrid TCE is a big step towards smart window applications suitable for building integrated photovoltaics.

Progress made/achieved

WP1: Screening materials and feasibility test towards large area TCEs with metal network (both sublimation and wet chemistry)

WP2: Fabrication of large area hybrid TCEs with metal mesh and graphene

WP3: Optimization of semi-transparent organic/hybrid photoactive materials to integrate with hybrid TCEs

WP4: Fabrication of large area (>10 cm^2) TCEs using printing methods

WP5: Fabrication and optimization of large-area semi-transparent solar cells with hybrid TCEs

WP6: Towards integration of smart windows and other applications

Partner 1 and Partner 2 (CeNS und Tata Steel):

The Indian project partners (CeNS and Tata Steel) concentrated on two important aspects. CeNS mainly optimized different large coating methods for large area templates (up to 30×30 cm^2) such as screen printing, spray coating and roll-to-roll (R2R) printing (on a laboratory scale). CeNS and Tata Steel also studied the formation of twisted multilayer graphene on a polycrystalline Ni-foil by a modified CVD process

Partner 3 (University of Bayreuth) (concerning WP3 and WP4):

At the University of Bayreuth (UBT) hybrid-TCEs were optimized for perovskite solar cells.

perovskite solar cells fabricated on metal/AZO hybrid-TCEs with good efficiencies can be fabricated even on Cu as cheap alternative. The devices are prepared on glass substrates with areas between 9-12 mm². In cooperation with PL large scale electrodes on PET foil were designed (see below) and will be used to fabricate perovskite solar cells.

Partner 4 (Papierfabrik Louisenthal GmbH) (concerning WP1 and WP4):

The Papierfabrik Louisenthal GmbH (PL) has developed a standard crack template recipe, which is suitable for the fabrication of metal networks on PET film in lab as well as via roll-to-roll (R2R) printing on a 810 mm wide foil. At the last METNETWORK project meeting in April 2018, PL has shown a piece of such a 810 mm wide PET foil having a 40 nm high aluminum network of (see Figure 2). Little issues with homogeneous demetalization were identified and the results were taken into consideration for further optimization (WP1).

PL is working together with UBT on metal network Electrodes for perovskite solar cells. The current electrode is designed for a 1.6 cm^2 perovskite solar cell. PL has prepared such electrodes based on UBT´s design. However, the substrate – a 20 µm PET foil – is thin for the further perovskite cell fabrication steps. Therefore, PL works on laminating this electrode - 70 nm Cu network on 20 µm PET – on a thicker 125 µm foil for better handling (WP4).

Salient Research Achievements

UBT optimized hybrid-TCEs for perovskite solar cells. Hexagonal Au-networks with defined size (Fig. 1a) were fabricated via photolithography for a detailed study on hybrid-TCEs. Due to an insufficient charge collection in perovskite solar cells on pure Au-networks of with TiO2 hybrid material only very low efficiencies were obtained. It could be shown that the conductivity of TiO2 is too low for a sufficient charge collection. A pronounced influence of the island size of the network on the short circuit current is a clear evidence for this. By using aluminum doped ZnO with a thickness of 80 nm and a sheet resistance of about 7000 °/□ we could obtain perovskite solar cells with efficiencies up to 8.2 % on Au/AZO hybrid-TCEs. In contrast to TiO2 no dependence on the island size can be observed showing that AZO with a thickness of 80 nm has a sufficient conductivity for charge collection. The AZO layers, obtained by sputtering, conform very well with the underlying network, which is fully covered. This might make it possible to reduce the AZO thickness to even lower values. AZO can also form stable hybrid networks on other cheaper metals like copper. The PCE of perovskite solar cells fabricated on Cu/AZO hybrid-TCEs were equivalent (PCE = 7.4 %) to the ones prepared on Au.

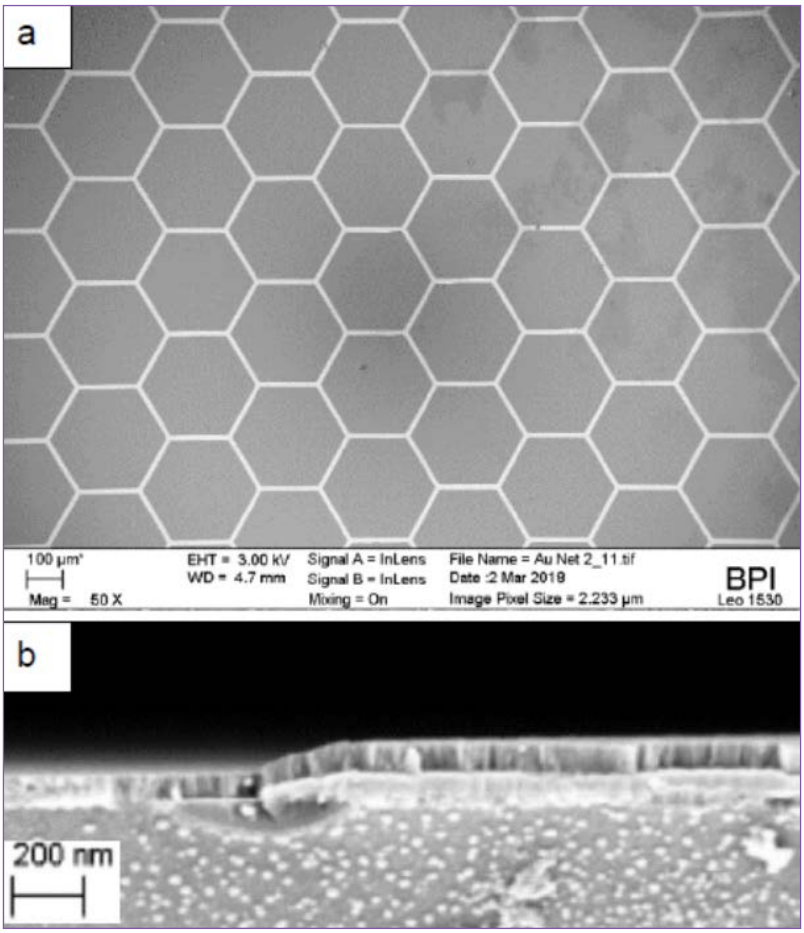

Fig.1 - Electron microscopy pictures of: a) A defined hexagonale Au-network with an island size of 195 µm and a metal width of 20 µm. b) A side view on a Au wire coated with an uniform AZO layer.

PL worked also on the further characterization of its metal network such as electrical, optical and mechanical properties. In detail, PL could show, that the fabrication of aluminum, copper and silver networks in different thicknesses up to 600 nm is possible (Figure 3a) to achieve a sheet resistance below 5 ohm/nm while having a high optical transmittance of 92 % (without substrate – see Figure 3b & 3c). In addition, such metal networks exhibit very high bending stability using a bending radius of only 2 mm and bending cycles up to 100.000 times (Figure 3d). Such a metal mesh was also integrated into a heated glove compartment lid, as a prototype for interior heating in electric cars. This prototype was a collaboration between BMW Group, Lohmann GmbH & Co. KG and Papierfabrik Louisenthal GmbH under the direction of KEX Knowledge Exchange AG. The prototype achieved a surface temperature of 60°C and was presented to public on September 27th 2018 at Aachen / Germany.

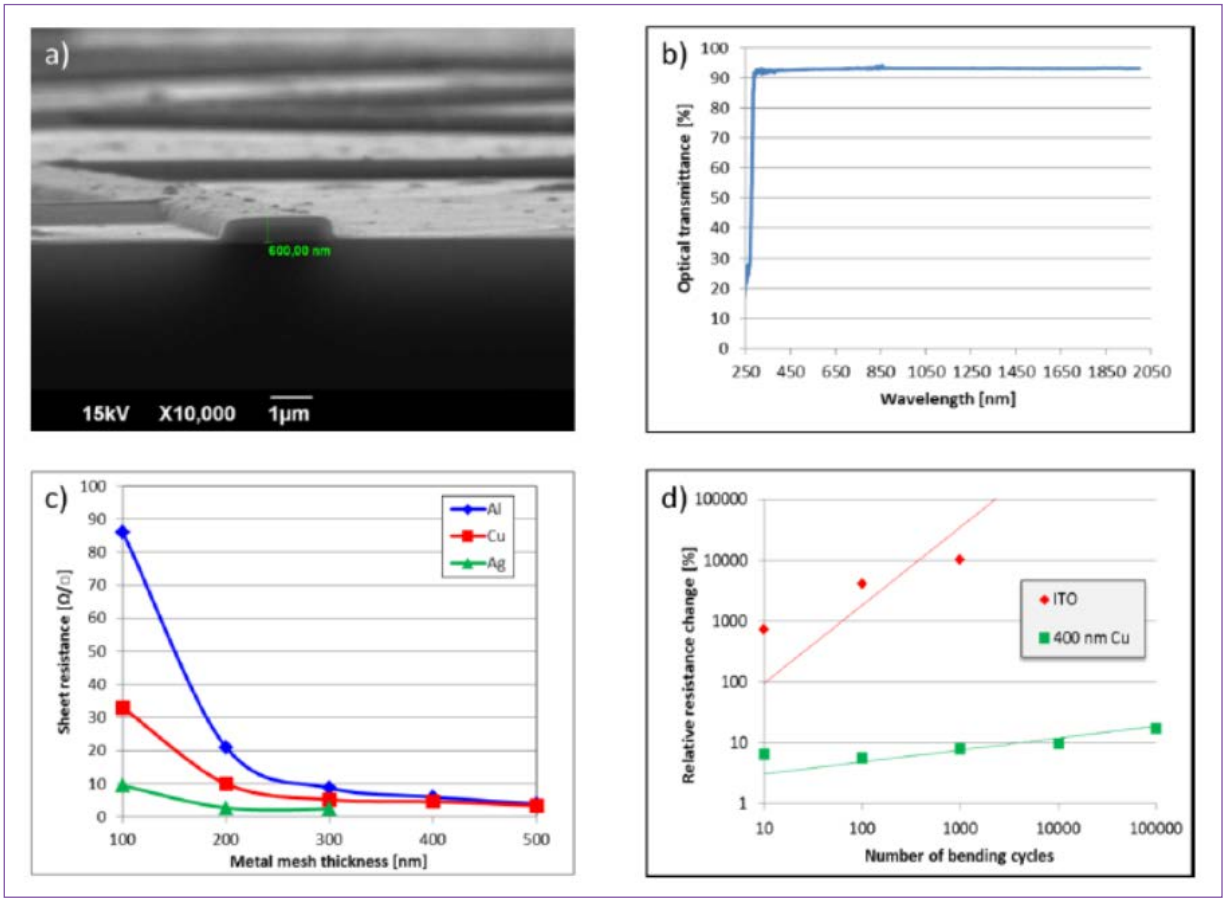

Figure 3. Properties of the Metal Network: a) SEM cross section of a 600 nm high Cu network b) Optical transmittance of a 400 nm high Al network measured on glass d) Sheet resistance dependence on metal network height of Al, Cu and Ag networks d) Relative resistance change of a 400 nm high Cu network during 2 mm bending tests.

The Indian project partners (CeNS and Tata Steel) concentrated on two important aspects. CeNS mainly optimized different large coating methods for large area templates (up to 30×30 cm2) such as screen printing, spray coating and roll-to-roll (R2R) printing (on a laboratory scale). Cu-metal networks (thickness - 150 nm) with a sheet resistance of 22 ohm/nm and an optical transmission of 70% could be fabricated. They showed that these networks are suitable as heater foils. Also, Sn-Networks (sheet resistance: 5 ohm/nm, transmission: 80%) on PET with an additional thermotropic hydroxypropyl methylcellulose (HPMC) layer were developed for thermally switchable transmission foils. CeNS and Tata Steel also studied the formation of twisted multilayer graphene on a polycrystalline Ni-foil by a modified CVD process

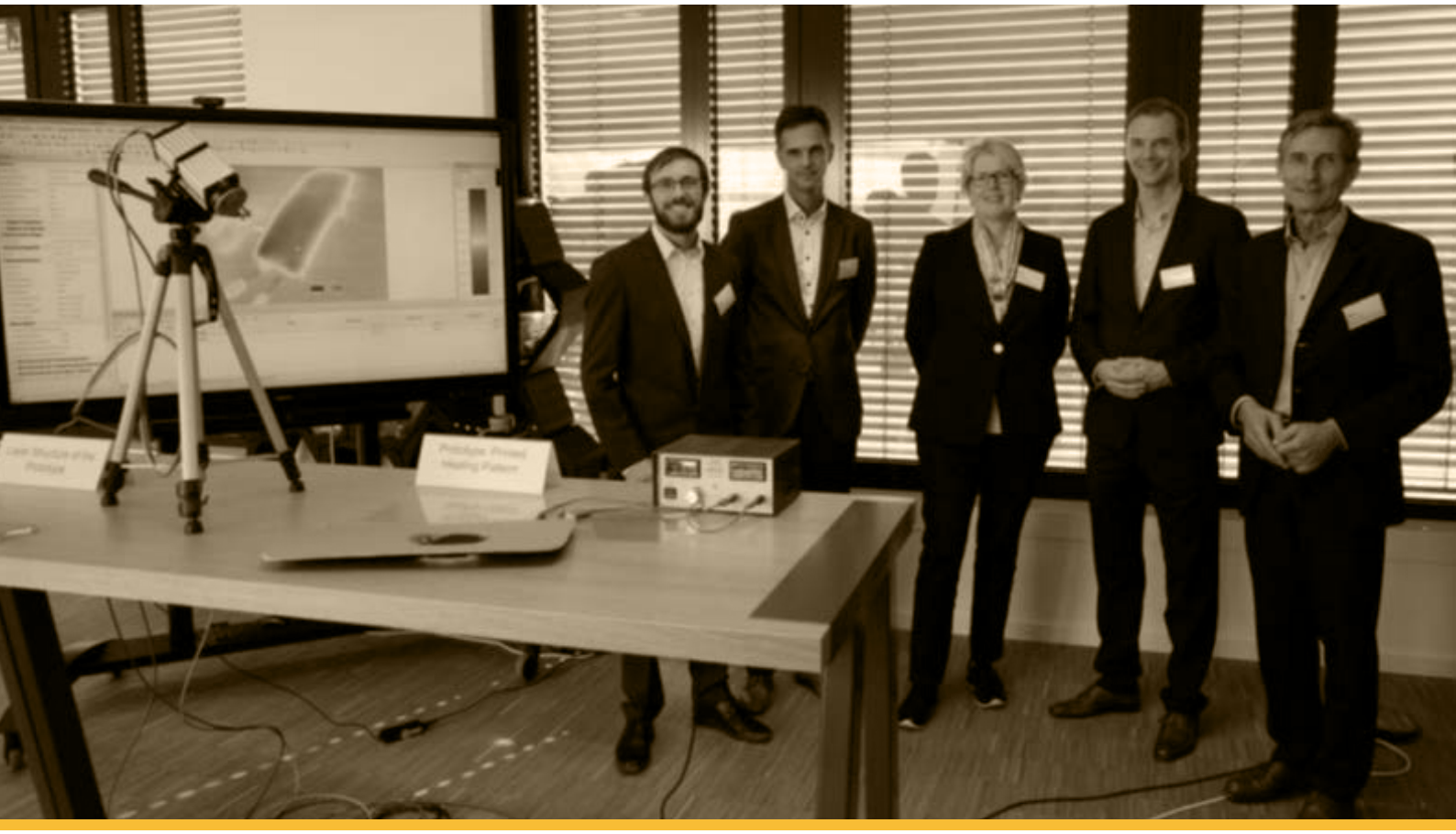

Figure 4. Photo taken at the presentation of a heating prototype for electric vehicle under the KEX consortium on September 27th 2018 at Aachen / Germany.

Publications

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- S. Kiruthika, S. Chaitali , G. U. Kulkarni, Transparent and Flexible Supercapacitors with Networked Electrodes, Small, 2017, 1701906.
- Hunger, C. (2018, March). A R2R fabricated metal mesh foil for transparent conducting electrodes. Poster presented at the LOPEC 2018 Conference. Munich

Patents filed/published

- US7172822B2 – Network conductor and its production method and use
- US9114425B2 - Method for manufacturing a mask having submillimetric apertures for a submillimetric electrically conductive grid, mask having submillimetric apertures and submillimetric electrically conductive grid
- WO 2014136039 A1- Composition, substrates and methods thereof
- WO 2018229561 - A process for producing graphene based transparent conductive electrode and the product thereof

General public relation activities

- LOPEC 2019 (conference): Exhibition of the metal mesh foil on the common OES booth (Organic Electronics Saxony) by PL.
- Press release: "Consortium develops prototype of new heating concept for EVs" Read more at: https://www.printedelectronicsworld.com/articles/16323/consortium-develops-prototype-of-new-heating-concept-for-evs (Retrieved April 15th 2019)
- A prototype of a heater foil for interior heating in electric cars was presented in public on September 27th 2018 in Aachen, Germany

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RESERVES

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

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Project Summary

The Government of India predicts dramatic demand increases for energy over the next 20 years which brings in several problems to the agricultural dependent Indian economy. An easily accessible alternative to energy imports and nuclear power is the abundantly available waste biomass to produce biogas through anaerobic digestion (AD). Mass flows of waste generated from the slaughterhouse, fruit- and veg-market waste are rarely utilized for the recovery of energy and nutrients. Biogas from this waste material could be an important and flexible energy source for the local consumer with high supply guarantee. In most towns/cities of developing countries including India, slaughterhouse wastes are disposed along with other municipal solid wastes (MSW) in open dumping leading to contamination of air, water, and land. However, with respect to resources and energy reliability, these wastes are highly valuable and regular/reliable sources of bio-energy. Treatment of slaughter waste alone for bio-energy generation in anaerobic processes is not effective in terms of optimum utilisation and performance of treatment system. Animal wastes contain more of proteinaceous matter with a high amount of nitrogen content and hence these wastes have low Carbon to Nitrogen (C/N) ratio. It is advantageous to add other organic wastes available in the Chennai city, like vegetable market waste, food wastes, agro-residues, industrial organic waste

etc. for the co-digestion process to enhance the biogas production in the anaerobic treatment process, and to improve the performance of the biomethanisation system and overall sustainability. In co-fermentation of organic waste, the German and Indian industries/ institutes have complemented experiences on sustainable anaerobic technologies for recovery of renewable energy in the form of biogas.

RESERVES proposes to investigate various combinations by co-digestion of wastes from slaughterhouses, vegetable market etc. in laboratory-scale reactors and the suitable combination will be studied in pilot-plant for biogas production and pre-treatment like bio-extrusion.

Concept and management for full-scale implementation (e.g. PPP, BOT) will be identified and transfer of knowledge takes place during the pilotscale study and with special workshops and training. Sustainability assessment of the process and the marketable product qualities using LCA and carbon footprints investigations will be carried out. Sustainable ways for biogas and digestate utilization will be investigated. Herewith material and energy flows will be optimized along with biogas upgradation and utilization efficiency. To ensure the acceptance of this project among various stakeholders, and to confirm the exemplarity of this project, capacity building by demonstration workshops/ training programme will be organised.

Progress made/achieved

Milestones achieved

1. Comparative study on the effect of shredding and bio-extrusion of Koyambedu vegetable market waste on biogas yield
2. Periodic survey of vegetable, fruit and flower waste from Koyambedu market
3. Comparative study of dry and wet anaerobic digestion of banana peduncle
4. Process design and detailed engineering of pilot plant
5. Characterization and elemental analysis of slaughter house and other organic waste generated from urban areas.
6. Biochemical methane potential of slaughter house and other organic waste.
7. Biochemical methane potential of various combinations of slaughterhouse and other waste.
8. Antagonistic and synergistic effect of various combination of waste.
9. Training of qualified staffs for operation and concepts for vocational training

Comparative study on the effect of shredding and bio-extrusion of Koyambedu vegetable market waste on biogas yield

CLRI and ISAH conducted a lab-scale comparative study on the effect of shredding and bio- extrusion on biogas yield from major fractions of Vegetable Waste from Koyambedu market using lab-scale shredder and bio-extruder. Based on the survey of waste generation from Koyambedu Market, the major fractions of vegetable waste generated were monitored and it was found to be cabbage waste, cauliflower leaves and banana peduncles which contribute more than 60% of the total vegetable waste generated from the Vegetable Market, Koyembedu.

Periodic survey of vegetable, fruit and flower waste from Koyambedu market, fish & slaughter house waste

In addition, samplings were carried out for 4 times in a month in Koyambedu Wholesale Market to account for the seasonal variations in the waste generation compositions. Recently monthly variations of waste generations were observed from October 2017 to February 2018. Based on the field visit and survey on the quantity generation as well as composition generation, it was observed that 150 tonnes from KMWC, contributes to 40-45% of Vegetable waste, 30-35% Peduncle waste, 20-23% Fruit waste and 2-3% Flower waste. This has been taken as a base for mixing the waste generated from KMWC for the design of pilot plant.

Comparative study of dry and wet anaerobic digestion of banana peduncle

This study deals with a specific biogas production of peduncle in wet and dry condition by keeping the volume of the reactor same and the ratio of food to microorganism (F/M) as 0.5. The experiment took about 90 days and the specific biogas yield of the peduncle was compared. The wet specific biogas yield of the peduncle was observed as 321 ml/g VS added at 30 days which do not have much influence with further increase in time. However, the dry specific biogas yield of the peduncle was observed at 60 days that gradually increased and the biogas yield obtained was 157 ml/g VS added. The benefit of dry anaerobic digestion over wet anaerobic digestion is, the reactor volume can be used to treat waste which is 5 times that of the wet condition.

Publications

1. C.J. Speier, M.Velusamy, R. Ravi, S.V. Srinivasan, D. Weichgrebe "Potentials of vegetable market and slaughterhouse waste for sustainable energy supply through co-digestion in Chennai, India", 15th IWA World Conference on Anaerobic Digestion (AD-15) in Beijing, China, October 17-20, 2017
2. Sampling and composition analyses of major Organic Fractions of Municipal Solid Waste generated from Chennai, Mozhiarasi V, Raghul R, Christopher Speier, Benish Rose P M, Dirk Weichgrebe, S.V. Srinivasan, International Conference on Solid waste management, ICONSWM 2017, December 15-17, 2017

Public Relation activities

Vocational Training Program on Operation and Maintenance of Anaerobic Digesters Organized by CSIR-CLRI and ISAH, Hannover at CLRI (03-10-2017 to 05-10-2017)

A 3 days vocational training program on operation and maintenance of anaerobic digesters was organized by CSIR-CLRI and ISAH, Hannover at CLRI from 03-10-2017 to 05-10-2017. Participants from various biogas industries were actively participated. Dr. S.V. Srinivasan welcomed the gathering and gave an introduction about the RESERVES project to the participants and it was followed by Mr. Christopher`s (ISAH) presentation on anaerobic digestion theory. On day two Mr. Aarmin from ISAH and Miss. Mozhiarasi from CLRI presented about the safety aspects and operational issues in the biogas industry. On day 3 the participants were allowed to visit the existing biogas plant in Koyambedu and the session was completed with Mr. Armin's lecture about safety handling.

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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 Summary

Through the pyrasol project, simple and robust processing technologies for urban organic waste is intended to combine in a synergetic manner and further develop to improve sanitation and welfare, supply regenerative energy, convert waste into products and reduce the carbon footprint of Smart Cities: an innovative solar sludge and waste drying system using the natural chimney effect followed by a high efficient single-chamber pyrolysis process. The aim of the project is to offer an innovative and for smart cities adequate approach to transform urban organic waste into biochar and energy. Thus, the optimum process and operation parameters of the solar dryer will be determined, and a unique condensing boiler system developed and applied to the pyrolysis process. 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 this valuable biochar is the only process output, this project contributes to the Zero Waste Approaches to Smart Cities.

Progress made/achieved

Tasks for attaining objective / milestone 1: Over the course of the reporting period, the lab-scale solar drying experiment was planned and designed with the support of ISAH. The scope of this lab-scale drying experiments includes:

- To investigate the drying characteristics of input substrate inside the solar dryer
  - Investigate the drying rate, residence time and online VOC emissions
  - Investigate the extent of bio-stabilization achieved through drying – suitability for pyrolysis.
  - Effect of additives to the input substrate
  - Effect of sludge sterilization prior to mixing with fibrous organic waste
- To measure the temperature profile along the substrate thickness and length of the dryer.
- To find out the optimal mixing ratio of FOW that optimizes residence time and bio stabilization inside the dryer.
- To investigate the effect of mixing AD digestate into the input substrate

Materials, aggregates and measurement systems were selected and ordered to handle 12 batches (drying trays) in 20-25 days. Parts of the lab scale drying unit are constructed in Chennai, and after installing the rest of the equipment, and after preliminary analytical experiments the test trials will start in May 2019.

Tasks for objective / milestone 2: An extensive study into the characterization of basic input substrates (banana peduncles and sewage sludge) using thermogravimetry analysis (TGA) was completed. These experiments provided the baseline information of the various mixing ratios of banana peduncles and sewage sludge prior to the start of the lab-scale drying and pyrolysis tests.

For banana peduncles and sewage sludge, TGA-FTIR analysis were conducted in triplicates in mixtures of 0:1, 1:9, 2:8, 3:7, 4:6, 5:5, 6:4, 7:3, 8:2, 9:1, 1:0 at a heating rate of 9K/min from 25 to 8000C. The sample size was 5±0.5mg in N_2 purge of 50ml/min. These preliminary results from differential thermogravimetry (DTG), TGA and differential scanning calorimetry (DSC) tests identified the possibility of also including digestate from anaerobic digestion of food wastes from residential and commercial sectors.

The inclusion of digestate into the PYRASOL input presents and extra potential of this project to co-process three of the main urban organic sources together. However, prior to its inclusion, further DSC and DTG tests are required to analyze its feasibility. Hence, another set of experiments was designed to test this.

At the time this report, pyrolysis TGA-FTIR experiments has started for the mixture of banana peduncles, sewage sludge and AD digestate from Chennai for various mixing

ratios. The objective is to investigate the optimal mixture in terms of heat release, exothermicity, biochar quality and GHG emissions. These experiment trails are conducted in two groups. A total of 155 experiments are scheduled to be completed by 5th May 2019.

The first group contains duplicate trials with linear heating rates of 5K/min, 7K/min, 10K/min, 15K/min, 20K/min and 30K/min from 25 to 10000C. The primary objectives of this are to understand the thermal decomposition characteristics of various proportions of the input substrates, heat release, and emission characteristics.

The second group of experiment includes the duplicate trials with isothermal heating at 2500C and 5000C for 1 hour. This helps in validating the reaction model obtained experimentally from the linear heating tests and help in analyzing any possible changes at low temperature pyrolysis.

Lab scale solar dryer is set up with structure, transparent covering and drying tray.

A C63-F pyrolysis machine is planned for the project. The machine is currently being manufactured in Rehburg-Loccum and completed according to plan until August 2019. In advance, constructive changes were made to simplify the operation of the machine on site. For example, the changes relate to increasing the entry cell wheel lock to prevent clogging at entry. Furthermore, due to other project experiences, a flexible discharge screw conveyor is not required. For the discharge system linear augers are to be used. This should be reduced noise in particular. For condensing technology, an exhaust gas heat exchanger is externally related and adapted to the system requirements. To achieve a condensing effect, the heat exchanger requires a return temperature of approx. 30°C.

The pyrolysis machine has a thermal rating of 63kW. In addition, the machine can be operated with a minimum power P_{min} = 30kW. The fuel must have a water content of less than 30% and the inorganic content must not exceed 10%. Possibly. is to provide for a necessary pre-treatment and pre-drying. The flow temperature is max. 95° C.

Salient Research Achievements

Lab Scale Experiment Design & Planning

This experiment primarily helps in understanding the various drying characteristics during the bio-solar drying of the urban organic waste mixtures, biological stabilization and possible contribution by biological drying with and without additives. Furthermore, the dried substrate samples can be subjected to lab-scale pyrolysis at 6000C to understand the influence of drying on the process and biochar output.

C63-F Pyrolysis machine (view on completed housing steel works).

C63-F Pyrolysis machine (side view)

Publications

Weichgrebe D, Mondal MM, Nair RR (2019) Biochar production through combined solar drying and single chamber pyrolysis. ECI conference on Bio-char II: Production, Characterization and Applications, Sep 2019, Italy. (Submitted)

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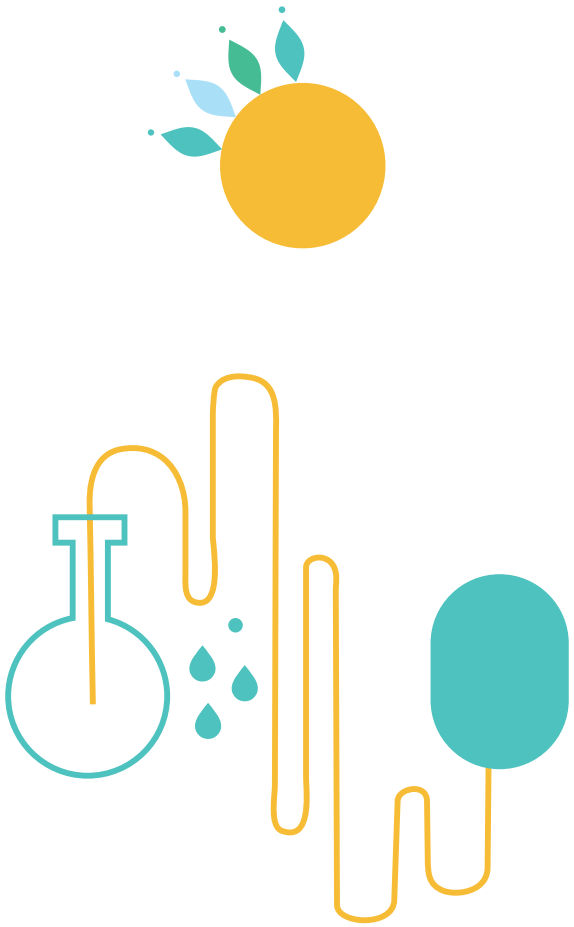
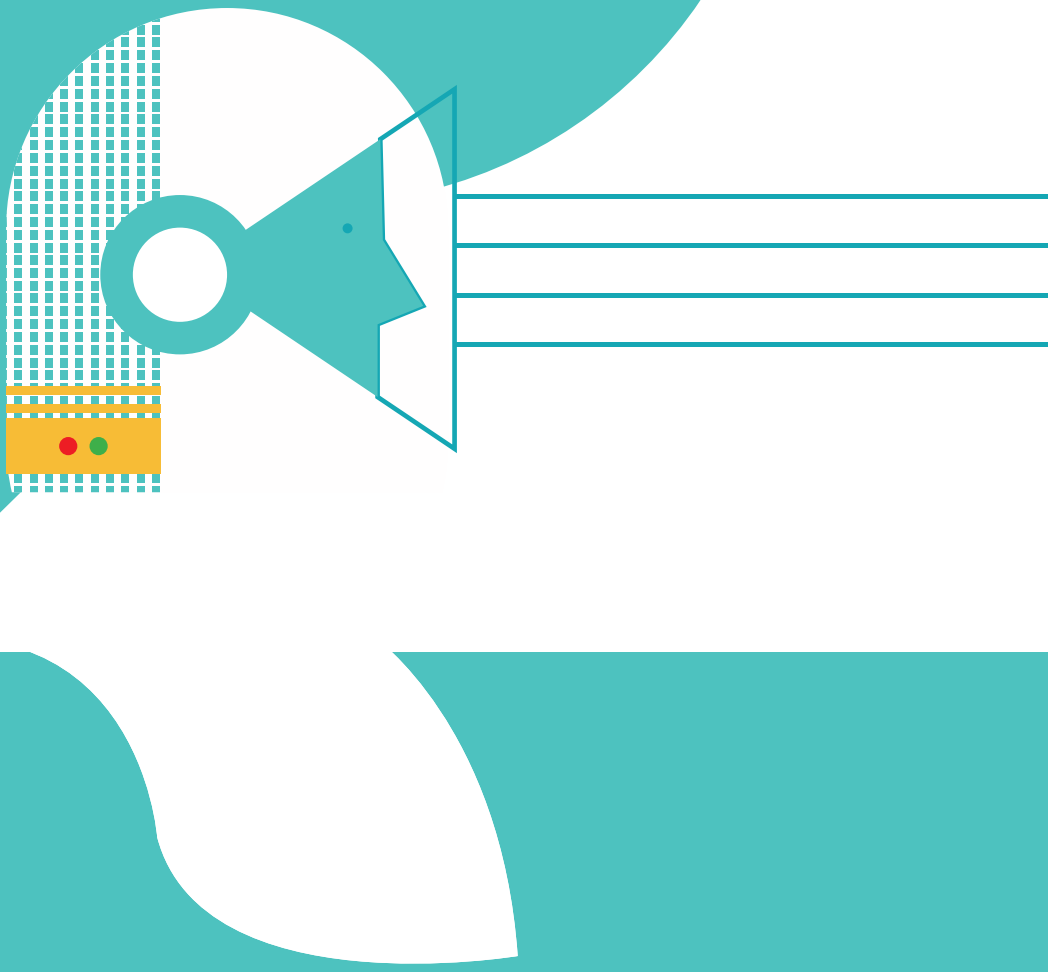


Biomedical Technology



SIBAC

Next-generation dynamic Scheimpflug imaging and biomechanical analytics for in vivo quantification of corneal viscoelasticity

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Sven Reisdorf
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Project Summary

Cornea has an intricate arrangement of collagen fibers encased in a cellular matrix. It has remarkable healing properties. Thus, surgical refractive procedures are one of the most common treatments in the world today. However, it is also well known that the cornea has a biomechanical response, which plays a significant role in refractive outcomes. At the same time, it is vital that biomechanically weaker corneas are eliminated from the surgical population to avoid the risk of ectasia. There are newer flapless techniques of laser vision correction, which were developed with the hypothesis that it leaves the cornea biomechanically uncompromised. If the collagen in cornea degenerates, then the cornea becomes steeper and vision worsens. There are techniques available now where the cornea can be biomechanically strengthened. Biomechanics of the cornea also plays an important role in the determination of intraocular pressure, which is the still the primary determinant of ocular hypertension. Thus, disease diagnostics and treatment planning require knowledge of the biomechanical properties of the cornea. Biomechanics can also play an important role in monitoring treatment outcomes. There are several

techniques being researched to quantify the in vivo corneal biomechanics, but none have been translated to the clinic so far. Thus, significant advancements in treatments are lacking. This project aims to develop a next-generation dynamic Scheimpflug imaging device and biomechanical software analytics for in vivo quantification of corneal viscoelasticity. The specific aims of the project are to develop this device with high temporal resolution and location-specific based corneal deformation measurement in response to air-puff, to develop fast computational algorithm for inverse estimation of biomechanical properties, and to validate the device and software in ex vivo and in vivo human subjects, both in normal and disease conditions.

Progress made/achieved

Partner 1 –Narayana Nethralaya Foundation, Bangalore & VIT University, Vellore

Measurability of corneal viscosity using Corvis-ST

Goals: Understanding the measurability of human corneal viscosity in in-vivo conditions

using Corvis-ST (only in-vivo biomechanical analysis tool)

Experimental design: A retrospective, observational study with 300 normal eyes, 102 fellow eyes of a keratoconic eye and 293 keratoconic eyes analyzed using a standard linear solid model (kelvin representation) (SLS) and a 2-compartment Kelvin-Voigt model (KV). SLS assume cornea as a purely elastic material, whereas KV model assumes cornea as a viscoelastic material. The models calculated corneal stiffness (kc), extra-corneal stiffness (kg) and extra-corneal viscosity (μc) from the Corvis-ST corneal deformation data. Both models were solved using non-linear least-squares technique in MATLAB (MathWorks, Inc, USA) software. Then the corneal deformation was artificially frameshifted (1 to 9 frames) equivalent to 0.231 msec to 2.079 msec respectively in the step of 0.231 msec. The artificial shift was used to validate the model's ability to pick up simulated viscous lag.

Results: The detected corneal viscosity was 4.36×10^{-9} [1.33×10^{-10} to 1.8×10^{-8}], 9.48×10^{12} [1.25×10^{-13} to 1.03×10^{-10}] and 4.29×10^{-12} [1.04×10^{-12} to 1.49×10^{-11}] Pa.sec for normal, fellow and keratoconic eyes (Median and 95% confidence interval of median) respectively. The detected magnitude of viscosity was clinically insignificant. The detected kc, kg and μg in all the groups agreed almost perfectly between both models with concordance correlation coefficient value greater than 0.98 in all instances. The artificial shift in frames was detected by the KV model,

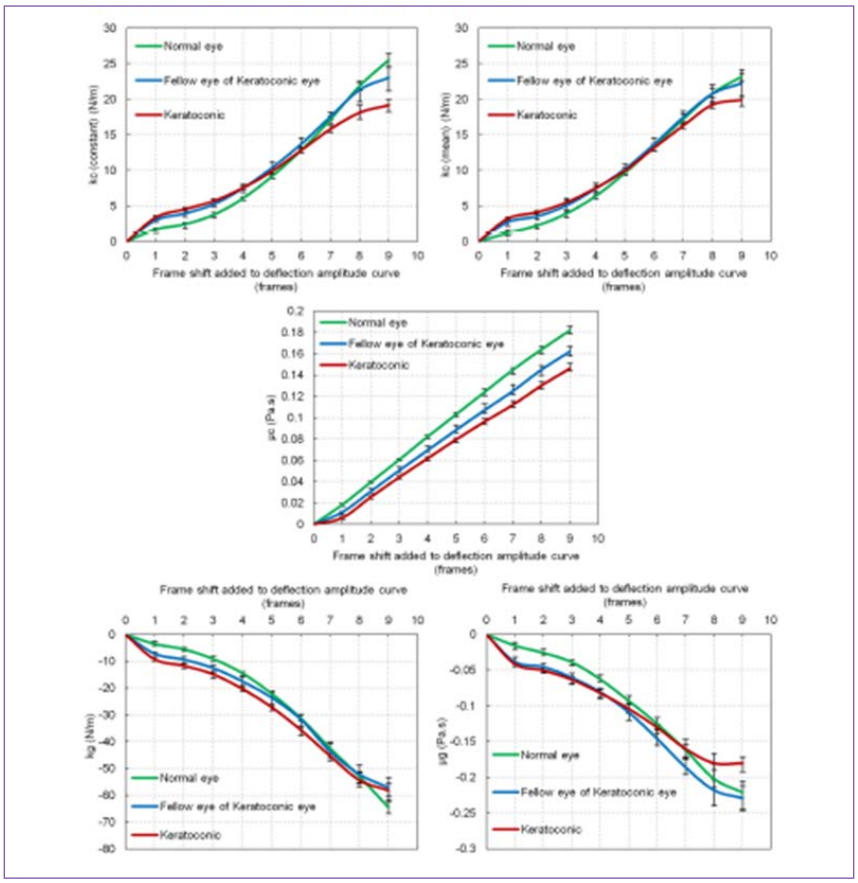

fig1: shows relative change in all parameters.

Conclusion: KV model accurately detected corneal viscoelasticity effects in normal and keratoconic eyes, only when the air-puff force curves were artificially frame shifted. However, corneal viscoelasticity effects were non-existent under in vivo condition. Under in vivo condition, time difference between force and corneal deformation was virtually non-existent. Thus, detection of corneal viscoelasticity effects with in vivo airpuff applanation weren't possible.

Biomechanics of LASIK flap and SMILE cap: A prospective, clinical study

Goals: To analyze the acute effect of flap cut through laser in situ keratomileusis (LASIK) and cap cut in small incision lenticule extraction (SMILE) eyes on corneal biomechanical properties of patients undergoing surgery.

Experimental design: This was a prospective, interventional, longitudinal case series. Forty-eight eyes of 24 patients underwent contralateral LASIK and SMILE. Corvis-ST measurements were performed preoperatively, intraoperatively, 1 week and 1 month after surgery. In LASIK eyes, flap

was cut but not lifted before intraoperative measurements. In SMILE eyes, the cap and side cut incision were made before intraoperative measurement. Thirty biomechanical variables were analyzed assuming multiple comparisons.

Conclusion: Flap and cap cuts induced biomechanical weakening in patient corneas. The flap caused more weakening than cap intraoperatively. However, biomechanical differences between LASIK and SMILE eyes were similar after removal of tissue and ongoing wound healing.

Some of the other milestones achieved are:

- Corneal tomographic features of post-refractive surgery ectasia
- Bilaterally asymmetric corneal ectasia following SMILE
- Influence of anterior biometry on corneal biomechanical stiffness of glaucomatous eyes treated with chronic medication or filtration surgery
- Quantification of ocular biomechanics in ocular manifestations of systemic autoimmune Diseases
- Regional biomechanics of corneal ectatic disorders
- In vivo prediction of air-puff induced corneal deformation using LASIK, SMILE, and PRK finite element simulations

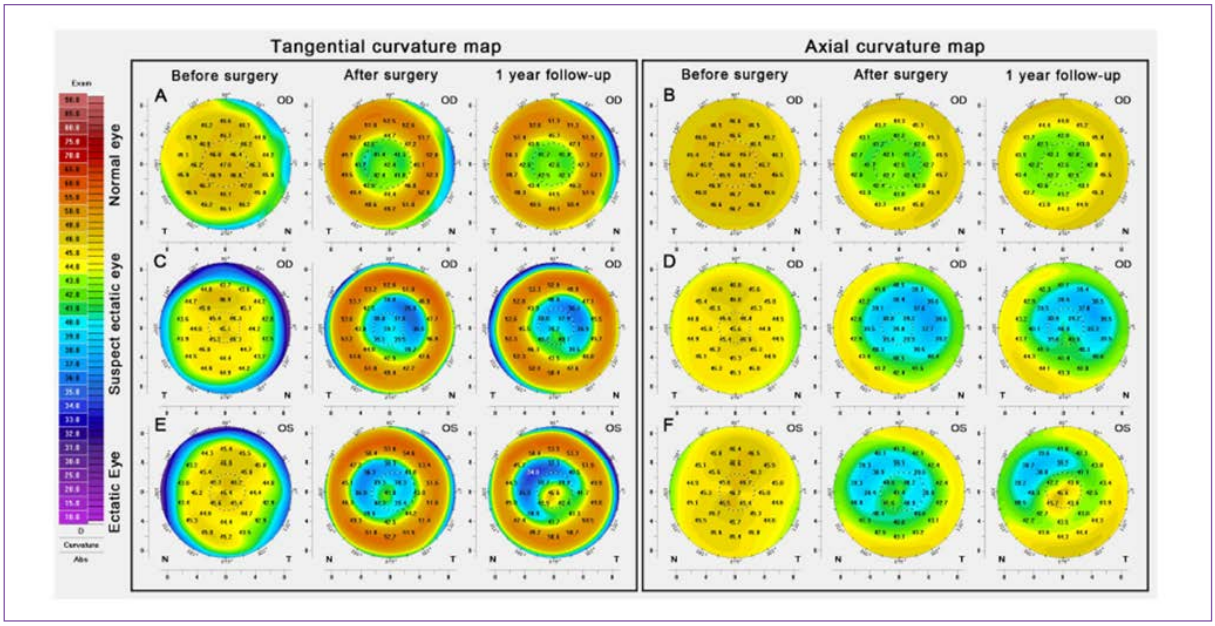

Fig2: Preoperative and postoperative curvature map of the patient who developed ectasia after SMILE surgery.

Partner 2 – Forus Health, Bangalore

- Forus is helping with the design of the software. NNF is working closely with Forus to finish this.

Partner 3 – University of Carl Gustav Carus, Dresden

Finishing of experimental investigation at porcine eyes regarding the characterization of corneal biomechanical properties after corneal cross-linking

- Goals: Relationship between stiffness in ex-vivo stress-strain measurements of corneal tissue (porcine eyes) and dynamic Scheimpflug based tonometry derived corneal stiffness parameters on porcine eye globes after CXL procedure
- Experimental Design: Prof. Spörl and Mr. Herber performed measurements on porcine eyes with the stress-strain extensometer and Corvis ST. Blinded raw data of Corvis ST are sent to Dr. Roy, who calculate new stiffness parameter kc[mean] and kc[linear]. Mr. Herber performs statistical approach.
- There were performed three commonly used CXL protocols (standard protocol –3mW/cm² for 30 min, accelerated protocol - 9mW/cm² for 10 min and accelerated protocol with 18mW/cm² for 5 min)
- Joint publication of The University of Dresden and Narayana Nethralaya Foundation is in progress.

  Investigation of long-term in vivo data after CXL
- Correlating the stiffness parameters to in-vivo measurements of progressive keratoconic eyes after CXL.

  Starting investigation of keratoconus and healthy patients with confocal microscope
- Corneal nerve fibers were examined of healthy participants, forme fruste keratoconus and frank keratoconus based on tomographical, topographical and biomechanical assessment by confocal microscopy.

  Investigation of repeatability and reproducibility in keratoconus patients concerning the severity of the disease
- Repeatability and reproducibility were investigated for DCR parameters in several stages of keratoconus
- Publication is submitted Developing algorithm for screening of normal tension glaucoma
- Algorithm to separate healthy patients from normal tension glaucoma using Air-puff tonometry (Corvis ST)
- accepted for publication in ACTA Ophthalmologica (March 2019)

Partner 4 - OCULUS Optikgeräte GmbH, Dresden

OCULUS has made available the prototype for clinical testing at NNF. The prototype is working as designed, where location specific measurements can be made on the patient cornea.

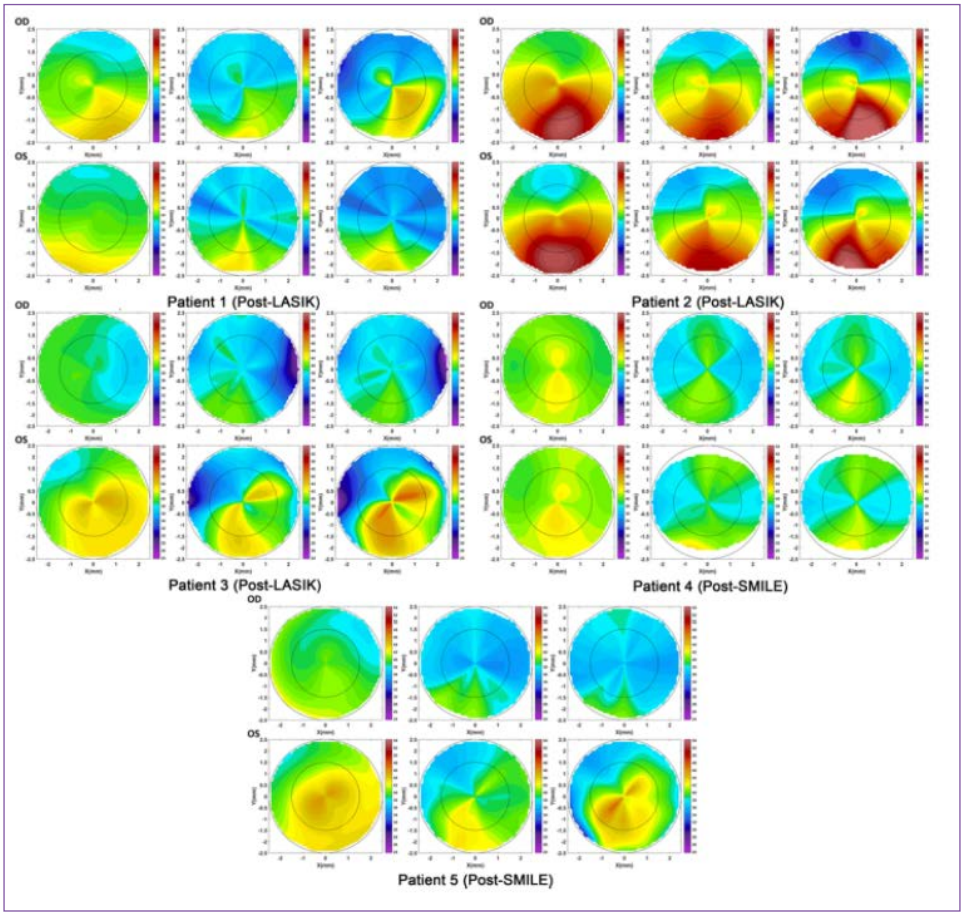

Fig3: Pentacam and OCT derived axial curvature maps for the 5 patients. Pentacam curvature is in the 1st column, air-epithelium interface (OCT) curvature is in the 2nd column and epithelium-bowman's layer interface (OCT) curvature is in the 3rd column.

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- Robert Herber; Mathew Francis; Eberhard Spoerl; Lutz E Pillunat; Frederik Raiskup; Abhijit Sinha Roy. Establishing the link between waveform derived corneal stiffness and ex vivo derived corneal elastic modulus: A prospective study with air-puff applanation of porcine eyes. ARVO, Honolulu, USA, 2018 and ESCRS, Vienna, 2018.
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- Naim Terai; Robert Herber; Lisa Ramm; Eberhard Spoerl; Lutz E Pillunat. Assessment of biomechanical properties using Scheimpflug imaging in keratoconus patients. ARVO, Baltimore, USA, 2017.
- Robert Herber, M.Sc.; Prof. Eberhard Spörl; Prof. Frederik Raiskup. Biomechanical assessment of keratoconic eyes after corneal cross-linking by Scheimpflug-based tonometry. CXL Experts, Zurich, 2017. Best Poster Award

Patents filed

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2. A system and method of artificial intelligence and tomography imaging of human cornea. Filed by Narayana Nethralaya Foundation, 2017. Application ID: 201741008796, TEMP/E1/8968/2017CHE
3. A method to quantify the quality of corneal donor tissue for transplantation using tomography imaging. Filed by Narayana Nethralaya Foundation, 2017. Application ID: TEMP/E1/15839/2017CHE.

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Sound4All

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

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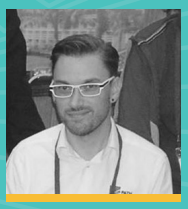
TU Munich, Munich



Thomas Resner
PATH GmbH, Germering

Project Summary

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

be referred for treatment early on, thereby significantly improving their chances of recovery or to prevent further deterioration. However, in order to significantly reduce the cost of screening devices, the newly designed devices will need to use completely different hardware and software architecture, without sacrificing the quality of the screening. Developing such architectures and evaluating them are the main scientific goals of this project. In particular, the team will rely on two main techniques: (i) offload the involved signal processing algorithms onto a mobile phone, and (ii) instead of using expensive and specialized probes, as is the case in existing screening equipment, they will use commercially available off-the-shelf components. This will introduce significant measurement distortions, which 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. Further, since processors in mobile phones are now very powerful, the quality of screening may not be significantly sacrificed.

Revised prototype with integrated sensors and smaller housing.

Progress made/achieved

PATH Medical

WP6: Finalization of a Prototype

Probe: OAE probes consist of one or two loudspeakers and a microphone that is placed into the ear-canal with an ear tip.

The latest prototype of the probe presented end of 2017 has been further optimized for injection molding. The optimization mainly focused on the probe and ear tip connection to get a good seal of the probe. After some iterations, we decided to move on to injection molding to get more precise parts and to evaluate different materials.

PATH contributed in optimizing the acoustics by adjusting the shape of the sound channels and the coupling of the probe tip to the probe body which is the most challenging part of the probe.

The design war regularly compared to PATH's commercial probe with regard to the frequency response of the speakers, sensitivity and frequency response of the microphone as well as distortion of the two speakers. The latter is the most important issue when measuring DPOAEs.

Device: The first prototype of the stand-alone device was further developed and optimized with regard to usability, test performance and user interface. The stand-alone device was expanded by a smartphone serving as user-interface for data entry, storage, and reporting (see section "TUM").

The usability was significantly improved by providing a convenient way of entering patient data. Result storage and reporting were implemented according to the recommendation of newborn hearing screening programs and tracking centers (e.g.PathTrack).

Moreover, PATH focused on enhancing the performance of the DPOAE and TEOAE algorithm implemented on the revised hardware platform. The initial recordings were conducted at PATH and TUM to evaluate the usability and performance of the OAE algorithms in quiet environments. Based on those results parameters of the algorithms for artifact rejection, weighed averaging and signal detection were optimized. The usability study at PATH served as input for UI optimization on the OLED display of the device for online monitoring during OAE recordings. These optimizations significantly improved the handling of the device and thus the performance of the operators.

TUM came up with the idea of adding some additional sensors (see section "TUM"). PATH developed some concepts for integrating

those sensors into OAE algorithms like the in-ear calibration conducted prior to OAE measurements. This will be further developed and implemented in future phase 2 of the project.

WP7: Device Evaluation

AIIMS conducted a comparative study between the Prototype developed and Neuro-Audio Screen which undergone in subject testing in order to get the performance and usability of the device. The initial measurements on adults were conducted at AIIMS and have been supervised by us during our visit in November 2018. The results show a good correlation between pure tone audiogram and the TEOAE screening results of the Sound4All device. So they decided to continue with the study in adults as wells in the pediatric population.

The results in 1498 ears from 749 subjects are described in section "AIIMS".

In summary the prototype is working better in adults as compared to the pediatric population (0-5 Years). This is mainly due to the prototype is having a greater percentage of blocked/error in babies and children than in adults. This requires the prototype's in-ear calibration to be further improved for detecting small ear canal volume against blocked ear probe.

Further work on this in phase 2 of the project will commence once the clinical results are satisfying.

OAE screening with the Sound4All stand-alone device.

TUM

M4: Prototype Built

It was decided that the architecture was supposed to be a mostly stand-alone device. That means, all the core features were implemented and contained on the device, for example, the OAE measurements and the associated signal processing. However, in addition to that, a near field communication (NFC) interface was added, to allow for data transfer with smartphones or other devices. This is intended to allow the operator to configure the measurement and enter patient data in a familiar environment (i.e. on their personal smartphone). Furthermore, this allows to keep the human-machine interface (e.g. display and buttons) on the stand-alone device relatively simple.

To experiment with the NFC interface and verify the intended workflow for the operator, the team implemented an Android-based smartphone app. This app can be used to enter patient data and transfer it to the standalone device alongside the measurement configuration. After the measurement is completed, the results can then be transferred back to the smartphone. Further development of the app would then allow the operator to browse and analyze the collected data.

In the second year of the project, they started experimenting with additional sensors to gain data that might be useful during our evaluation phase and could possibly be used as an active feedback component for the operator. These sensors had to be integrated into the hardware, i.e. in the electronics as well as the enclosure and ear tip. On the software side the sensors are mostly sampled in fixed intervals, either triggered by the sensor hardware or in a time-triggered fashion.

To collect and store the data during the evaluation, a logging system was implemented. It is based on SD cards that can be directly inserted into a standalone device. A lot of effort was put into optimizing this subsystem so that it would be able to capture the raw data of the microphones. However, due to the limited resources of the low-cost microprocessor, this feature cannot be used with resource-intensive OAE measurement algorithms.

Due to these additions to the hardware, the circuit boards had to be majorly revised and more prototypes had to be assembled. Also, the enclosure underwent multiple design iterations to balance handling quality and the functionality of the extra sensors.

M5: Evaluation results

In preparation to the final evaluation, the team started evaluating some devices during their project meeting in Delhi on October 2018. The evaluation is still ongoing, with the standalone devices still being continuously improved based on the feedback of AIIMS.

Sound4All Workshop

IIT Delhi

One of the main requirements for measuring otoacoustic emissions (OAEs) is a miniature microphone with a reasonably constant microphone sensitivity up to about 10 kHz and low noise floor. The frequency response of the speaker shall be as flat as possible with an impulse duration around 1ms. Acoustical cross-talk must be 20 dB below the real signal, so the probe must be designed to provide sufficient isolation to protect from crosstalk. This can be ensured by an acoustically isolating microphone and speaker channels and making sure that the transducers fit tightly into the probe housing. If there is any leakage inside the probe body or at the transitions from probe housing, middle part to the probe tip, the low-frequency sound components cannot be recorded properly. By considering these factors, the team designed and evaluated different designs of ear probe but there was some leakage because of the transition with the same material. To overcome this they have designed a new hybrid design, where hard material probe body is in contact with soft material soft part holding transducer and soft tip for tight sealing of the components. This helped to increase the performance of the probe.

After finalizing the designs. IIT Delhi manufactured moulds for the injection moulding machine. Different moulds were prepared for two designs (Since each design consists of multiple parts). The first design which can accommodate old path transducers and second design which can accommodate new commercial and inexpensive transducers. Parts are printed using these moulds. Probes are assembled using injection moulded parts and transducers with the help of ultrasonic welding. Results were compared with a commercially available path probe.

IIT Delhi carried acoustic simulation of the ear canal to study the sound pressure levels at the tympanic membrane for different frequencies from 200Hz to 20kHz. This will help in understanding how the geometry of the ear canal affects the sound transmission to the middle and inner ear. Finite Element (FE) simulations were carried based on the 3D reconstructed geometry of ear canal from archived clinical CT scan data. The reconstructed 3D geometry was meshed and used for FE simulation study. A sound pressure of 94db was simulated on the entrance of the ear canal and pressure changes on the tympanic membrane were studied.

The results of the work involved the study of two cases 2 year old male and 21 year old male were presented in 8th world congress of biomechanics: WDB 2018 held in Dublin Ireland, from 8th -12th July 2018. As a standard procedure male subjects left ear canal was reconstructed and studied. A total of 17 cases were studied covering all the age groups. Cases were grouped into five groups as <5, 5-12, 13-18, 19-30, 31-50 years with 1,2,4,8,2 cases in each group respectively. It was found that the frequency at which peaks in pressure on the tympanic membrane increases with age. This shift in frequency response correlates to increase in-ear canal volume with the aging of the person.

AIIMS

Based on Milestone 5: Evaluating Results, AIIMS conducted a comparative study in between the Prototype developed and Neuro-Audio Screen which undergone in subject testing in order to get the performance of the device. A total of 1498 ears from 749 subjects were involved in this study. Patients were recruited from the department of otolaryngology, AIIMS, Delhi coming for hearing assessment and from the rural setup. The comparison was done in between the TEOAEs of the prototype/ Neuro Audio Screen and gold standards tests (ABER/PTA).

Salient Research Achievements

Hard- and software functionality of the revised prototypes built have been successfully verified and validated in clinical environments in 1498 normal hearing- and hearing-impaired ears at AIIMS.

Publications

- Presented a poster titled "Three-dimensional study of steady state sound pressure of ear canal using finite elemental analysis" in 8th world congress of biomechanics: WDB 2018 held in Dublin Ireland, from 8th -12th July 2018.

Ph.D / Master thesis supervised

"Data Collection and Management in a Standalone Otoacoustic Screening Device", Michael Erdl

"Controlling a Hearing Screening Device using a Smartphone and NFC", Aleksander Gloukhman

"Developing the Firmware for an Easy to Use Otoacoustic Emission Screening Device", Henri Eckhardt

"Behavior of the Extrusion System in Additive Manufacturing of Liquid Silicone Rubber", Andreas Stückl

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MIDARDI

Microfluidic based detection of microbial communities and antibiotic responses in the management of diabetic foot ulcers

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Project Summary

Chronic, non-healing diabetic foot ulcers (DFU) are a major pathophysiology associated with diabetes mellitus. These are further exacerbated by the presence of certain pathogenic bacteria such as Pseudomonas spp., Staphylococcus spp. and several others. The standard treatment regimen for DFU is usually a combination of various broad-spectrum antibiotics; prescribed based on wound presentation (Wagner grade). Such empirical treatment depending on slower culture methods due to lack of faster, rapid microbiological tests has led to the rise in multi-drug resistant (MDR) bacteria. The need of the hour is expeditious, sensitive and specific culture-independent methods that can aid the clinicians in their diagnosis and prescription.

Goal of the project was the development of a microfluidic solution for a point-of-need test for the fast identification of bacteria species and their resistances. This requires knowledge on the wound microbiome and development of the appropriate taxonomic markers that can identify the pathogenic bacteria (via next- generation sequencing), knowledge of the minimum number of microbial colonies that are required in a

predefined sample input to be detected by the chip, choice of amplification technology (ideally one that can be performed independent of a thermocycler) and standardization of the same.

Based on the next-generation sequencing of diabetic foot ulcer samples, top wound microbiome species were selected, a microarray was designed, realized and transferred to microfluidic cartridges with integrated pumping and heating functionality. The biochemical assays were first established in the lab before transferring and integrating them to the microfluidic cartridges. Assay steps include lysis, purification, amplification, digestion, and hybridization. To control the microfluidic cartridges, a novel instrument was developed which is also able to optically read the microarray directly on the cartridge.

Final proof-of-concept experiments, both with spiked samples and DNA from clinical isolates, were able to demonstrate the function of the whole system with cartridges, instrument, assay, and microarray.

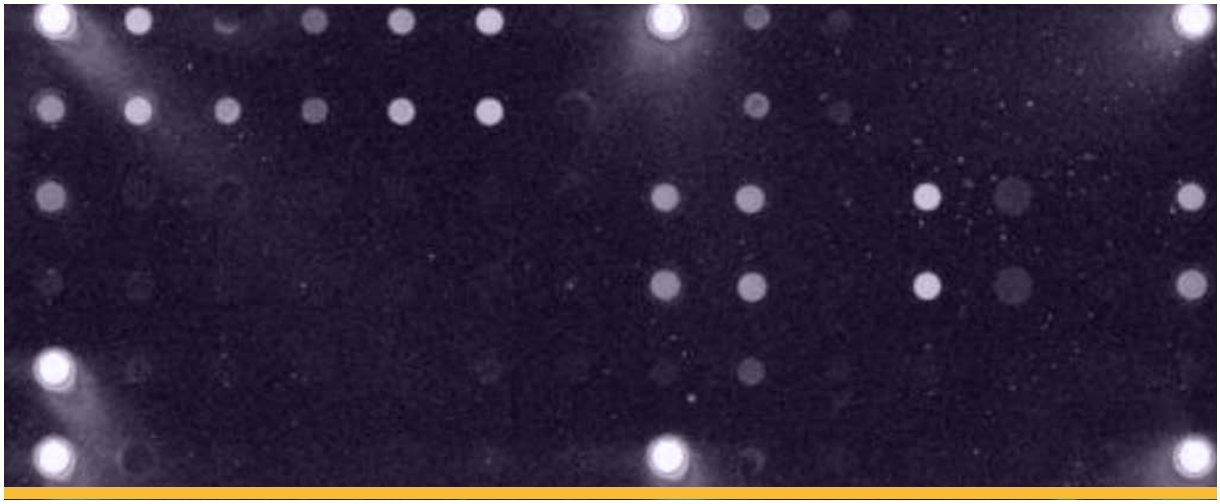
The technical solutions include successful spotting of the microarray, identification, and optimization of the process steps of the assay, transfer of these steps to the microfluidic cartridge, development of the cartridge and its controls to cater to the assay requirements, a sensitive miniaturized readout setup and an integrated, automated benchtop instrument requiring little manual intervention. These, together with the gained knowledge of wound microbiome, resistance gene, and virulence markers will provide powerful weapons in the global fight against the rise of infectious diseases and multi drug-resistant bacteria.

Progress made/achieved

The work in the third year was dedicated mainly to transfer the single scientific results into an integrated format targeting a final proof of concept with an integrated assay.

- Sample preparation protocol (reagents, volumes, components, conditions), PCR protocol (reagents, volumes, components, conditions) and microscope slide microarray defined and working (for later integration)
- Single assay steps with model substances work in cartridge format, steps ready for integration
- Single assay step work on cartridge format (not fully-integrated)
- Integrated Cartridge (1st iteration) and readout instrument has shown performing together
- Testing of a functional prototype
- IP Communication

Readout instrument developed by Achira Labs.



False-color image of a microarray after running a hybridization assay fully-autonomously in a microfluidic cartridge (MRSA sample).

Publications

- Kavitha S, Spoorthi J, Deepika VB, Raviraj A, Ramachandra L, Satyamoorthy K, Murali TS. 2017, Virulence determinants in clinical Staphylococcus aureus from monomicrobial and polymicrobial infections of diabetic foot ulcers, Journal of Medical Microbiology 65, 1392-1404. DOI:10.1099/jmm.0.000370

- K. Shettigar, D. V. Bhat, K. Satyamoorthy, T.S. Murali. 2018, Severity of drug resistance and co-existence of Enterococcus faecalis in diabetic foot ulcer infections, Folia Microbiol., 63, 115-122. DOI: 10.1007/s12223-017-0547-2

- Streit Petra, Nestler Joerg, Shaporin Alexey, Graunitz Jenny, Otto Thomas: Design methodology and results evaluation of a heating functionality in modular lab-on-chip systems. J. Micromech. Microeng. 28 (2018). DOI: 10.1088/1361-6439/aab0ca

- Paper: J. Nestler, H. Peter, F. F. Bier: Towards a Fully Integrated Lab-On-A-Chip Flexible opto-fluidic platform for fluorescence and microarray-based molecular diagnostics at the point of care, Optik&Photonic, Vol 13 (2018), 28-31, DOI: 10.1002/opph.201800004

- Murali TS, Jnana A, Satish N, Varghese VK, Ramya V, Chakrabarty S, Peter H, Andreas M, Nestler J, Bier FF, Satyamoorthy K. "Microbial spectrum of diabetic foot ulcers – an NGS approach" at the 87th Annual Conference of Society of Biological Chemists (India) "Genome Biology in Health and Disease", School of Life Sciences, MAHE, November 25-27, 2018. (Oral presentation)

- Apoorva J, Ramya V, Varghese VK, Chakrabarty S, Paul B, Nestler J, Harald P, Morschhauser A, Bier F, Dendukuri D Murali TS and Satyamoorthy K. (2016). Modelling the wound microbiome: Microbiological insights based on next generation sequencing. 2016 NextGen Genomics, Biology, Bioinformatics and Technologies Conference, Cochin, India. (Poster)

- TS Murali, A. Jnana, N. Satish, VK Varghese, S Chakrabarty, D Dendukuri, A Morschhauser, J. Nestler, H Peter, FF Bier, K Satyamoorthy: Unravelling the polymicrobial diversity of foot ulcer infections via Next Generation Sequencing, 7th Annual Conference of Clinical Infectious Diseases Society CIDSCON at Nagpur, India, from August 18-20, 2017 (Poster)

- TS Murali, A. Jnana, N. Satish, VK Varghese, S Chakrabarty, D Dendukuri, A Morschhauser, J. Nestler, H Peter, FF Bier, K Satyamoorthy: Deciphering polymicrobial diversity in diabetic foot ulcers with microbiome analysis, Indo-

Australian Biotechnology Conference, Queensland University of Technology, October 30-31, 2017(Poster)

- Murali TS, Jnana A, Satish N, Chakrabarty S, and Satyamoorthy K, Next Generation Sequencing to study fungal diversity in Diabetic Foot Ulcers, 44th Annual Meeting of Mycological Society of India and National Conference on Fungal Biology: Recent Trends and Future Prospects, Jammu University, November 16-18, 2017. (Poster)

- Murali TS: Next Generation Sequencing for Studying Environmental Samples. 6th Annual Conf. of Society of Biological Chemists Coastal Karnatataka chapter (India) , November 4th, 2017 (Poster)

- Apoorva J, Ramya V, Varghese VK, Chakrabarty S, Paul B, Nestler J, Harald P, Morschhauser A, Bier F, Dendukuri D, Murali TS and Satyamoorthy K. (2016). Modelling the wound microbiome: Microbiological insights based on next generation sequencing. 2016 NextGen Genomics, Biology, Bioinformatics and Technologies Conference, Cochin, India, October 3-5, 2016. (Oral)

- D. Dendukuri: Scale-up and Commercialization of Microfluidics Technologies, Biosensors Workshop at Indian Institute of Technology – Madras, November 25th, 2017. (Oral)

- J. Nestler: Lab-on-a-Chip Systems with integrated pumps: Flexible platform for rapid assay development with microarray-based biosensors", Scienion Workshop "DIAGNOSTICS 7.0 - Innovative Solutions for Multiplexed Tests", September 7-8, 2017. (invited talk)

- J. Nestler: Lab-on-a-Chip Systems for DNA-based Point-of-Care Diagnostics – Use Case Scenario Diabetic Foot Ulcers, IVAM High Tech Forum, MEDICA/COMPAMED fair, November 13-16, 2017, (invited talk)

- In addition, a conference paper on the whole project was submitted to µTAS 2019 conference in Basel, Switzerland

Project team at final project workshop in Manipal/India, March 2019

General public relation activities

- Talk by Dhananjaya Dendukuri on 24th February 2019 at R&D showcase at International Institute of Information Technology, Hyderabad, titled 'Development and validation of a microfluidic platform for multiplexed diagnostics at the point-of-care' where the MIDARDI project was mentioned and results discussed
- Discussion with Mr. Annaswamy Vaidheesh, CEO of GlaxoSmithKline, India and key management team members on May 15th, 2019 at GSK HQ, Mumbai, about using MIDARDI product for reducing overuse of antibiotics. CSR budget from GSK could be available for such testing.

Ph.D / Masters thesis supervised

- Amitha R. 2018. Antibiotic Resistance Genes in Bacterial Strains Colonizing Diabetic Foot Ulcer Infections. M.Sc. Dissertation submitted to Manipal Academy of Higher Education.
- Ms. Kavitha S – Ph.D. Thesis entitled "Molecular characterization of bacterial and fungal communities in the diabetic foot ulcer". Dissertation submitted to Manipal Academy of Higher Education.
- Mr. Ankit Singh Tanwar – M.Sc. Thesis entitled "Genome comparison of four strains of Staphylococcus aureus isolated from diabetic foot ulcer". Dissertation submitted to Manipal Academy of Higher Education.

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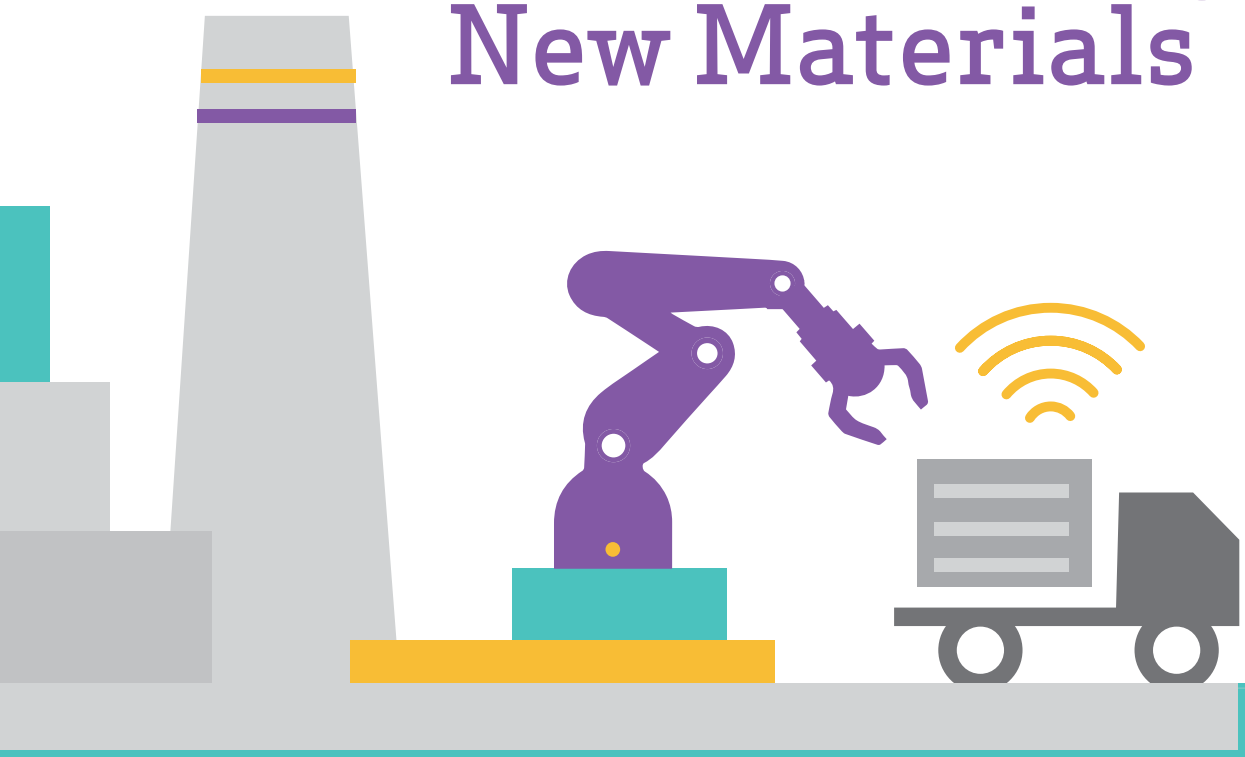
Advanced Manufacturing and New Materials



Six projects approved under the Call 2017 in the overall thematic area of Advanced Manufacturing and New Materials (sub-topics: Industry 4.0, Machine building, Process technologies for new materials including nanomaterials, Light weight design and processes) will soon start. The projects will be for three years with the possibility of a 2 years extension after a competitive evaluation. The total funding sanctioned for the projects stands at Rs 317.7 million / € 3.97 million.

LABELONIK

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

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Indian Institute of Science Education and Research Kolkata

Rohitt D Mistry
Holographic Security Marking Systems

Frank Ellinger
Technische Universität Dresden

Moazzam Ali
Saralon GmbH

Project Summary

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

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TransLearn

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

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Karlsruhe Institute of Technology

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Project Summary

Industry 4.0 will be driven by two basic technologies: AI and Robotics – and especially the combination of both – allowing robots to learn skills and tasks without explicitly programming them. Learning and optimizing complex and interactive robot manipulative skills through reinforcement learning algorithms is a multifaceted challenge and an unsolved problem. With the goals of (i) significantly reducing robot programming costs and (ii) reducing robot cycle times, project plans to developing 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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NearNetMAC

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

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Project Summary

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

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STEEL4LTC

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

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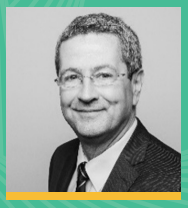
G. Balachandran
JSW Steels Salem Works



Robert Brandt
Universität Siegen

Steffen Klapprott
Muhr und Bender KG

Project Summary

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

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PPAM

Metal powder production for additive manufacturing

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Hans Jürgen Odenthal
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Project Summary

For laser powder bed fusion (LPBF) a fine metal powder is solidified in layers using a focused laser beam. The properties of the product depend strongly on the uniformity of size and consistency of the powder particles. This project addresses the production of steel powder using a 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 modeling 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 facilities and one as an end-user. Improved quality, lower cost and an expanded product design parameter space can be expected.

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SELBA

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

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M. Venkateswarlu
Amara Raja Batteries Limited, Tirupati

Maximilian Fichtner
Karlsruhe Institute of Technology

Andreas Hintennach
Daimler AG

Project Summary

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

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

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Workshops

Indo-German workshop on intelligent mobility

In an effort to evolve and give direction to the emerging intelligent mobility landscape in India, IIT KGP and the Technical University of Munich (TUM), Germany organized a two-day workshop at IIT KGP on October 29th-30th, 2018. This workshop is being held in the context of the newly-established Indo-German Collaborative Research Center on Intelligent Transportation Systems, which is currently a joint Center of IIT KGP and TUM, located within the IIT KGP campus, but seeks to involve multiple Indian and German academic and industry partners in the future. The workshop was supported by the Indo-German Science and Technology Center (IGSTC) and the German Federal Ministry of Education and Research (BMBF).

Dr. Roshan Paul, Director IGSTC addressed the gathering giving a brief of the current and upcoming programmes. This workshop brought together various transportation experts from Indian and German academia and industry – such as TUM, IIT KGP, TU Berlin, TU Chemnitz, IIT BBSR, IIT Patna, ISI Kolkata, TH Ingolstadt, Siemens, Bosch, Infineon, Intel, TCS, Ola Cabs, – as well as policy makers and law enforcement agencies, who discussed potential solutions in the domains of Intelligent Solutions for Transportation Integration, Technologies for Electric Vehicles and Batteries, and Systems & Software Challenges in next generation vehicular technologies. While many Indian cities have a variety of transportation modalities ranging

Prof P.P. Chakraborty

Prof Samarjit Chakraborty

Prof Pallab Dasgupta

from metro trains to autorickshaws, India also has unique transportation challenges and vast opportunities that are of huge interest to both German scientists and the German industry. In order to meaningfully address such challenges, a close cooperation between Indian and German institutions is of mutual interest.

"Future transportation solutions in India or other Megacities must be developed with a holistic view of the wide milieu of options available in cities, and integrated end-to-end solutions will make public transport more reliable and comfortable, and reduce the dependency on private vehicles" opined Prof Samarjit Chakraborty of TU Munich, who along with Prof Pallab Dasgupta from IIT KGP were the main initiators of the new Indo-German Collaborative Research Center on Intelligent Transportation Systems. "The focus of innovation today is in intelligent software for safety, driver assistance, comfort and entertainment. Combining the software and AI expertise of India with the manufacturing leadership of Germany can bring about transformational benefits to both countries. At this Center and with appropriate collaborations with industry partners in India and Germany, we are looking forward to shaping our research goals and schemes for long-term sustainability of the Center," remarked Prof Pallab Dasgupta, who is also the Dean of Sponsored Research & Industrial Consultancy, at IIT KGP.

Group Photo of the workshop participants

Plenary Session

Plenary Session

India, with its Smart Cities Mission, aims to develop 100 smart cities in the near future. Intelligent and integrated green transportation systems will be a key component of these cities. This would not only bring forward challenges in integrating the wide milieu of transportation options in Indian cities but might also require designing new transportation systems for addressing the huge demand for public and private transportation in Indian cities. At the Indo-German Center, experts from various industries of the two countries, traffic control, policy makers, and Indian and German academics would work together towards finding India-centric solutions for these challenges, along with new business opportunities. In addition to new automotive technologies by combining German engineering and Indian software skills, the research in this center could potentially revolutionize management, analysis, and intelligent services in transportation, including fleet management, vehicle-to-infrastructure interactions, and cloud-based vehicle health monitoring, by combining technologies from the domains of wireless networks, smart sensing, smart wayside infrastructures, AI and machine learning.

Indo-German Collaborative Research Center on Intelligent Transportation Systems aims to establish collaborations at both academic and industry levels between Germany and India for developing next generation transportation technology suitable for Indian cities and to create an ecosystem in India that is conducive for the German and Indian Industry.

Additive manufacturing of metals: current issues and way forward

An Indo-German bilateral workshop on "Additive manufacturing of metals: Current issues and way forward" was held at CSIR-National Metallurgical Laboratory (CSIR-NML), Jamshedpur during 4th-6th February 2019. The workshop was supported by IGSTC under its 'open call for Indo-German bilateral workshops' fostering interaction between scientists/researchers from industry and academia. The coordinators of the workshop were Dr Volker Uhlenwinkel, Leibniz-IWT, Bremen and Dr Vikas C. Srivastava, CSIR-NML, Jamshedpur. The Chief Guest, Prof Indranil Manna, AJC Bose Fellow and Institute Chair Professor, IIT Kharagpur inaugurated the workshop. Dr Debashish Bhattacharjee, Vice President, Technology and New Materials Business, Tata Steel was the Guest of Honor and Dr G. Padmanabhan, Director, ARCI Hyderabad, was the Guest Mentor. Dr I. Chattoraj, Director, CSIR-NML welcomed the experts/participants and stressed upon the fact that the workshop has assumed immense importance as additive manufacturing represents a process paradigm in the development of new and intricate products. Director, IGSTC addressed the participants and highlighted the aims and scope of IGSTC, its activities and opportunities for further cooperation between India and Germany.

This bilateral workshop brought together Indo-German scientific, educational and industrial fraternity, working on different aspects of additive manufacturing, on a common platform and provided an opportunity for the dissemination of knowledge and learning in the still emerging additive manufacturing technologies. The workshop consisted of 25 expert talks as well as a poster session for young researchers; culminating into cross-fertilization of ideas, networking for cooperation and discussion on important current issues on additive manufacturing of metals and alloys. The major points of the discussion and reflections were spread over six technical sessions, namely, additive manufacturing technologies; materials and metallurgical characteristics; feedstock materials for metals and alloys; defects in additively manufactured materials; modeling, simulation and automation; industrial outlook on additive manufacturing: issues and prospects. The contributions of young researchers were recognized and two best posters were awarded.

Inaugural function at CSIR-National Metallurgical Laboratory, Jamshedpur

The internationally renowned scientists deliberated on various topics during a panel discussion e.g. important current challenges in additive manufacturing, metallurgical issues and defects in additive manufacturing, requirement for new alloy design, way forward for sustainable production of cost effective good quality powder production and possibility of further cooperation between various research groups and industrial establishments in Germany and India. The panel unanimously agreed on the fact that unavailability of cost effective good quality powders is an impediment to the extensive proliferation of this technology. The experts also emphasized on the new opportunities in the areas of microstructural modeling, software development, post-processing of additively manufactured parts, understanding metallurgy of microstructural development and criteria for qualification of products for application. The difficulty of product qualification, in absence of a standard for machines, processes and products, has been identified to be a hurdle, specifically for the industrial establishments catering to aerospace, defence and medical applications. The interaction between the panel and the participants led to identification of burning challenges in additive manufacturing of metals, in particular. The panel discussed the opportunities available for research cooperation and agreed that joint project proposals, joint student supervision and exchange programmes should be explored.

Opportunities and Cooperation

The presence of over 100 participants from academia, industry, national laboratories and the active involvement of research students led to lively interactions bringing synergistic discussions among stakeholders. The participation of major institutions, actively involved in additive manufacturing, from Germany (Leibniz-Institut für Werkstofforientierte Technologien, Bremen; Helmholtz-Zentrum Geesthacht, Geesthacht; Fraunhofer Institute for Mechanics of Materials IWM, etc.) and India (CSIR-NML, Jamshedpur; IIT Kharagpur; IIT Madras; CSIR-CMERI, Durgapur, etc.) ensured fruitful knowledge networking and active interactions. The event was truly aligned to the activities and mandate of IGSTC and was successful in achieving all its aims. It is expected that the outcome of this platform would further promote bilateral cooperation in the area of additive manufacturing at different levels.

Membranes for water and energy

Indo-German bilateral workshop on Membranes for Water and Energy was organized at CSIR-Central Salt and Marine Chemicals Research Institute, Bhavnagar (CSIR-CSMCRI) during 18th-20th February 2019. The workshop coordinators were Dr Vinod K. Shahi, Senior Principal Scientist, CSIR-CSMCRI and Prof Mathias Ulbricht, Universität Duisburg-Essen.

The workshop is organized in the backdrop of high demand for the membranes with better selectivities, less electrical resistance, high chemical, mechanical and thermal stability as well as good durability. For social and economic growth across the world, need of clean potable water and green energy source (without carbon footprint) have always been crucial, and require sustainable technologies to fulfil the social and industrial demand. Rapid growth of water and energy sectors and fuels the demand for the need of reliable green membrane technologies, which play significant roles in sustainable water desalination/purification and energy generation. These include water desalination/purification by reverse osmosis, nano-filtration, ultra-filtration, electrodialysis, and energy conversion devices such fuel cells, redox-flow batteries, storage batteries and reverse electrodialysis for concentration gradient energy, etc.

Technical Session

This three-day workshop provided an opportunity for membrane technocrats/ researchers to discuss stable membrane and sustainable membrane technologies, their potential applications and current status; and development challenges for membrane materials in this field. Further, active synergy and collaboration between Indian and German membrane researchers provided greater clarity in membrane criteria targets, industrial end-users with emerging membrane technologies and reinforce the engagement between researchers and application aspects.

The workshop had technical sessions on following topics : water desalination/ purification; pressure-driven membrane based technologies (RO, NF, UF, and hollow fiber); electro-membrane processes for water desalination and production of nutrient water; anti-fouling membrane, membrane transport phenomenon and tailoring of high performance membrane; membranes based bio-reactors and bio-remediation; membranes for energy: fuel cell, redox flow batteries and reverse electrodialysis and membranes electrolysis and water splitting. The technical sessions brainstormed on various aspects of current research, prospects and to build-up future collaborations of bilateral nature.

Poster Session

Scientists from leading Indian and German universities such as ICT Mumbai, IIT Kharagpur, IIT Bombay, CSIR labs, central universities, TU Munich, Karlsruhe institute of Technology, RWTH Aachen, Helmholtz Centres etc. participated in the event. Director, IGSTC attended for a day and gave a talk on the programmes and activities of IGSTC.

Inaugural session of the workshop

Waste to wealth

The Indo-German workshop on waste to wealth was jointly organised by CSIR-Advanced Materials and Processes Research Institute (CSIR-AMPRI), India and Martin-Luther-Universität Halle-Wittenberg, Germany. The workshop was held in CSIR-AMPRI premises during 25th-26th February 2019. Dr A.K. Srivastava, Director, CSIR-AMPRI welcomed the audience and stressed on the need to dispose of waste in an environmentally friendly way. Commodore K Srinivas, Commanding Officer, INS, Shivaji, Indian Navy, Lonavala was the chief guest of the function. He appreciated the theme of the workshop which is important both for India & rest of the world. Director, IGSTC also addressed the participants and briefed on the activities of IGSTC.

During the workshop, 29 lectures on various waste recycling and utilization techniques such as fly ash, red mud, steel alag, blast furnace slag, plastic, agro waste, bio-waste, e-waste, municipal waste, other mineralogical waste, nuclear waste, glass industrial waste, solar assisted waste water treatment, etc., were held. Industries such as NTPC Ltd (India), H&R Johnson (India) Division, Ecoreco (India)

Technical Session

and BauMineral GmbH (Germany) have presented the challenges existing in the utilisation of various waste. 140 participants were benefitted out of this workshop. Here are the some of the important points addressed during the technical session:

- The use of pozzolans in construction industries has to be increased because it emits less CO2 and economically viable.
- The artificial pozzolans like fly ash, slags, pond ash, rice husk ash, etc., can be a better replacement for the currently used cements.
- Fly ash can be used to fabricate bricks, hume pipes, tetrapod, paver blocks, roads, etc., through alkali activated binders through proper optimization of its pH and composition.

Apart from the technical session, 1 hr poster session was organized for the participants to present their work. 46 participants presented their work.

Group photo of the participants

Outcomes

Several projects on various pressing issues were discussed and being planned out of interactions and deliberations held at the workshop.

To get rid of the accumulated solid waste, people in the Himalayan region have adopted informal means of disposal by open burning and dumping in the gorges and rivers polluting the freshwater streams. A project for the development of an integrated solid waste management model for an alternative to open burning in the Indian Himalayan Region (IHR) is being planned and proposed for further collaborations.

Burning of agro-waste is one of the main issues which cause severe pollution every year in India, especially in New Delhi and surrounding regions. During the technical discussion session, this issue has been further discussed and participants have decided to submit a common proposal on the extraction of biofuels from the municipal and agro-waste along with German collaborators to various funding agencies.

During the fly ash session, participants addressed large scale utilization of fly ash for the fabrication of paver blocks, tetrapod, roads, etc., through alkali activated binders. After seeing their works, Prof. Herbert Pöllmann has requested to contribute two book chapters regarding the status of Indian fly ash in his current book on "Industrial Waste."

सिटी एंकर

एम्प्री में आयोजित इंडो-जर्मन इंटरनेशनल वर्कशॉप में डॉ. एसके श्रीवास्तव ने दी जानकारी

भारत-जर्मनी के रिसर्चर्स मिलकर करेंगे वेस्ट पर रिसर्च

सिटी रिपोर्टर | भोपाल

एम्प्री में आयोजित इंडो-जर्मन इंटरनेशनल वर्कशॉप का समापन मंगलवार को हुआ। वेस्ट टू वैल्थ विषय पर आयोजित यह वर्कशॉप संयुक्त रूप से एम्प्री और मार्टिन लूथर यूनिवर्सिटी, वाय सिलस, जर्मनी के द्वारा आयोजित की गई। इसमें विभिन्न अकादमी, संस्थानों, इंडस्ट्रियल संस्थानों और भारतीय व सेना से प्रतिभागियों ने अपना योगदान दिया। वर्कशॉप में जर्मनी से 9 प्रतिभागियों ने हिस्सा लिया था। समापन समारोह के मुख्य अतिथि मार्टिन लूथर विवि जर्मनी के प्रो. हरबर्ट पोल्मान थे। वर्कशॉप में शोध पत्र, विचार, प्रजेंटेशन और पोस्टर प्रजेंट किए गए। यहां एम्प्री के निदेशक डॉ. एसके श्रीवास्तव ने कहा कि भारत और जर्मनी के शोधार्थी मिलकर सभी प्रकार के वेस्ट पर शोध करेंगे।

वेस्ट से जल्दी से जल्दी कम्पोस्ट बनाने वाले बैक्टीरिया को ढूंढ रहे

सीएसआईआर पालमपुर से आए डॉ. रक्षत कुमार ने बताया कि मैं हिमालय दूसरे कामों के लिए जाता था। मैंने वहां पाया कि हिमालय में जो ट्रैकिंग के लिए जाते हैं, वो लोग काफी गंदगी करते हैं। हम ऑर्गेनिक वेस्ट पर काम करते हैं, उसमें हम ऐसा बैक्टीरिया ढूंढ रहे हैं। जिसके जरिए जल्दी से जल्दी कंपोस्ट बना सकें और साथ ही उससे आने वाली दुर्गंध को भी कम किया जा सके। जो 45 से 50 दिन में कंपोस्ट तैयार होता है, उसे हम 15 से 20 दिन में तैयार कर सकें। हिमाचल, लेह स्पीति जैसे एरिया के ह्यूमन वेस्ट को भी कंपोस्ट में बदल सकें। अभी हमें साइक्रोट्रोफिक बैक्टीरिया मिला है।

50 मैट्रिक टन पर हो रहे डे वेस्ट डिस्पोज

आज सिक्किम और हिमाचल में 50 मैट्रिक टन पर डे वेस्ट डिस्पोज हो रहा है। इसका सही इस्तेमाल किया जाएगा। इस पर काफी स्कोप है। अगले सत्र में जर्मनी की मार्टिन लूथर विश्वविद्यालय की सबरीना गल्लुक्किओ ने सीमेंट वेस्ट और सीमेंट के पूरक पदार्थ का खनिजीय प्रमाणन विषय पर शोध प्रस्तुत किया। वहीं डॉ. करस्टेन गेल [illegible] ने रेड मड के क्षेत्र में अर्थव्यवस्था और वर्तमान गतिविधियों के लिए प्रौद्योगिकी विषय पर विचार [illegible] उन्होंने बताया कि कच्चे माल [illegible] फिटकिरी और अपशिष्ट नि[illegible] वैश्विक मुद्दे हैं।

Recent advances in nanoscience and nanotechnology

Joint Indo-German workshop on recent advances in Nanoscience and Nanotechnology was held at IIT Madras under the aegis of Open Workshop Call of IGSTC during 25th – 27th March 2019. The workshop coordinators were Prof S. S. Bhattacharya, Department of Metallurgical & Materials Engineering, IIT Madras and Prof Horst Hahn, Institute of Nanotechnology, Karlsruhe Institute of Technology. After the inaugural session, Director, IGSTC addressed the gathering and elaborated on the programmes.

Several independent research efforts in nanoscience and nanotechnology are taking place in India and Germany with some academic exchanges and engagements between the two but a coordinated and focused effort is needed to look for strong collaborative research in order to synergize the available expertise and capabilities. With this basic premise, this high-level workshop was organized which brought leading experts under one umbrella to present their research

Group photo of the participants

results and showcase some of the recent advances. Emphasis was given to the science and technology of (a) purification and removal of toxic substances to mitigate pollution, (b) energy materials for greener battery applications, (c) multicomponent systems as novel materials, (d) printed electronics, and (e) nanoelectronics and nanophotonics. In addition, a discussion session was scheduled to see how to take already existing collaborative research activities forward and to seek out opportunities for future research collaborations between India and Germany in general and IIT Madras and KIT in particular. Discussions also focused on how to identify research groups and exchange programmes to work on the topics identified.

Technical sessions on several topics viz., synthesis of nanomaterials; synthesis of nanomaterials and tuneable properties; electron microscopy; battery materials and energy systems; chemistry of nanoclusters; printed electronics and semiconductors; modelling of nanomaterials; multicomponent systems; nanofabrication, sensors and nanophotonic were conducted during the workshop. Poster session was also organized on above research topics. Participants ranged from pan Indian & German institutions such as IIT Madras, IIT Bombay, IIT Kharagpur, IIT Guwahati, ARCI, IISc Bangalore, JNCASR Bangalore, NIIST-CSIR, IISER TVM, Karlsruhe Institute of Technology, Darmstadt University of Technology, University of Ulm, University of Saarland, etc.

HIPSTER Workshop

Helmholtz-Indian Platform on Science, Technology, Education and Research (HIPSTER)

Helmholtz-Indian Platform on Science, Technology, Education and Research (HIPSTER) workshop was organised by IGSTC on 13th – 14th February 2019 in Bengaluru, India. HIPSTER results from an agreement between Dr. Harsh Vardhan, Hon'ble Minister of the Ministry of Science & Technology, Ministry of Environment, Forest and Climate Change, and Ministry of Earth Sciences, Government of India, and Prof. O. Wiestler, President of the German Helmholtz Association, the largest non-university research organization in Germany. The agreement was also subject of the 11th Meeting of the Indo-German Committee on Science & Technology (WTZ) in Berlin in May 2017, where both, the German Ministry for Education and Research (BMBF) and the Indian Department for Science and Technology (DST) acknowledged the agreement, and further entrusted its organisation and funding to IGSTC.

Prof Hüttl, Vice president, Helmholtz Association delivering the keynote

Mr Sanjeev Kumar Varshney, Head, IBCD, Department of Science & Technology delivering the keynote

Participants at the workshop

The overall idea of HIPSTER is to foster the bilateral collaboration with a special focus on young talents. It will provide the platform to discuss current developments in R&D in both countries and to work together on ideas on how to promote a cross-disciplinary exchange and on how to open new channels for research and innovation. The goal of the workshop is to develop future-oriented ideas for further interaction and research cooperation between the Helmholtz Association and Indian research institutes and universities. As a final result of the workshop, a "White Paper" will summarize the output of the discussions. It will be handed over to Helmholtz and DST as a potential agenda for future collaboration and/or further arrangements.

The workshop format consisted of a mix of keynote overview presentations and breakout sessions. To guarantee a structured discussion, seven promising subtopics from the Helmholtz portfolio – 1. Georisks/ Landslides/Marine Biochemistry, 2. Physics of the Atmosphere, 3. Plant Sciences 4. Epidemiology/Infectious Diseases/Oncology, 5. Renewable Energy, 6. Material Sciences and 7. Artificial Intelligence with mutual interest were identified. Each subtopic was co-chaired by an Indian and German scientist.

Dr Roshan Paul, Director, IGSTC welcomed the distinguished guests and the participants and briefed on the programme. Inauguration of the workshop was done by Prof Reinhard Hüttl, Vice President, Helmholtz Association and Mr Sanjeev Kumar Varshney, Head, IBCD, Department of Science & Technology, Government of India. Prof Hüttl welcomed the participants and gave an overview of the workshop. He stressed on the need for developing significant ideas to be taken up for future collaborations between India & Germany. Mr Varshney while welcoming the participants, talked about various initiatives and programmes of DST and role of IGSTC in furthering Indo-German collaborations. He emphasized on the need for preparing a White Paper and Vision Document to carry forward collaboration between DST & Helmholtz

and also through IGSTC. Director, IGSTC presented an overview of IGSTC activities. He explained the various funding programmes of IGSTC and the role IGSTC playing in growing research partnership between India & Germany. Dr Ludwig Stroink, International Division, Helmholtz Association presented various funding opportunities available through Helmholtz. Dr Martin Goller, DLR-PT summarized the programmes of Federal Ministry of Science & Technology (BMBF), Government of Germany. Dr Heike Mock, German Academic Exchange Service (DAAD) Regional Office, New Delhi briefed on other funding opportunities existing for Indian students and researchers in Germany.

Artificial Intelligence team

Plant Sciences team

Epidemiology/Infectious Diseases/Oncology team

Physics of the Atmosphere team

Renewable Energy team

Material Sciences team

Group photo of the participants

The sub-topics were further discussed in-depth around the following lines:

- identification of promising topics, tailor-made for a successful and sustainable bilateral collaboration.
- preparation of an overview on existing (large scale) research infrastructures, as a platform for potential joint projects.
- industrial research and involvement of companies.
- design of first concepts for joint research projects (e.g. within the framework of 2+2 calls of IGSTC).
- ways to establish partnerships between institutions, taking the collaborative efforts beyond the usual PI-based bilateral interactions.
- discussion on potential and innovative funding opportunities.

IGSTC-CONNECT

Plus Programme

Indo-German Science & Technology Centre and Alexander von Humboldt Foundation (AvH) signed a Letter of Intent (LoI) for the implementation of IGSTC-Connect Plus on 25th May 2018. LoI was executed and signed by Dr Roshan Paul, Director, IGSTC and Dr Thomas Hesse, Deputy Secretary General, Alexander von Humboldt Foundation.

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.

INDOGFOE is a series of interdisciplinary, bilateral conferences, which brings together outstanding, early career Indian and German engineers and scientists from industries, universities, and other research institutions. This creates a platform to introduce their

areas of research and technical work, thereby facilitating an interdisciplinary transfer of knowledge and methodology, which may lead to the development of cooperative networks of young scientists from both countries.

To encourage collaboration among the participants of INDOGFOE, AvH has devised a follow-up Programme CONNECT, which allocates residence allowances for working visits of participants in INDOGFOE partner countries for up to a total of 30 days per conference. In order to support working visits of successful CONNECT applicants from India and Germany, IGSTC will implement, administer and manage the IGSTC-CONNECT Plus Programme. Under this program, IGSTC will support international travel expenses for successful Indian and German CONNECT participants, thus promoting the scientific exchange and networking.

Who can Apply?

The applicant must have participated in one of the INDOGFOE in India or in Germany and must have started a cooperation with at least one participant of the partner country. Cooperating partners must have participated in the same conference. Either the applicant or the hosting partner must be based in India or Germany at the time of application.

Evaluation

All IGSTC-CONNECT Plus applications from Indian and German scientists submitted to AvH along with AvH-CONNECT scheme will be exclusively and independently reviewed and evaluated by AvH according to the principles and practices of AvH-CONNECT. IGSTC will further scrutinize the AvH recommended applications before taking a final decision on travel support.

Funding Support

Travel expenses of successful Indian and German IGSTC-CONNECT Plus applicants are covered in accordance to the following procedure:

- The travel expenses covered by IGSTC are economy class flight tickets, medical insurance and visa fees. Further, local journey may be covered by shortest route and preferably by public transport.
- For Indian applicants, IGSTC may purchase flight tickets or reimburse tickets purchased by the applicant, in accordance with the envisaged travel period (as stated in AvH-CONNECT granting note and ultimately confirmed by the applicant).
- For German applicants, IGSTC will acquire flight tickets in accordance with the envisaged travel period (as stated in AvH-CONNECT granting note and ultimately confirmed by the applicant) and may consider the air connection suggestions by the applicant. After execution of the ticket purchase, IGSTC will provide digital flight ticket / ticket confirmation details to German applicant in due time.

How to Apply?

Applications should be submitted directly to the Humboldt Foundation along with CONNECT applications. Successful applicants will be informed by IGSTC in writing within a period of three months.

IGSTC will not accept and consider any applications submitted directly to IGSTC.

For more information and application procedure contact AvH Berlin office.

IGSTC-CONNECT Plus Fellows

Dr Matthias Pfriem

Postdoc
Institute of Vehicle System Technology
Karlsruhe Institute of technology (KIT)

Title of the Project

"Towards a demand-based design of an unmanned aerial vehicle for a maintenance and monitoring task"

Host Institute

Dr Deepu Philip, Associate Professor, Department of Industrial & Management Engineering, IIT Kanpur

Visit Period – 1st -19th October 2018

Dr Anup Kumar Keshri

Assistant Professor
Dept. of Metallurgical and Materials Engineering
Indian Institute of Technology, Patna

Title of the Project

Plasma sprayed thermal barrier coating over Zr/CNT reinforced additively manufactured NiCrAlY substrate

Host Institute

Prof Thomas Niendorf, Institute for Materials Technology, Univversitat Kassel, Germany

Visit Period – 11th -21st December 2018

DST-MPG

DST–Max Planck Society Programme
Connecting Excellence

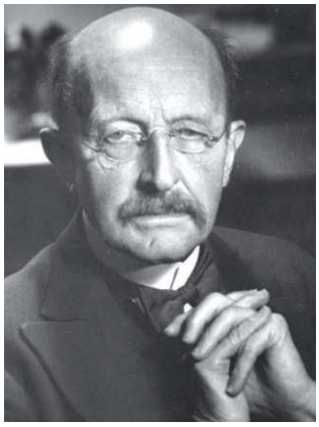
Department of Science & Technology
Government of India

MAX-PLANCK-GESELLSCHAFT

The Department of Science & Technology (DST), Govt. of India and Max Planck Society (MPG), Germany have collaborated, through an agreement signed in 2004, to constitute and operationalise DST–Max Planck Society Programme.

Running since year 2004, the DST-Max Planck Society Programme has two flagship initiatives under its umbrella aimed at creating opportunities for collaboration and sustained interactions with S&T research priorities.

IGSTC has been entrusted with the responsibility of implementing the DST-MPG Programme from Indian side.



Source : Max Plank Society

"Science cannot solve the ultimate mystery of nature. And that is because, in the last analysis, we ourselves are part of nature and therefore part of the mystery that we are trying to solve."

Max Planck

Max Planck Partner Groups at Indian Institutes

The "Partner Group" is an instrument created by the Max Planck Society (MPG) for the purpose of strengthening the ties between Max Planck Institutes and research institutes from other countries. Partner Group is a mechanism to intensify cooperation between individual scientists through jointly conceptualized and implemented S&T research projects. The "Max Planck Partner Group at Indian Partner Institute" has been developed as an instrument for supporting collaborative research in target areas prioritized on the basis of their relevance to immediate problems and interests of institutions involved from both sides. Partner Groups are headed by Indian scientists who return to India after completing their extended research residency at a Max Planck Institute. Partner Groups allow the involved scientists to lead appropriately equipped research groups in order to continue their research activities in close co-operation with their former German hosts. Each Partner Group is supported to the tune of €20000 per year by MPG with a matching contribution of equivalent ` amount by the DST. Grants are expected to be utilized, as far as possible, for the purpose of creating MPI like facilities at the respective Indian host institutions

Centre for cosmology and gravity

S. Shankaranarayanan
IIT Bombay

Hermann Nicolai
MPI for Gravitational Physics, Potsdam

Solar Physics: Coupling and dynamics of solar atmosphere

Dr Durgesh Tripathi
Inter-Univ Centre for Astronomy and Astrophysics, Pune

Prof Sami K Solanki
MPI for Solar System Research, Lindau

Visiting Fellowships/Mobility Grants

Max Planck-India Visiting Fellowship is a distinction for highly qualified and talented scientists. The Fellowship is awarded to scientifically outstanding, promising young Indian scientists.

Individuals selected for the award get the opportunity to work with Scientists at the Max Planck Institute (MPI) relevant to their area of expertise for up to one months a year for four consecutive years.

Fellowship holders receive from MPG a sum of € 3,000 per year, for up to four years, with Indian side providing travel support for each research stay.

S. No	Fellow	MPI Counterpart	Field of Research / Title
01	**P Anil Kumar** Institute of Microbial Technology Chandigarh	**Friedrich Widdel** MPI for Marine Microbiology, Bremen	Physiology of mixotrophic planktonic bacteria
02	**Satya Pal Nehra** Deenbandhu Chhotu Ram Univ of Sci & Tech, Murthal	**Dwayne Miller** MPI for Dynamics and Structure of Matters Hamburg	Preparation and characterization of semiconductor photocatalysts for surface reaction dynamics study and their applications
03	**Richa Rai** Banaras Hindu University Varanasi	**Jonathan Gershenzon** MPI for Chemical Ecology Jena	Applicationof metabolite, transcript and flux measurements to investigate the effect of elevated ozone and carbon dioxide on yield and pest protection of C3 and C4 crops
04	**Kamal P Singh** IISER Mohali	**J M Rost** MPI for Physik Komplexer Systeme, Dresden	Sub-fs control of photo-dynamics in atoms/molecules using shaped XUV pulses
05	**N Ramesh Kumar** NIIST, Thiruvananthapuram	**Ian Thomas Baldwin** MPI for Chemial Ecology, Jena	Identification and functional characterization of seed borne bacterial endophytes of Nicotiana attenuata and the elucidation of their transmission to the progeny using culture-dependent and-independent approaches
06	**Areejit Samal** Institute of Mathematical Sciences, Chennai	**Jürgen Jost** MPI for Mathematics Sciences, Leipzig	Computational methods for identifying and analyzing design features of metabolic networks
07	**Arjun Bagchi** IIT Kanpur, Kanpur	**Stefan Theisen** Gravitational Physics, Golm	Minkowskian Holography

S. No	Fellow	MPI Counterpart	Field of Research / Title
08	**V Pramitha** IIT Madras	**Joachim P Spatz** MPI for Intelligent Systems, Stuttgart	Direct patterning of vortex generating diffractive optical elements on fibre tip using a focused ion beam
09	**Karthik V Raman** TIFR, Hyderabad	**Klaus Kern** MPI for Solid State Research, Stuttgart	Tailoring interface spin transport: towards molecular spintronics
10	**Srikant Sukumar** IIT Bombay	**Peter Benner** MPI for Dynamics of Complex Technical Systems, Magdeburg	Cooperative control and consensus, nonlinear control, adaptive control, time-varying systems
11	**K Sowjanya Sree** Central University of Kerala, Kasaragod	**David G Heckel** MPI for Chemical Ecology Jena	Transcriptional responses of Helicoverpa armigera to the insecticidal mycotoxin, Destruxin
12	**Venkat Gundabala** IIT Bombay	**Katharina Landfester** MPI for Polymer Research Mainz	Water-based nanocomposite coatings
13	**Anshu** IIT Delhi	**R J Dwayne Miller** MPI for the Structure and Dynamics of Matter, Hamburg	Structure and Dynamics of Functionalized and Catalysts Modified Carbon Nanotubes for Charge and Mass Transport Applications

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