IGSTC
INDO-GERMAN SCIENCE AND TECHNOLOGY CENTRE

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Annual Report 2017-18

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Annual Report 2017-18

Department of Science & Technology
Government of India

IGSTC
INDO-GERMAN SCIENCE AND TECHNOLOGY CENTRE

Federal Ministry
of Education
and Research

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:

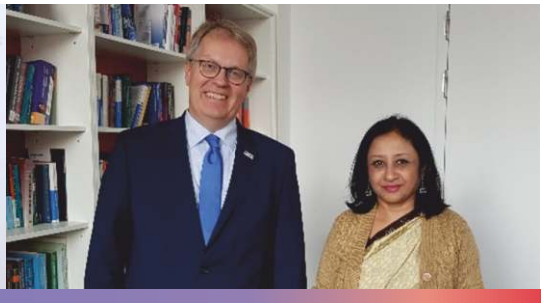
1. Play a proactive role in facilitating participation of industry in joint R&D+I projects.
2. Provide/assist in mobilizing resources to carry out industrial R&D+I projects.
3. Promote electronic exchange and dissemination of information on opportunities in bilateral science & technology cooperation. 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 2017-18 AT A GLANCE

Indo-German Science & Technology Centre (IGSTC) is in the 8th year after it came into existence. The 2+2 model, connecting academia and industry for translation of research results into products/processes and services received widespread acceptance as a unique model of research partnership for socio-economic contribution through technological interventions.

Dr Harsh Vardhan, Honourable Union Minister of the Ministry of Science & Technology and Earth Sciences visited BAM and gathered information about the work in two research projects funded by IGSTC. Source: BAM



Indian Ambassador Mukta Dutta Tomar visited BAM in September to find out about the ongoing IGSTC projects Source: BAM

During the year 2017-18, IGSTC supported 21 joint projects in 2+2 mode in areas of (i) sustainable energy (ii) advanced manufacturing (iii) biomedical devices and biotechnology (iv) water & wastewater technologies (v) nanotechnology and (vi) embedded system & ICT (vii) energy materials, energy storage and (viii) water biosensors & wastewater technologies. This also includes six new projects from Call 2016 in the overall thematic area "Smart Cities" started in March 2018. Currently, ongoing IGSTC Projects involve 84 (eighty four) project partners from academia and industry from India and Germany with total project investment (both Indian and German) of estimated INR 120 Cr or 15 million Euros. There are 10 (2+2) projects already completed. It means a network of more than 125 project partners representing academia and industry from both countries could be created. Approximately 400 scientists, researchers, engineers from both countries are networked through this programme.

Dr R Chidambaram, Principal Scientific Adviser to the Government of India, Prof Ashutosh Sharma, Secretary, DST and several other dignitaries including Directors of various national labs including DRDO labs visited IGSTC booth during 3rd IISF in Chennai

The 11th meeting of the Joint Committee (JCM) between India & Germany was held on 8th May 2017 in Berlin. The JCM was Co-Chaired by Prof. Ashutosh Sharma, Secretary, DST and Dr. George Schuette, State Secretary of Federal Ministry of Education and Research. The joint committee reviewed the ongoing science and technology cooperation between India and Germany and recommended several new activities of collaboration. Director, IGSTC gave a brief about the progress, activities and future plans of IGSTC to the Committee. JCM was attended by various Indo-German institutions, DST and CSIR officials.

The fourth Inter-Governmental Consultations [IGC] between India and Germany were held in Berlin in May 2017. In the Joint Statement, Prime Minister Modi and Chancellor Merkel also acknowledged the flagship role of IGSTC in promoting industrial R&D projects that have potential for application towards the development of new breakthrough technologies.

The 3rd Finance meeting (FC) and 9th Governing Body (GB) of IGSTC was held from 24th-25th October 2017 in Jodhpur, India. The meeting was co-chaired by Dr Arabinda Mitra, DST and Dr Lothar Mennicken, BMBF. The GB expressed their satisfaction over the progress IGSTC made in the past few years. The meeting deliberated on various issues related to IGSTC based the extension of IGSTC and the enhancement of funding limit from 2 to 4 million euros each year by each side. GB decided to start new programmes in the context of the doubling up of funding by the governments.

The new programmes are as follows:

- Indo-German Industrial and Academia R&D Network Call aiming to promote application oriented joint R&D activity by leveraging already existing infrastructure and funding available with the partners at both sides through an IGSTC supported linkage in the form of a virtual R&D Network.
- Industrial Research Fellowship Programme at two levels - PhD Student and Post-doctoral level in an industrial research set up in Germany aiming to capacity building among researchers at an early stage of their scientific career.
- IGSTC-CONNECT Plus to provide travel grant for the follow-up programme for the participants of Indo-German Frontiers of Engineering Symposia (INDOGFOE) Programme of Alexander von Humboldt Foundation and DST.
- IGSTC will organize Helmholtz-Indian Platform on Science, Technology, Education and Research (HIPSTER) workshop to create a platform for young researchers from India and those from various Helmholtz institutes.

3rd Finance Committee and 9th Governing Body meeting of IGSTC

In conjunction with the 9th GB Meeting, IGSTC organised its Partners Meet on the 23rd October 2017. The Partners Meet was aimed to demonstrate the progress and outcome of the IGSTC projects. It also helped networking amongst the consortium partners as well as with other project consortium members. PIs expressed their views/suggestions on IGSTC funding model and their expectations from IGSTC for future, the status of the consortium/continued networking, and success stories on the projects. There were constructive deliberations on the projects and the IGSTC funding model.

Partners Meet

The IGSTC Call 2017 for 2+2 grant applications in the overall thematic area advanced manufacturing and new materials, with subtopics: 1) industry 4.0 (new human-machine interaction processes / digital and cloud manufacturing), 2) machine building (low cost sub-systems / components for improved precision, reliability, productivity), 3) process technologies for new materials including nanomaterials and 4) light weight design and processes attracted large number of applications and the final results to be decided in the upcoming Joint Scientific Committee Meeting in May 2018. The selection of projects is being done through a two step process to award project consortiums for possible funding.

IGSTC launched the Open Call for Workshops giving the stake holders flexibility to apply for funding support any time throughout the year. This facilitate the prospective applicants to submit workshop proposals conveniently on any topic coming under the purview of DST and BMBF.

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. Currently IGSTC is implementing seven Partner Groups and 14 Visiting Fellowships.

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

GOVERNING BODY

Arabinda Mitra
DST
Indian Co-Chair

Lothar Mennicken
BMBF
German Co-Chair

J B Mohapatra
DST

Gerold Heinrichs
DLR-PT

G Padmanabham
ARCI

Stephan Lanzinger
German Embassy

Sandeep Verma
IIT Kanpur

Eberhard Abele
TU Darmstadt

Ratika Jain
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.

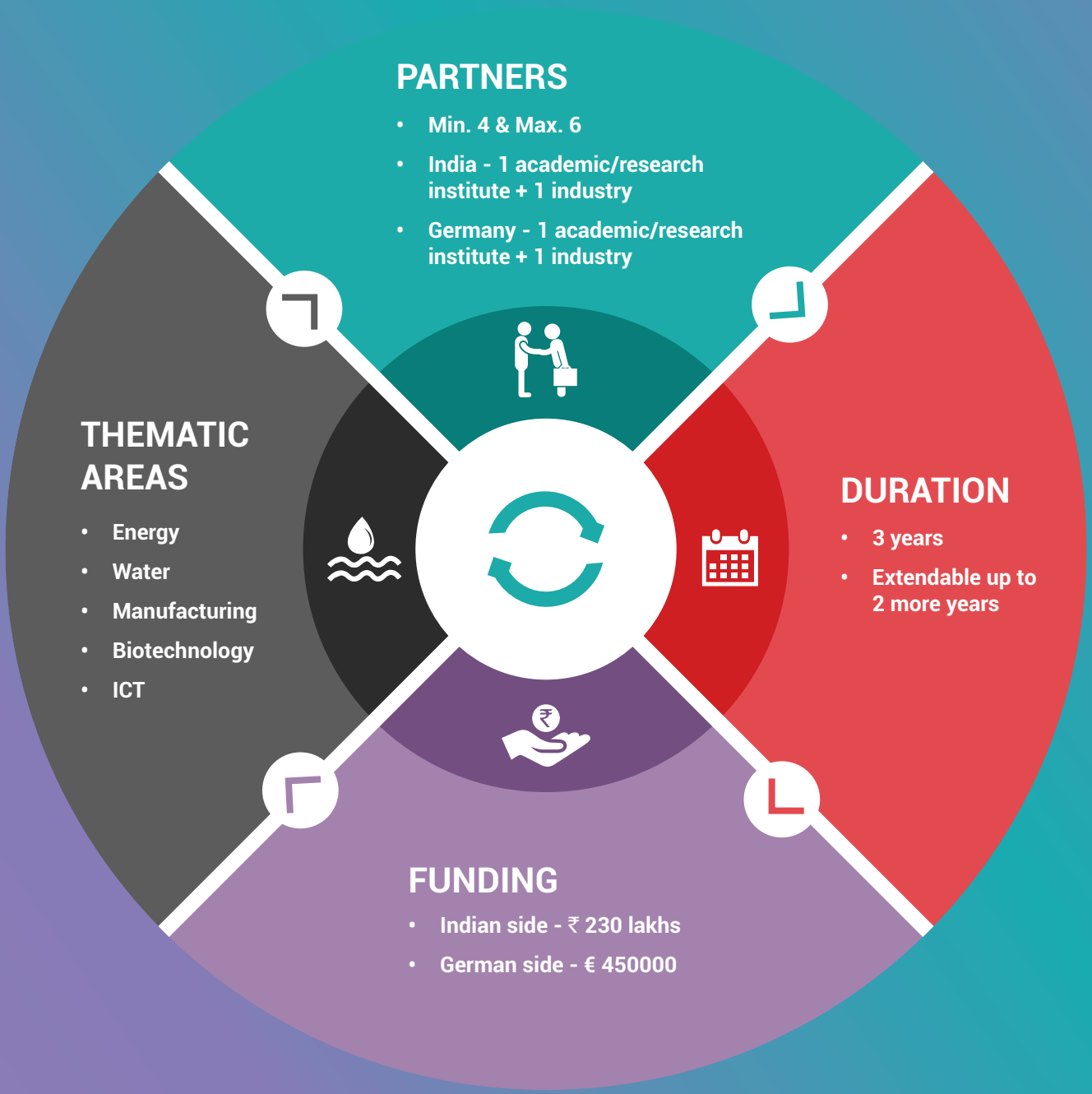
Industry partners are expected to contribute 50% of their eligible cost.

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.

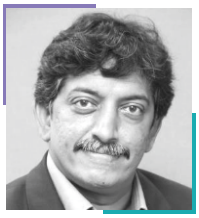

PARTNERS
• Min. 4 & Max. 6
• India - 1 academic/research institute + 1 industry
• Germany - 1 academic/research institute + 1 industry
THEMATIC AREAS
• Energy
• Water
• Manufacturing
• Biotechnology
• ICT
DURATION
• 3 years
• Extendable up to 2 more years
FUNDING
• Indian side - ₹ 230 lakhs
• German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

BIOMEDICAL TECHNOLOGY

MIDARDI

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

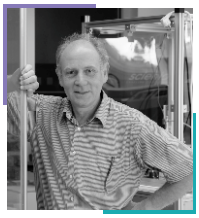
Project Investigators



K Satyamoorthy
Manipal University
Manipal

Dhananjaya Dendukuri
Achira Labs Pvt. Ltd.
Bangalore

Thomas Otto
Fraunhofer ENAS
Chemnitz



Frank Bier
Fraunhofer IZI
Potsdam-Golm

Joerg Nestler
BiFlow Systems
GmbH, Chemnitz

Project Summary

Europe and India face an epidemic of obesity and Type 2 diabetes (T2D). Development of T2D strongly correlate and very often predisposes to increased risk of many disabling chronic diseases including Lower Extremity Amputations (LEA) such as foot infections. Bacterial communities in such foot infections show diverse morphological and physiological characteristics and their bioburden in diabetic foot ulcers (DFU) show a distinct pattern of antibiotic resistance which significantly delays wound healing. Though infected ulcers require proper antibiotic therapy, rapid and accurate detection of polymicrobial communities in wound environment is critical in proper wound management. In this polymicrobial setting, the project aims at developing a microfluidics-based lab on-a-chip for rapid and accurate detection of different types of bacteria, their virulence/fitness factors and antibiotic resistant genes that may contribute to dominance of certain types in DFU settings. The detection module would aid clinicians in decision-making process to improve specific outcomes that would concomitantly improve wound healing per se in DFU scenario.

- Assay development for species identification and antibiotic resistance testing based on gene and mutation detection
- Fully-integrated, disposable Lab-on-a-Chip System to perform DNA sequence detection assays
- Readout unit dedicated to local environment to demonstrate species and drug resistance testing of pathogenic bacteria
- Proof-of-concept of mutation detection for translation

After clearance by the ethics committee Diabetic foot ulcer samples were collected from patients at Kasturba Hospital, Manipal following strict inclusion and exclusion criteria. For each patient, a minimum of two swab samples were collected for microbiological and culture independent (16S rRNA gene sequencing) processing. Collected specimens were brought to the microbiology laboratory at the School of Life Sciences, Manipal. Both culture-based and next generation sequencing

(NGS) based technologies were carried out to understand the identity and differences in microbiome.

Microfluidic cartridges with pumping and heating capabilities to run all required process steps were developed together with the required instrument and biochemistry. The figure below shows a hybridization cartridge, illustrated by thermochromic liquid filled in the reservoirs. A blue-colored liquid is pumped through the sensor region, where it bleaches due to the elevated temperature in that area. Such cartridges have been used with a newly developed microarray containing probes for selectively binding nucleic acid strands from bacteria. Various positions on the microarray can detect so-called SNPs (single nucleotide polymorphisms), which can be used either to discriminate between bacteria of the same family, or to determine their antibiotic resistance profile. The bottom right picture shows the result of such a hybridization assay on the microfluidic cartridge (false-color fluorescence image and normalized quantitative results).

Next steps to complete will be the validation of the instrument and the newly-designed cartridge both as standalone sub-systems and together. Cartridges and instrument will then be prepared for tests with real samples during the last phase of the project.

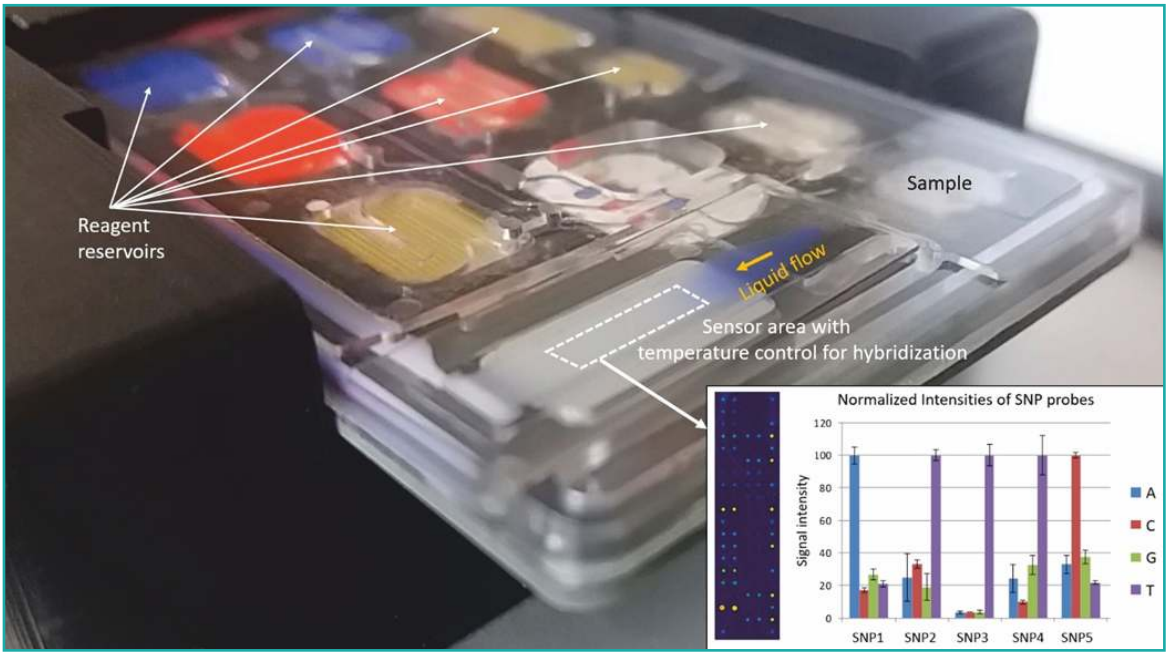


Fig: Microfluidic cartridge to run hydridization assay, and results of hybridization assay on a microarray (fluorescence detection)

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

PhD/Master thesis supervised

- Ms Kavitha S – Ph.D. Thesis entitled "Molecular characterization of bacterial and fungal communities in the diabetic foot ulcer"
- Mr Ankit Singh Tanwar – M.Sc. Thesis entitled "Genome comparison of four strains of Staphylococcus aureus isolated from diabetic foot ulcer"

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SIBAC

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

Project Investigators

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Forus Health Bangalore

Eberhard Spoerl
University of Carl Gustav Carus, Dresden

Sven Reisdorf
Oculus Optikgeräte GmbH, Dresden

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 determination of intraocular pressure, which is the still the primary determinant of ocular hypertension. Thus, disease diagnostics and treatment planning require knowledge of 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 – University of Carl Gustav Carus, Dresden

Start of experimental investigation at porcine eyes regarding 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
- Long-term goals: Correlating the stiffness parameters to in-vivo measurements of progressive keratoconic eyes after CXL
- Experimental Design: Prof. Spörl and Mr. Herber performed measurements on porcine eyes with 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.

Clinical pilot studies (approved by ethical review committee EK 91032013)

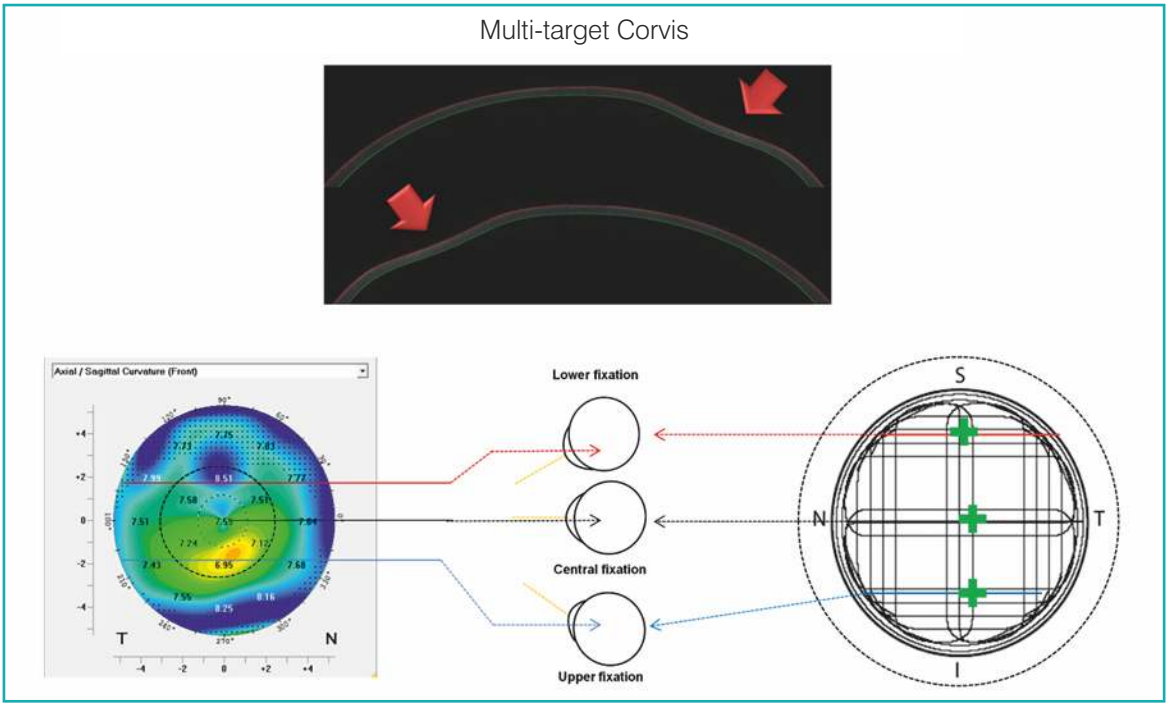
- Clinical examination of keratoconic patients before and after corneal cross-linking
- Establishment of a database of healthy participants, keratoconus patients and glaucoma patients

Partner 2 - Oculus Optikgeräte GmbH, Dresden

- Further optimization of a prototype with different fixation targets that also includes the new auto-tracking system and new optimized measurement modes (firmware optimization).
- Optimization of the air pulse system: For better compliance of the patient to the new system which requires three measurements the air-pulse had to be optimized in order to reduce noise.
- The work on the electronics of the new camera system has been finalized: This included the programming or the Field Programmable Gate Array (FPGA), development of image optimization such as noise reduction and binning. Furthermore, the electronics to control the camera during the image acquisition and to transfer images after image acquisition has been developed.
- Joint work with the University of Dresden on a database of glaucoma patients: Based on the algorithm of the Indian Partner in combination with machine learning approaches a new screening software for the detection of normal tension glaucoma based on biomechanics shall be developed.

Partner 3 – Narayana Nethralaya Foundation, Bangalore & VIT university, Vellore

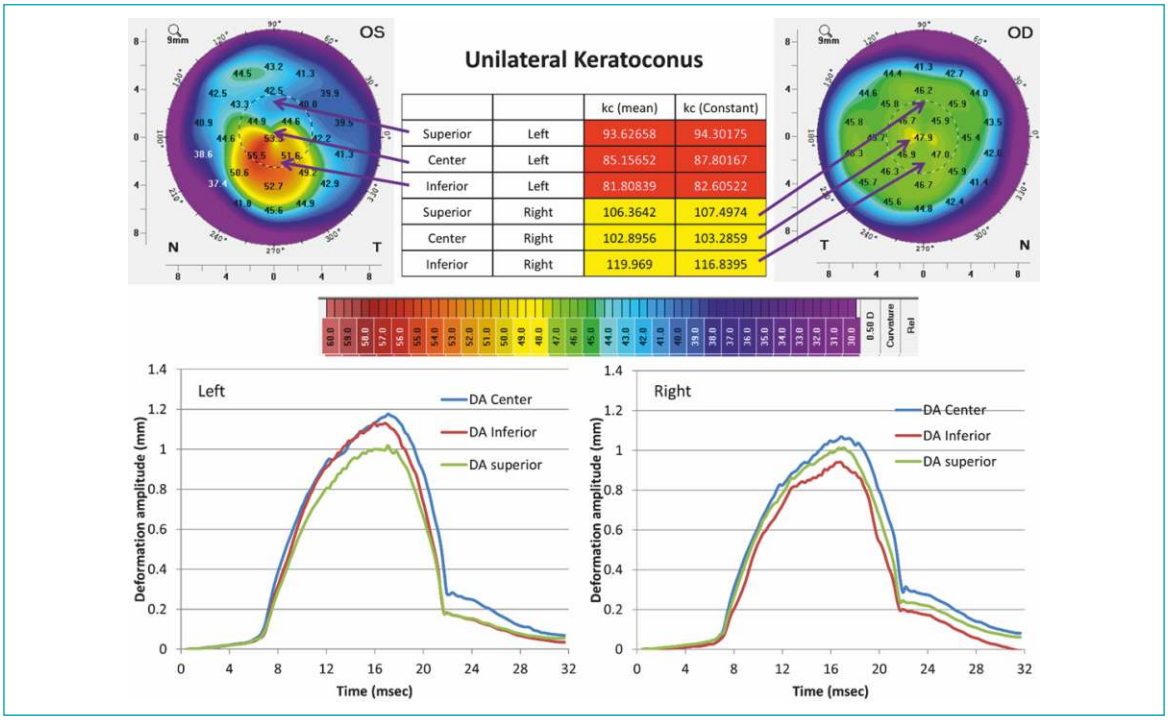
Software development ongoing: Meshing tool for automated meshing of corneal geometry has been completed. Finite element simulation tool is process of development. With the arrival of the prototype (proposed completion was early to mid-2017) only in February 2018, the development work is expected to finish by December 2018. We have parallelly started clinical testing of the prototype in refractive patients, keratoconus and glaucoma eyes at the eye hospital.



Top image shows a B-scan of the deforming cornea captured by the high speed Scheimpflug camera (Corvis).Lower left image shows corneal topography of a keratoconus cornea. Lower right image shows a schematic representation of the deformation measurement at different locations (green cross).

Partner 4 – Forus Health, Bangalore

Forus is guiding NNF and VIT in development of the software, particularly in the refinement of Graphical user interface and memory optimization.



Sample measurement and analyses from the new device. OS (left eye) is keratoconus and OD (right eye) is normal. Arrows show location of deformation measurement. Table shows the corneal stiffness at each location. Note the significant different between the eyes and also difference between the locations (Table). Lower plots show the temporal corneal deformation (DA or deformation amplitude) measured at different locations.

Publications

Journals

- Shetty R, Francis M, Shroff R, Pahuja N, Khamar P, Girrish M, Nuijts RMMA, Sinha Roy Corneal Biomechanical Changes and Tissue Remodeling After SMILE and LASIK. IOVS, 2017
- Shetty R, Pahuja N, Roshan T, Deshmukh R, Francis M, Ghosh A, Sinha Roy A. Customized Corneal Cross-linking Using Different UVA Beam Profiles. JRS, 2017
- Matalia J, Francis M, Gogri P, Panmand P, Matalia H, Sinha Roy A. Correlation of Corneal Biomechanical Stiffness With Refractive Error and Ocular Biometry in a Pediatric Population. Cornea 2017
- Sinha Roy A, Shetty R. Why Indentation Cannot Be Considered Exactly Equivalent to Non-contact Tonometry. JRS, 2017
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Conferences

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- Tushar Grover, Rohit Shetty, Sinha Roy A. An artificial intelligence method to estimate region of biomechanical weakness in keratoconic corneas. ARVO, 2017
- Mathew Francis, Natasha Pahuja, Rushad Shroff, Rohit Shetty, Kavya Devanapalli, Sinha Roy A. A novel inverse finite element approach to analyze corneal deformation after SMILE and LASIK. ARVO, 2017
- Sinha Roy A, Shetty R, Pahuja N, Roshan T, Deshmukh R, Francis M. Outcomes of spatial modulation of UVA beam intensity to minimize delivered UVA energy in corneal crosslinking. ARVO, 2017
- Khamar P, Francis M, Shroff R, Pahuja N, Roshan T, Shetty R, Matalia H, Sinha Roy A. A diagnostic biomechanical framework to distinguish keratoconus and normal eyes using air-puff applanation. ARVO, 2017
- Shroff R, Rachana CS, Franics M, Matalia H, Shetty R, Sinha Roy A. OCT topography: A novel, non-invasive method to analyze the Eptihelium-Bowman's interface in normal and keratoconus eyes. ARVO, 2017
- Herber, R, Spoerl E, Raiskup F. Biomechanical assessment of keratoconic eyes after corneal cross-linking by Scheimpflug-based tonometry. CXL Experts Meeting 2017
- Herber, R, Spoerl E, Pillunat LE, Raiskup F. Beurteilung cornealer Deformationsparameter mittels dynamischer Scheimpflug-Tonometrie nach Hornhautvernetzung. DOG 2017 and Ophthalmologische Nachrichten

Patents filed

- Quantification of Bowman's layer for diagnosis of disease and prognosis of treatments in the human cornea, Filed by Narayana Nethralaya Foundation, 2015. Application ID: 6539/CHE/2015, PCT/IB2016/057422
- 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
- 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

Project Investigators

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Amit Chirom
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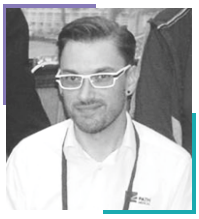
Samarjit Chakraborty
TU Munich
Munich



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 we 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. 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 a completely different hardware and software architecture, without sacrificing the quality of the screening. Developing such architectures and evaluating them are the main scientific goals of this project. In particular, we 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, we 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.

Progress made/achieved

PATH Medical

WP2: Probe design (PATH + IIT)

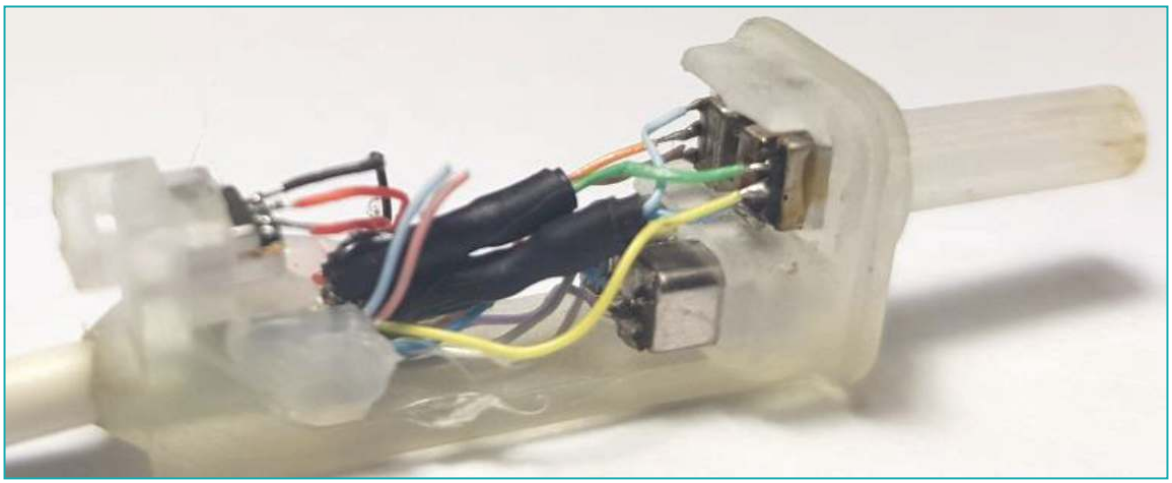
Results of the initial ear probe design developed in the first-year show that the design suffered from acoustic leakage at the transition from probe body to probe tip. Moreover, the design was made for the existing small but expensive transducers used in the PATH probe, aiming to evaluate the channel shape and 3D printing capabilities. Based on these findings a new prototype has been developed which holds cheaper but bigger transducers and the design focused on simple and inexpensive manufacturing procedures.

Based on the selected transducers a new ear probe concept ("S4A probe") was developed holding cheap RC1206-S speakers and a POM-3535-L microphone. The design is composed of two half shells for simple assembly, a soft inner part to get it tight and soft removable probe tips. The probe was 3D printed and evaluated using Larson Davis 824S calibration equipment and the AEC304 ear simulator. The results have been presented on the workshop in Delhi and the probe was successfully tested in normal hearing and hearing-impaired subjects.

WP4 and WP5: Development of candidate architectures (PATH+TUM)

PATH was working together with TUM on defining low-cost candidates of prototypes. The suggested device architectures have been developed and evaluated by TUM, including smartphone-based approach, stand-alone device as well as a wireless ear probe design. PATH contributed on selecting hardware components for the stand-alone device matched to the PATH and S4A probe. PATH supported TUM in evaluating the recordings and results of the smartphone-based devices as well as the recordings with the wireless probe. Due to significant hard- and software deviations of different smartphone types and the size of the wireless probe we have decided to finalize the stand-alone device approach in the last year of the project.

The entire system was calibrated to get proper stimulus and microphone levels. The stand-alone device candidate was presented in Delhi in December 2017 within a live demo where normal hearing and hearing-impaired subjects have been successfully tested on stage.



Sound4ALL: Evaluation ear probe with additional transduces

TUM

The last twelve months were focused on evaluating different hardware architectures and identifying a possible candidate for prototype.

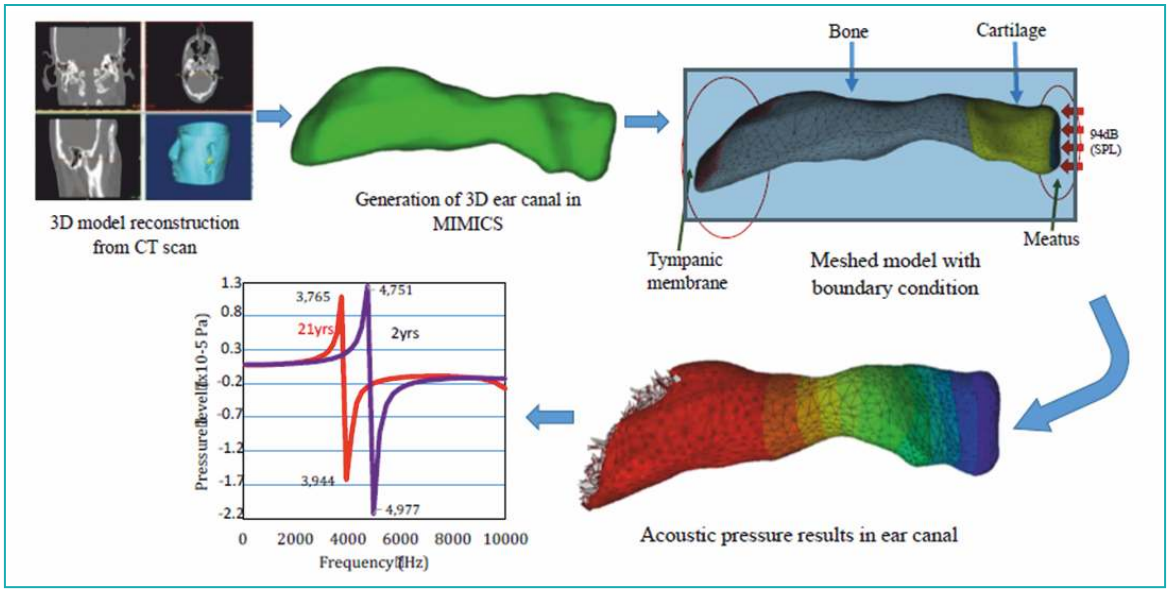
The two basic goals of this project are to reduce cost and improve the usability by laypersons. By improving the signal processing, the measuring time can be reduced. This always leads to a better usability. Based on

frameworks built earlier in the project and results gained in WP2 and WP3 further, more specialized methods were explored: To improve resilience of the measurements to external noise sources, experimental devices were fitted with additional ambient microphones. Using adaptive filters, external noise can be lowered in the ear canal microphone signal. At the same time, alternate probe configurations were investigated, which included custom 3D printed and laser machined parts. The tested configurations included multiple ear canal microphones and even setups without dedicated microphone.

To improve usability, first experiments were conducted with additional sensor input. These included environmental data and IMU data. The goal is to assist the operator in setting up the measurement (selecting the probe tip) and placing the probe.

Since one of the approaches to cost reduction and usability increase is adding a smartphone to the measurement, we explored were exactly we could benefit from computational offloading in regard to signal processing. The algorithms were implemented on an embedded system connected to a host. All meaningful combinations of placing algorithms on the embedded systems or the host were investigated. At the same time parameters like CPU utilization, memory demand, power consumption and communication throughput were observed. All these parameters must be considered for the prototype and influence the system level choices. Especially in terms of available communication technologies (Bluetooth etc.) and battery lifetime.

Steady State Sound Pressure of Ear Canal using Finite Elemental Analysis



Acoustic simulation of the ear canal

One of the suggested architectures is based on a probe directly connected to the headphone jack of a smartphone. This setup required individual consideration. Therefore an android based app was developed, which allowed to qualify smartphones and their audio capabilities. While some devices showed promising results, others performed poorly, either due to circuit/electrical limitations or poorly written firmware.

Based on the results of the prior work at TUM and also the probe design, which was mainly pursued by IIT/PATH, a hardware prototype was drafted. If all parameters are considered, it is most advantageous to put almost all processing into the device. This is mostly driven by the energy overhead of communicating large amounts of raw data over a wireless interface.

IIT Delhi

IIT Delhi with PATH has designed a new probe for holding the commercial and inexpensive transducers which are available in the market. Different designs were evaluated and finalized to hybrid design, which helps in avoiding acoustic leakage. Soft part holding transducers and speaker channels was designed in such a way that there is no cross talk between speakers and mic. This design was evaluated and displayed in sound4all workshop conducted in AIIMS. Comparative results of the standalone device with commercially available path probe was also presented in workshop.

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 94 db was simulated on the entrance of the ear canal and pressure changes on the tympanic membrane was studied.

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 aging of the person. These inputs will help in fine tuning the design of the probe. Currently IIT Delhi is optimizing the current design and evaluating the design for manufacturing through injection molding.

AIIMS

AIIMS conducted a very ambitious Sound4All workshop at AIIMS. The workshop was attended by not only project partners but various experts and young students working in field of bioengineering, audiology and otolaryngology. The day's deliberations brought many ambitious minds to discuss the hearing and deafness related devices. The workshop was held on 16 December, 2017 and found good media and press coverage. During the workshop, the first functioning prototype stand Alone Device was demonstrated to the audience and it was well appreciated.

AIIMS team is conducting a study focusing on hearing loss and neonatal hearing screening by presently available Oto-Acoustic Emission device and ABR device. This will help our audiologist to get familiarised with these instruments so that critical evaluation of our project OAE can be performed.

Meetings/Conferences/Networking Events

On December 16, 2017, All India Institute of Medical Sciences hosted a full-day workshop entitled "Hearing Loss Detection: Status and Future Directions", Theme: Devices and technology.

Salient Research Achievements

Hardware and software functionality of the early prototypes have been successfully verified in our labs. The performance of the OAE recording algorithms have been validated in a small subject sample of normal hearing and hearing-impaired adults. We identified some minor issues to be improved regarding handling, usability and performance which will be implemented in the next version of the prototypes. The revised and cost-optimized prototypes will be ready for a usability study at AIIMS to finalize the proof of concept.

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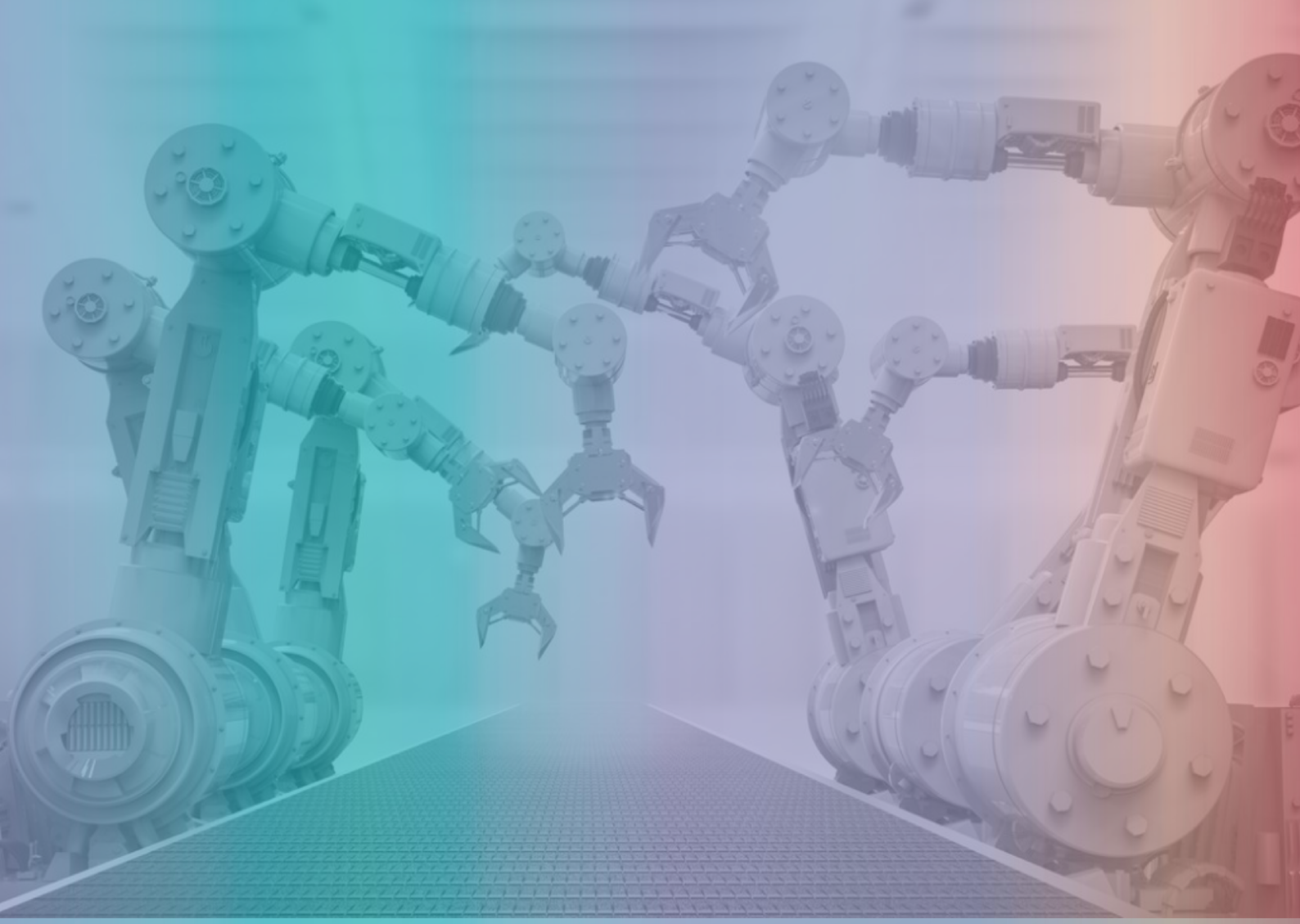

ADVANCED MANUFACTURING

AMPLAST

Advanced manufacturing process monitoring using in-line laser thermography

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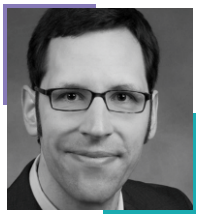

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Matthias Krauß
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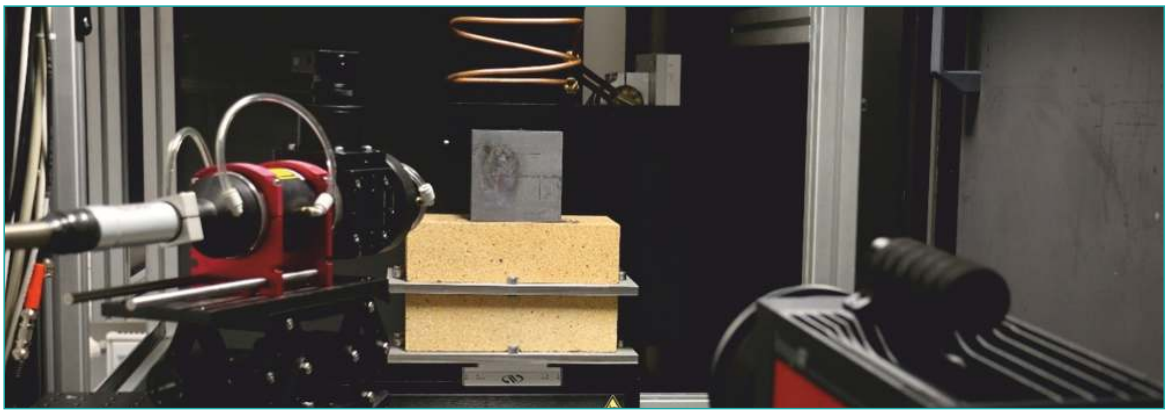
Project Summary

The overall goal of the project was the realization of quantitative, fast and non-destructive laser thermography testing methods and technologies for inline production monitoring in steel production, which can withstand both difficult process conditions and deliver reliable results and thus represent significant added value for the manufacturing industry. The methods to be developed are based on a combination of a laser-based excitation (i.e. local heating of the component surface) and a locally and temporally resolved detection and analysis of the transient heat flow, which makes important material and process variables accessible and thus enables statements on the condition of the manufacturing process and the quality of the finished product. Some of these variables are surface and near-surface cracks and other defects, surface and near-surface temperature distributions, anisotropies of density and thermal conductivity, surface hardness. The project addresses the field of advanced manufacturing and is intended to provide insights that will lead to new inline-capable sensor technology for production equipment in the steel industry. The expanded and improved knowledge of the manufacturing process and the product should lead to cost savings through the reduction of scrap, real-time process control and the reduction of downtimes. The collaboration of German (BAM) and Indian research institutions (IITM) with a main focus on non-destructive material testing, industrial partners with a focus on infrared thermography (InfraTec) and system integration/software development (Dhvani) as well as Indian technology evaluation partners (Tata Steel, BHEL) should bring together the individual aspects (e.g. BAM: crack detection, IITM: anisotropy of thermal conductivity) that have so far only been processed separately and provide an attractive sensor system with an industrial character.

A major result is the successful development and commissioning of laboratory systems with which the conditions in the steelworks could be simulated. Among other things, a special high-temperature calibration made it possible to transfer the findings, which were previously only available at room temperature, to problems at high temperatures of several hundred degrees Celsius. The knowledge gained in this development was used at IITM to develop its own laser thermography system. These laboratory setups were characterized and validated and allowed measurements under controlled conditions with respect to all relevant parameters. In further steps, numerical models on the Indian side (IITM) were developed. The further development towards a

realistic numerical model was continuously accompanied by experiments on the German side (BAM). With the available laboratory setup and the model, all conditions relevant for crack detection in steel production could be simulated in the laboratory. A systematic investigation of the laser thermographic crack detection of hot samples was carried out and the detectability of cracks was determined depending on the relevant measuring parameters. These parameterizing investigations allowed estimations of the efficiency of the process and gave indications of possible limits and difficulties. Parts of these studies were carried out within the framework of a scientific exchange between IITM and BAM. At regular project meetings and discussions with the scientific and industrial partners, the online capability of the process proved to be essential for its application in steel production. During the course of the project, work was therefore intensified on the development and optimisation of the evaluation algorithms. For example, InfraTec was able to transfer important parts of the data and signal processing directly into the IR camera, and specialized image processing and crack detection algorithms, which were previously only available offline, could be implemented directly into the image acquisition software with a user interface. This was a decisive step towards online capability. This work was originally to be followed by field studies at the Indian associated partners Tata Steel and BHEL. However, due to access restrictions and safety regulations, actual on-site measurements could not be carried out until after the end of the project in 2018. Therefore, the hoped-for industrial prototypes could not be created and reliable data bases for the adaptation of the evaluation algorithms were missing. Therefore, part of the work focused on detailed parameter studies at different temperatures.

Another part was devoted to the topic of changing the material properties of steel at high temperatures. There, a superficial scale effect appeared, which represents a decisive restriction for thermographic investigations. The optical and partly also the thermal properties of the steel are therefore very heterogeneous, so that with conventional methods they cover practically all relevant signatures of the defects to be detected. Different approaches to compensate for this disadvantageous phenomenon were investigated and finally an image processing method was developed that achieved at least partial compensation.



Experimental setup- Laser Thermographic Testing

Milestones Achieved

- Development of the laboratory based experimental apparatus
- Validation of the laboratory based apparatus
- Development and validation of the models for improved understanding
- Performance and validation of parametric study data sets and obtain confidence in the measurement techniques
- Development of Hardware and software that are robust and fieldable.
- Conduct of field studies and analysis of the data obtained
- Development of improved hardware and software based on field data

Salient Research Achievements

Several major research results have been achieved which are listed in the following:

- Development and commissioning of laboratory systems with which the high-temperature conditions (several hundred degrees Celsius) in steelworks could be simulated. The systems are automated and shielded. These laboratory setups were characterized and validated and allowed measurements under controlled conditions with respect to all relevant parameters.

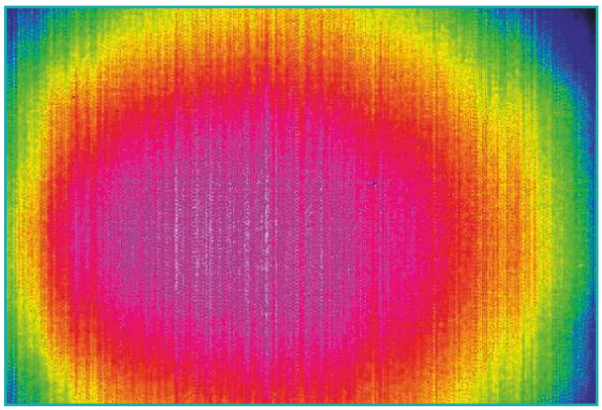
- Development of numerical models that describe the laser-thermography methodology. The numerical models have been compared and validated with experiments. Many different parameters could be set and allowed to gain a very precise picture of the physical phenomena that lead to crack indications. Furthermore, the ideal conditions for specific testing problems can be derived from these models.

- With the available laboratory setup and the model, all conditions relevant for crack detection in steel production could be simulated in the laboratory. A systematic investigation of the laser thermographic crack detection of hot samples was carried out and the detectability of cracks was determined depending on the relevant measuring parameters. These parameterizing investigations allowed estimations of the efficiency of the process and gave indications of possible limits and difficulties.

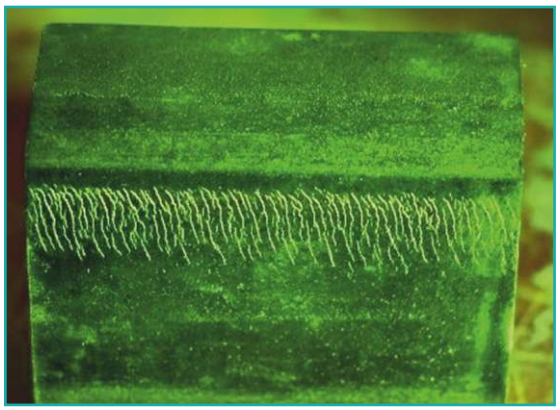
- Development of specialized image processing and crack detection that facilitated a principle transfer of the knowledge from the initial flying-spot laser thermography technique and the procedures from room temperature to the actual experiments under high-temperature conditions.

- For dealing with the major obstacle found during the project, the formation of scale during heating of steel at high temperatures under atmospheric conditions, an additional image processing algorithm has been developed. Although it was not possible to recreate the same defect detection sensitivity as for the original technique at lower temperatures, the developed image processing method achieved at least partial compensation.

- The infrared camera equipment was upgraded to allow for high-temperature measurement. An important part of the image processing was moved from computer into the infrared camera and the crack detection algorithms as well as specialized image processing algorithms for the moving sample condition were implemented within the image acquisition software, i.e. not offline anymore. In this way, the in-line capability of the thermography hardware and software has been upgraded and made more robust and fieldable.



Infrared image of an InSb detector array without correction



Magnetic particle imaging of railway block

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DNDHCSA

Design and development of hollow crankshaft for automobiles

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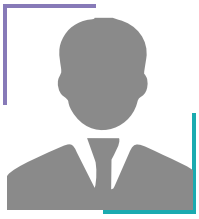

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Project Summary

The awareness of climate change and the limited availability of resources also lead to reconsideration of the resources used in heavy weight vehicle production. As often the raw material costs are considerably higher than the labour costs, in addition to previous factors, new, resource-efficient factors of competition will decide about the success of a company in the future. Thus, the prices for resources and especially their availability or accessibility will gain more and more importance.

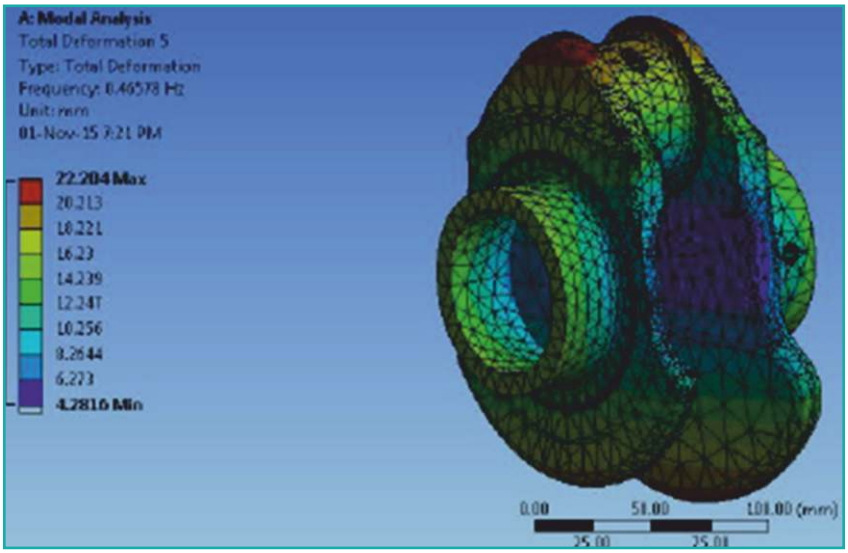
Therefore, sustainable action starts with sustainable production. For this reason, the drivers for progress and innovations in production technology are completed by another topic: resource efficiency. Strategies and approaches leading to efficient use of resources are, e.g. methods for increasing the process stability, the application of efficient technologies, the use of efficient production plants or the optimization of process chains by process integration and combinations.

However, not only product manufacturing can be optimized in terms of resource efficiency using such strategies. There is also the opportunity to achieve corresponding savings in resources in the operation of the product, i.e. during vehicle (truck or tractor) operation. Thus, the consistent use of strategies for lightweight construction in conventional vehicles making leads to a reduction in fuel consumption and also to a reduction in CO_2 emissions.

Considering these aspects, the objective of the planned project is the development of a new, innovative design for lightweight crankshafts segments which offers additional potentials concerning the reduction of the resources used for part manufacturing. Additionally, real prototype segments will be realized by appropriate manufacturing technologies. With the help of the test cycle investigations, achievable effects regarding lightweight design increase of manufacturing efficiency, cost minimization etc. can be proved and further potentials will be estimated. Since the production requirements and conditions (e.g. part numbers, part variants, manufacturing equipment, etc.) will be considered, scalable and re-configurable processes and process chains can be identified to guarantee the later optimum crankshaft manufacturing at OEMs or suppliers regarding lightweight design and manufacturing costs.

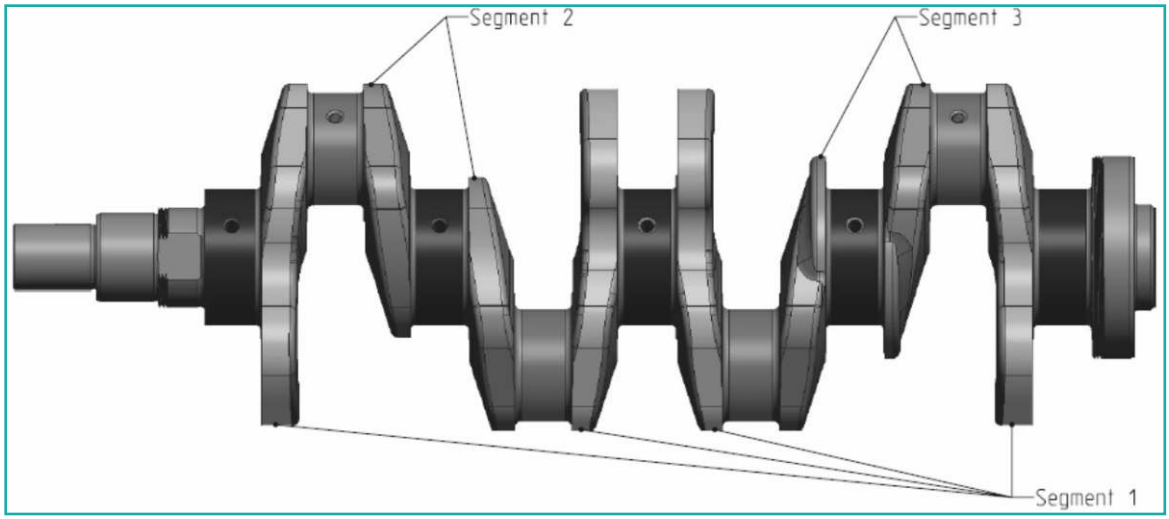
Milestones Achieved

1. Design - Definition of specifications, shaft design, design evaluation (simulation) / optimization
2. Development of Process Chain - identification / evaluation of processes, feasibility studies / optimization, definition of appropriate process chain
3. Realization of prototypes - Design / construction / testing of required tools / rigs, prototyping, optimization loops
4. Evaluation of Prototype Shafts - Prototype tests (test rigs, real cars), identification of optimization approaches, optimization loops



Modal analysis for hollow crank shaft [CSIR-CMERI]

Progress achieved in the progress were base crankshaft finalization, conceptual design and manufacturing process, crankshaft material selection, hollow crankshaft segment dummies, crankshaft geometrical design, prototype manufacturing.

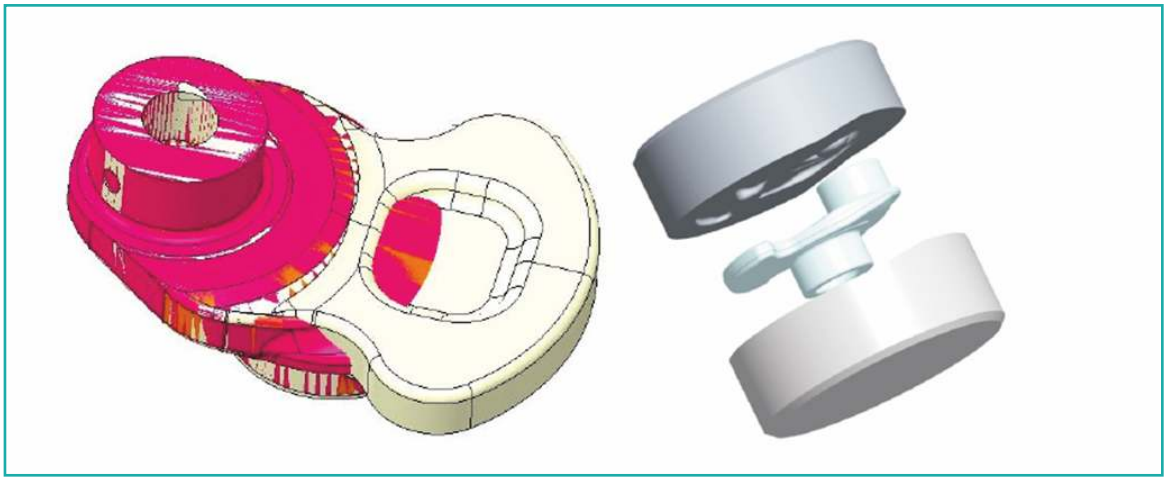


Segmentation of final hollow crank shaft [BFL / Fraunhofer]

Salient Research Achievements

The material selection for hollow crankshaft was done based on several different manufacturing processes (forging, machining and welding) and different involved and required metallurgical parameters. Micro-alloyed steel was found as suitable, because it contains micro-alloying elements which precipitates at higher temperature and restricts uneven grain growth. The resulting grain structure achieved in finely distributed grains without external heat treatments. This resulted into better mechanical and fatigue properties.

In addition the forging die design for hollow crankshaft prototype segments as final step for further geometry definition was made by superposition of all three segment types. By acceptance of intermediate cutting processes, which will be done by partners IWU and Seidel, all segments will be forged with same die geometry (see Fig. below).



Superposition of all three segment types to one master segment [Fraunhofer] and tool making principle [Seidel]

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DP-FORGE

Combined process and alloy design of a micro-alloyed DP forging steel based on integrative computational materials engineering

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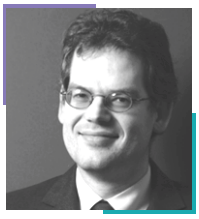

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Project Summary

There is an ever-increasing demand for efficient production of power transmission components with improved power density which are exploited in various engineering sectors including automotive and aerospace industries. Majority of gears used in automobiles industry is manufactured by a process of forging and machining followed by surface hardening by means of carburization, employing case hardening steels. Quenching-induced distortion is a common problem occurring during the application of case hardening process of carburized steel components. This originates from different factors among which the process parameters and the materials chemical composition play a major role. Distortion in gear leads to increased noise. Thus, in order to minimize and control the dimensional instabilities during processing of such components, which require high geometrical precisions in the range of micrometers, there is a serious need for developed materials with modified chemical compositions and also innovative heat treatments. Moreover, to shorten the designing and developing cycle there is no longer any space for using traditional trial-and-error approaches and instead agile methodologies with a holistic view must be utilized. Integrated Computational Materials Engineering (ICME) has shown to be a very promising methodology in order to meet these requirements.

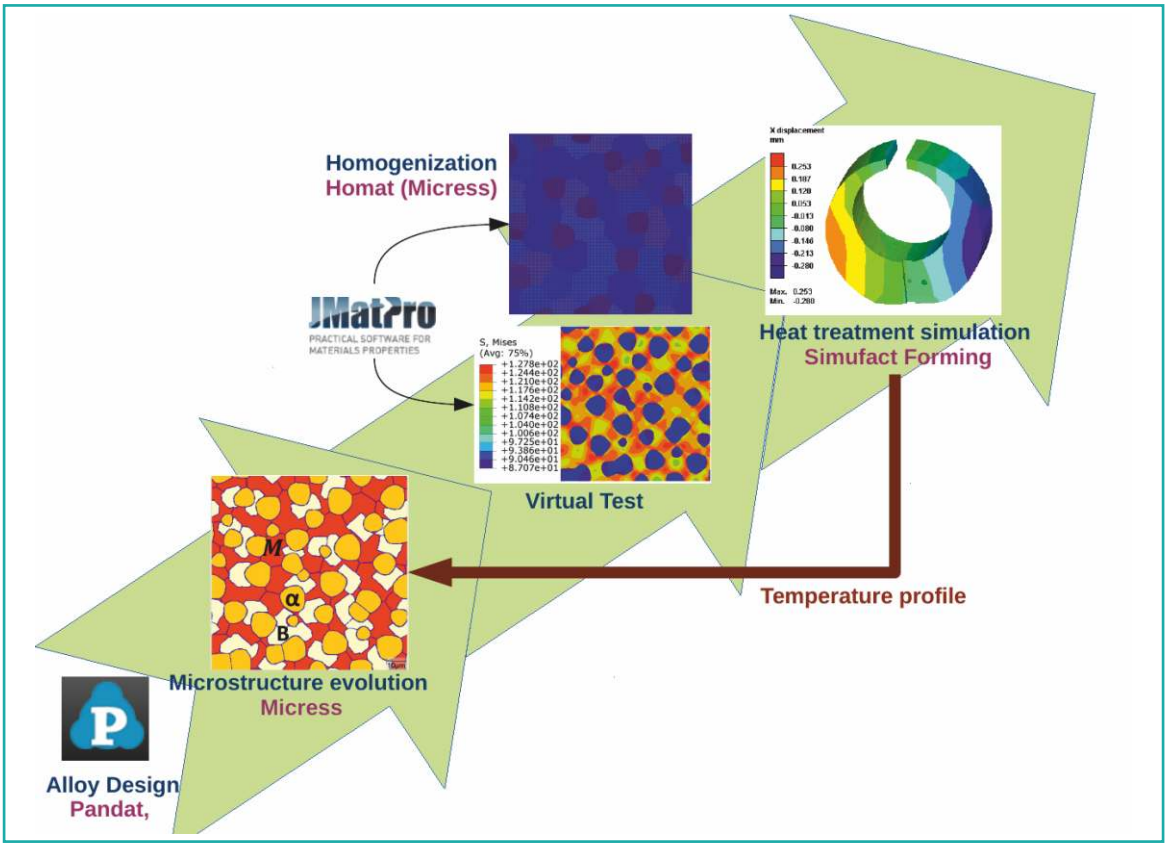
This project aims at the development of an energetic production of forged gears with dual phase microstructure leading to reduced distortion. The material and production design will be realized by means of a generic ICME framework. The scientific approach is based on integrative numerical material and process simulation spanning over length scale from nanometre up to component scale of centimetres. It takes into account all relevant process steps including hot forming, annealing and local final material properties in component in application. This project aims to also illustrate the emerging ICME paradigm that is giving a digital push to the materials engineering domain.

During the first stage of the project, a new chemical composition along with a set of modified heat treatment process parameters were numerically designed in line with the project's objective. The microstructural evolution during the entire case hardening and subsequent heat treatment process was also modeled at a micro-scale level. In this concern,

some of the input parameters such as time-temperature profiles were provided through macro-scale simulations. For the macroscale simulations, inputs from the microstructure simulations were provided through calculation of effective properties by mathematical homogenization and virtual testing. Hence, a multi-scale modelling approach (vertical integration aspect of ICME approach) was adopted. The numerically-developed steel was casted in laboratory scale and subjected to further characterizations required for validation purposes. Later on, during the validation stage, it was shown that by performing the modified heat treatment on the developed steel the quenching-induced distortion can be reduced up to 27% without any loss in hardness and tensile strength of the critical regions (core and case) as compared to the reference heat treatment. Based on the obtained results, the functionality of the employed ICME approached was confirmed.

Milestones and Objectives Achieved

- Numerical design of alloy composition
- Experiments on thermomechanical process simulation
- Microstructural phase and grain size characterization
- Precipitation modelling on Nano scale during hot forming
- Microstructure evolution modelling during thermomechanical processing
- Microstructure transformation modelling during cooling
- Model implementation and parallelization
- Linking of models
- Multiscale modelling of hot forming process chain
- Benchmark and validation trials



Vertical Integration workflow for ICME approach

Salient Research Achievements

- This project has supported the acquiring and maintenance of several software tools and hardware at the Department of Metallurgical and Materials Engineering, IIT Madras. This has helped the department to reach a better level for implementation of any ICME work in future. This project is the first ICME project in India. Thus, MME can act as a nodal point for further propagation of relevant projects.

- This project has supported formation of the Laboratory for Integrated Computational Materials Engineering at the Department of Metallurgical and Materials Engineering, IIT Madras. This is the first lab on ICME in any academic institute in India. The lab presently hosts more than 35 students in MME who work in a collaborative environment.

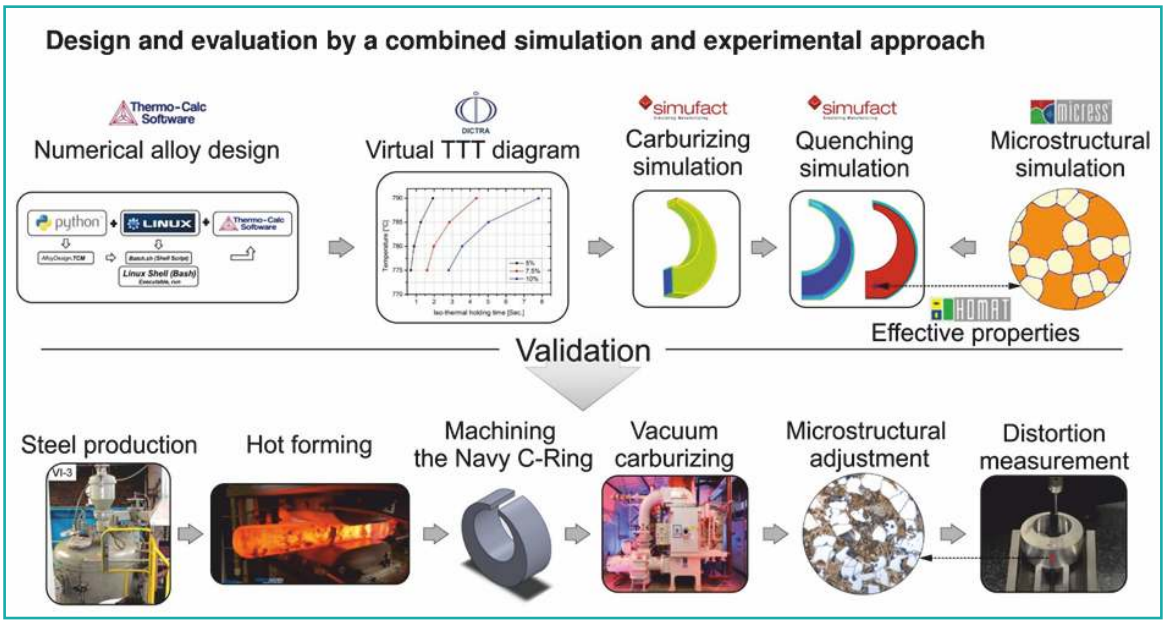
- Through the project, the students in MME has got the opportunity to attend international conferences, workshops, training programme and summer school. These events and the follow-up activities has helped the Department in improving itself in the area of ICME.

- Utility of TCS PREMAP as a ICME enabling platform was demonstrated with the help of this project. The TCS team got opportunity to interact with academic partners which helped in enrichment of our approach towards development of next generation platform for materials and product engineering.

- Through this joint project, IEHK has managed to boost its expertise in the field of ICME technology and get benefited by direct collaboration with the Indian and German partners. Thanks to this joint project, the level of transferable knowledge to the young researchers has substantially increased where many young researches got involved in this project and well trained who can serve during the further projects.

- This project enabled Simufact to include the simulation of diffusion and thus casehardening processes into Simufact Forming. A main driver for this was the collaboration with the project partners. It enabled Simufact to gain and to implement up-to-date scientific findings and to use an experimentally proven process to validate the new functionality. The feedback of the project partners was a valuable source for corrections and improvements. Shortly after the end of the project, Simufact released a new version of Simufact Forming which made the case hardening functionality available to the public.

- Within the project, a full software development cycle starting from a specification of technical necessities and resulting in a software module ready for industrial use has been fulfilled. Nevertheless, this is not the end of the development. Further improvements of the software (Simufact Forming) are still desired to enhance the applicability to industrial processes. Moreover, enhancements to the mesh generation algorithms need to be considered in order to enable a fully automated meshing of complex structure with a mesh capable to capture the high gradients near the surface which are typical for case hardening processes.



Future Outlook

An energy-efficient DP steel to be employed in power transmission applications such as automotive gears with reduced distortion was designed and the distortion levels were examined through Navy-C ring specimens. ICME was used at various stages to help in the design process. The ICME workflows used for the alloy design and for simulations at various length scale got wide appreciation at different venues. The limited mechanical property analysis on the material, carried out in this project reveals promising results. Continuation of the work could be planned with an automobile gear manufacturer with more focus on the mechanical properties of the newly developed class of alloys and implementation in Automobile Industry. In this context, a visit was undertaken to Shanthi Gears Ltd. at Coimbatore, India for discussion on the possible implementation of the project outcomes in Indian gear manufacturing sector. With further mechanical property analysis, the material and the process could be implemented in the automobile gear manufacturing industry.

Publications

1. Deepu Mathew John, Hamidreza Farivar, Gerald Rothenbucher, Ranjeet Kumar, Pramod Zagade, Danish Khan, Aravind Babu, BP Gautham, Ralph Bernhardt, G. Phanikumar, Ulrich Prahl. An attempt to integrate software tools at microscale and above towards an ICME approach for heat treatment of a DP steel gear with reduced distortion, Proceedings of the 4th World Congress on Integrated Computational Materials Engineering (ICME 2017), pp 3-13 (DOI: 10.1007/978-3-319-57864-4_1).
2. M.J. Deepu, H. Farivar, U. Prahl, G. Phanikumar. Microstructure based simulations for prediction of flow curves and selection of process parameters for inter-critical annealing in DP steel, IOP Conference Series: Materials Science and Engineering, Volume 192, conference 1 (DOI: 10.1088/1757-899X/192/1/012010).
3. Farivar, H., Rothenbucher, G., Prahl, U., Bernhardt, R. ICME-Based Process and Alloy Design for Vacuum Carburized Steel Components with High Potential of Reduced Distortion, TMS ICME 2017 to be held in Michigan, USA from 21st to 25th May, 2017 (DOI: 10.1007/978-3-319-57864-4_13).

4. Farivar, H., Richter, S., Hans, M., Schwedt, A., Prahl, U., Bleck, W., 2018. Experimental quantification of carbon gradients in martensite and its multiscale effects in a DP steel. Materials Science & Engineering A: 718, 250-259 (DOI: 10.1016/j.msea.2018.01.106).

5. Farivar, H., Prahl, U., Hans, M., Bleck, W., 2018. Microstructural adjustment of carburized steel components towards reducing the quenching-induced distortion. Journal of Materials Processing Technology (DOI: 10.1016/j.jmatprotec.2018.08.040).

6. Ralph Bernhardt and Georg J. Schmitz, Overview of Processing Methods and Process Chain, in: Georg J. Schmitz (Editor), Ulrich Prahl (Editor): Handbook of Software Solutions for ICME (DOI:10.1002/9783527693566).

Public relation activities

Conference Presentations

1. An attempt to integrate software tools at microscale and above towards an ICME approach for heat treatment of a DP steel gear with reduced distortion,4th World Congress on Integrated Computational Materials Engineering (ICME 2017), Ypsilanti, Michigan, USA. (21-25 May, 2017).

2. A study on the effect of incorporation of microstructure information on macroscale finite element simulation of inter-critical annealing in Dual Phase Steel, Material Science and Engineering (MSE) Congress 2016, TU Darmstadt, Germany. (27-29 September, 2016).

3. An ICME approach towards the design of a new gear steel with reduced distortion, Heat Treatment and Surface Engineering (HT&SE) conference 2016, Chennai, India. (12-14 May, 2016).

4. Farivar et al., On the role of prior austenite carbon inhomogeneity on martensite transformation kinetics in a low alloy dual phase steel, 15th European workshop on modern developments and applications in microbeam analysis (EMAS 2017), Konstanz, Germany (07-11 May 2017).

5. Farivar, H., Rothenbucher, G., ICME-based process and alloy design for vacuum carburized steel components with high potential of reduced distortion, 18th Simufact RoundTable, Marburg, Germany (30.05-01.06 2017).

6. Farivar et al., Quantification of the effect of heterogeneous carbon distribution in prior austenite in a low carbon low alloy DP steel, European congress and exhibition on advanced materials and processes (EUROMAT 2017), Thessaloniki, Greece (17-22 September 2017).

7. Farivar et al., On the role of ferrite in suppressing the quenching-induced distortion of carburized steel components, European congress and exhibition on advanced materials and processes (EUROMAT 2017), Thessaloniki, Greece (17-22 September 2017).

Seminars Delivered

1. Seminar on 'ICME for DP steel Gear with Reduced Distortion' at Ohio State University, Ohio, USA (30th May, 2017).
2. Seminar on 'ICME based Microstructure and Property Evolution Simulation in DP Steel' at AK Steel Research and Innovation Center, Ohio, USA (1st June, 2017)
3. Seminar on 'ICME for DP steel Gear with Reduced Distortion' at NIST, Maryland, USA (20th June, 2017).
4. Seminar on 'Microstructure and Property Evolution Simulation towards Integrated Computational Materials Engineering (ICME)' at Aditya Birla Science and Technology Company (ABSTC), Mumbai, India (29th March, 2018).

PhD\Master thesis supervised

1. Master Thesis (M.Tech): Aravind Babu, Simulation and experimental validation of residual stresses in multi-phase steels, Indian Institute of Technology Madras.
2. Master Thesis (M.Tech): Durgesh Kumar, Thermodynamics and kinetics calculation for multicomponent alloy design and development towards an ICME approach, Indian Institute of Technology Madras.
3. Master-Thesis: Shima Ansary (Matr. –Nr. 341745), Microstructure-mechanical properties correlations of intercritically annealed low carbon quenching and partitioning (Q&P) steel. Student was supervised by M. Sc. H. Farivar, Dr.–Ing. U. Prahl, RWTH Aachen University, Department of Ferrous Metallurgy.
4. Two doctoral theses, one by Mr. Hamidreza Farivar at RWTH Aachen and one by Mr. Deepu Mathew John at IIT Madras are in progress.

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WATER & WASTEWATER TECHNOLOGY

CANDECT

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

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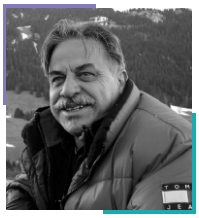

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Project Summary

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 present a vast, hugely unexplored and scientifically challenging market. The development of suitable sensor technologies using advanced materials that can be integrated to hand-operated pumps or decentralized water supplies is the subject of this proposal. The 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 i-phones. Atomically precise clusters with specific interactions with inorganic and organic contaminants developed by IIT Madras for 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 select 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 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 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 (Ag29(BDT)12(TPP)4) and its analog i.e. Ag29@DPPP were synthesized (BDT, 1,3-benzenedithiol; TPP, triphenylphosphine, DPPP, 1,3 Bis(diphenylphosphino)propane).

- Characterization of clusters was done with ESI MS (Electrospray Ionization Mass Spectrometry) to determine its size and composition precisely at the atomic level.

- Optical and luminescence properties of clusters were studied by UV-Vis absorption and photoluminescence spectroscopy.

- Influence of arsenic (As) on these luminescent entities was investigated which showed promising results. We are currently working on enhancing the required interaction among the species.

- Cluster-As interaction in carbonate buffer medium resulted in the decrease in the intensity of cluster luminescence and indicated the possibility of the reduction of As(V) to As(III) in presence of phosphine ligand.

- Hence, the mechanism behind the change in the luminescence of Ag cluster is currently being studied in detail with the help of techniques like ion chromatography which specifically quantifies As(V).

- The reduction mechanism of As(V) getting converted to As(III) in the presence of phosphine in the cluster system is suspected and being evaluated.

- Some phosphine ligands which were specific towards As have been identified and attempts to synthesize them are in progress. This is done so that these specific phosphines can be incorporated in the luminescent cluster systems to achieve better sensitivity towards As.

- After evaluating multiple methods for the fabrication of cluster-fiber composite, the method to immobilize luminescent materials on nanofibers by electrospinning has been identified.

Better sensitivity of the cluster towards As and repeatability of the fluorescence experiments will be achieved by systematic experiments. The solution phase cluster-As interaction will be transferred to solid phase so as to use the cluster immobilized- electrospun nanofibers for luminescence based sensing of As in contaminated water.

Partner 2 – KIT

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

- Various designs available for luminescence based sensing and readout using mobile attachment were evaluated and approaches necessary to implement the same in present project were identified.

- Various electronic hardware components necessary for the building of mobile attachment were identified.

- Design for sensor holder was made. Prototype was 3D printed.

- Various components of filter excitation and readout methodology were integrated with smartphone. An android app was developed for sensor readout using smartphone camera.

- Water samples from various sites in West Bengal, India were collected and analyzed using ICP-MS 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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FEC-ONLINE

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

Project Investigators

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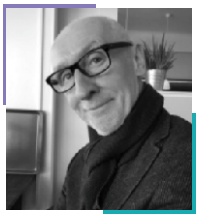
New Delhi



Wido Schmidt
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Christian Moldaenke
bbe Moldaenke
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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

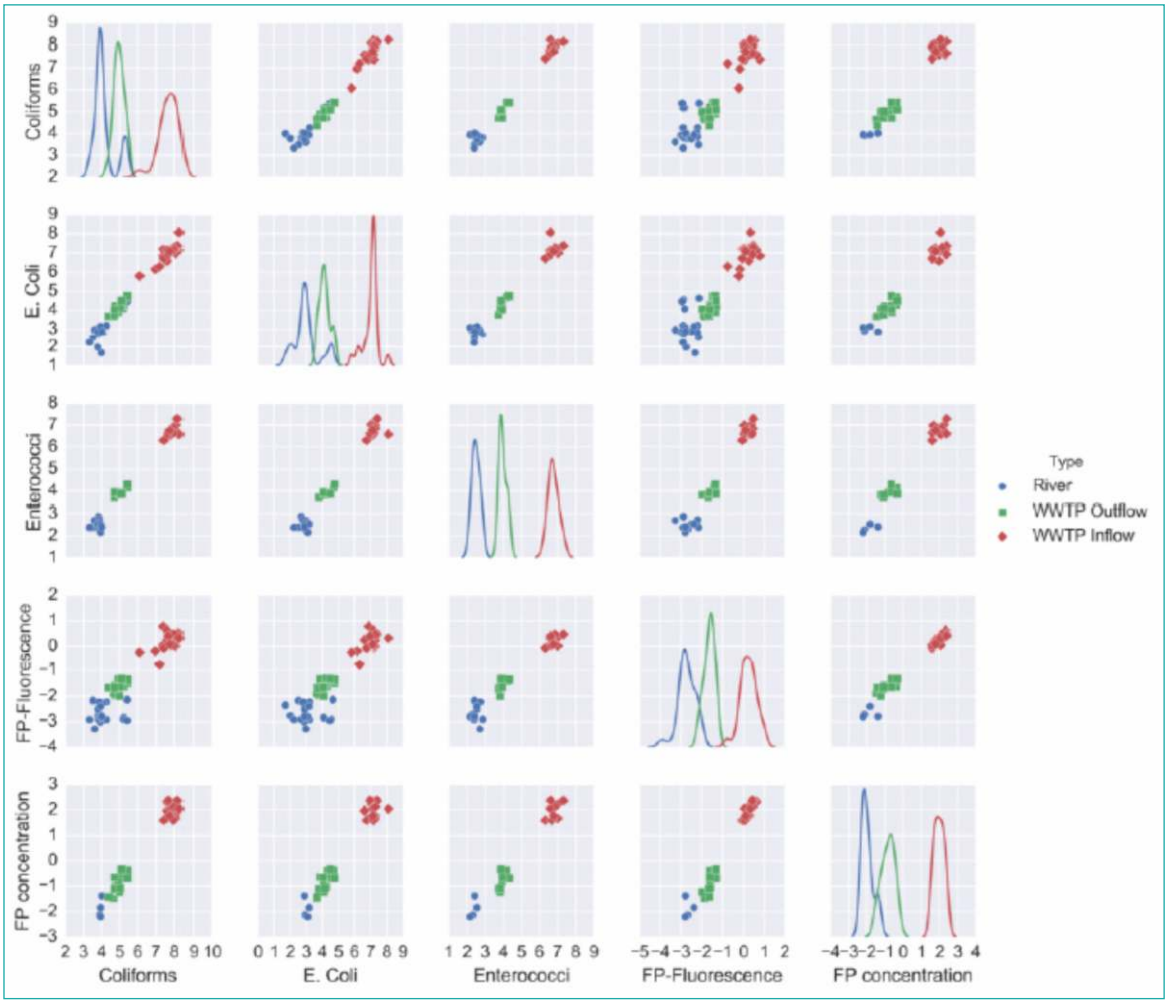
Progress made/achieved

Partner 1 – TZW

- Improvement of the fluorescence-based method to detect fecal pigments
- Application of the improved method in frame of an environmental monitoring program.

An LC-MS methodology was developed as an independent referenced method for the detection of urobilin and stercobilin. First of all, the sampled is enriched using SDB-cartridges. The analysis of the sample and the quantitative evaluation is then carried out on the basis of the characteristic mass transitions for stercolibin and urobilin.

As part of a monitoring program, the method was tested on real samples. For this purpose, samples were taken from the inlets and outlets of two sewage treatment plants and from the receiving waters belonging to both plants (downstream) in a weekly, later bi-weekly interval. The described fluorescence as well as LC-MS analyses were performed for all samples as well as the determination of the microbiological parameters coliforms, E. coli (Colilert-method, DIN EN ISO 9308-2 and Enterococci (Enterolert- method, alternative method according to FEA (Federal Environmental Agency)-list).



Correlation between the parameters Coliforms, E. Coli, Enterococci, FP fluorescence and FP concentration. All values are shown on a logarithm scale. The microbial parameters are in n/100 mL, the FP fluorescence Raman units the FP concentration µg/L.

Partner 2 (IITM)

Objectives for IITM:

- Calibration of FP in water (WP2)
- Software for identification and quantification of FP in water using fluorescence (milestone, WP2)
- Evaluation of the whole unit (milestone, WP6)

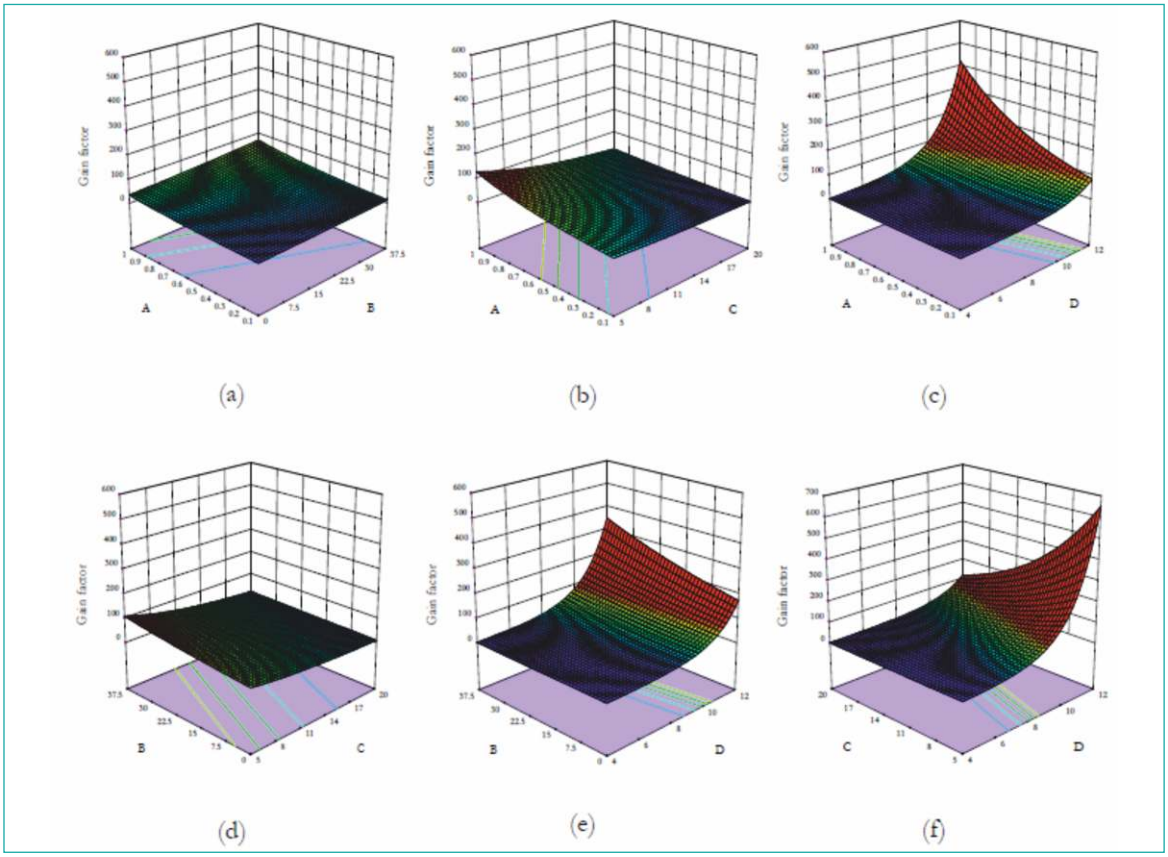
The Overall Summary of research carried out at IITM are as follows:

The photophysical study of UB-Zn had been carried out during the first year of the project. A similar comprehensive photophysical study of Stercobilin-Zn complex was carried out. It was identified that aggregation of the pigment as well as the complex is responsible for the fluorescence related changes.

Ethanol: water (6:4 v/v) was identified to be the best medium for (i) significantly reducing decay of fluorescence intensity of the complex with time, (ii) enhancing the fluorescence of the complex, when [Stercobilin] ~10-6 M, and [Zn++] = 3 mg mL-1 (almost saturated).

To overcome the aggregation problem and issues involved in the higher ethanol: water ratio, a combination of cocktail is optimized and the best possible combination can be drawn for pH 10.3 with 10% ethanol in double-distilled (DD) - water, DH10-water and DH20-water. (DH: Degree of water hardness)

The best possible combination for enhancement of fluorescence sensitivity as well as highest intensity is shown at pH 10 with a variation in concentration of Stercobilin and Zinc as well as water hardness and pH to figure out the highest enhancement of fluorescence intensity. This data was illustrated in a central composite design model, which shows how the combinations of all four named factor act within this design space.



3D- surface defect plots showing the defect of (a) A: Stercobilin (mg/L) and B: Zinc (mg/L), (b) A: Stercobilin (mg/L) and C: hardness (°dH), (c) A: Stercobilin (mg/L) and D: pH, (d) B: Zinc (mg/L) and C: hardness (°dH), (d) B: Zinc (mg/L) and D: pH, and (f) C: hardness (°dH) and D: pH. The factors were set at A: Stercobilin 0.75 mg/L, B: Zinc 25 mg/L, C: hardness 12.5, D: pH 10.(IITM)

IITM has also studied the defect of various associated matrix defects like time, temperature, light, pH and dissolved gases on fluorescence intensity of Stercobilin Zinc complex (SB-Zn). This essentially enabled to understand and implement a tight control over the parameters during real-time analysis of surface water.

Towards the second objective, Software for identification and quantification of FP in water using fluorescence; the development of the software for the instrument being designed, will be carried out at bbe as a part of instrument development. The software will implement the results from all calibration steps obtained by IITM, TZW and Spectro.

Partner 3 (Spectro)

The main activities of Spectro in Fec-Online in 2017 were the monitoring program using the analytical standard procedure. In a first step the calibration and recoveries of stercobilin and urobilin were determined. The measurement program in Indian water of different origin followed. As a result of a regularly monitoring of waster- pool- and river waters, a waste water location was selected for a regularly monitoring.

The main important outcome can be concluded as follows:

1. Initially Spectro followed the SOP provided by TZW, wherein we found the 82% recovery at 50ppb level, done in MilliQ water.

2. After some revision in pre-concentration, an improved recovery percentage with good chromatographic peak shape (urobilin) was reached.

3 The work for improving the stercobilin peak shape is still in progress.

4. A suitable monitoring place was defined after controlling several pool-, waste and river waters.

Partner 4 (bbe)

The part of bbe in the project is dealing with sensor design and transfer of suitable technique for improvement of fluorescence sensitivity into field conditions.

bbe Moldaenke finished the development of the first demonstrator of the online instrument

Salient Research Achievements

- Stercobilin occurs regularly in µg/L-level in municipal waste waters in Germany and India. In India also, river water can show this level.
- The removal deficiency of FP in waste water treatment was determined to be very high (approx. 3 log stages (99.8%).
- A further log staged reduction is determined between outflow of waste water and river water, there the FP-concentration was determined about 10 ng/L (Germany).
- There is a strong linear correlation between FP-concentration (LC-MS), FP-fluorescence and the cell count of Enterococci, E-coli, and Coliforms.
- Because of its high stability, stercobilin functions as indicator in case of fecal contamination of water.
- The sensitivity of fluorescence can be increased up to ng/L-level in case of Zn-addition to 10 % ethanol / 90% water mixture.
- bbe-designed and manufactured a prototype of a field sensor with manual sample preparation.
- The enhanced analytic determination by further porphyrine- like FP- structures by LC-MS is in work. In a first step of this work segment is the calibration including the analytical recovery of 11 metabolites in different water matrices.
- The student exchange (Bachelor/Master/PhD) between TZW and IITM was continued.

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MULTI-WAP

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

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Project Summary

The main aim of the project is to develop cost-effective, multiplexed label-free fiber optic array biosensor system for simultaneous detection of up to 7 or more waterborne pathogens that are prevalent in Indian sub-continent. 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 analytical/diagnostic platform to be developed is an optical absorbance biosensor, with the prerequisite of having the ability to perform online measurements. Our ambition is to improve the analytical method further to function as a highly efficient screening method for the early detection of life-threatening waterborne diseases in resource-limited settings. This project addresses a clearly identified need for tests which can significantly surpass the performance of the currently available water monitoring tests. Throughout this project, special attention will be paid to both end-user requirements (performance, cost, ease-of-use) and to manufacturability. The combination of low cost and high accuracy will be achieved through a unique integration of several state-of-the-art concepts, which the partners have separately developed and of which the integration maturity in Multi-WAP platform has to be tested.

IIT (Madras) shall develop the novel fiber optic sensor array with optoelectronic instrumentation and software. The German Research partner (IOT, Braunschweig) shall perform critical surface modifications of the fiber probes. The German industrial partner (LIONEX) shall produce highly specific antibodies to surface biomarkers of E. coli as model analytes and for waterborne faecal pathogens as final arrays followed by their immobilisation on biosensor. The Indian industrial partner (ubio) shall integrate in the device assembly and evaluate the final lab-device using model and pathogen contaminated water samples (along with LIONEX). LIONEX shall do evaluation and compare the sensor performance with industry standard. Today, there are no analytical methods on the market that fulfil the criteria of being rapid, accurate, label-free, and online for the detection of waterborne pathogens. This is especially true when it comes to screening situations or the performance of diagnoses in resource-limited settings.

Technical work done: IITM has made progress as per the proposed work packages WP1 and WP5. A more efficient 3rd generation automatic fiber bending machine is developed to fabricate U-bent fiber optic probes. The

repeatability of the probes was verified. A biosensor with simulated analyte, ie Immunoglobulin G (IgG), is realized as proof of the concept. A design for optoelectronic instrument for array biosensor was realized.

IOT has made progress as per milestones by the end of 16 months upon work on functionalization of quartz slides and quartz-fiber optic light guides. Plasma treatment conditions and silanization conditions were investigated. Silanization conditions which are suitable for industrial application were developed. Optimization process is still in progress with model objects (quartz slides) and with U-bent lightguide probes. Development of a thermostatic discharge and treatment chamber for silanization at controlled elevated temperature is in progress.

ubio start stablishing the protocol for validating of the model antibody from LIONEX. Moreover, ubio will send also the available Vibrio cholera antibody to LIONEX for characterization.

In this period of report at LIONEX, a first batch of anti-non-pathogenic E. coli and anti-LAM was produced. Purified antibodies were subjected to extensive quality control. Moreover, data reveals that anti-LAM IgM has KD below 10-9 M which means this antibody possesses high affinity towards mycobacterium Avium complex LAM. The genes of the membrane – bound antigens OmpA and Eae from E. coli O157:H7, FimH and FliC from Salmonella enterica subsp. enterica, Blc from Vibrio cholerae, IcsA and IpaB from Shigella dysenteriae; MyfA from Yersinia enterocolitica subsp. enterocolitica and FlaA and CadF from Campylobacter jejuni subsp. Jejuni were cloned and purification of final arrays biomarkers and antibodies is progressing well.

Progress made/achieved

Partner 1: IIT Madras

OB1.1: Fabrication of highly-sensitive identical U-bent probes

OB1.2: Evaluation of fiber optic sensor probes in terms of refractive index (RI) sensitivity

OB1.3: Evaluation of sensor probes using simulated analytes

OB1.4: Design of fiber probe array cartridge and optoelectronic instrumentation for multi-pathogen biosensing

OB5.1: Fabrication, assembly and calibration of first generation Lab-Prototype instrument.

OB5.2: Optoelectronic instrumentation and sensor cartridge platform evaluation

Milestones related to Objectives 1.1, 1.2 and 1.4 have been achieved as per the proposed plan. Work as part of Objectives 1.3 is yet to be complete as the work plan. Stage III evaluation Photometric analysis with UV-LED and UV-enhanced CCD is yet to be realized . This delay in the execution of work was mainly due to the delay in the installation of multi-channel spectrometer that was neessary for the stage II evaluation. However, work under Objectives 5.1 and 5.2 are initiated during M12 as per the plan.

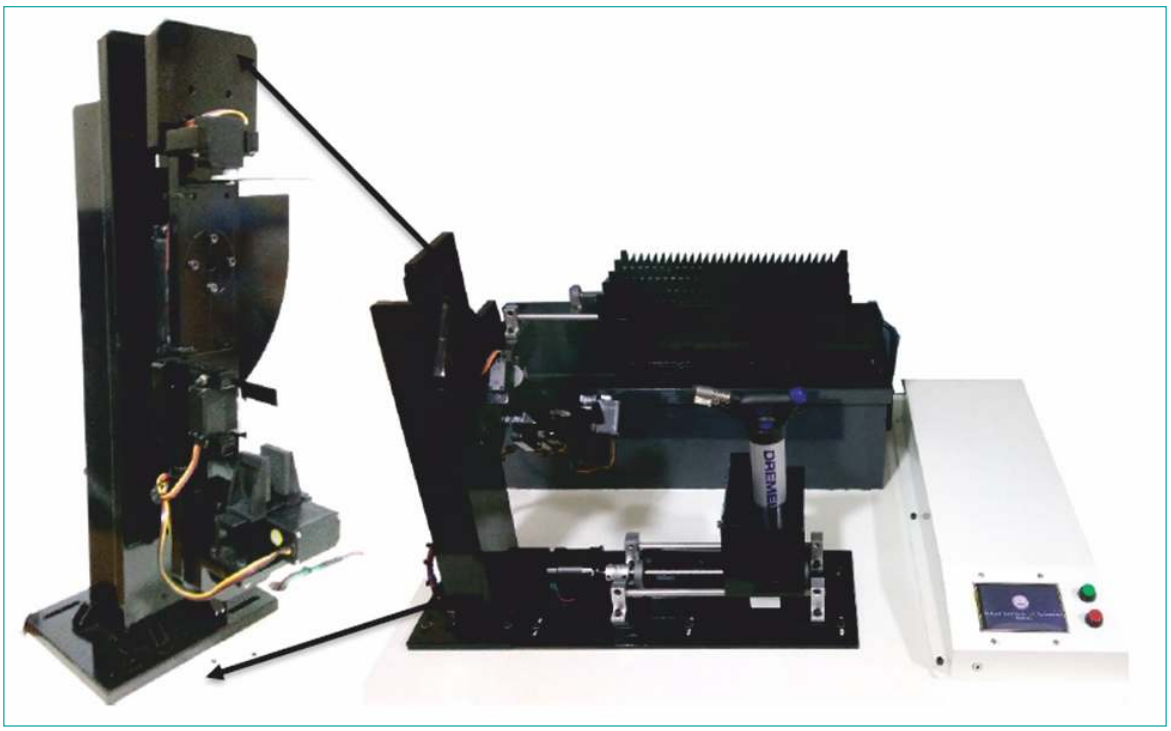


Fig. Automatic Fiber bending machine

Partner 2: ubio Biotechnology Systems Pvt Ltd.

ubio started stablishing the protocol for validating of the model antibody from LIONEX. Moreover, ubio has already one antibody against Vibrio cholera and this particular antibody will be send to LIONEX for affinity measurement and full characterization.

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

Optimized conditions

Plasma treatment

- Gas mixture: Ar 6.0 2 SLM, Ar 6.0 saturated with H2O vapor 0.2 SLM, water partial pressure in gas mixture 5 mbar at 25 °C. Linear gas velocity 1 m/s.
- DBD reactor dimensions: Gas gap 1.6 mm thick, 21 mm wide, 2 quartz dielectrics of 1.6 mm thickness, AC voltage: 86 kHz, 9.5 kV.

Gas-phase silanization:

Gas mixture:

- With (3-Aminopropyl)trimethoxysilane (APTMS): Ar 6.0 saturated with APTMS vapor 0.2 SLM, APTMS partial pressure in gas mixture 0.5 mbar.
- With (3-Aminopropyl)triethoxysilane (APTES): Ar 6.0 saturated with APTES vapor 0.2 SLM, APTES partial pressure in gas mixture 0.2 mbar.

Silanized probes were cross-linked in oven at 115 °C within 1 h before further experiments. Gas-phase derivatization of silanized samples was provided in closed vessel at 80 °C (oil bath temperature) at residual pressure of 1 mbar over 0.1 g of p-nitro-benzaldehyde within 1 h. Derivatized samples were rinsed twice with methanol and then sonicated in methanol within 3 min., dried in nitrogen gas stream before measurements.

Samples

Quartz slides of 10 mm x 20 mm or 15 mm x 35 mm dimension (1.1 mm thick, GVB GmbH, Germany) as well as U-shaped probes made of commercially available quartz lightguides (200 µm diameter, FT200UMT, ThorLabs, USA) bent by IIT were used for experiments.

Results

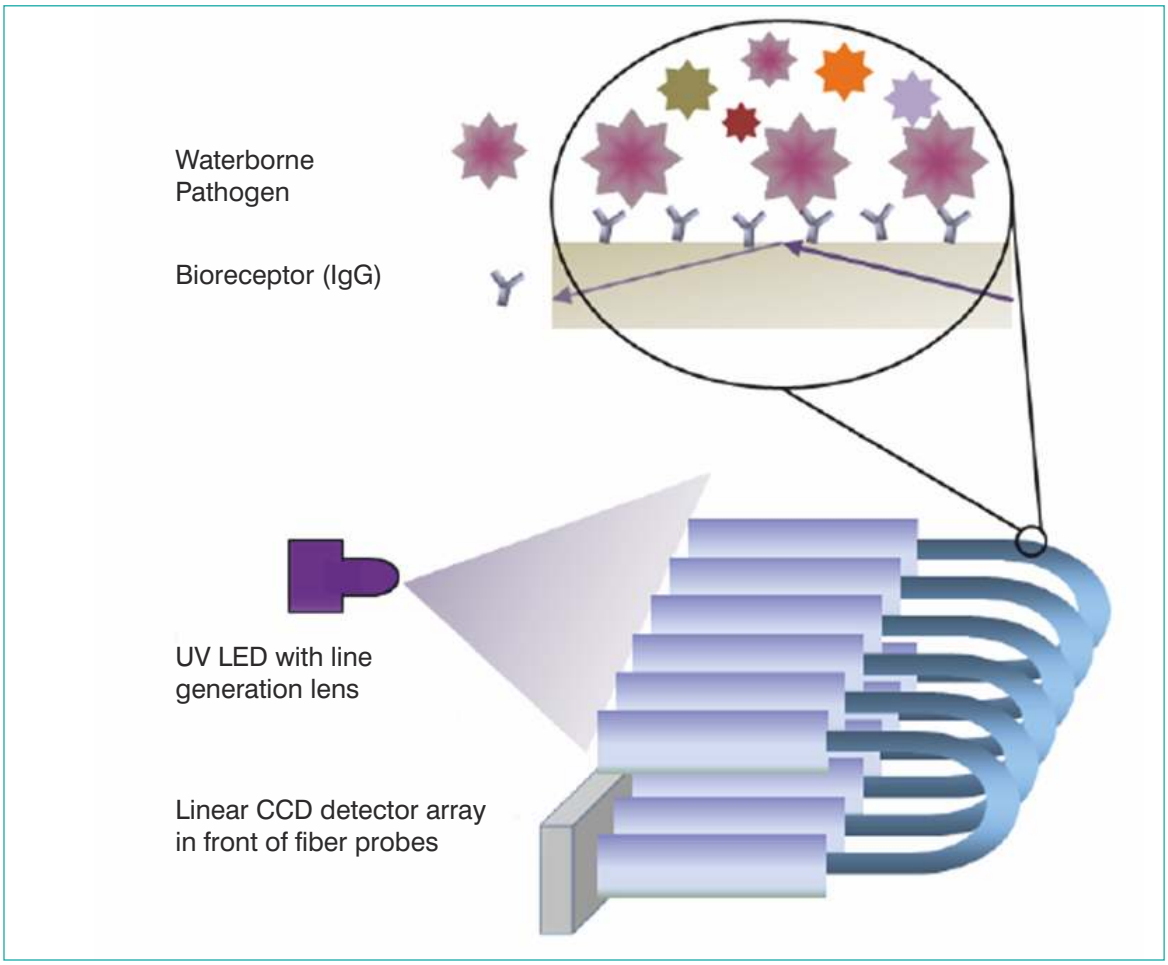
UV-Vis spectra were obtained on Agilent Cary 5000 instrument for quartz slides and Avantes fiber AvaSpec 2048L spectrometer with AvaLight-DHc light source equipped with ATT-DA fiber optic attenuator for lightguides. All measurements were done in air at ambient temperature.

Partner 4: LIONEX

- The first batch of the model E.coli antibodies were successfully produced and intensive QC analysis was done. These antibodies will be used as model analyte for Multi-WAP platform.
- High quality of anti-LAM antibodies was produced with high affinity (KD below 10-9 M) toward Mycobacterium avium complex LAM. These antibodies will be used also as model analyte for Multi-WAP platform
- The production of the quality controlled biomarkers for the real arrays for waterborne pathogen under progress; several biomarkers were already produced during the last period and sent to immunization.

Salient Research Achivements

- A novel mechanism for fiber bending is developed that efficiently reduced the CO2 laser exposure times and improved repeatability of the U-bent probe geometry. A large number of U-bent probes as many as ~200 nos are fabricated and about 90 probes have been shared with the partners for further work.
- Experiments on evanescent wave absorbance (EWA) measurements from U-bent probes show good sensitivity in detection of proteins such as IgG as low as 10 ng/mL. Further studies are necessary to establish this novel concept of EWA based label-free protein detection at 280 nm wavelength.
- A compact optoelectronic instrumentation unit for array biosensor



Schematic showing the proposed multiplexed, label-free fiber optic array biosensor for detection of waterborne pathogens. The sensor works on principle of light intensity changes due to increase in evanescent field absorption by specific-binding of pathogens to antibodies immobilized on highly sensitive U-bent fiber probes (Sai et al., 2009). The 'U' portion of U-bent probes of certain fiber core and bend diameters (silica fiber, 0.2 mm and 1.5 mm) or (PMMA fiber, 0.5mm and 1.5 mm) is decladded and coated with bioreceptors. A probe array is placed rigidly into a slot that allows easy light coupling from UV LED into one end of the probe and onto CCD from other end of the probe. The array is exposed to water samples after noting the reference signal. The proposed array of 8 or 12 probes could be more compact, ergonomical in design, and be exposed to a single sample simultaneously

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WATERCHIP

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

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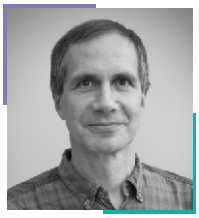

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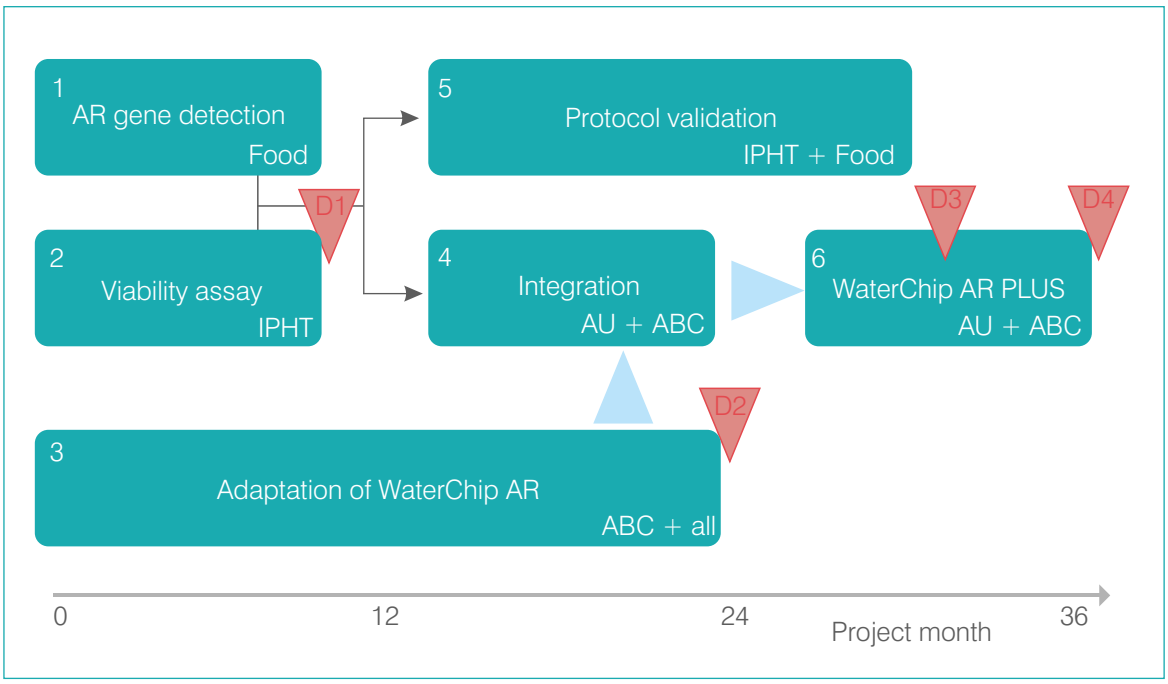
Project Summary

Globally, nearly 6,000 children die each day due to water-related illnesses. Treatment based approaches must be implemented to minimize these deaths. Rapid (< 1 hr) detection platforms covering most waterborne pathogens of concern, their indicators, and associated sources of antibiotic resistance bacteria on a single chip are urgently needed. Such platforms must be operable under field conditions with personnel requiring minimal training. This proposal focuses on such a multiplexed chip by adapting an already developed robust and low cost platform (WaterChip AR) for on-site water pathogen detection. Genetic markers associated with at least a dozen waterborne pathogens, indicators, and antibiotic resistance bacteria are 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. When fully developed and validated, the chip and platform will provide a number of key benefits compared to other existing technologies and approaches including fast results, ease of use, specificity, sensitivity, and low cost. Differentiating characteristic compared to other molecular biology technologies include multiplexing of bacteria and protozoan, use of multiple virulence markers, live vs. dead differentiation, and measurement of antibiotic resistance genes. The consortium combines academic and industry partners with expertise in molecular biology, bioanalytics, and on-site detection technology development.



Scheme of the work flow packages

Progress made/achieved

Partner 1 - Ahmedabad University

WP1: Protocols for AR gene detection ; WP2: Development of cell viability assay

Studies were continued under work package 1 & 2. In the earlier activity, set of primers were designed using PrimerExplorer V5 for LAMP for selected target organism with specific markers: E.coli (eaeA, stx2), Shigella spp. (ipaH), Legionella pneumophila (dotA, lepB), Cryptosporidium parvum (Hsp70, Gp60), Giardia intestinalis (beta-giardin) along with primers for ARGs: Carbapenem (KPC and NDM), Tetracycline (tet-M).

Validation of the designed primers were carried out using cells and/or DNA standards for the organisms that were either commercially available or available within ILS-AU as confirmed isolates from previous work (Fig 1A). Additional primers not listed above (e.g., for Klebsiella pneumoniae khe gene and for Legionella pneumophila 16S rRNA gene) were also designed and used.

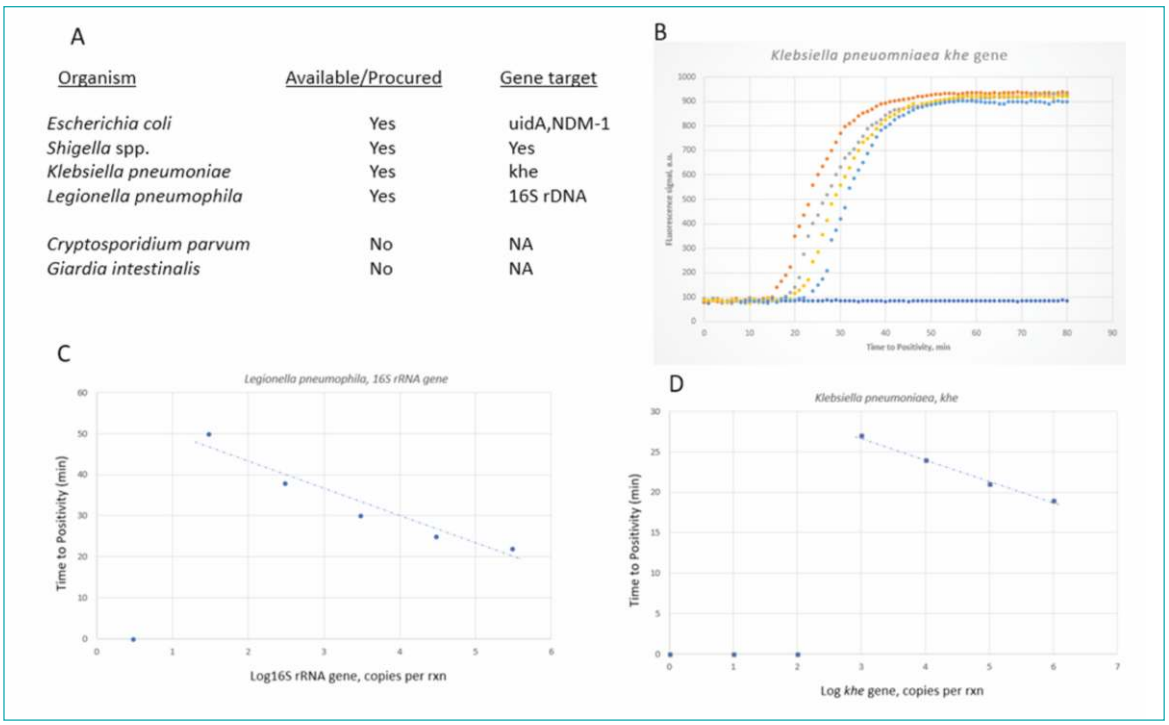


Figure 1. List of organisms available at ILS-AU and gene targets for which the primers have been designed (A); example of an amplification curve for Klebsiella pneumoniaea khe gene (B); standard curve and lower limit of detection of K. Pneumoniaea (C); and standard curve for an organisms where 16S rRNA gene was used as target - Legionella pneumophila (D).

Partner 2 - ABC

WP3: Provision of WaterChip AR platform (ABC Genomics)

Under this work package, the team has to accomplish the following four tasks activities to be between months 1-24 by ABC Genomics.

- Production of WaterChip AR platform as well as cartridges
- Provision of a WaterChip AR platform per partner
- Delivery of cartridges for partners
- Development of adapted cartridges for viability tests

Towards the first task (Production of WaterChip AR platform as well as the cartridges), ABC has identified an electronics device manufacturing company in New Delhi, India and has gone through two cycles of development and prototype testing. Work has been completed on internal components required (PCB, heater, excitation and emission sources and readings, optical fiber and photodiode assembly, and data transfer using BLE). Compared to the originally planned date, there has been considerable delay in this task because of several factors including i) problems in procuring small items due to GST and demonetization, ii) changes in the design of the PCB, iii) changes in the enclosure design, and iv) delay in procurement of CO_2 laser-which was needed to fabricate the microfluidic chips. These bottlenecks are more or less resolved now, and we are hoping to get our first working version by the end of October 2018.

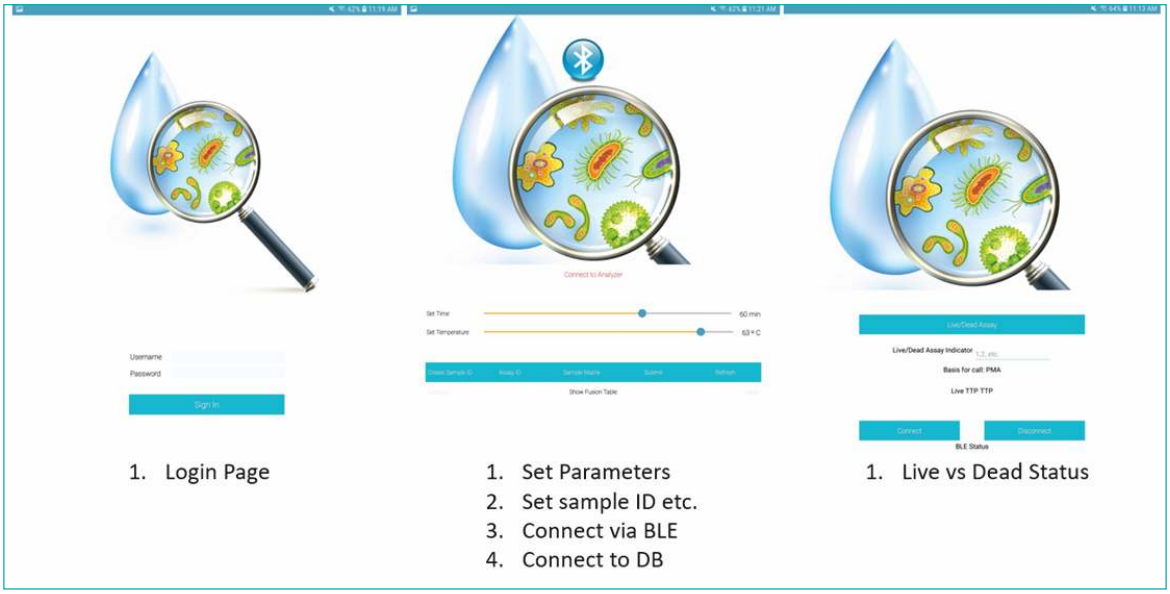


Figure 2. Screenshots from Water Chip App (Tablet version). This App also includes information about the antibiotic resistance markers. Viability assay status functionality is being added at present.

The associated App for control, reading, and processing of WaterChip AR platform with on an Android system for the water chip (currently called Water Chip App to be consistent with the proposal but the name may change at the time of product launch) is ready (Fig 2) and will be integrated with the WaterChip AR Plus device (hardware)

Partner 3 - Leibniz Institute of Photonic Technology (IPHT)

WP 2: Development of cell viability assay

On the basis of the Indian partners suggested data, IPHT started extensive studies for LAMP. Several dyes were tested with model microorganisms, such as methylene blue, neutral red, propidium iodide, Calcein-AM and the SYTO82 orange fluorescent nucleic acid stain (Invitrogen) as recommended by the partners. The viability assay was tested without the WaterChip AR platform.

The LAMP assay was forwards optimized and their LODs and protocol is established. Both the Blue-LAMP method and LAMP with fluorophores, and ddLAMP was investigated.

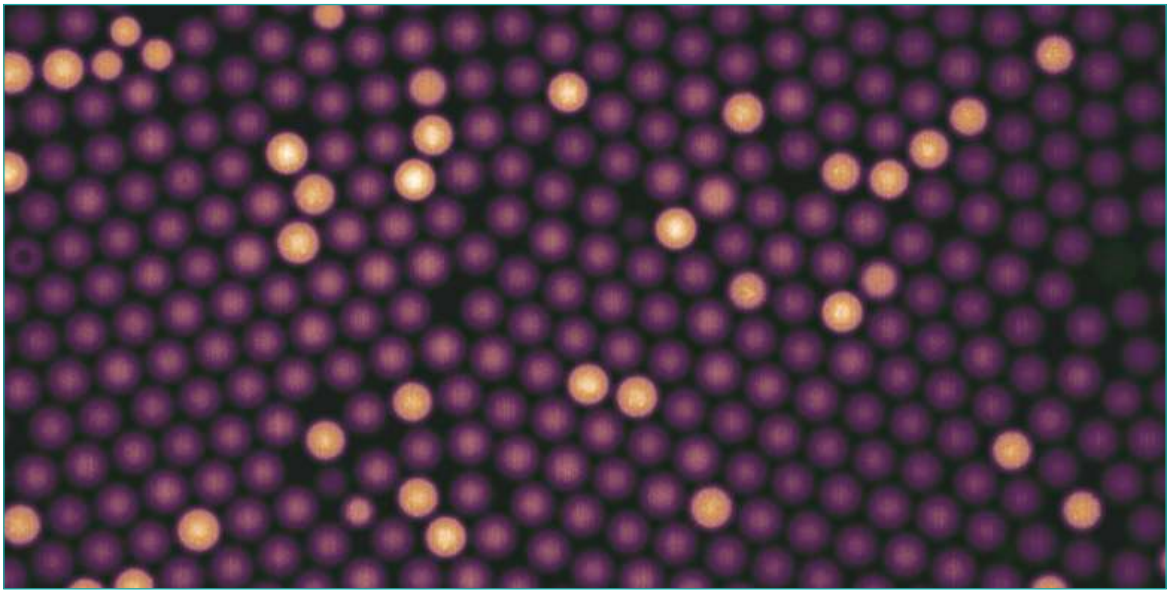


Figure 3 False colored fluorescence image of the ddLAMP chip (orange: positive probes; violet: negative probes – no amplification)

Partner 4 - Food GmbH

In the reported period the adaptation and optimization of the isothermal amplification LAMP was realized in cooperation with the IPHT and after the scheme of the Indian partners.

LAMP-primer system for blaTEM (ß-lactam resistance) and qnrS (fluoroquinolone resistance) was developed and for real surface water (German river) samples tested. As control, blaTEM and qnrS genes was detected with real-time (RT)PCR. The comparison of both methods for blaTEM gives an optimal match to each other (Fig. 4). LAMP was in the majority of samples the most sensitive method.

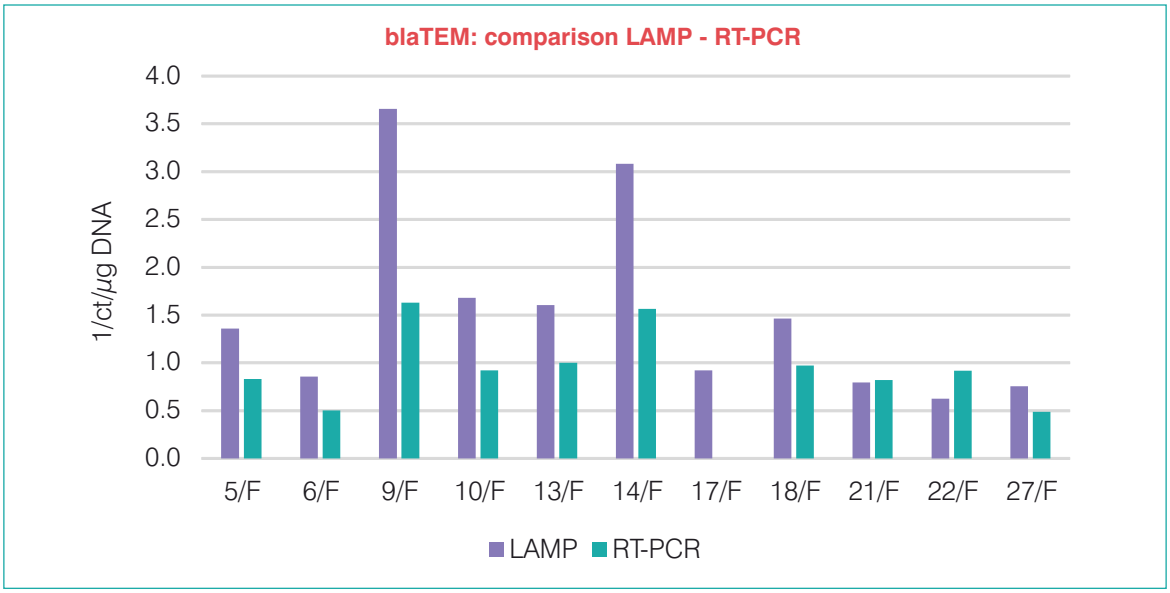


Figure 4 Comparison of LAMP- and RT-PCR-detection of the ARG blaTEM in surface water in river.

Salient Research Achievements

- A set of primers for LAMP for pathogens were designed: E.coli, Shigella spp., Legionella pneumophila, Cryptosporidium parvum and Giardia intestinalis.
- A set of primers for LAMP for ARGs were designed and some tested: Carbapenem KPC and NDM, Tetracycline
- Model system for LAMP in table cycler for future validation were established
- LAMP protocols with different dyes were established and optimized
- Several LAMP protocols for pathogens were tested with real surface water
- The WaterChip AR platform device is optimized for better manufacturability
- App is 90% complete

Publications

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.

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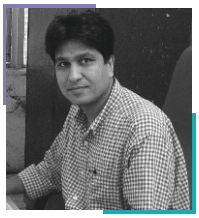
SUSTAINABLE ENERGY/ ENVIRONMENT

LOWCOSTEPS

Low-cost emergency power system based on printed smart supercaps

Project Investigators



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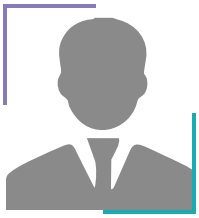

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Project Summary

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 till 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.

The project team estimates to bring 100 systems into the market after a successful project end. In the second year, 500 systems should be supplied. A mid-term goal could be defined within a best-case-worst-case scenario: A pessimistic scenario assumes the supply of 4000 systems (2.5 to 10 kVA) per year, an optimistic one calculated with 20,000 systems per year.

Progress made/achieved

A detailed description of the results obtained regarding the objectives has been given in the following sections.

Supercap test set up on standard glassine paper (non-print/print): pmTUC, WP3

In the previous report, the general super capacitor layout was defined (Figure 1): Two half cells are prepared on a substrate, by printing a current collector layer with electrical contact lines and a subsequent application of a gel electrolyte. To increase the contact area, a mixture of the current collector material and the electrolyte material is added in between the current collector layer and the gel electrolyte layer. The two half cells are then laminated with a separator layer to avoid unintentional electrical shorts.

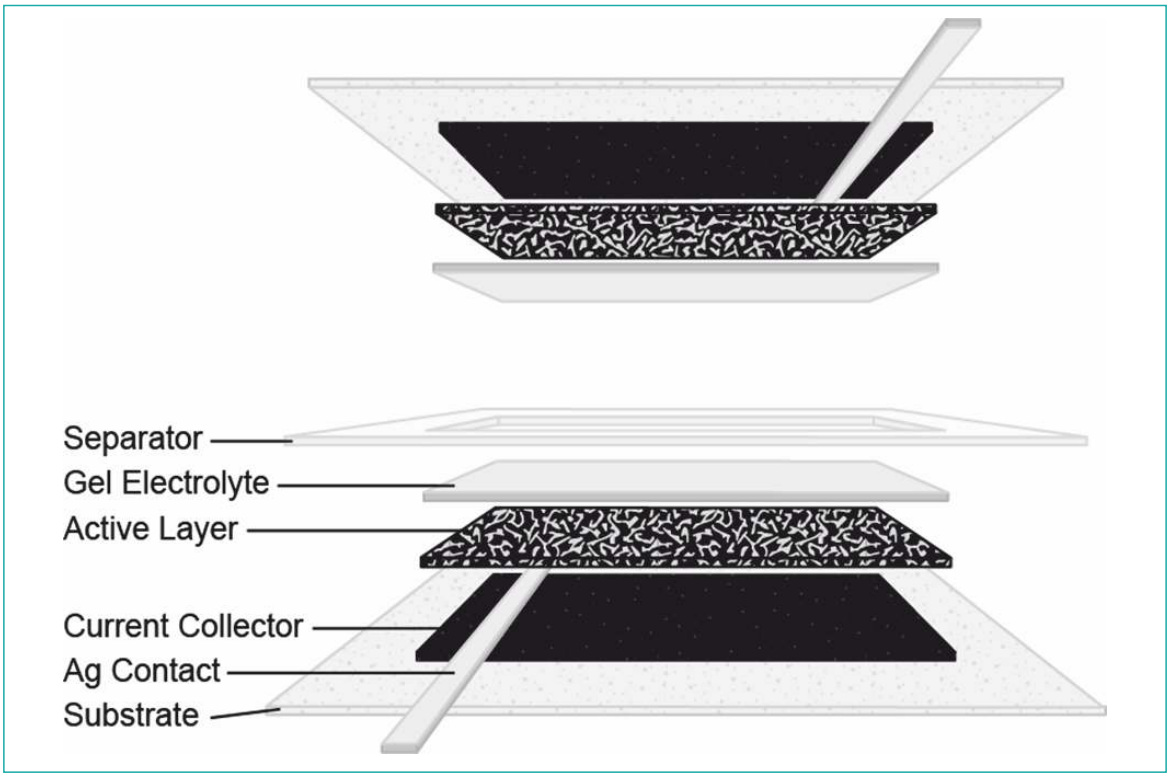

Figure 1. Layer components of fully printable supercapacitor.

Different paper materials were provided by project partner GRP and it was found that bleached glassine paper (60 g/m2) equipped with waterproof ingredients provided the best compatibility with the carbon ink used to print the current collector.

WP4: Development of solid state and polymer electrolyte materials as well as conjugated polymers: IITB

In close cooperation of IITB and pmTUC, the choice for a gel electrolyte system due to its ease of preparation and low cost, was made. According to this, all project partner decided during the meeting in June 2017 that the focus of synthesis should be on the materials of the electrode active layer used in this project.

Development of Graphite/Graphene-Based Printable Inks

In our work, we have opted for an electrochemical process to produce graphene. Our process involves an electrochemical expansion of graphite into small expanded flakes which are further exfoliated by a mechanical process in solution phase. This method is faster than direct solution exfoliation method.

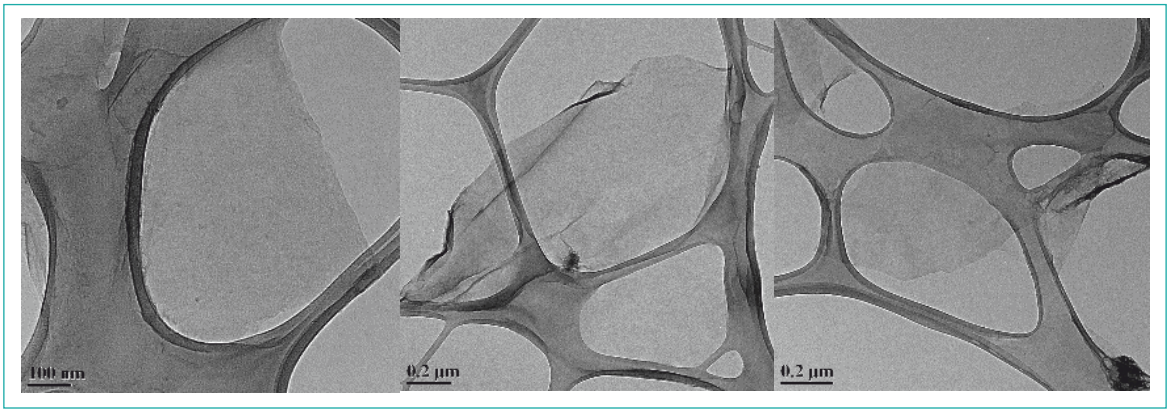

Figure 2 FEG-TEM images of graphene samples (supernatant@10k).

Development of PANI-Graphene Based Inks

Graphene and polyaniline (PANI) are good candidates for electrical double-layer capacitors (EDLCs) and pseudocapacitors, respectively. PANI has an advantage of very high specific capacitance due to the reversible redox processes involved.

The project group synthesized PANI-graphene composite with two different aniline concentrations. The TEM images (Figure 3) of these composites show that high aniline concentrations (0.16 M) will not only lead to polymer coated graphene sheets but also to polymer in the solution.

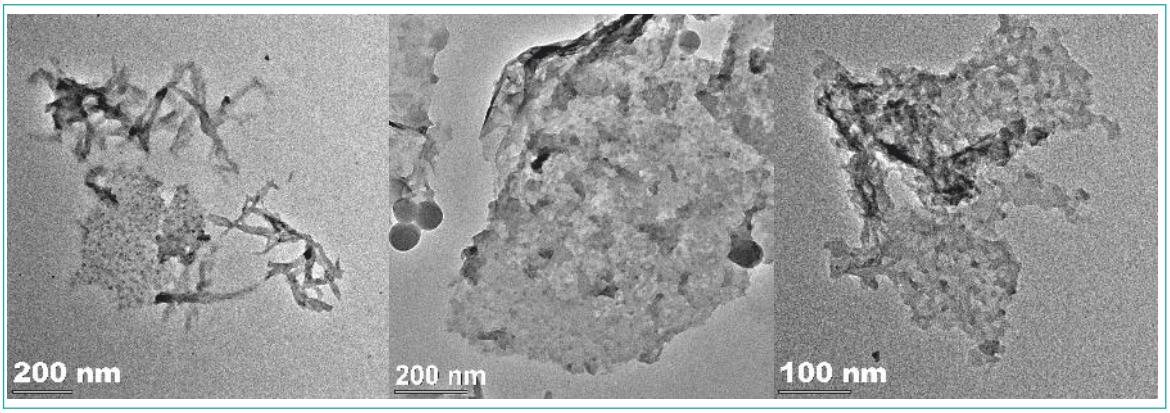

Figure 3 (a) PANI-Graphene synthesized with (a) 0.00 M, (b) 0.08 M aniline and (c) 0.16 M aniline.

WP5: Development of EPS circuitry: SLN

The preliminary design of EPS circuit has been completed, however, until the exact working DC voltage is not established, the EPS circuit for 2.5 KVA cannot be implemented. The exact working DC voltage depends on the number of capacitors which can be connected in series-parallel combination and their charge-discharge characteristics. Also, as the maximum current that can be drawn from the capacitor is not yet established, detailed design of EPS circuitry is not possible. SLN will be able to develop a working EPS circuitry within 2.5 months after finalization of both working DC voltage and maximum current that can be drawn from the capacitor.

WP6: Modification of glassine paper parameters: GRP

Different types of paper have been considered during the duration of the project. The requirements for the paper are:

- Thin and light: Lowering volume and weight increases the density of capacity, energy and power of the EPS.
- Smooth and closed surface: A smooth surface improves the printability and

prevents a penetration of the ink through the paper, which would otherwise create electrical shorts.

- Ideal surface tension: The surface tension is important for the ink transfer and improved printability of the substrate.
- Dimensional stability: During processing, the paper should not swell significantly, which would lead otherwise to waves in the surface.
- Low Cost: An inexpensive fabrication improves the cost of the whole EPS device

WP7: Supercap test set-up on modified glassine paper (non-print/print) pmTUC

As a result from the high internal resistance of the supercaps prepared in WP3, the experiment was repeated using a bleached filter paper (Grünperga FPG90) with a higher mass per area (90 g/m2) to improve the dimensional stability during printing (high mechanical strength) and the adsorption of the solvent of the inks. Using flexographic printing, silver and carbon ink for connecting lines and current collector where applied. The resulting resistance of the silver lines was found to be 27±3 Ω per element and slightly worse than on the glassine paper reported in WP3. After a first application of the carbon ink forming the current collector (2300±600 Ω/□), a second carbon layer ink was applied, resulting in considerably lower resistance of 700±100 Ω/□ , without affecting the mechanical stability or negatively.

The production of large quantities of glassine paper with a weight of 60 g/m^2 and an improved mechanical stability is currently under production as explained in WP6.

WP8: Upscaling of electrolyte materials: IITB, pmTUC

According to the results from WP3 and WP7, the material and layout for the upscaled fabrication of supercap stacks are currently under discussion. The layout will be adjusted according to WP7 to lower the internal resistance. Ex-situ test of the currently used electrode material have shown power densities of over 2 Wh/kg, meeting milestones. Possible changes to further improve capacity and energy density according to WP 4 are possible at this stage.

As soon as the final modification of the glassine paper web is provided by GRP, large quantities of electrolyte and electrode material will be prepared.

WP9: Investigation of mass-production technology for printed supercaps: pmTUC, GRP

Paper material from project partner GRP has been print in first trials with the first two layers of the supercap multilayer setup: Dupont 5028 silver and SunTronic GFT4600 Flexo Conductive Graphite Ink were used to prepare 500 m of printed web, corresponding to 3500 supercaps. As soon as the final version of the modified glassine paper is provided, this printing procedure will be repeated.

A cutting and folding unit is currently installed at our MAN LaborMAN printing press. First manual tests worked as expected.

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METNETWORK

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

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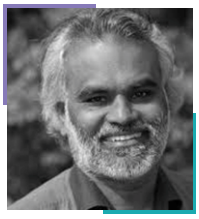

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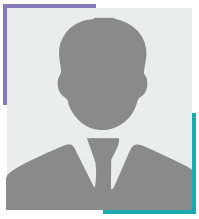

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Project Summary

The main objectives of the project are

- 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 large area substrates, flexible substrates and printing techniques. We expect to fabricate large area TCE by a general concept based on polymer cracked template, which is very universal and simple. Therefore, it is of general use wherever transparent thermal/electrical conduction is desired. The proposed work will provide viable solutions to the pertinent issues related to fabrication of large-area 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.

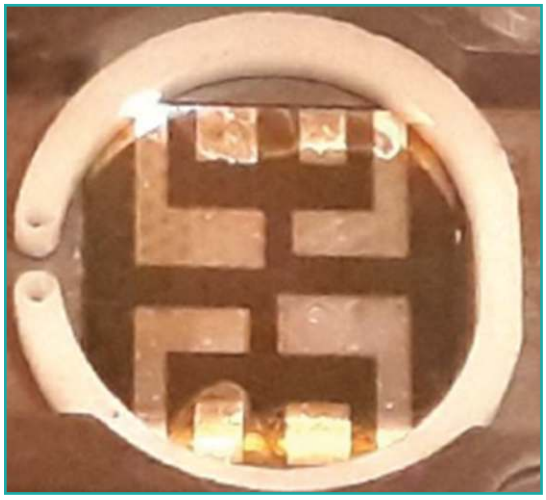
Progress made/achieved

The details of progress and planned work from each partner are described below.

Partner 1 (CeNS): (concerning WP1) CeNS has attempted to upscale the process of crackle lithography for the fabrication of low-cost TCEs by adapting different coating processes. Spray-roll coating proved to be successful in fabricating up to 10 inch wide crackle film and the spray process has been optimized to achieve 12-15 μm wide uniform and stable crack patterns. A4 size films have been

fabricated by rod coating and A3 size uniform films have been achieved through spin coating. Screen printing as well as roll to roll coating methods, have been extended for the fabrication of crack templates. Metal deposition on these films was carried out. The screen printed large area TCEs show transmittance (~70%, with respect to air as reference) and 20 Ω/□ resistance. The as-prepared transparent conducting electrodes are shown to find applications in smart windows and large panel displays.

10×10 cm2 Al mesh TCE prepared by spray pyrolysis



perovskite solar cell device

Partner 2 (Tata Steel: TSL): (concerning WP2) TSL is attempting to grow graphene on low melting point substrate by exploring PECVD process. Commercial PECVD setup has been modified by adding a home built solid precursor vaporizer at PECVD gas inlet pipe. Further studies are in process which involves feeding of natural precursor vapour into the PECVD through the gas inlet valve, to convert to graphene which gets adhered to the substrate maintained at room temperature. This study will help in understanding the growth parameters and property of grown film when chemically reactive plasma of precursor molecules is exposed to substrates at different temperatures.

Partner 3 (UBT): (concerning WP1) UBT has screened different polymer dispersions, which can be used as a template to obtain a metal mesh network. Among these, several polymer dispersions showed uniform micrometer scale cracking during thin film formation, especially dispersions having a minimum film formation temperature > 50°C. One candidate of polymer dispersion was chosen for testing on PET substrates. First metallization tests were done with thermal evaporation (sublimation). The light transmission for the 60 nm thick Ag network on PET foil (23 µm) was 95% in the wavelength range between 300 nm and 1000 nm. The sheet resistance of the foil was 32 ohm/square. Metallization based on wet chemistry have not done up to now. The candidate was further sent to the German industry partner (PL) for printing this polymer dispersion on a Roll-to-Roll pilot printer.

Partner 4 (PL): (concerning WP1 and WP4) PL ordered polymer dispersions with different minimum film formation temperature and sent them to UBT for screening their suitability as template material for crackle lithography. After UBT found a suitable polymer dispersion, PL optimized the dispersion for a R2R pilot printer. This optimization is still ongoing, due to special issues of the water-based dispersion on PET foil. At present, several additives for influencing the surface tension and rheology are under investigation.

From the prepared transparent conducting Electrodes, the following devices have been fabricated:

Indoor light control using thermotropic materials is an active area of research. While active materials are available to switch transmittance with temperature, large area heaters with desired transparency are not easily affordable. In this work, the fabrication of thermochromic devices using inexpensive Sn mesh electrodes (5 Ω/□, transmission, 80%) produced by crackle lithography with hydroxypropyl methyl cellulose (HPMC) as an active material is demonstrated. When laminated and coated on the inner surface of a PET window (8×8 cm2), the mesh served as a transparent heater to cause gelation in HPMC at ~ 40 °C to switch from water-clear transparency to paper-white opaqueness with 1 mm thickness of the active layer. The power consumption was only 0.2 W/cm2. Few drops of a color ink produced interesting effects in this smart window prototype as reported in S. Kiruthika and G.U.Kulkarni, Sol Energ Mat Sol C, 163, 231 - 236 (2017)

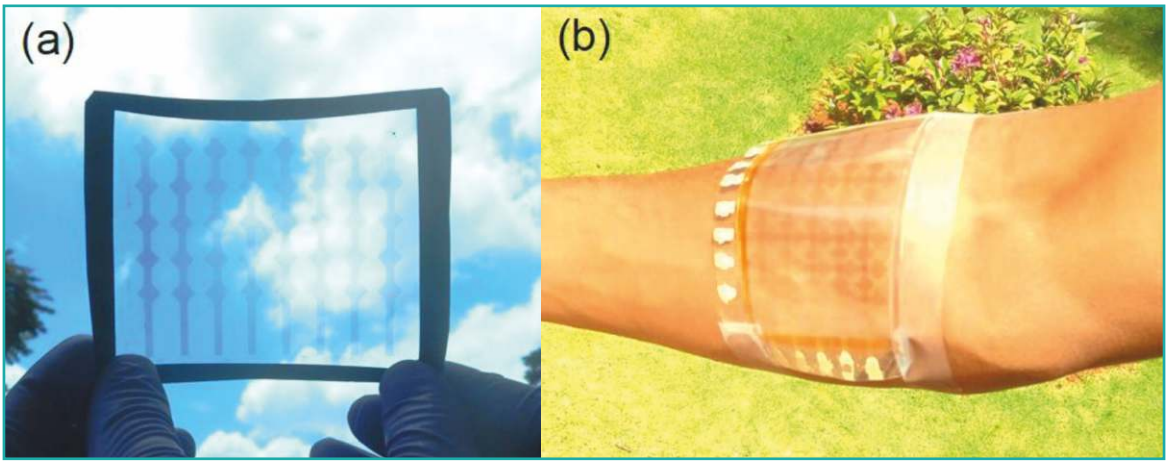


Figure (a) Photograph of a patterned metal mesh (b) Transparent capacitive touch panel fabricated using a patterned metal mesh

Invisible Cu mesh electrodes used as ITO alternative serve as transparent heaters for large area smart window applications with commercial thermochromic pigments and gels as active layers as thermoactive layers requiring minimal input power (~ 0.2 W cm-2) for activation. The device configurations and the low cost materials and processes developed will be appealing to further industrial applications and futuristic energy efficient buildings to achieve zero energy demand.A. K Singh, S. Kiruthika, I. Mondal and G. U. Kulkarni, J. Mater. Chem. C, 5, 5917-5922 (2017).

Transparent behaviour of the prepared graphene was also studied. Graphene in its purest form is expected to exhibit a semiconducting to metallic transition in its temperature dependent conductivity with a transition temperature, Tc, depending sensitively on the disorder or defects present in it. Even for good quality graphene, these disorder are nonnegligible and the transition temperature appears above the ambient, practically rendering it to be only semiconducting over a wide range of temperature. Here we show, an experimental study on the transport behaviour of decoupled twisted multilayer graphene (tMLG) exhibiting Tc well below the ambient temperature. The graphene layers in these tMLG are highly decoupled with one another due to the angular rotation among them, as a result, they exhibit very high Raman I2D/IG values (up to 12) withnarrow 2D width (16 – 24 cm-1). The photoresponse behaviour also corroborates well with the transition in transport behaviour. Umesha Mogera, Sunil Walia, Bharath Bannur, Murali Gedda, and Giridhar U. Kulkarni, J. Phys. Chem. C, 2017, 121 (25), pp 13938–13943

Transparent and flexible energy storage devices, such as supercapacitors have become increasingly popular as they provide higher power densities than the lithium ion batteries and higher energy densities than the

electrolytic capacitors along with additional advantages such as long cycle life and fast charging-discharging rates. In this work, a flexible Au/MnO2 supercapacitor has been fabricated with a visible transparency of ~75% and areal capacitance of ~3 mF/cm2. The transparent Au wire network-based current collector was obtained using the crackle template method over a membrane separator. The Au wire networks were decorated with high surface area pseudocapacitive MnO2 nanostructures by an electrodeposition process. The fabricated device shows high stability over 5000 charge-discharge cycles in two electrode configuration. In this case, the membrane separator itself was used as a substrate, which allowed the two electrodes to place one over the other rather than making them face each other with a separator in between, as in generally done. Thus, the device brings in the desired transparency and lightweight while additionally exploiting its porous nature in enhancing the interaction of electrolyte with the active material, thereby enhancing the storage capacity. In addition, a solid-state flexible supercapacitor was also fabricated by sandwiching two Au/MnO2 electrodes with gel electrolyte, which shows high flexibility towards very low bending radius. Furthermore, lightweight device has been fabricated on either sides of the separator taking the advantage of porous nature of the separator with no loss in transmittance and capacitance values. S. Kiruthika, C. Sow and G. U. Kulkarni Small 13(40) (2017). DOI: 10.1002/smll.201701906

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2. Singh, Ashutosh K., S. Kiruthika, Indrajit Mondal, and Giridhar U. Kulkarni. "Fabrication of solar and electrically adjustable large area smart windows for indoor light and heat modulation." Journal of Materials Chemistry C 5, no. 24 (2017): 5917-5922.
3. Mogera, Umesha, Sunil Walia, Bharath Bannur, Murali Gedda, and Giridhar U. Kulkarni. "Intrinsic Nature of Graphene Revealed in Temperature-Dependent Transport of Twisted Multilayer Graphene." The Journal of Physical Chemistry C 121, no. 25 (2017): 13938-13943.
4. Mogera, Umesha, A. Sundaresan, and Giridhar U. Kulkarni. "Graphene–Ni (111) Synergy Influencing Crystalline Orientation, Grain Morphology and Magnetic Properties of Poly-Ni." The Journal of Physical Chemistry C (2018).
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REMSOLAR

Reduction of earth metals in chalkopyrite-based solar cells

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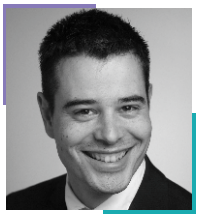

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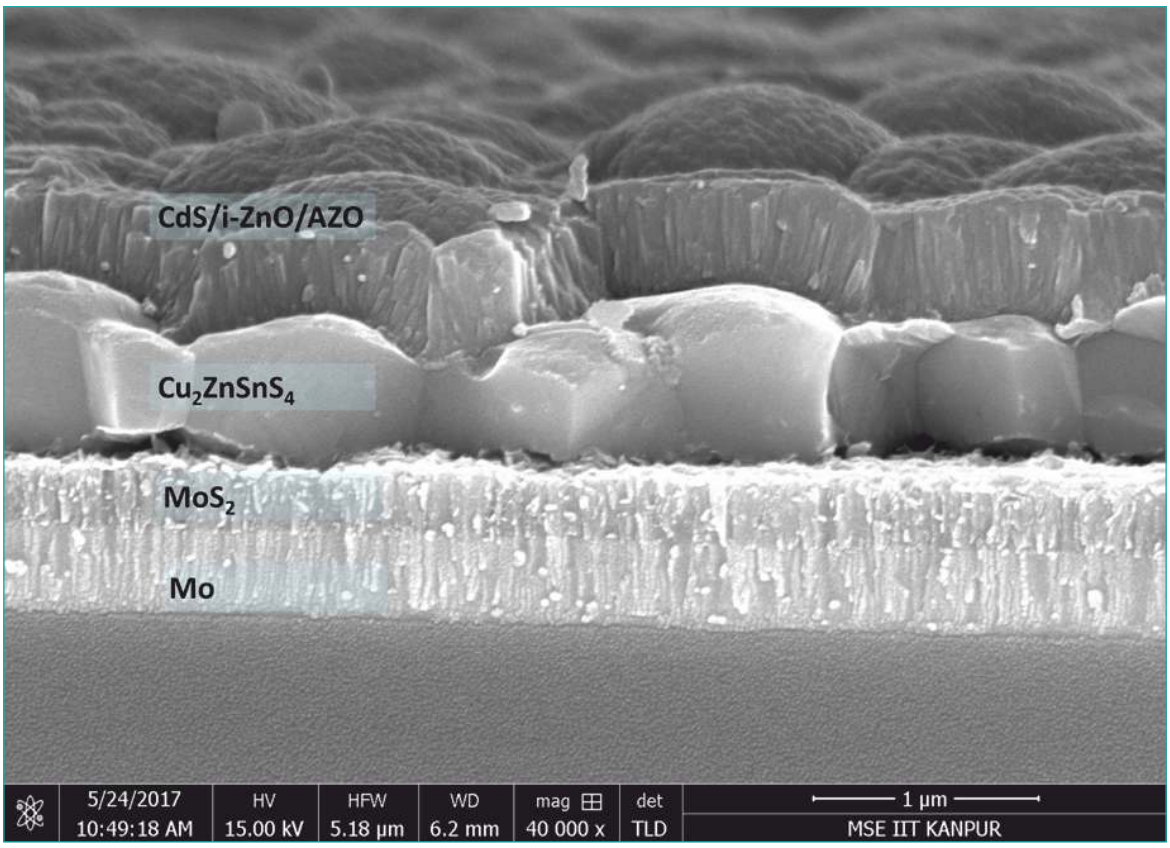
Project Summary

Considering the significance of the global challenge of future energy production and the role of photovoltaics within it as well as the conditions of international division of labour, the enhancement of links between Germany and India on the field of research and development in thin-film photovoltaics is of strategic importance, and hence one of the major objectives of the project.

$Cu(In,Ga)(Se,S)_2$(CIGS) as absorber layer constitutes one of the most important thin-film technologies, which are challenging silicon-based solar cells. The main drawback of this system is that it contains the comparatively rare elements indium and gallium, the availability and price of which are suspected to worsen in the future and to reduce the economic potential. Within the project, two approaches for the reduction of these earth metals will be followed and compared. One approach is the reduction of absorber layer thickness while maintaining power conversion efficiency, the other is the replacement of indium and gallium by tin and zinc, leading to the material $Cu_2ZnSn(Se, S)_4$ known as Kesterite, which shows promising photovoltaic properties.

Both approaches include optimized preparation processes based on deeper understanding of physics and chemistry of film formation. The preparation of single-phase material with enhanced photovoltaic properties requires in-depth investigations of condensation, crystallization and phase transition processes, which are one of the major objectives of the project. In-situ characterization of layer growth and ex-situ characterization of layers and complete devices will be applied in order to clarify the correlations between process parameters and photovoltaic properties. For both approaches, industrial scale model processes will be realized, which will allow for study of issues relevant for fabrication. These results will be used to evaluate and benchmark both approaches against each other. The results of the project will remove significant road blocks in the development path of thin-film photovoltaics and to considerably influence research and development strategy of contributing partners and other players in the field.



Cross-Sectional image of CZTS PV device

REM Solar pursues two routes towards the reduction of earth metals in Chalcogenide solar cells: (A) Reduction of Cu(In, Ga)Se_2 (CIGSe) earth metal utilization by reduced film thickness (or other measures) and (B) replacement of Indium and Gallium by development of kesterite type $Cu_2ZnSn(S,Se)_4$ (CZTSSe) solar cells. An important deliverable is the comparison of economic potential of both approaches as defined in D3.

Concerning the reduction of film thickness of CIGSe it was found within this project in 2014 that by increased Selenium supply a CIGSe film thickness reduction of 14% can indeed by achieved at identical module performance. However, this provides no viable path as Selenium consumption in production by itself is a cost factor (the element Selenium is close to a rare earth element). Also a change in the Ga depth profile as tried by Manz was not successful. Thus, MLU continued to look for other ways to reduce the CIGSe film thickness and Manz tried to enhance the material utilization at original CIGSe film thickness. Manz was successful by changing the Selenium deposition rate and thereby increased the metal utilization rate in production in 2016. Thus, milestone 3 was reached.

Concerning the development of CZTSSe solar cells, MLU used co-evaporation up to the entry and operation of IITK. MLU showed by in-situ XRD that deleterious secondary phases in CZTSe could be avoided by minimal group III alloying – this being an important finding for the CZTSSe research. IITK developed a sequential based process for CZTS formation which was successful in providing the first functional solar cells. IITK together with Thermax defined the conditions for in-situ XRD experiments to be performed at MLU. IITK and MLU found, however, that this process cannot be reproduced in the in-situ XRD set-up. IITK had reported an efficiency of 0.12 % in the last report, since then the team has made a progress and now a CZTS PV cell with 1.9 % has been achieved. Further enhancements are underway before the process could be considered for transfer to the industry finally. MLU, stimulated by the research of others [Giraldo 2016], has looked into Germanium alloying of CZTSe in order to further improve the solar cell efficiency.

Progress made/achieved

Milestones achieved

- Experimental conditions for in-situ characterisation of CIGS growth based on results from model experiments
- Detailed description of CIGS growth process as basis for large scale experiments.
- Evaluation of the potential and possible limitations for transfer of laboratory results to production for the case of CIGS as input for model process development
- Experimental conditions for in-situ characterisation of Kesterite based on the results from model experiments

CIGS solar cells with reduced material consumption

MLU showed a largely improved solar cell efficiency on 1 µm CIGSe films. Manz consolidated the higher material utilization by changed Se flux being a very important achievement of this project. The outcomes have been detailed in thier project completion report.

Earth abundant $Cu_2ZnSn(S,Se)_4$ CZTSSe solar cells

IITK has obtained a CZTS thin film of controlled morphology and composition via solution route comprising studies of (1) the type of metal salt (acetate/chloride) and their relative amount in the solution, (2) high temperature treatment for crystallization (sulfurization), and (3) Effect of silver alloying for favourable changes in the properteis of CZTS. Photovoltaic cells were fabricated from thus optimized CZTS films. The best PV cell resulted into open circuit voltage (Voc) of 0.62 V which is close to the Voc of 0.7 V for the best reported CZTS PV cell. However, the short circuit current density Jsc is only 9.5 mA/cm2 which is low compared to 20 mA/cm2 for the best reported CZTS PV cell. The fill factor (34%) is also low leading to the efficiency of 1.9 %. This issue is being addressed currently. FESEM micrographs of the precursor films obtained from precursore solutions containing different combinations of copper chloride and acetate salts while keeping the amount of other metal salts fixed.

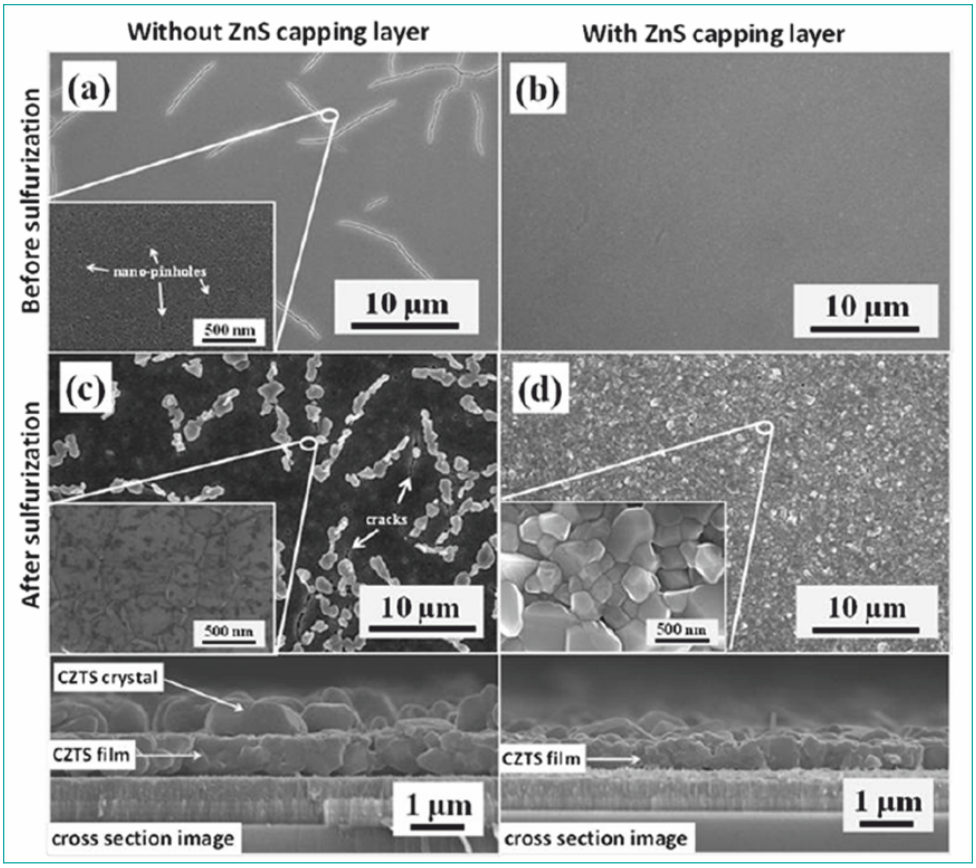


Figure . FESEM micrographs of the precursor films. (a) without ZnS capping layer. (b) with ZnS capping layer. (c) The top and cross-sectional view of the film in (a) after going thourhg sulfurization. (d) The top and cross-sectional view of the film from (b) after going through sulfurization.

PV Cell fabrication

Using the optimized process, a PV cell having a structure of SLG/Molybdenum/ultra-thinZnO/Ag-alloyedCZTS/Cadmium-sulfide/intrinsic ZnO/AluminaDopedZnO/Aluminum-contact was integrated.

Publications

Kumar, J., & Ingole, S. (2017). Structural and optical properties of $(AgxCu1-x)_2ZnSnS_4$ thin films synthesized via solution route. Journal of Alloys and Compounds, 727, 1089–1094. https://doi.org/10.1016/j.jallcom.2017.08.222

PhD/Masters Thesis supervised

- Jitendra Kumar, Cu_2ZnSnS_4 Thin Films through Solution Chemistry for Photovoltaic Application, IIT Kanpur (Ongoing, expected completion in 2018)
- Neha Kumari, Engineering the Mo-CZTS interface for high efficiency, IIT Kanpur (Started)
- Namita Mishra, Cd1-xZnxS thin-films through Spin Coating, IIT Kanpur, 2018
- S. Hartnauer "Phasenbildung am System Cu-Zn-Sn-In,Ga-S-Se untersucht mit Echtzeitmethoden für Chalcogenid-Dünnschichtsolarzellen", MLU Halle 2016
- F. Obereigner "Zeitabhängige Leerlaufspannung und Dotierdichte von Cu(In,Ga)Se2-Solarzellen", MLU Halle 2016

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RESERVES

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

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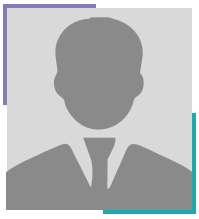

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Project Summary

The Government of India predicts dramatic demand increases for energy over the next 20 years which brings in several problems to 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 slaughterhouse, fruit- and veg-market waste are rarely utilized for recovery of energy and nutrients. Biogas from this waste material could be an important and flexible energy source for local consumer with high supply guarantee. In most towns/cities of developing countries including India, slaughter house 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 proteineous matter with 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 co-digestion process to enhance the biogas production in 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 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 pilot scale 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

- Comparative study on the effect of shredding and bio-extrusion of koyambedu vegetable market waste on biogas yield
- Periodic survey of vegetable, fruit and flower waste from koyambedu market
- Comparative study of dry and wet anaerobic digestion of banana peduncle
- Process design and detailed engineering of pilot plant
- Characterization and elemental analysis of slaughter house and other organic waste generated from urban areas.
- Biochemical methane potential of slaughter house and other organic waste.
- Biochemical methane potential of various combinations of slaughterhouse and other waste.
- Antagonistic and synergistic effect of various combination of waste.
- 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 bioextrusion on biogas yield from major fractions of Vegetable Waste from Koyembedu market using lab scale shredder and bio-extruder. Based on the survey of waste generation from Koyembedu 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 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 usedto treat waste which are 5 times that of the wet condition.

Publications

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- 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 activites

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 Koyampedu and the session was completed with Mr. Armin's lecture about safety handling.

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SeNaMeB

Design of selective nanoporous membrane bioreactor for efficient production of bio-butanol from lignocellulosic sugars

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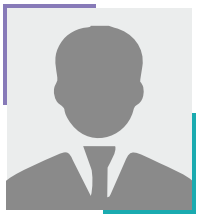

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Project Summary

Butanol is a liquid of high energy density comparable to gasoline. Bio-butanol is made from renewables and CO2-neutral. The production of bio-butanol from lignocellulosic waste materials is hindered by the low efficiency of the process chain what will be overcome in the project.

Aim of the project is the development of a novel membrane bioreactor for the efficient synthesis of bio-butanol from lignocellulose containing raw materials. A novel nanoporous membrane for continuous butanol separation will be developed and integrated in a new developed two-step bioreactor. The direct combination of a nanoporous membrane with the two step fermentation process will allow an energy and cost efficient butanol production from lignocellulose containing raw materials

A fluidized bed reactor (FBR) with immobilized Lactobacillus spp. on Ca-alginate beads is used for continuous lactic acid production. The lactic acid formed in this continuous operation is diluted and feed to Clostidium spp. for butanol production.

A nanoporous butanol selective membranes made of hydrophobic zeolites (Silicalite) is developed and will be directly combined with the fermentation for continuous butanol separation by pervaporation at low temperature.

The integration of the novel membrane with high butanol/water selectivity and high butanol permeance with the bioreactor (fermenter) will enable: (1) continuous recovery of butanol from bioreactor thereby giving butanol production at higher rate without inhibition or toxic effects on the metabolizing cells, and (2) continuous upgrading of butanol from low concentration broth of < 1 wt% to > 8 wt% (the boundary solubility of butanol in water).

The direct combination of the new membrane technology with continuous FBR based fermentation is allowing energy and cost efficient butanol production. It opens the opportunity of using sugar derived from lignocellulosic agricultural residues for sustainable and economic 2nd generation bio fuels.

Progress made/achieved

Milestones achieved

- Fermentative production of butanol, using Clostridial spp.
- Zeolite or mixed matrix membrane of ButOH/H2O > 30 and permeance of > 1.5 kg/(m^2h) in synthetic butanol/water mixture (40°C, 1 wt% butanol)
- Zeolite or mixed matrix membrane of ButOH/H2O > 30 and permeance of > 1 kg/(m^2h) in real fermentation broth (40°C, 1wt% butanol)
- Membrane in semi-industrial scale

M1 was achieved at the end of October 2014. M2 and M3 were achieved in 2015. In both cases membranes of lower fluxes (M1: 0.5 kg/(m^2h), M2: 0.2 kg/(m^2h)) but much higher selectivities (M1: 350, M2: 150) were prepared what is of very high value for the practical application. Therefore, in agreement between the partners the achieved values are fulfilling the conditions of M2 and M3.

In the reporting period both, zeolite membranes and mixed-matrix-membranes were prepared in a semi industrial scale. Zeolite membranes were prepared inside of 0.5 m long multi-channel tube elements. Mixed-matrix-membranes were prepared continuously on a tape-casting machine and > 1m^2 membrane area were produced. So M4 was achieved in time.

Development of organophilic zeolite and mixed matrix membranes and membrane characterization by microcharacterization and separation tests in synthetic mixtures (IKTS, Atech)

Atech developed ceramic support tubes. The tubes were prepared by extrusion of an ceramic mass followed by a drying and high temperature sintering procedure.

IKTS prepared Zeolite-Silicalite on top of the last supporting layer by a seeding with zeolite powders followed by a hydrothermal treatment. Best butanol/H2O-selectivity of 18 was achieved on top of a 5kDa-support.

In a second step atech prepared several tubes of one pore size of the final layer (5kDa-support) again in the length of 250 mm. IKTS proceeded an optimization of MFI-membrane preparation on top of the support. For this purpose all parameters of zeolite membrane synthesis were systematically varied. After stepwise optimization a perfect selectivity $\alpha_{ButOH/H20}$ of 200 and a flux of 1 kg/(m^2h) were achieved in synthetic butanol water mixtures.

Fabrication of the membrane plant and integration with ICT fermenter/s

On basis of the results of membrane testing the general butanol plant design was created . A microfiltration step will be used after every fermentation step to separate coarse components. The butanol/water-mixtre also will be pre-filtrated by ultrafiltration for protein separation. The butanol-upgrading will performed with two hydrophobic pervaporation steps (PV I) and one hydrophilic pervaporation step (PV II, Fig. 5). All components are calculated and production facility at PBL is constructed.

Fig. Pilot plant facility for Micro, Ultra, and Nano filtration modules

Integrated Fermentation-Recovery runs and Process Optimization at 5L scale

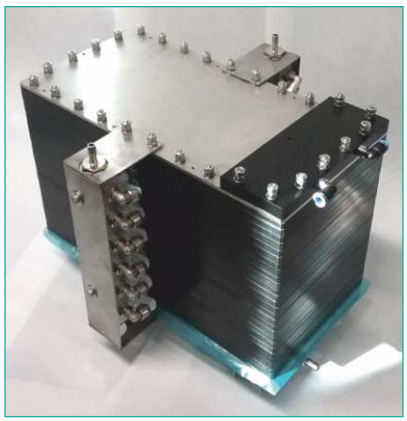
Zeolite membrane on ceramic supports were tested at IKTS in direct combination with a butanol containing fermentation solution from classical ABE-fermentation. The butanol content was around 1 wt%. By using the zeolite membrane very high concentrated butanol of 60 wt% were achived. A very high selectivity $\alpha_{ButOH/H20} = 150$ but low flux of 0.2 kg/(m²h) were achieved. For milestone M3 (Nov 2015) a selectivity of $\alpha_{ButOH/H20} > 30$ and a flux of > 1 kg/(m²h) were necessary. Again the achieved selectivity was much higher than necessary and permeance lower. From point of application the higher selectivity compensates the reduced permeance. Therefore the archived results were accepted by the partners for fulfilling the criteria of M3.

Scale up to Pilot level at 500-5000L scale

Fermenter system and liquid filtration system was scaled-up by Privi up to a scale of 500.

Fermenter module (20, 100, 500 liter fermenter)

Basing on the results of WP 1 and WP 4 Atech prepared ceramic supports of optimized pore size and final support layer in a length of 0.5 m in single, 7- and 19-channel geometry. IKTS developed the synthesis equipment for membranes of this geometry. All supports were proceeded in an autoclave of a length of 800 mm to prepare MFI-membranes. Atech developed a stainless steel module for testing the membranes of this dimension.



Membrane stack of app. 1 m² membrane area for hydrophobic mixed-matrix-membranes

Publications

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- M. Villwock, H. Richter, M. Stelter; Organophilic pervaporation properties of silikalite/polyalkylsiloxan composite membranes and its scale-up, Annual Meeting of Process Net group membrane technology, March 6-10, 2017, Köln, Proceedings

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SMART CITIES

Four out of six projects approved under the Call 2016 in the overall thematic area of Smart Cities were started. 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 327.3 million / € 4.67 million. Projects will develop next generation technologies and framework for existing and future smart cities in India & Germany.

ECO-WET

Efficient coupling of water and energy technologies for smart sustainable cities

Project Investigators

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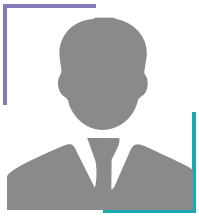

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Project Summary

Coupling of cross commodity infrastructure and integration of energy storage is a challenge for smart cities. This project focusses on water management and energy efficiency for smart cities. The project will develop integrated advanced energy storage technology and renewable energy sources to enable the coupling and modularization of electricity and water infrastructures. 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 and optimization techniques for energy-efficient management of both water and electricity in the purview of the infrastructural constraints in the smart sustainable cities is also envisaged.

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SMART & WISE

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

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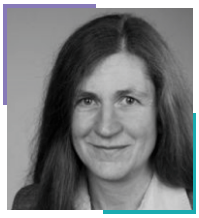
Theo Schmitt
Heidrun Steinmetz
TU Kaiserslautern



Martina Scheer
Ingenieurbuero Scheer
Oberstdorf

Gerald Angermair
tandler.com GmbH
Buch am Erlbach

Project Summary

The overall project goal is to support the implementation of reliable and sustainable water and wastewater infrastructure systems (WIS) with added value for smart cities. Systematic planning methods and tools will be developed to face current and future challenges on three levels; conventional, advanced and smart WIS. E.g. automated planning based on mathematical optimisation to improve conventional sewerage system planning with incomplete planning data base. Application of developed methodologies and tools will be demonstrated in pilot studies in India (Coimbatore) and Germany (Giessen, Lindenberg, Aulendorf)

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IDC-WATER

Integrated diagnostics of contaminants in water supply and management system

Project Investigators

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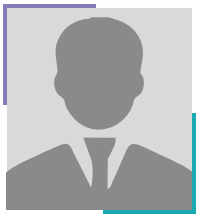
IISc Bangalore

J Manjula
Bigtec Labs Pvt. Ltd.
Bangalore

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. System will be designed in such a way that it can be installed in the water pipe-lines in the water treatment plant settings and in building infrastructure settings for remote monitoring.

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BIO-CUINGE

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

Project Investigators

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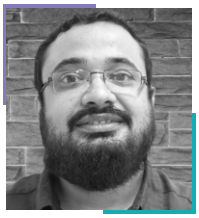
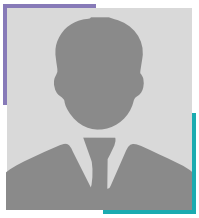


S K Ziauddin Ahammad
IIT Delhi

G Venkat Saravanan
Laksmi Life Sciences
Coimbatore

Katrin Pollmann
Helmholtz Zentrum
Dresden Rossendorf
Dresden



René Kermer
GEOS
Ingenieurgesellschaft
mbH, Halsbrücke

Project Summary

Germanium (Ge) and Indium (In) are important elements for high-tech industry and their future supply is not assured. Copper (Cu) dust waste from smelters hold Ge and In, however, there is no technology for their recovery from these dusts. Further, the large volume of the produced Cu dust waste is challenge for Cu smelters. This project proposes to develop environmental 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 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 mould manufacturing for recovery of Cu. The project, for the first time, will attempt bioflotation for recovery of Cu mineral from Cu smelter dust with the help of biosorptive biocomposites.

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WORKSHOPS

International Workshop on Ecological Processes and New Technologies for Sustainable Development

Indo-German workshop was held along with the "International Workshop on Ecological Processes and New Technologies for Sustainable Development" from 21 – 25 February 2018 in Jaipur. This was the first workshop to be supported by IGSTC under the new "**Open Workshop Call**". The coordinators for the workshop were Prof Sanjay Mathur, University of Cologne and Prof A. S. Khanna, IIT Bombay. The workshop was embedded within the two well-established events namely the 19th International Symposium on Eco-materials Processing and Design (ISEPD 2018) and Expo on Environment-friendly Surface Engineering Technologies (EXPO) - an industry exhibit on greener and eco-friendly processing and engineering technologies. With over 400 international participants of the ISEPD & EXPO, the bilateral Indo-German workshop maximized the synergy of discussions between partners from industry and academia. Within the overarching theme of "Material Technologies for Sustainable Development", the Indo-German workshop established a novel platform integrating two of the most critical facets of materials science and engineering, namely materials innovation and sustainability manifested in the concepts of nanotechnology and ecological pathways towards materials development as well reduction of materials usage. This interdisciplinary Indo-German forum with selected international experts discussed the necessity to identify, develop, assess and integrate novel materials for sustainable energy solutions. A panel of internationally renowned scientists put forward their thoughts on forming new scientific alliances and cooperation among scientists from India, Germany and abroad to tackle the materials challenges for

new technologies. Some of the topics discussed at the workshops were innovative materials synthesis procedures with ecological merit; Remediation of waste materials for energy applications; Cutting edge concepts for energy generation and storage; Heterogeneous catalysts for electrochemical processes; From black to green – towards optimal use of resources; Technology Readiness: the crucial role of cost-effectiveness and sustainability.

Director, IGSTC was the Guest of Honor at the opening ceremony of workshop and introduced IGSTC to the audience.

Scientific Impact and Future Efforts

With over 200 international participants, the bilateral Indo-German workshop was optimally positioned to maximize the synergy of discussions between partners from industry and academia. The active involvement of major German institutions (Fraunhofer Institute for Ceramic Technologies and Systems, IKTS, Dresden; Helmholtz Zentrum Berlin; Technical University Darmstadt; Max-Planck Institute Erlangen, Karlsruhe Institute of Technology, Carl Zeiss AG, Germany, INMATEC Technologies GmbH, Germany, Materials Alliance Cologne GmbH and University of Cologne) and Indian partners (Indian Institute of Technology, Bombay; Indian Institute of Science, Bangalore, Indian Institute of Technology, Delhi, Malviya National Institute of Technology, Jaipur, Manipal University, Jaipur, Indian Association for Cultivation of Science, Dayalbagh Educational Institute, Agra; Indian Institute of Technology, Banaras; Indian Institute of Technology Jodhpur) guaranteed the alignment of this event along the mission of IGSTC and the expected outcome is expected to foster the bilateral ties at various levels.

DST-MAX PLANCK SOCIETY PROGRAMME

DST–Max Planck Society Programme
Connecting Excellence

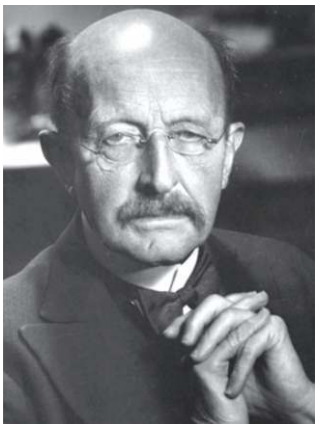
Department of Science & Technology
Government of India

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

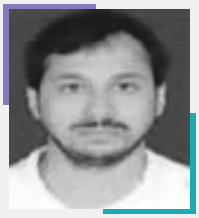
The “Partner Group” is an instrument created by the Max Planck Society (MPG) for the purpose of strengthening the ties between Max Planck Institutes and research institutes from other countries. Partner Group is a mechanism to intensify cooperation between individual scientists through jointly conceptualized 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.

Structural Biology of vesicular trafficking: Screening of putative Rab5 GAPs for their role in Rab5 to Rab7 conversion



Sunando Datta
IISER Bhopal

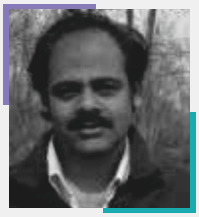
Marino Zerial
MPI of Molecular Cell Biology and Genetics, Dresden

Genetic Diversity Studies: Studies on human salivary microbiome in Indian populations and its implications in human genetic diversity studies, health sciences and evolutionary biology

Madhusudan Reddy
CDFD Hyderabad

Mark Stoneking
MPI for Evolutionary Anthropology, Leipzig

Chemical Ecology: The role of small-RNA pathways in plant defense against insect herbivores



Shree Prakash Pandey
IISER Kolkata

Ian Thomas Baldwin,
MPI for Chemical Ecology, Jena

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

Role of cellular membranes in stress signalling and protein homeostasis maintenance

Dr Swasti Raychaudhuri
CSIR-CCMB Hyderabad

Prof F Ulrich Hartl
MPI of Biochemistry Martinsried

Multifunctional hybrid nanostructures for alternative energy systems

Dr Amreesh Chandra
IIT Kharagpur

Prof Katharina Landfester
MPI for Polymer Research Mainz

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	**Subbulakshmi Chidambaram** Pondicherry University, Pondicherry	**Reinhard Jahn** MPI for Biophysical Chemistry, Goettingen	Dissecting the regulatory role of Adiponectin signalling in human retinal synaptic vesicle trafficking under physiological and pathological conditions
02	**P Anil Kumar** Institute of Microbial Technology Chandigarh	**Friedrich Widdel** MPI for Marine Microbiology, Bremen	Physiology of mixotrophic planktonic bacteria
03	**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
04	**Richa Rai** Banaras Hindu University Varanasi	**Jonathan Gershenzon** MPI for Chemical Ecology Jena	Application of 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
05	**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
06	**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
07	**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
08	**Arjun Bagchi** IIT Kanpur, Kanpur	**Stefan Theisen** Gravitational Physics, Golm	Minkowskian Holography

S. No	Fellow	MPI Counterpart	Field of Research / Title
09	**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
10	**Karthik V Raman** TIFR, Hyderabad	**Klaus Kern** MPI for Solid State Research, Stuttgart	Tailoring interface spin transport: towards molecular spintronics
11	**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
12	**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
13	**Venkat Gundabala** IIT Bombay	**Katharina Landfester** MPI for Polymer Research Mainz	Water-based nanocomposite coatings
14	**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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