IGSTC

INDO-GERMAN SCIENCE AND TECHNOLOGY CENTRE

OF INDO-GERMAN S & T COOPERATION

ANNUAL REPORT 2023-24

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विज्ञान एवं प्रौद्योगिकी विभाग
DEPARTMENT OF
SCIENCE & TECHNOLOGY

सत्यमेव जयते

IGSTC
INDO-GERMAN SCIENCE AND TECHNOLOGY CENTRE

AN INITIATIVE OF THE
Federal Ministry
of Education
and Research

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

IGSTC AIMS TO

- Play a proactive role in facilitating participation of industry in joint R&D+I projects.
- Provide/assist in mobilizing resources to carry out industrial R&D+I projects.
- 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.
- Provide advice to institutes and industries from both the countries on the possibilities of Indo-German cooperation and help identify suitable partners.
- Facilitate and promote Indo-German collaboration in Science and Technology S&T through substantive interaction among Government, academia and industry
- Encourage Public-Private Partnerships (PPP) to foster elements of innovation and industrial application and cultivate a culture of cooperation between science and industry
- Nurture networking between young and mid-career scientists and technologists to develop a sense of mutual trust, leadership and entrepreneurship.
- Develop cooperation through the identification of scientists and scientific institutions of the two countries.
- Organize workshops, seminars, training programmes and other types of events on topics of mutual interest.

CONTENT

The Year 2023-24 at a Glance

The Indo-German Science & Technology Centre (IGSTC), a joint initiative of the Department of Science & Technology (DST), Government of India and the Federal Ministry of Education and Research (BMBF), Government of Germany has been spearheading various bilateral Indo-German programs such as applied research projects, scientific workshops, early career fellowships, support for female researchers, etc. and carving a unique Indo-German S&T network to enhance collaborations. These initiatives have resulted into several innovations, technologies, network of young researchers, etc. thus strengthening further the overall S & T cooperation between the two countries.

On 7th March 2024 India and Germany celebrated the milestone of the 50th anniversary of the signing of the Agreement about Indo-German S&T Cooperation. A series of events have been planned over the years to commemorate the occasion.

In the Year 2023-24, IGSTC has supported several activities. A brief of different activities is presented below.

2+2 projects, the flagship program of IGSTC supports joint R&D&I projects of industrial relevance by means of “2+2 Mode of Partnership” i.e. involvement of at least one research/academic institute and one public/private industry from both the countries. Project proposals are expected to provide insights and exploitable research results leading to new technologies, products, processes, patents and/or services. To date, the 2+2 scheme has supported 54 projects partnering research institutions, academia and industries creating a network of more than 220 organisations.

During the year 2023-24, IGSTC has provided funding support to 16 ongoing 2+2 projects in emerging areas of sustainable energy, advanced manufacturing, biomedical devices and technology, water & wastewater technologies, smart cities, etc. These 16 Projects involve more than 100 project partners from academia and industry from India and Germany with a total project investment (from BMBF and DST) of an estimated ₹ 74 Cr or € 9.2 million.

Furthermore, six new projects were recommended for funding under the 2+2 call on "Waste to Wealth and Sustainable Packaging" by the Scientific Committee.

The **bilateral workshop** programme of IGSTC creates a platform for substantive interaction between scientists/researchers from academia and industry from both India & Germany to explore new avenues for Indo-German scientific collaborations. This year IGSTC supported 15 workshops in various topics such as bio-circular economy, agriculture, robotics, catalysis, material science, resilient smart urban infrastructure, AI, etc. The workshops networked more than 1500 academicians, industry personnel, policy makers and early career researchers.

The IGSTC **Industrial Fellowship** programme, an unique fellowship provides exposure of PhD students/young researchers from India at a German industrial setup to promote applied research and technology development.

Fellowships are offered annually at two levels, PhD Industrial Exposure Fellowship (PIEF) and Post-Doctoral Industrial Fellowship (PDIF). From the Call 2023, twenty (10 PDIF and 10 PIEF) candidates were selected from various institutes of India. Currently, there are 60 fellows at different German organisations who have either completed or are close to completing their fellowship. The fellowship has provided a distinct outlook and exposure on international research environment to the young researchers working at German industrial and applied R & D setup.

The Industrial Fellowship programme has chartered a new path for PhD/Post-Docs to perform industrial research in Germany at an early stage of their career.

Call 2023 – Industrial Fellowship Awardees

The **Women Involvement in Science and Engineering Research** (WISER) programme provides an opportunity to female researchers from India and Germany to be a part of an ongoing R&D project of interest with acceptance from the host team. The second batch of WISER awardees were selected in the year 2023-24 – 10 Indians and 5 German. They will carry out projects in various fields such as the solar cells, cancer therapies, tissue models, etc. WISER programme has created a pathway for female researchers in both countries to embark on international collaborations. The WISER program thus has opened opportunities for women researchers in both countries to participate in international collaborations.

Indian WISER awardees

Dr Ozlem Gunay-Esiyok felicitated by H.E. Parvathaneni Harish, Ambassador of India to Germany in October 2023

The **Paired Early Career Fellowships in Applied Research** (PECFAR) provides an opportunity to early-career scientists & engineers to explore Indian & German research landscape on various aspects, including entrepreneurship, collaborative research, innovation and sharing of lab facilities & infrastructure. In the call of 2023, 12 pairs from various parts of India and Germany were selected. These pairs of researchers will build networks in different areas of STEM such as AI/ML for glacier modelling, Additive manufacturing, material scientists, hydrogen storage technologies, biotechnology, quantum physics, etc.

The **Small Immediate Need Grants** (SING) supports proposals/initiatives that requires modest funding to kick start or has the potential to embark on good bilateral Indo-German collaboration. Under this programme, 2 candidates have been funded during the year.

The Indo-German Science and Technology Centre (IGSTC) has been increasing its outreach and visibility by conducting events at various tier-2 cities of India. IGSTC organized five successful outreach events in Lucknow, Chandigarh, Nagpur, Dharwad and Bhopal. The events were attended by invitees from several academic & research institutions and industries. The outreach events have introduced around 500 participants across various spectrum of scientific community to IGSTC and its programs.

Group Photo at Chandigarh outreach event

The IGSTC has facilitated and created a sustainable mechanism for researchers from India and Germany to collaborate through various channels. IGSTC will continue to flag-bear the collaborations in S & T between India and Germany in the coming days, months and years. The initiatives and the corresponding networks created will definitely take the partnership in S & T to greater heights in coming years.

IGSTC GOVERNING BODY

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DST

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ARCI

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Sanjeev Kumar Varshney
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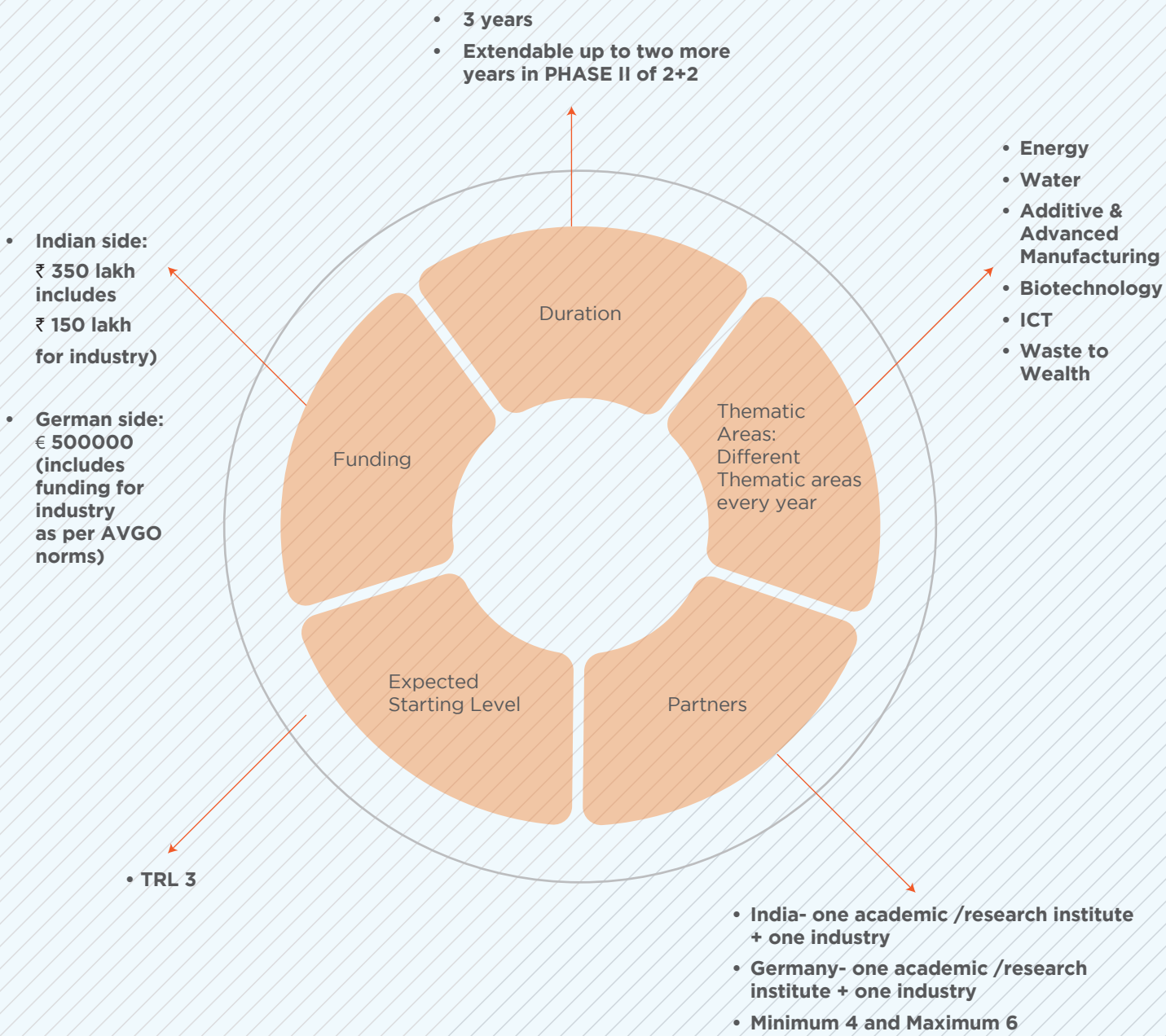
Sanjiv Rangrass
Zetwerk Manufacturing Pvt. Ltd.

Andrea Frank
Stifterverband

2+2 Projects

IGSTC intends to catalyse innovation centric joint R&D+I projects of industrial relevance by means of "2+2 Mode of Partnership" with the participation of research/academic institution and public/private industry from both India and Germany. The project proposal is expected to produce insight and exploitable research results leading to new technologies, products and/or services.

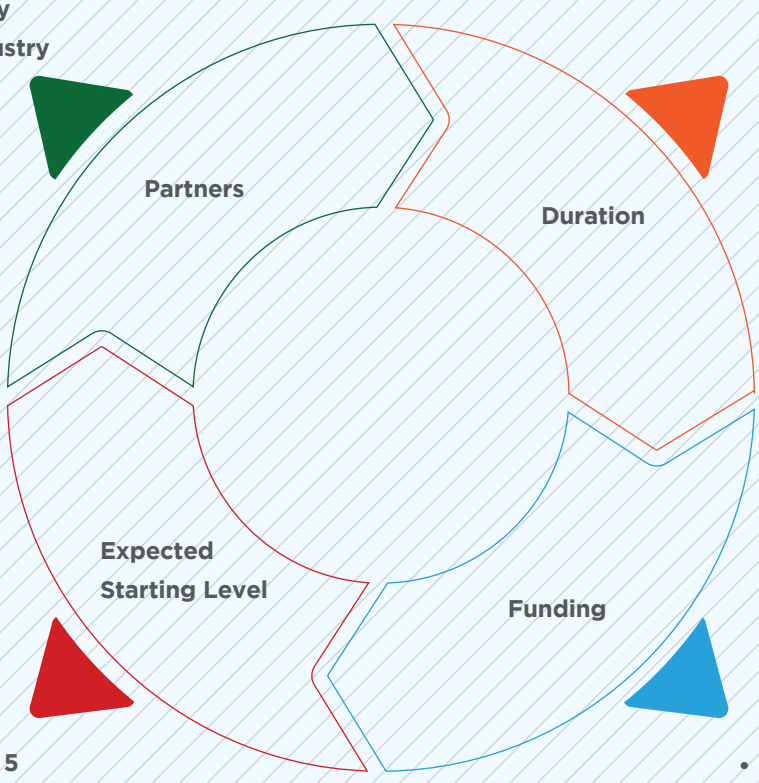


PHASE II of 2+2

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

- **One partner from both India and Germany**
- **Minimum one industry**

- **2 Years**



- **TRL 5**

- **Indian side: ₹ 230 lakh (includes ₹ 100 lakh for industry)**
- **German side: € 300000 (includes funding for industry as per AVGO norms)**

ModAMtool

Material and process development for additive manufacturing and post-processing of tools made of modified hot work tool steel

Project Brief

The Laser Powder Bed Fusion (LPBF) additive manufacturing process is suitable for tool making due to the small batch size and the ability to produce curved cooling channels that are not conventionally possible. When processing standard steel for hot work and plastic moulding tools H13 with LPBF, cracking must be prevented by using high preheating temperatures or by significantly limiting part size. To overcome these limitations, a modified hot work tool steel is being developed that can be processed at preheating temperatures of 200 °C or less to enable industrial use. For efficient parameter selection, software for LPBF process development will be adapted and used. For a high surface quality of the functional outer surface and the complex cooling channels, polishing with a polymer rheological abrasive in a semisolid to liquid medium is used. The process chain to produce a tool is demonstrated and the tool is implemented in a plant environment.

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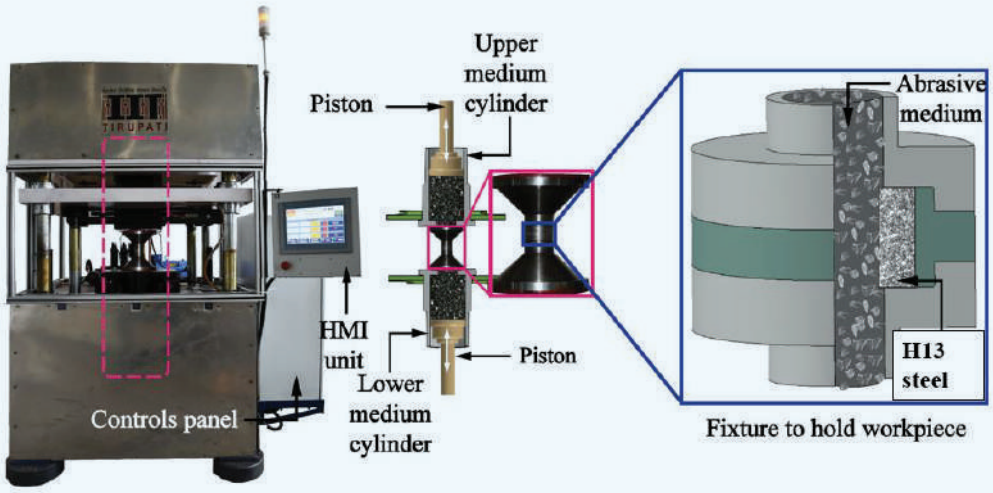
Progress made/achieved

Fraunhofer Institute for Laser Technology (ILT) and Deutsche Edelstahlwerke Specialty Steel GmbH & Co. KG (DEW)

Fraunhofer ILT, and DEW, collaborated on several work packages for material and process development. In WP1, they utilized the miniaturized process module "Petit" for LPBF manufacturing of samples, enabling rapid alloy development by DEW. In WP2, they varied LPBF process parameters to manufacture samples for analyzing relative density, tensile properties, Charpy impact strength, and microhardness, and adjusted contour parameters to assess the surface roughness of inner and outer features. WP3 focused on LPBF manufacturing of samples with inner cooling channels to test post-processing techniques at IIT Tirupati using a polymeric rheological abrasive medium. Finally, in WP4, they provided consulting services for transferring parameters to an industrial LPBF machine at Intech and facilitated the manufacture of an aluminium die casting tool demonstrator at Intech.

Build platform with cylinders

The base of the development is the common tool steel H13/1.2344. Thermodynamic and thermokinetic simulation are done and three candidates are identified. Laboratory heats of the new design alloys are produced and investigated. The production of powder of the most promising alloy is in preparation.



Overview of abrasive flow finishing with polymer rheological abrasive medium

IIT Tirupati

IIT Tirupati focused on the preparation of the polymer rheological abrasive medium, conducting rheological studies, and performing finishing experiments on additively manufactured tube structures. Various compositions were tested through trial and error to finalize the medium's formulation. The polymer rheological abrasive medium was successfully prepared using a suitable polymer and cross-linker. Dynamic rheological studies were conducted to understand the flow and deformation behavior of the abrasive flow finishing medium. Fixtures for abrasive flow finishing were designed and developed. Metallurgical characterization of as-received H13 steel samples was performed. Finishing experiments were conducted on H13 steel, analyzing the impact of abrasive particle distribution on material removal and surface roughness.

Abrasive media

Intech

Between December 2022 and March 2023, Intech Additive Solutions Pvt Ltd demonstrated their AMOptoMet software for creating parameters for new materials, procured powder with modified chemical compositions for printability checks, and provided IIT Tirupati with specimens made from different materials for initial polishing trials. From April 2023 to February 2024, a delay in powder shipment from Germany prompted discussions between Intech and IIT Tirupati about alternative material procurement. Subsequently, Intech conducted printing trials using H13 material, optimized the printing parameters, and produced coupons that were tested for density, hardness, and tensile properties, achieving values close to nominal standards. Additionally, they supplied IIT Tirupati with hollow cylinders for post-processing trials.

Publications

1. Basha, S.M., N. Venkaiah, T.S. Srivatsan, and M.R. Sankar. "Post-processing Techniques for Metal Additive Manufactured Products: Role and Contribution of Abrasive Media Assisted Finishing." Materials and Manufacturing Processes (2024). https://doi.org/10.1080/10426914.2023.2289678.

2. Basha, S.M., N. Venkaiah, and M.R. Sankar. "Development and Performance Evaluation of Galactomannan Polymer Based Abrasive Medium to Finish Atomic Diffusion Additively Manufactured Pure Copper Using Abrasive Flow Finishing." Additive Manufacturing (2023). https://doi.org/10.1016/j.addma.2022.103290.

3. Basha, S.M., N. Venkaiah, and M.R. Sankar. "Experimental Investigation on Deballing and Surface Finishing of Selective Laser Melted 18Ni300 Steel Using Polymer Rheological Abrasive Medium." Wear (2023). https://doi.org/10.1016/j.wear.2023.204813.

4. Basha, S.M., M.R. Sankar, and N. Venkaiah. "Experimental Investigation on Deballing and Surface Finishing of Selective Laser Melted 18Ni300 Steel Using Polymer Rheological Abrasive Medium." Paper presented at the 24th International Conference on Wear of Materials, 2023.

RAMFLICS

Robust additive manufacturing of functional lightweight integrated customisable metallic structures

Project Summary

Light-weight high-performance components such as motor casing and battery enclosures require the assembly of multiple parts with complex geometry for the efficient design of electric vehicles. Design innovation to reduce the part counts without compromising the desired structural, thermal and mechanical performances is needed but limited by the ability of the traditional processes. The recourse is to produce parts with an innovative design by printing additional features on a cast or extruded part using wire-arc additive manufacturing (WAAM) thereby reducing part counts and the need for elaborate assembly processes. WAAM is a novel technique and involves rapid melting, deposition and solidification of materials to build geometric features layer-by-layer on a base. An understanding and precise control of the WAAM process are needed to produce a defect-free, structurally sound and dimensionally consistent component.

The present project aims at WAAM based printing of three-dimensional features on cast / extruded aluminium alloy parts to enhance their functionality. The work packages include the development of in-situ monitoring and process control systems, computer-based models to predict the structure, property, residual stress and distortion and defect generation and printing of parts with enhanced features as demonstrators. These demonstrators will be put under standard tests to check their performances for further commercialization and mass production. The tasks will be carried out by all the partners in a systematic manner to ensure the reproducibility of the developed technology and completion of the overall targets.

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Gefertec GmbH

Progress made/achieved

Process conceptualization and design (TRL 3)

- An inventory of parts, their corresponding manufacturing routes and overall fabrication procedures for state-of-the-art EV motor casings was carried out.
- A design analysis was done to build 3D functional features on an extruded part with an objective to reduce the inventory of part counts.
- Procurement process of earmarked WAAM facilities at both IITB and IITM is completed.
- An in-person kick-off meeting was conducted at IITB and Hindalco premises involving all the six partners and senior personnel from IGSTC. It was learnt that activities for German partners was started after six months as compared to the Indian partners.
- Hindalco has agreed to deliver the substrates on which printing of 3D features will be attempted at IITB and IITM.

Process understanding and validation (TRL 4)

- Efforts were made to develop printing parameters for building 3D features of automotive grade aluminium alloys on selected EV substrates using WAAM based 3D printing.
- An impact of process conditions on dimensional consistency of printed features, defects such as porosity and cracking, and structural integrity is studied in laboratory scale.
- Efforts are made to develop computer based numerical models to understand the effect of power and speed on thermal cycles, feature profile, microstructure, residual stress and distortion evolution during printing.

Process development and integration (TRL 5)

- Printing of envisaged 3D features on wrought substrates using the WAAM facilities is completed.
- Effect of important WAAM process variables on the dimensional consistency and structural integrity of the printed features is being evaluated.
- Computer based models to correlate the effect of important WAAM variables on lack-of-fusion, warpage and residual stress, and structural integrity are developed and being evaluated.
- In-situ process monitoring methodoogy for laboratory scale printing of 3D features is developed and efforts are being made to integrate the same for part-scale printing.

Demonstrator production and evaluation (TRL 5)

- Hindalco delivered extruded substrates for printing of sample level features. Printing of actual features true-to-design on the extruded motor casing is being undertaken.

Utilisation of results (TRL 6)

- In January'2024, a consortium meeting was organized at IITM with active participation from potential end-users and their OEMs. HINDALCO and GEFERTEC presented the potential of the proposed WAAM based flexible and rapid manufacturing route of EV motor casings. Further deliberations for industry adaptation is undertaken by the Indian Industry partner.

MAMM-WAAM
Multi-Axis multi-material wire arc additive manufacturing

Project Summary

The powder-feed metal Additive Manufacturing (AM) systems can realize the Functionally Graded Materials (FGMs) but remain inefficient and challenging to control the localized material composition. Therefore, this project proposes a novel approach, "Multi-Axis Multi-Material Wire Arc Additive Manufacturing (MAMM WAAM)," to efficiently fabricate large-scale metallic objects of FGMs. The proposed system will be a robot-cell consisting of two multi-wire plasma welding torches attached to two 6-axis Robotic Arms mounted on the curved tracks. This system will produce large-scale FGMs objects of size up to 2m×2m×1m. Also, a Computer-Aided Process Planning (CAPP) software will be developed for efficiently operating the proposed system. New algorithms for (i) representing FGMs CAD models, (ii) build strategies, (iii) volumetric simulation, and (iv) collision detection will be developed for this CAPP software. The system will demonstrate its capabilities through industrial case studies.

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Rahul Sharma
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Progress made/achieved

IIT Guwahati

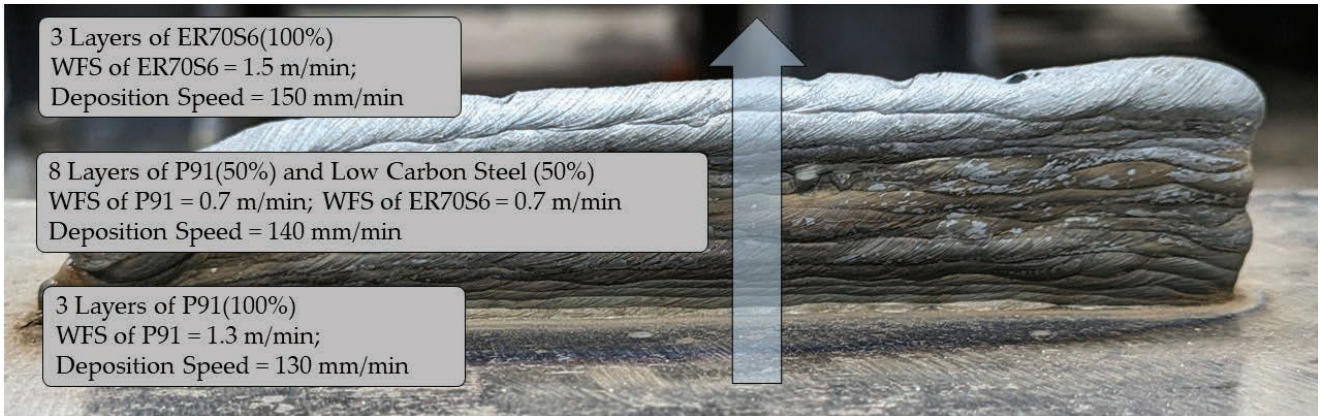
After discussion with the stakeholders, the Robot – cell has been designed and arrived at the following specifications of the robot cell:

- Robotic Arms: Two 6–axis robotic arms with 11-12 kg payload and 2.2-2.4-meter reach will be mounted on two parallel tracks.
- Controller: A dual arm controller will operate the 14 (6+1+6+1) axes and six analog switches (changing the wire speed and current).
- Linear Tracks: there will be two parallel tracks of 3.5-meter stroke length.

It was decided to use linear tracks instead of the curved tracks due to CAM environment complexities. It has been concluded that the deliverables and capabilities of the robotic cell will not be compromised even if parallel tracks are used.

Also the team came – up with a new build strategy that is called as drop-on-demand deposition to locally control and engineer the microstructure and hence to fabricate microstructure based FGMs. A thin wall was deposited successfully using this method and same was given to IIT Kanpur for characterization. The results obtained through SEM analysis are very encouraging and soon the work will be submitted in a reputed journal.

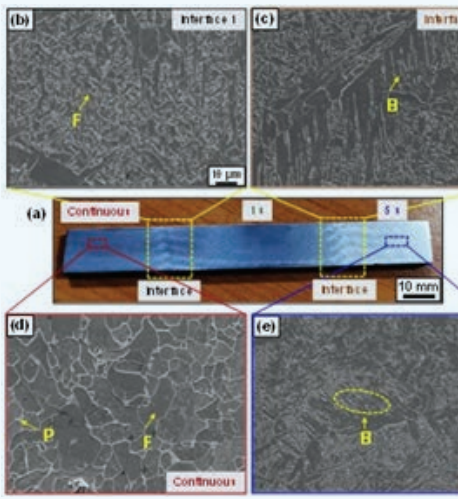
MAMS WAAM System at IIT Guwahati



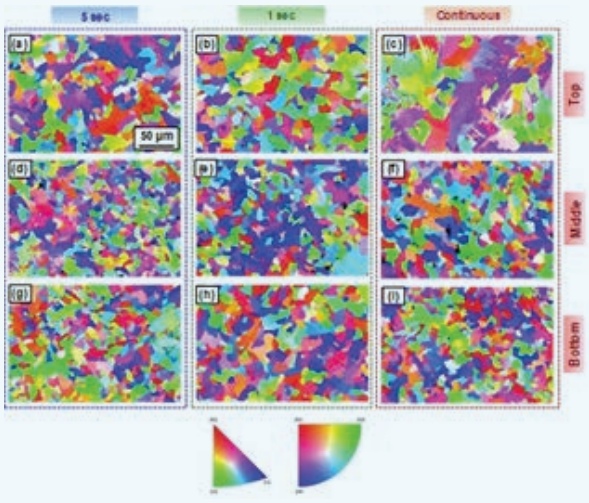
Initial FGM Structure deposited by MAMS WAAM

IIT Kanpur

IIT Kanpur is working on characterization and on the dynamics of robots. IIT Kanpur had received drop on demand deposited mild steel wall (shown below) from IIT Guwahati prepared using WAAM for microstructural and mechanical characterization. The SEM micrographs for the three regions are shown in Figure below. The T1 sample showed completely pearlitic microstructure, whereas the T3 sample exhibited bainitic + pearlitic microstructure. This shows that continuous deposition the cooling rates are slower as compared to pulsed deposition, which results in the formation of bainite in the latter. To understand the effect of cooling rates on the grain size and orientation, EBSD was also carried out. The inverse pole figure (IPF) maps of the top, middle and bottom regions of all the deposited walls are shown in the Fig. 3



(a) Macroscopic view of the deposited FGM with different IDCTs. SEM micrograph of (b) interface (bright pattern) of continuous and IDCT of 1s, and (c) interface (bright pattern) of IDCT of 1s and 5s. SEM micrograph of the deposited wall by (d) continuous deposition and (e) using IDCT of 5s.



IPF maps of the top, middle, and bottom region of deposited wall during continuous cooling and IDCT of 5s and 1s.

Ace Manufacturing Systems Ltd.

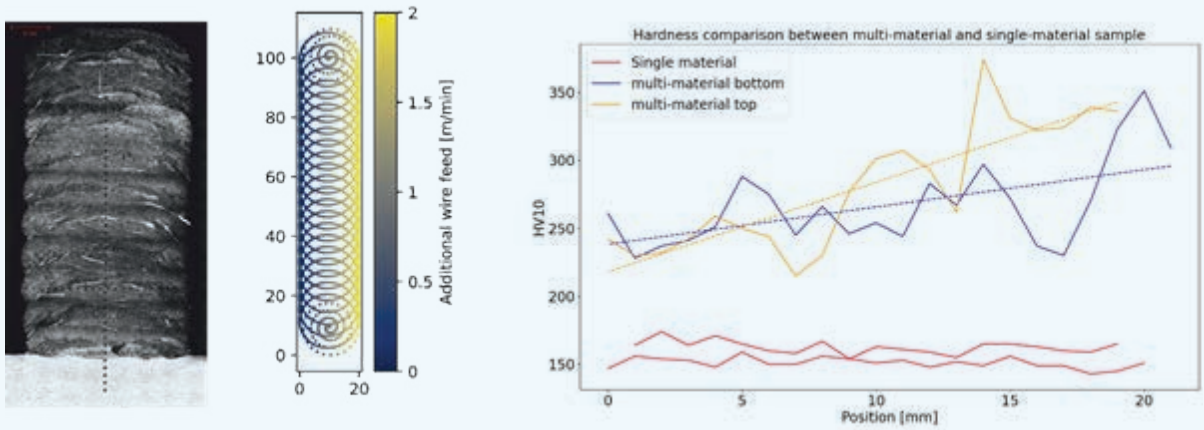
A MIG Welding based Wire Arc Additive Manufacturing System

- Experimented Arc DED (Make: Fronius MIG – CMT, Model: TSI – 400i) and studied the various aspects of Wire ARC-DED.
- Interfacing of MIG unit to CNC Machines to understand various process parameters like, Voltage, Current, Feed rate of Wire and Axed feed rate required to achieve the desired job, programming from CNC controller.
- Visit to IIT Guwahati to discuss more on the project integration, tool path and other tests done by them, inputs required for present project.
- An in-situ interlayer cooling method was developed to improve the productivity of the system.

Welding experts team visit to AMS

RWTH Aachen

During this project RWTH Aachen will develop a multiwire plasma torch to create multi-material additive manufactured parts. Creating multi-material parts will enable the development of functionally graded structures. Two use cases have been determined: Creating a seawater resistant FGM which has a high strength and low cost and a FGM which fills the requirements of die and mold operations. These shall be tested in further experiments. Initial multiwire samples have been produced using MAG welding, which is a more flexible process in terms of height variation. Variable wire feeds have been tested. The possibility of in-line multi-material trochoidal paths has been explored and hardness tests have been carried out.



Macroscopic cross section, welding path and hardness measurement of multi-material sample

Weld samples with straight beads were produced using the plasma nozzle. On visual inspection, the weld beads were free of porosity. However, trochoidal paths resulted in a lot of porosity. It was assumed that the porosity was due to insufficient shielding gas coverage.

Therefore, modified plasma nozzles were analyzed using a high-speed camera and schlieren optics with variable gas flow rates to overcome porosity problems in trochoidal tool paths.

In order to produce complex multi-material structures, a path planning tool must be implemented in the setup. The path planning tool implements point-specific material combinations. The interplay between the robot, the welding power supply and the additional wire feeders has been established. First demonstrators have been produced with the integration of the robot and the welding power supply for a MAG process.

First demonstrator with new path planning setup

ModuleWorks

At the current status of the project, ModuleWorks is working on the integration of the dual robot cell into the ModuleWorks software libraries. The system is now also available for customers. More precisely, it is the first robot cell with several robots in the ModuleWorks software portfolio. Therefore, the dual robot cell of the project is the first demonstration of the software's capabilities.

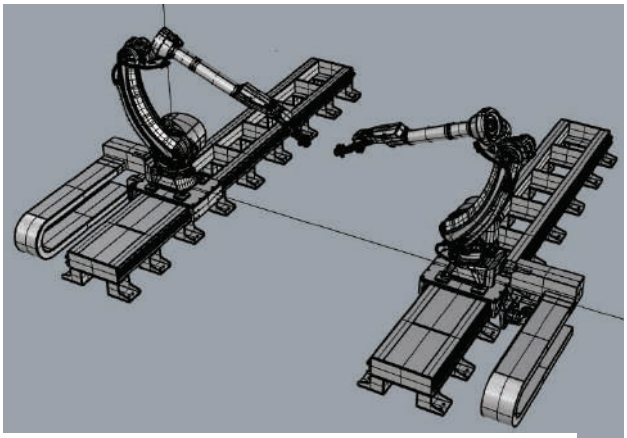
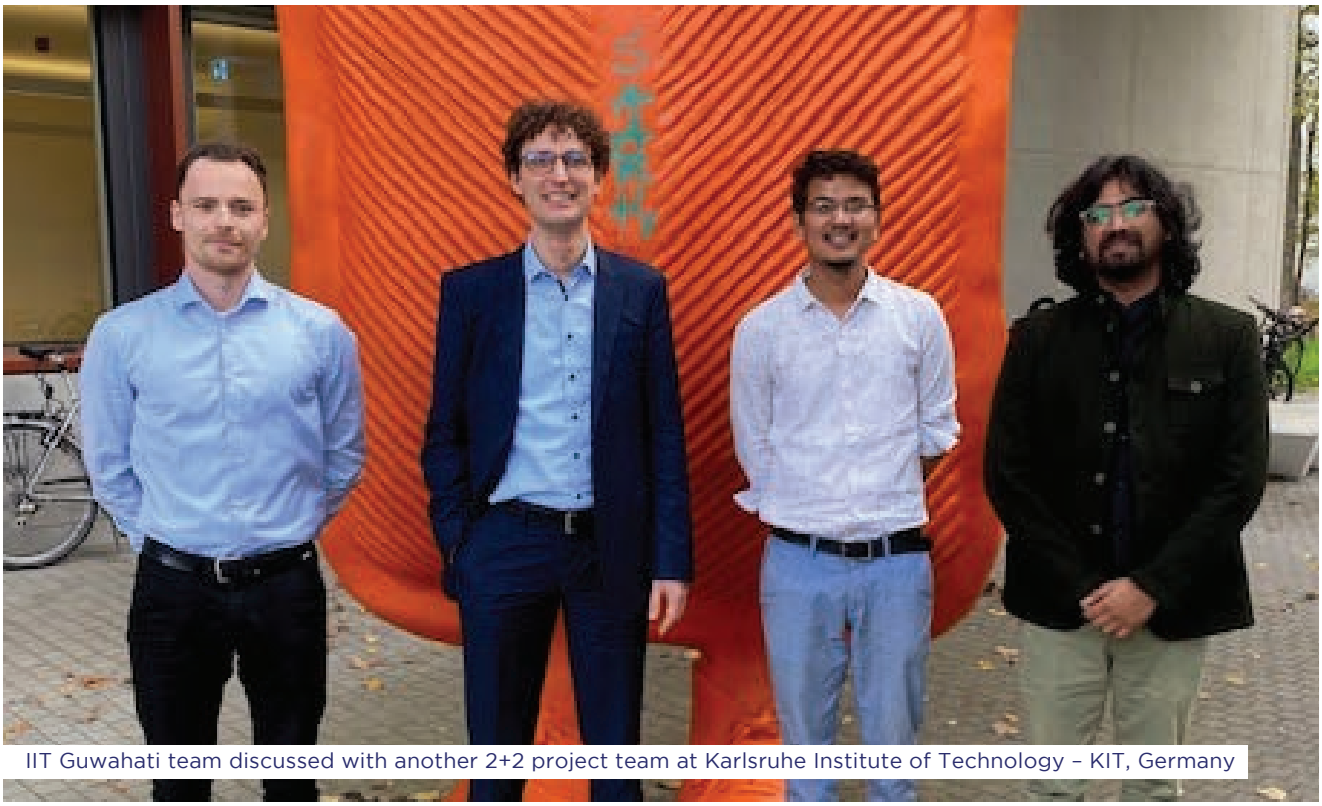


Figure: Dual Robot Cell in ModuleWorks Software

RWTH Aachen and IIT Guwahati team at Formnext-2023 event in Germany



IIT Guwahati team discussed with another 2+2 project team at Karlsruhe Institute of Technology – KIT, Germany

INGERBDIAM
Development of biodegradable alloys and AM processes for soft tissue anchors

Project Brief

Presently used metallic bioimplants are non-degradable and remain permanently inside the body necessitating secondary surgery for removal. To overcome such problems, biodegradable (BD) metallic implants (Fe-Mn, Mg, Zn) are being developed. Mg based alloys are recently being commerciallized for dental, trauma and orthopedic appilcations. However, their usage is not extended to the applications which require longer period due to higher degradation rates and hydrogen evolution. These can be reduced by incorporating fine grain structure and coatings. Fe-Mn based alloys are recently gaining importance due to high specific strength and low cost. The challenge with Fe-Mn based alloys is lower degradation rates which can be addressed by miniaturizing. Presenlty, these BD implants are being developed by conventional techniques. Additive manufacturing (AM) is an advanced manufacturing technique that makes complex and custom made components with fine grained structure, controlled porosity and degradation rates. In addition, the challenges in fabrication of Mg based implants due to issues with forming and machinability can be overcome by AM. The reported studies on AM are preliminary. The use of soft tissue anchors (STA) as implants is projected to increase due to wider usage for fixing sports injuries as well as repairing wear and tear of tendons, ligaments and cartilage. The proposed study envisages design of STAs, development of Mg and Fe-Mn alloy powders with suitable composition and demonstration of AM process for the manufacture of prototypes. The proposed work also involves characterization (microstructural, mechanical and biological) of AM built and surface modified coupons as well as components.

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Progress made/achieved

ARCI
Large scale development of BD Fe-Mn alloys and powders for AM

ARCI has developed two biodegradable alloys, namely Fe-Mn and Mg-Zn based alloys. The Fe-Mn alloy (Fe-35Mn-5Si-0. 25Cu) ingots of 65 kg were produced by Vacuum Induction Melting (VIM) and the powder was synthesized from the pre-alloy ingots by inert gas atomization (IGA). The powder was sieved for -63 Qm and +25 Qm fractions by sieves shown in below Figure , and the SEM image, and DLS particle size are shown in Figure below. More than 15 batches of powders were synthesized and their properties were reproduced.

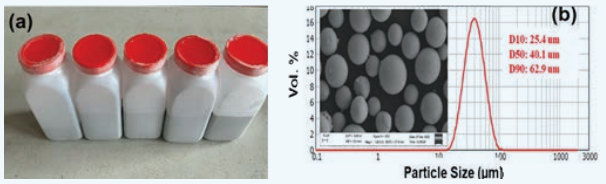


Figure (a) Fe-Mn alloy powder made by IGA and (b) DLS particle size and size distribution and inset is SEM image after sieving

About 23 kg of powder was supplied to Indian industrial partner WIPRO 3D to optimize the powder bed fusion process parameters for printing the coupons. The phase and microstructure of AM coupons were studied to narrow down the processing parameters to get defect-free builds. Similarly, ARCI has optimized powder bed fusion (SLM) process parameters. A defect-free microstructure of the AM coupon has been obtained, as shown below.

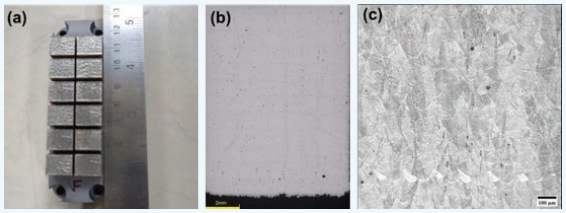


Figure: (a) AM coupons fabricated using in house synthesized Fe-Mn powder and (b) and (c) coupon microstructure (optical)

WIPRO 3D

- **Development of AM process (TRL 4)**

Approximately 30 different coupons have been printed using Fe-Mn alloy powders by powder bed fusion techniques (SLM). Using 15 different printing parameters coupons were printed successfully. Good microstructures were observed at the coupon level with good internal soundness as shown below.

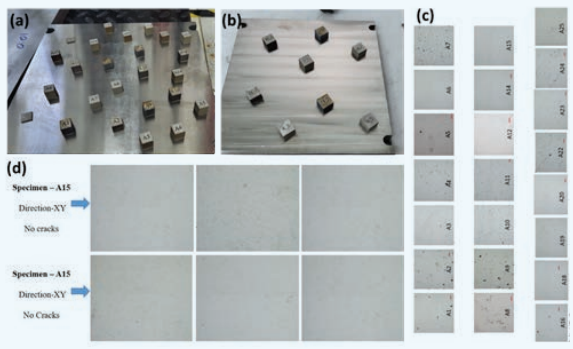


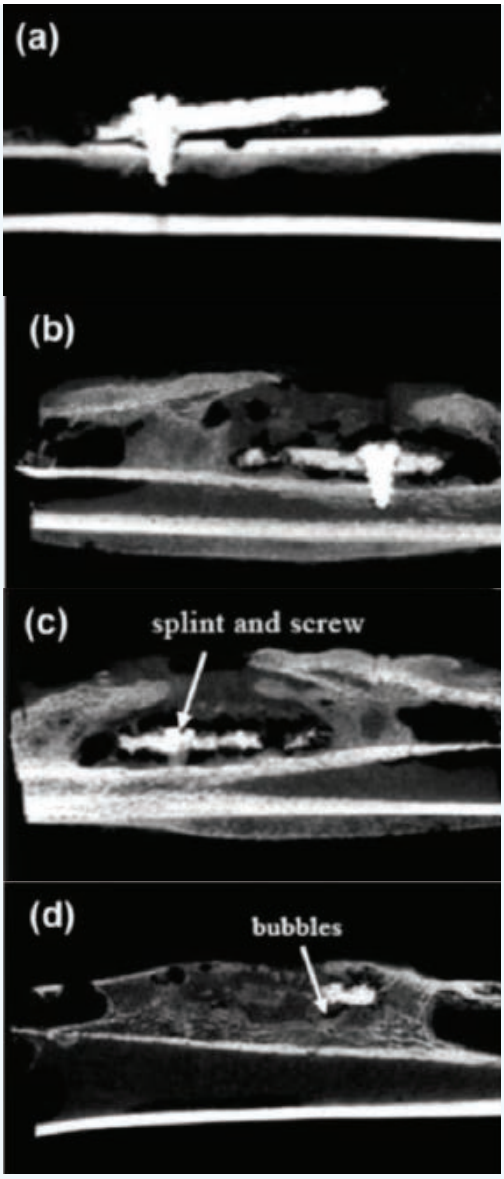
Figure (a) and (b) Fe-Mn alloy coupons printed by powder bed fusion and (c) their respective microstructures and (d) microstructure of coupon with optimized process parameters showing defect free.

Charité, Berlin

• STA design

After detailed studies of commercial STA and literature, Charite proposed two different STAs designs for Fe-Mn and Mg based alloys. The model was prepared with the help of software Autodesk Fusion 360. Design 1 is for Fe-Mn Alloys with sharper threads and having tapping in for Design 2 for Mg based alloy. The head tip idea comes from the most stable screw, designed for Mg-Zn alloys. The design has been reported to all partners and was updated by ARCI and it is now awaiting production of sample anchors by AM. Mechanical testing, such as the pull-out strength of 3D printing of STAs and investigation of degradation in a simulated body fluid environment will be carried out.

Electrochemical working platform



CT-images of Mg-Zn implant after (a) 2, (b) 4, (c) 8 and (d) 12 weeks of surgery

KCS Europe

Ti and Ti and Ag coating on Fe-Mn:

To identify a suitable layer system for a coating, KCS first conducted a literature search on the corrosion behavior of conventional biodegradable soft tissue anchors. This showed that they lose their integrity after just 8-12 weeks and a corrosion inhibiting coating is therefore necessary.

In the next step, suitable elements for a corresponding layer system were identified. Since there is a direct reaction between blood and the implant during implantation, the layer materials must be both corrosion-resistant and biocompatible, i e. biologically tolerable and bioreactive. Since some of these alloys are not conventional for PVD application, the necessary targets had to be requested and ordered from various suppliers. A series of tests to determine the various separation parameters is planned as the project progresses.

NOMIS

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

Project Brief

Fertilizers and pesticides can exhibit moderate to lethal levels of toxicity in humans. Although they are used in farm-fields to boost agricultural productivity, these chemicals move up through the food chain, which leads to biomagnification. Most of the reported methods for the detection of fertilizer and pesticides in the soil are expensive, have a short shelf life, and are difficult to realize as a device outside laboratories. By combining the complementary expertise of the Indian and the German partners, our project aims to address this unmet challenge by developing an efficient multiplexed device for the detection of nitrate ion (NO3–) (a major fertilizer-based soil/ground water contaminant in India and Germany) and organophosphates (a class of pesticides) in soil samples. The device will comprise a microfluidic platform integrated with printed electrodes based on analyte-sensitive ink formulations and will facilitate the regular screening of NO3–and organophosphates to monitor the quality of soil samples. Envisioned for commercial marketing, the device will be an important step towards sustainable agriculture, which will significantly improve the livelihood of rural farming communities in the countries and help in safeguarding water resources from pollution. Additionally, through the development of a user-friendly soil testing device in this project, awareness on environmental protection will be enhanced.

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Progress made/achieved

IIT Kharagpur

Partner 1 (IIT KGP) has proposed and synthesised a new Allylamine capped copper nanoparticle for NO3– sensing due to its better stability and sensitivity. Since the previously proposed Cu/CNT composite didn't work due to its absence of characteristic response for NO3– , instability and high background current. This may be attributed to the possible oxidation of copper NPs in the material which was solved and replaced with a highly stable allylamine capped copper nanoparticle. In deliverable 2 (Developed ink formulation of the synthesized electrode material) successful homogenised dispersion of allylamine-capped copper nanoparticle-functionalised CNT nanocomposite dispersed in water was achieved and electrodes were fabricated by drop casting method for NO3– sensing. Ink formulation plan was deviated due to the usage of a higher concentration of binder and stabilizer in it which encapsulates the active catalytic sites of the material, reducing the accessibility of NO3– analyte to the material and thereby decreases its catalytic activity. For pesticide sensing previously PEDOT:PSS with Gold nanoparticles over GCE surface was used. For the final sensor development, we reduced the fabrication step and used gold sputtered electrode to make the process low cost and robust as giving comparable data with Gold/PEDOT:PSS modified surface. Therefore, PEDOT:PSS ink formulation plan was deviated.

The validation of the sensor platform is ongoing and the different analyte concentration data obtained from real soil sample by the help of proposed sensor is being cross-validated with conventional techniques from established analytical laboratories. The field testing of the sensors was initiated with the help of industrial partner Coromandel International Ltd.

TU Munich

The design and fabrication of printed microelectrode arrays were conducted. To facilitate the fabrication process and allow faster design iterations, an alternative fabrication strategy based on laser ablation was also developed and will be used within the project. For the fabrication of the fluidic system that is meant to be integrated into an electrode array, polymer (adhesive) thin foil patterning was explored and utilized to improve the transferability of the fabrication process into possible large-scale fabrication techniques. Therefore, a fluidic system based on thin polymer foils will be used within the project.

Coromandel International Ltd

Field testing of the nitrate sensor and organophosphate sensor was intiated and done at Annasagar village, Telengana, India. Further field testing will be done with the full device within this year.

Field testing of pesticides and nitrate at Annasagar village, Telangana, India with the help of Coromandel International Ltd

Bernhard Wolfrum, Joachim Wiest, and Marta Nikic visited IIT Kharagpur from Germany side to discuss the project progress and exchange the knowledge of the project

CirCulTex

Circular urban cultivation systems with re-useable textile growing substrates

Project Brief

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

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German Institutes of Textile and Fiber Research Denkendorf (DITF)

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Eschler Textil GmbH (ETF)

Progress made/achieved

After trials with existing textile structures from ETF, in 2023, two new textile structure development steps were made. The textiles from both development steps were evaluated in cultivation trials in hydroponic (UHOH, DITF, BCKV, AUK and HMA), aquaponic (BCKV) and terrabioponic systems (UHOH, DITF) and their characteristic properties were analyzed at DITF. Subsequently, the used substrates were employed for the experimental development of suitable cleaning process at DITF, BCKV, UHOH and AUK ensuring proper hygienisation of the textiles for a safe re-use. Both the substrate and the cleaning process development is informed by respective professionals, e.g. hydroponic growers, a manufacturer of cleaning agents, a laundry company and other research institutions, to which contact was established.

Results from the hydroponic cultivation of Pak Choi, Basil, Lettuce, Spring Onion, Swiss Chard and Spinach in NFT (UHOH, DITF, BCKV, AUK, HMA) and deep water culture (BCKV) as well as cherry tomato in dutch bucket (AUK, BCKV) show that the crops grown on textile structures achieve the same yield level as the reference substrates rockwool, coconut coir and clay bubbles.

These cultivation experiments showed further that the arrangement of the textile in the net pots does not have an influence on the yield. Therefore, the rolled arrangement of the textile is determined based on handling, automation and costs effectiveness. Cultivation trials in an aquaponics system at BCKV reveals that the textile structures are as well suitable for this integrated crop and fish production system.

For the terrabioponic systems (UHOH), the textile structures were found to be suitable as replacement of heavy gravel currently used for the drainage layer of the underground irrigation in the planting containers irrigation. The replacement leads to a considerable weight reduction of a terrabioponic system, making it suitable for new, weight-sensitive urban cultivation areas like flat roofs, facades and balconies. However, the costs of the systems increase.

The used substrates were employed for the experimental development of suitable cleaning processes for both countries' contexts. A thermal and a chemical multi-step cleaning process was developed. Both processes ensure proper hygienisation of the substrates, eliminating all phytopathogens based on a novel combination of existing and standardized technologies, processes and cleaning agents.

Re-use of cleaned substrates (up to 3 cycles) shows no yield degression in the cultivation experiments conducted at BCKV, AUK, DITF and UHOH, irrespective of the crop. Consequently, cleaning and re-use of the same substrate for multiple times is possible.

Biological cleaning through vermicomposting was found to be un-suitable. After vermicomposting the roots inside the textile structure are hardly removed and seeds placed on textiles after vermicomposting show a low germination rate.

In addition, a novel microbial bio-stimulant was formulated at AUK, which improves salt tolerance of crops in hydroponic systems. Further, the textile substrates are found to be suitable and cheaper replacement for high-cost agar in plant tissue culture with Banana.

In the final project phase the cultivation and cleaning experiments will be continued to further standardize the process and increase the number of re-use cycles. Further it was found that textile structures allow for NFT cultivation without net pots. This adaptation of the hydroponic systems will be further investigated (DITF, UHOH, AUK, BCKV), along with a new setup and design of a terrabioponic system that cultivates crops on a mixture of textile and pure vermicompost (UHOH).

Along with the development of suitable business models (all partners) for different target groups (private and professional growers), the industry partners HMA and ETF envisage a potential market entry by developing the textile pricing and starting to exchanging with potential customers.

Amity University Kolkata (AUK)

Research achievements at Amity University, Kolkata in the third year of project includes growth of leafy vegetables (Italian basil, lettuce) and tomato on the previous 6 textile substrates sent by German partners in the following lab-based hydroponics systems: i. Dutch Bucket system ii. Nutrient Film Technique (Horizontal) iii. Nutrient Film Technique (Vertical) All the essential parameters of hydroponics like pH (5.8-6.3), EC (1-1.8 mS/cm for leafy vegetables and 1.8-2.4 mS/cm for tomato), Temperature (18-24 C) and TDS (800-1100 ppm for leafy vegetable and 1400-1750 ppm for tomato) were maintained accordingly. After a complete crop cycle, the once used textile substrates were subjected to physical cleaning method. This process removed the algal and salt deposition by 90%. After one round of cleaning, the substrates were reused. By the end of the crop cycle, the FINAL (385154) novel textile substrate was sent by the German partners, and it was used for growing the same crops under same experimental conditions. Few of the previous set of textile substrates has also been applied in plant tissue culture technique to check its efficacy as an alternative to high-cost agar.

Tomato in Dutch bucket (AUK)300

Bidhan Chandra Krishi Viswavidyalaya, Kalyani

Research achievements at BCKV, Mohanpur in the third year of project includes growing of leafy vegetables and tomato in hydroponics system with re-used substrates as well as the final substrate. All the essential parameters of hydroponics like pH, EC,Temperature and TDS were maintained accordingly.

Leafy vegetables and tomato plants were grown in two different arrangements (Rolled and folded). After a complete

crop cycle, the once used textile substrates were subjected to physical cleaning method. Biological cleaning of the substrates was also standardised.

Inference: Results indicated better performance of substrates over rock wool (RW) for all crops.

Plant growth was slower in aquaponics than hydroponics, may be due to imbalance ratio of fish and plant number. Water is circulated from the fish tank to aquaponics NFT pipes through mechanical and biological filters (the ammonia in water by the fish waste is converted into nitrite by Nitrosomonas bacteria and nitrite is converted to nitrate by nitrifying bacteria which is available to the plants). Koi (Cyprinus carpio) andTilapia (oreochromis niloticus) were grown in the fish tank.

Project Team at German Institute of Textile and Fiber Research, Germany

Harimitti Agro Pvt Ltd. Kolkata (HMA)

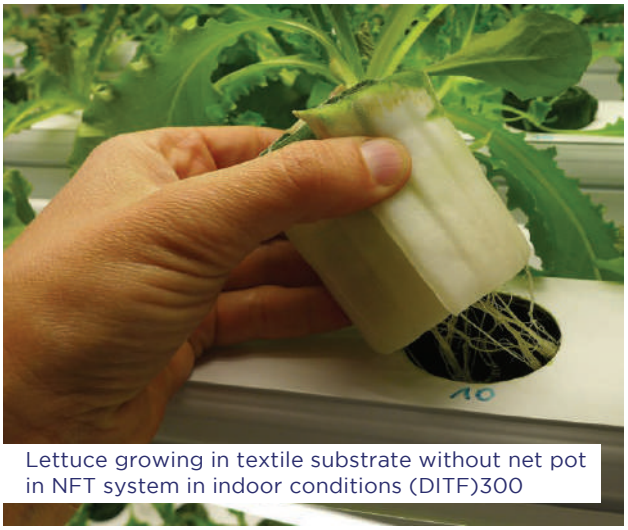
Mentioned below the work executed in last one year. 1. Attending Exhibitions to interact with different Hydroponics Service providing companies. 2. Indian perspective of Hydroponics Cultivation in Commercial and Domestic Space. 3. Establishment of the different types of Hydroponic Setups (Small to Big) 4. Cost analysis of different medium which holds the root the plants. 5. Interacting with Urban People about the acceptance of the Hydroponic System. 6. Interacting with commercial grower to use our substrate as trial and share their experience.

University of Hohenheim (UHOH), German Institutes of Textile and Fiber Research (DITF) & Eschler Textile GmbH (ETF)

Design of the cultivation trials: In consultation with all project partners, cultivation trials with Pak Choi, Basil, Lettuce and Spring Onion were planned and carried out. Lettuce and basil were selected as model plants for the German partners because leafy vegetables and herbs are economically relevant and have proven themselves in hydroponic cultivation. An experimental plan was drawn up jointly with these two model plants so that several cycles of cultivation and cleaning could be carried out and analysed at UHOH and DITF.

Development and production of new reusable textile substrate in two variations by ETF: Based on the results in various hydroponic cultivation systems with the samples developed and produced by ETF, the textile substrate was further engineered and adapted. Finally, ETF has developed and produced a knitted fabric in two variations.

Lettuce germinating on newly developed textile substrate at UHOH300



Lettuce growing in textile substrate without net pot in NFT system in indoor conditions (DITF)300

Hydroponic crop cultivation on textile substrate: After the proof of concept was achieved in 2022, the textile structure was developed further. ETF achieved two more development steps. In the reporting period four cultivation tests were conducted, using the newly designed textiles. Four different plants were cultivated in the nutrient film technology (NFT) systems in the lab at DITF (128 planting spaces, indoor conditions) and UHOH (256 planting spaces, greenhouse conditions).

Cleaning experiments at DITF:
Six cleaning experiments were carried out at DITF with the substrates used at UHOH and DITF.The results of the discussion were then incorporated into the next test to develop the cleaning processes further. Economic aspects were included in the work. Only procedures that can later be automated and scaled accordingly were developed and tested. To this end, the project partners are in regular dialogue with a large laundry company (Alpirsbacher Wäsche-Service) and a manufacturer of disinfectants and cleaning agents for plant production (MENNO CHEMIE VERTRIEB GmbH):

General Public Interactions

- Participation at the international exhibition **GreenTech 2023** for vegetable production in Amsterdam on June 13th and 14th, 2023.
- DITF took part in the **World Green Building Congress** from 27th to 29th of June 2023. One of the topics was urban farming. The congress was used to establish contacts and obtain information on current topics from research, development and business.

AutoNutri

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

Project Brief

The aim of the project is to develop an on-site multi-ion monitoring system for automated on-line control of nutrient input in vertical hydroculture systems with closed circulation systems based on feedback-controlled supply of nutrients. One of the most critical objectives of this project is to ensure that the system is compatible with crops that are commercially important in terms of growth, nutrient consumption, vital metabolite production and its content. With respect to this, consortium have selected Lettuce (Lactuca sativa var. crispa 'Lollo Rossa'), Brahmi (Bacopa monnieri), Thyme (Thymus bulgaria), Stevia (Stevia rebaudiana) & Basil (Ocimum basilicum) as model crops for this project. In the initial phase, three out of the five model plants (Basil, Lettuce and Brahmi) were cultivated hydroponically in the selected Nutrient Film Technique (NFT) system at our indoor facility. Throughout the study, the selected hydroponic system was monitored in terms of temperature, climatic parameters, nutrient elements, pH and EC to study their nutrient requirements and absorption patterns at each growing stage.

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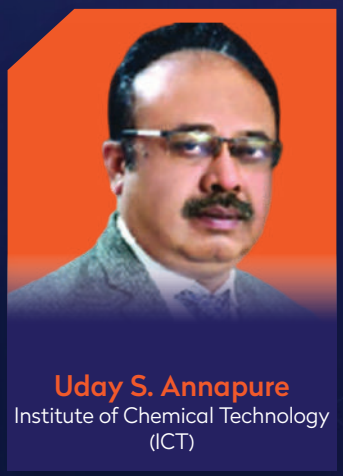
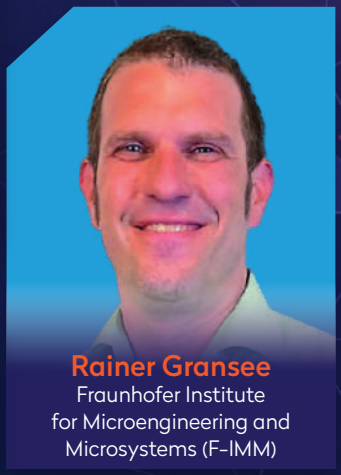


Uday S. Annapure
Institute of Chemical Technology (ICT)



Rainer Gransee
Fraunhofer Institute for Microengineering and Microsystems (F-IMM)

Oliver Stegen
RM Geraetebau Oliver Stegen

Progress made/achieved

The proposed equipment has been procured and installed at the HiM facility to determine relevant ions concentration and to evaluate nutrient absorption patterns in five model plants and further validate the AutoNutri prototype. Standard operating procedures have been developed for various equipments for elemental nutrient analysis of nutrient solution samples to validate the ion selective monitor system. HiMedia laboratories provided commercially available hydroponic nutrient formulations to F-IMM for sensor array and testing purposes. Subsequently, F-IMM is currently working on the development of a multi-ion monitoring system that uses solid-contact liquid-membrane ion-selective electrode based sensors to directly detect major ions for crop growth. Five (5) most relevant ion types and corresponding concentration ranges were identified, to be measured within hydroponic systems: ammonium, nitrate, phosphate, calcium and potassium. For the corresponding ion types commercially available ionophores were identified and purchased, except for Potassium for which ionophore solutions were made at IMM, serving as a basis for the manufacturing of miniaturized ion selective electrodes (ISE). With all ionophores ISE's were manufactured and tested, initially with aqueous solutions containing only the corresponding ion type in the relevant concentration range. For that, a lab demonstrator was set up, including electronics with shielding against EMI, as well as microfluidic chips made of polycarbonate. During the project the chip design was improved, to compensate air bubble formation above the ISE's. The corresponding microfluidic chips have been fabricated by 3D printing with an epoxy resin. The best results were achieved with potassium and ammonium ISE's, the slope of the concentration dependent potentiometry curves showed a Nernstian behaviour with values close to the theoretical limit of 59mV. The reproducibility of these electrodes was good. The Phosphate ISE's require a pH value of 7.4 for correct operation which does not correspond with the typical value for hydroponic solutions of 6-7. The corresponding ISE's showed a bad reproducibility as well as a non-nernstian behaviour. Further investigations with an adapted pH value are required. With the lab demonstrator also more cost-efficient peristaltic pumps have been tested which shall be applied in the demonstrator, instead of expensive syringe pumps. During these tests, with higher flow rates and pressures, a strong noise appeared on the sensor signal, caused by the movement of small air bubbles at the surface of the ISE's. This can be avoided by switching off the pump during the measurement. After a short relaxation time the sensor signal stabilizes on a constant level with low noise. The transfer of the laboratory demonstrator into a prototype to be tested in India, has been discussed within a meeting with the German industrial partner RM Geraetebau. A state-of-the-art outdoor hydroponic farm of around 40,000 sq. ft. and an indoor hydroponic lab facility of around 380.3 sq. ft. has been set up at Igatpuri (120Km from Mumbai) and Ghatkopar (Mumbai) respectively. Five model plants will be grown in soil to study their growth requirements in soil. By comparing the growth patterns and nutrient absorption rates in soil-grown plants with those grown hydroponically, the researchers can identify the differences and determine the applicability of AutoNutri in traditional farming.

Milestones Achieved

Institute of Chemical Technology ICT

Standard analysis procedure for the detection of nutrient concentration has been determined. Standardization of nutrient values of the five selected plants required for the sensors will be completed by the mid of this year. Once the prototype is prepared and delivered, it can undergo comprehensive testing with respect to the nutrients to identify and address any potential glitches.

HiMedia Laboratories Pvt. Ltd. (HiM)

The prototype of the AutoNutri is due to arrive at the HiM facility for its testing and validation. It is expected to receive it by mid of this year. Fraunhofer IMM has developed the first electronic board and transitioned it to the RM Geraetebau for the initial realisation. The prototype needs to undergo an extensive testing and validation to assess its functionality using 5 plants. HiM will identify parties for beta testing and training, allowing for further testing and validation of the prototype.

Growth of Basil (Ocimum basilicum) at outdoor hydroponic facility

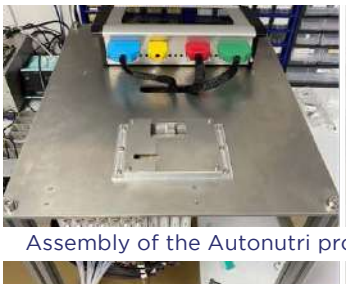
Growth of Bacopa monnieri plants at outdoor hydroponic facility

Growth of Lettuce (Lactuca sativa var. crispa 'Lollo Rossa') at outdoor hydroponic facility

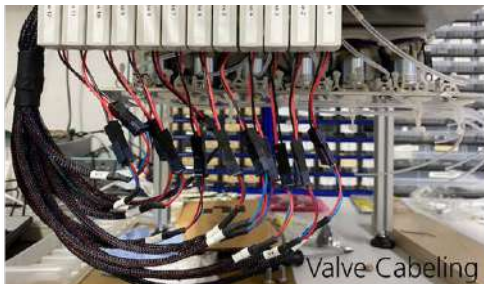
Growth of Stevia rebaudiana plants at outdoor hydroponic facility

Fraunhofer Institute for Microengineering and Microsystems

Ion selective electrodes (ISE) have been developed for 5 key ions (K^+, Ca^{2+}, NH^{4+}, NO_3^{2-} and HPO_4^{2-}), based on commercially available ionophor solutions as well as selfmade solutions with commercial ionophores. The ISE have been successfully tested in laboratory environment with lab demonstrator of IMM. The corresponding results and experiences served as input for the demonstrator development by industrial partner RM Geraetebau, including the electronics for the demonstrator. Moreover, a concept for nutrient uptake has been developed, based on cost efficient peristaltic pumps, valves and light barriers for fluid control. The concept has been transferred into an electronics design to be realized by RM Geraetebau.



Assembly of the Autonutri prototype



RM Geraetebau Oliver Stegen

Based on the results achieved at IMM with lab demonstrator a prototype and electronic design was developed, and electronics was manufactured, to be applied in the prototype device.

Salient Research Achievements

- Two abstracts from Indian partners related to the project were accepted for a poster and oral presentation in a National Conference, 2023. One of these papers has been accepted for full-length text proceeding. Another review article has been sent for publication in a text proceeding for a National Progressive Horticulture Conclave, 2024.
- IMM participated in Microsystem Technology Congress in Dresden, where first results of ISE fabrication and characterization were presented as a poster. The paper was also published in IEEE Xplore.
- RM Geraetebau developed and realized two electronic boards for the prototype device.
- Development of sensor controlled and automated farm has been set up at both outdoor and indoor HiM facility in Igatpuri (120Km from Mumbai) and Ghatkopar (Mumbai) respectively required for testing and validation of prototypes.

HERCET

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

Project Brief

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

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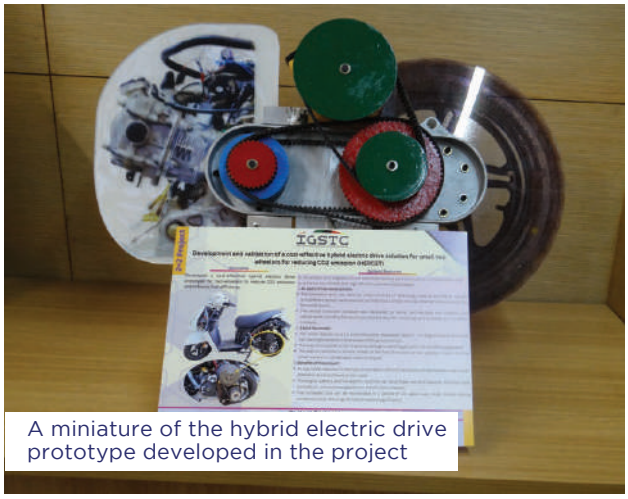
Progress made/achieved

- Fifteen different hybrid topologies were initially conceived and then discussed in detail by all the partners. Four of these hybrid topologies were finally selected for further evaluation by considering various aspects like drivability, efficiency, economy, safety and packaging. The scooter platform and the engine that will be used were taken as inputs. It was then decided to evaluate these topologies through simulations so that the one/s that can be developed into prototype/s can be selected.
- TVS Motors provided two vehicles one for IITM and the other for RWTH. Spares and technical support and additional engines were also supplied to IIT Madras as needed.
- A state of the art engine test rig with facilities for performance, emissions and combustion evaluation was developed specially for this work at IIT Madras. Variation of several parameters were automated using in-house developed hardware and software systems. The engine has been tested at both steady state and transient conditions and its performance and emissions have been characterized. Simultaneously two different engine simulation models one based on maps and other based on thermodynamic process models were developed and validated. The Map based model was then found to be simpler to handle and was further optimized using emission and performance data. These were discussed by all the partners and taken up further for simulations.
- Transient vehicle level experiments were conducted in TVS Motors by the IITM and TVSM teams. These experiments were aimed at collecting data to understand the behavior of the CVT under steady and transient conditions. These tests were conducted on the vehicle in a chassis dynamometer.
- Based on the test results, the map-based engine model that was built was further optimized to predict engine torque, fuel consumption and conversion efficiency of the catalytic converter. An ANN based model was also developed at IIT Madras to predict the transient engine-out emissions. This was then discussed with all the partners and implemented.
- A Physics based model of the CVT was also parallel developed at IIT Madras and validated using the measured data at TVS Motors. Efficiency of the CVT obtained from TVSM was taken as a map of speed and torque.
- Another vehicle was evaluated by RWTH. Vehicle tests were done on their test track to assess the different components of driving resistance.
- The engine and CVT model and the vehicle model were used by the teams at IIT Madras and at RWTH to do vehicle level simulations on the four topologies. Based on several technical discussions between the partners three layouts (P2, P3 and ePGS) are currently being evaluated for their mechanical complexity, integrate-ability, cost and other features by TVSM.
- TVSM developed a secure information exchange platform which is being used by the partners.

- During this time VEMAC came out with initial specifications of the controller and also demonstrated their first version on a go-kart developed by RWTH with an ePGS drive.
- VEMAC has also come up with an upgraded controller hardware. This hardware has been provided to IIT Madras and has been successfully integrated with the vehicle.
- Finalization of the drive layouts at RWTH and IITM were completed and the 1-speed HEDD was identified as the way forward at IIT madras.
- The 1-speed HEDD has been designed, manufactured and installed on the vehicle successfully.
- A drive by wire throttle has also been successfully developed at IIT Madras and integrated with the engine. The ISG provided by TVS Motors has also been integrated with the engine and is in use.
- The 1-speed HEDD has been integrated with the VCU, Battery, Engine and other interfaces and is now in operation. The operation has been fine-tuned and the drivability is good. The VCU software logic is further being fine-tuned for improved drivability and for final evaluation.
- Simulations indicated that a two-speed transmission will further enhance the capabilities of the HERCET drive. Hence, a novel two speed drive was conceptualized. It was decided to use only devices like one way and centrifugal clutches and toothed belt drives in order to maintain simplicity. A patent has been applied for this concept.
- The 2-speed HEDD has been designed and fabricated. It is currently being evaluated on a special test bed.
- The drive has been installed on the transient dynamometer setup and is being taken up for experiments under simulated conditions using the 1-speed HEDD.

HERCET project Proto Vehicle being test driven by Mr. Lars Posdena of VEMAC



A miniature of the hybrid electric drive prototype developed in the project

Publications

Patents filed:
Mechanically automated, speed and torque sensitive two speed drive system (Patent Application No. 202341069161).

Ph.D. / Master thesis supervised

- PhD thesis – "Experimental and simulation studies to reduce CO2 emissions and enhance performance of a hybrid electric two-wheeler" – Student: Pradeev E
- Master thesis – "Development of a Simulation Model of a SI Engine for hybrid Applications for Implementation in a Hardware in the Loop Platform" – Student: Raghav Kakani
- Master thesis – "Hybrid Powertrain Modelling & Control for a Two-Wheeler Application" – Student: Abhiram Shenoi

EfectroH$_2$O

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

Project Brief

The project aims to improve the process of water treatment in industries to reduce harmful toxicological effects in receiving environments. One promising technology to address the problems of desalination and dye removal is Capacitive Deionization (CDI). Compared to reverse osmosis, flow CDI can deal with highly concentrated brines and suffers less from organic fouling. Micropollutants will be removed by a synergetic combination of CDI and Advanced Oxidation Processes. The novel treatment technologies will be scaled-up and piloted in the textile industry. The findings will enable replication and transfer to other key industries. Water quality and treatment efficiency will be monitored by emerging effect-based methods (EBM), which are complementary to chemical target analyses. The advantage of EBM is that they provide a holistic indication of toxicological effects from complex mixtures typical of process waters, which covers unknown oxidation by-products and synergistic effects. A bioassay test battery will be developed and transferred from Germany to India.

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EffectroH$_2$O targets the United Nations Environment Programme Sustainable Development Goals 6 to "Ensure availability and sustainable management of water and sanitation for all" by contributing to the reduction of water consumption in water-scarce regions such as India.

The technologies will be studied at a lab scale and subsequently scaled up and piloted in the textile industry: M/s Rohini Textiles ETP and Kunnakalpalayam CETP. The findings will enable replication and transfer to other key industries. The major pollutants present in textile effluent are recalcitrant organics, dyes, salts, and other toxicants. Advanced Oxidation Processes (AOP) for wastewater treatment experiments were performed. It included several bench-scale experiments, reactor studies, and pilot-scale treatment system evaluations to test the effectiveness of the electroperoxone process for treating dye bath effluent and synthetic wastewater. Based on the study results, various strategies for textile wastewater treatment are suggested, and the effects of different dyes and cathodes on the AOP process were investigated. Capacitive Deionization (CDI), a technology that removes ions from water using a low-voltage electrical field, was studied. In this study, the performance of fixed electrode capacitive deionization (Fixed CDI) in various capacity and pilot scale systems using synthetic wastewater was tested. Additionally, the effects of flow rate in the pilot system and experiments with flow capacitive deionization setup were also performed, and a new Flow CDI system was fabricated. Studies will be conducted by varying operating conditions of the skid-mounted pilot system in the Rohini textiles and Kunnapalayam CETP.

Progress made/achieved

IIT Madras

Testing of the combined Fixed Capacitive Deionization (CDI) + AO reactor for the removal and advanced oxidation of micropollutants, using specified synthetic waters and industrial water samples at bench scale, has been completed. This includes investigating the order of treatment and assessing the influence of electrode materials. Additionally, Flow CDI has been tested with synthetic wastes. Small-scale CDI pilot testing, involving some operating parameters, has been conducted. Furthermore, the pilot system (350 liters) for the electrochemical Advanced Oxidation Process (AOP) has been fabricated and installed at KCETP, Tiruppur. Pilot trials are currently underway in Tirupur. A stakeholders meeting was conducted in Tiruppur in December 2023 as part of the Pilot reactor commissioning, with all partners involved. Lab scale studies are being conducted simultaneously to further enhance the efficiency of the system.

TWIC

The pilot system (350 liters) for the electrochemical Advanced Oxidation Process (AOP) has been installed at Kunnankalpalayam CETP, Tiruppur on 09.11.2023. The operation started on the trail plant with Raw effluent, Dye bath, Secondary clarifier, RO feed and wash water to optimize the best result. To improve the optimization studies are being discussed with academic partners for further improvements.

RWTH Aachen, Goethe University Frankfurt, Ibacon/Eurofins

RWTH Aachen

Optimal process conditions were used as initial conditions for FlowCDI experiments. However, the experimental setup had to be improved and optimized (Two-Cell Approach). Knowledge transfer was done during our visit in Chennai/Tiruppur with the Indian project partners. Different aspects of FlowCDI and FixedCDI were discussed regarding the upscaling of Fixed-CDI. Synthetic textile waste waters have been successfully desalinated and decolorized in the One-Cell Approach. However, the membrane stability issues could only be resolved by transferring the system to a two-cell approach. At the moment, the reached TLR is 4/5. Further optimization regarding long term operation of the process and desalination degree for the coupled Two-Cell Approach is required.

IGSTC project meetings (IITM, TWIC, RWTH, Eurofins/iBACON, Goethe University and IGSTC members)

Inauguration: Onsite Pilot scale reactor inaugurated at Kunnankalpalayam CETP by District Collector Thiru. T. Christuraj, I.A.S., Tirupur.

EfectroH2O group photo with District Collector Thiru. T. Christuraj, I.A.S., Tirupur

Goethe University + Ibacon/Eurofins

EBM adapted to case study environment (high salinity): Specific effect-based methods were applied to raw textile wastewater to investigate endocrine activity, excluding the influence of salts and pH. Organic substances were extracted and tested for toxicity and endocrine effects, comparing results with raw wastewater to address the high-salinity case study environment goal.

EBM battery as SERVICE with emphasis on acute toxicity and endocrine disruption for water quality monitoring in textile industries: The adapted methods from Goethe University's preliminary tests are now being applied directly in India for on-site wastewater analysis. This approach minimizes sample alteration due to transport and simplifies logistics. Concurrently, a comparative study is conducted between Eurofins Advinus India and Goethe University Frankfurt.

Identify drivers of toxicity: Based on a previously established database of substances in textile wastewater, we developed a specific target list of organic compounds for LC-MS analysis, complemented by a metal analysis, to identify a wider range of compounds. Additionally, wastewater was fractionated into primarily organic and primarily inorganic fractions. These fractions, along with the raw wastewater, were analyzed using both bioanalytical and chemical analytical methods.

CO_2BioFeed

CO_2 and Biomass as feedstock for the production of fuels and chemical intermediates

Project Brief

Catalytic processes that are ecologically & economically advantageous form the base of sustainable value chains in the industry. However, fossil resources are currently used as the primary raw materials in the production of fuels and in the chemical industries. In the CO_2BioFeed project, a consortium of academic institutions and industry partners from India and Germany are collaborating to use Carbon dioxide (CO_2) and biomass as sustainable feedstock to produce high value chemical intermediates such as epoxides and acrylates.

CO_2 plays an important role as a soft oxidizing agent for the epoxidation of short-chain alkenes and other highly valuable follow-up products. It can be also used as a carboxylating agent to produce acrylic/methacrylic acid. Carbon monoxide (CO), obtained as a renewable by-product can be utilized in other industry-relevant production processes. Furthermore, a key process in the industrial value chain to produce a basic chemical containing only carbon from sustainable sources will be compared via a Life Cycle Assessment (LCA). The main goal of the project is to scale-up the process to industrial scopes, confirm the performance of the newly developed catalysts under industrial conditions and assess the cost benefits and environmental impact of the processes.

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Praveen K Chinthala
Reliance Industries Ltd. (RIL) Jamnagar

Jens Hannes
RWE Power Aktiengesellschaft (RWE) Essen

Gernot Nell
Parr Instrument GmbH Frankfurt

Progress made/achieved

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

Innovative highly active metal phosphates $Mo(PO_4)_x$ and $Nb(PO_4)_x$ were developed (IIT), sent to Germany and successfully tested at RUB for the glycerol dehydrogenation. The catalysts gave propene, acrolein and acrylic acid as products. Environmental (RUB) and economic (RIL) evalua- tions are in the final stages. IIT/IACS/RUB are working together to increase the selectivity to acrylic acid/acrolein in a batch process using ethene and CO_2. In last year's report, ICAS and RIL presented a two-step high yield protocol starting from ethene and CO_2 for the production of acrylic acid. Ethene is brominated to 1,2-dibromoethane, which is converted to vinyl bromide upon treatment with ethanolic KOH. Subsequently, the vinyl bromide reacts with CO_2 over novel Pd-FFM-catalysts to form acrylic acid in almost quantitative yield. The reaction was carried out in a liquid phase batch reactor. This time, the one-step production of acrylic acid from ethene using Ag-FMM-catalyst (IACS) was investigated in batch experiments at the RUB. Acrolein and acetone were obtained. At the same time, novel Pd based catalysts were tested by IACS and IIT (ISM). IIT (ISM)/IACS/RUB) worked on heteroatom doped carbon supported Fe catalysis for the oxidative dehydrogenation of ethylbenzene to styrene using CO_2. IIT (ISM) tested RIL Ni based catalyst for CO_2 hydrogenation reaction.

Novel catalysts based on redox-active multi metal oxides with supported metallic silver have been developed and characterized by IR, BET, SEM-EDX, XRD and XPS measurements (IIT/RUB). The evaluation results (RUB) show that the materials are able to transfer oxygen to alkenes. Successful reoxidation of the oxides with CO_2 with concomitant formation of CO has also been demonstrated. Optimization to control the selectivity of oxygen transfer to alkenes is underway (IIT/RUB). In addition, the silver-doped molybdenum tellurium and vanadium mixed oxide produced in oxygen-limited oxidation experiments with propene, mainly acrolein and acetone, but also propene oxide at 400-500 °C. Work is underway to narrow the process window and shift the selectivity to the propene oxide. Additional safety measures are being implemented for the conversion of ethene to ethylene oxide (RUB).

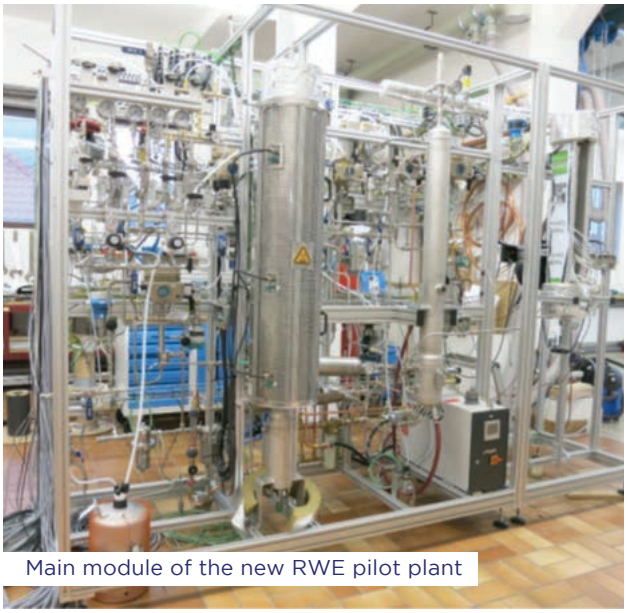
Online high-pressure and high temperature autoclave reactor integrated with GC at IIT (ISM) Dhanbad

Reliance Industries Ltd. (RIL) has developed various mixed metal oxide and supported metal oxide catalysts. Online GC installations were completed in March 2023. The performance evaluations for various carboxylation and glycerol conversions using CO2 were evaluated at IACS Kolkata. The catalysts have also been evaluated in RIL's high pressure fixed bed reactor and the results are impressive. The data generated is currently used as input for process simulation.

Ruhr-Universität Bochum (RUB)

CO_2-activation and the transfer of atomic oxygen to the catalyst surface, were investigated with a cerium oxide and an indium oxide catalyst in order to identify the process window for the operation of the high-temperature mini-plant and to derive process simulation data. For further process validation and development, an on-line gas chromatograph for analytical purposes was purchased with project funds and integrated into an existing setup at the RUB, together with the experimental Berty- reactor from Parr, which can be operated at 200 bar and 300 °C. Several catalysts were obtained from the Indian project partners, characterized and tested. As part of the process development, the activity of the catalyst for CO_2 hydrogenation was investigated. The IACS/ISM/RIL catalysts were compared with RUB-made catalysts for this purpose. The initial functional MOF catalysts (Cr-MIL-101, Fe-MIL- 101) impregnated with nanoparticles (Ru and Ag) of the Indian partners did not meet the expectations and seem not to be sufficiently stable at the higher reaction temperatures that are needed for the envisioned performance. The metal nanoparticle modified SBA15 catalysts showed promising results at RUB in reactions activating CO_2 and for producing valuable synthesis gas. Fe,Ag@SBA-15 nanocomposite materials received end of 2021 were found to be more stable and showed promising reactivity with regard to reverse water gas shift (RWGS) and epoxide formation.

The catalysts were characterized by IR, BET, SEM-EDX and XRD measurements. Further investigations of the Fe,Ag@SBA-15 catalysts in batch operation for the epoxidation of styrene were promising. Additional measurements have shown that, for the intended activation of CO_2, temperatures of more than 300°C are required and a temperature window of 370-390°C may be promising. On the basis of these results Parr constructed a proto- type high-temperature (design temperature up to 500°C) Berty-Reactor. The new prototype was tested thoroughly in Bochum in 2022 and produced encouraging results for process simulation. The methanol synthesis was used as prime example for the characterization of the Berty-Reactor and revealed promising selectivities and conversions of 36% and 28% for MeOH, respectively. In parallel with the experimental work, evaluation of the process chain is almost complete. Several student theses concern the evaluation and life-cycle-assessment of different process routes for ethene production.



Main module of the new RWE pilot plant

RWE Power RWE, RIL and RUB jointly discussed the safety concept required for possible pilot-scale tests. The most suitable site for each reaction was evaluated, as well as the safety, legal and technological limitations of the sites and the materials required. After involving other safety experts (Rembe GmbH), the evaluation was successfully completed and a safety concept for the laboratory tests was developed and finalized. The results of the safety concept and the first results of the process development at RUB led to a re-evaluation at RWE as to which of their available pilot plant reactors could be used for the project.

Publications

1. **A metallic nickel site in a complex multimetallic design for controlled CO_2 reduction and symmetric supercapacitor device.** R. Patil, N. Kumar, Sudip Bhattacharjee, B.M. Matsagar, P-C Han, K.C.W. Wu, R.R. Salunkhe, **Asim Bhaumik*** and S. Dutta, Materials Today Chemistry **2023**, 28, 101374.

2. **Selective Styrene Oxidation Catalyzed by Phosphate Modified Mesoporous Titanium Silicate.** Rupak Chatterjee, Avik Chowdhury, Sudip Bhattacharjee, Rajaram Bal and **Asim Bhaumik***, Chemistry **2023**, 5, 589-601.

3. **Influence of catalase encapsulation on Cobalt@ Nanoporous carbon with multiwall shell for supercapacitor and polyurethane synthesis using carbon dioxide.** Rahul Patil, Nitish Kumar, Sudip Bhattacharjee, Hsi-Yen Wu, Po-Chun Han, Babasaheb M Matsagar, Kevin CW Wu, Rahul R Salunkhe, **Asim Bhaumik*** and Saikat Dutta, Chemical Engineering Journal **2023**, 453, 139874.

4. **Influence of heteroatom-doped Fe-carbon sphere catalysts on CO2-mediated oxidative de-hydrogenation of ethylbenzene.** Anindya Ghosh, Aniruddha Singha, Rupak Chatterjee, **Thomas E. Müller*, Asim Bhaumik*, Biswajit Chowdhury***, Molecular Catalysis **2023**, 535, 112836.

5. **N-Heterocyclic Carbene Moiety in Highly Porous Organic Hollow Nanofibers for Efficient CO2 Conversions: A Comparative Experimental and Theroretical Study.** Sudip Bhattachar- jee, Anjana Tripathi, Rupak Chatterjee, Ranjit Thapa, **Thomas E. Müller, Asim Bhaumik***, ACS Catalysis **2024**, 14, 718-727.

Workshops

IGSTC bilateral workshops are platforms for substantive interaction between scientists/ researchers from academia and industry from India a& Germany to explore new avenues for Indo-German scientific collaborations. These workshops play an important role in connecting relevant stakeholders for future collaborations.

Revisiting the potential of bio-stimulants: A journey from lab to farmer's field towards enhancement of crop sustainability and resilience in stressed environments (BioSusTres)

13-15 March 2024 | Coochbehar, India

Workshop Coordinators

Prof. Prateek Madhab Bhattacharya
Department of Plant Pathology
Uttar Banga Krishi Viswavidyalaya
Cooch Behar, West Bengal

Dr. Markus Weinmann
Department of Nutritional Crop Physiology University of Hohenheim,
Hohenheim

The multi-faceted workshop on bio-stimulants covered a broad spectrum of topics, including regulations, diverse beneficial bacteria and fungi species, their modes of action, and frameworks for enhancing their effects. Discussions encompassed crop-specific aspects such as organizing microbial communities, increasing soil fertility, and optimizing growth in various agricultural systems. Tools for characterizing and enhancing these microbes were highlighted, including genome editing. The workshop emphasized the importance of bio-stimulants in transitioning towards sustainable agriculture and ensuring food security. It stressed the need for stakeholders to collaborate effectively, regardless of ideological constraints, and for rigorous validation of tools under different conditions. Collaboration between Indian universities and German research organizations was also emphasized as crucial for advancing research and development in this field.

The workshop started with welcome address by the Indian Coordinator, Prof. Prateek Bhattacharya emphasising on the future collaborations in research and adaptation studies in the field of bio-stimulants and related science and the ways to convert it to field technologies. Hon'ble Vice-chancellor of the Uttar Banga Krishi Viswavidyalaya greeted the audience with highlights on the participatory learning and transfer activity of technical knowledge created at universities to business models that are socially acceptable and sustainable. Dr. P. K. Chakrabarty, who served the apex body of Indian Agriculture Research Institute, discussed on merits of the required transformation towards nature-based agriculture and the important role of bio-stimulants, where India is pioneer country.

In the inaugural session, Saquib Shaikh from IGSTC introduced the programmes implemented by the organization with a mention that this is an important milestone for the organization being the 50th anniversary of Indo-German cooperation. The German coordinator, Dr. Markus Weinmann introduced the workshop objectives to the audience with emphasis on use of biologicals to replace the use of precarious pesticides and mineral fertiliser in India and Europe.

This is not only urgently needed for protecting the environment and climate as well as health and safety of farmers but have a high economic potential (CGAR 14%). The session ended with introduction of the participants and initial discussion on the direction of the workshop with present scenario of agriculture of both the countries and to find solutions for sustainable development of agriculture in the given context.

The technical sessions covered a wide array of topics related to bio-stimulants and sustainable agriculture. Talks emphasized policy and regulatory challenges in India, including the recent development of guidelines under FCO 1985, as well as the need for consistent definitions and regulations to ensure product quality. Discussions also delved into the historical development of chemical-based agriculture in Europe and advocated for a paradigm shift towards holistic consideration of bio-stimulants. Presenters highlighted the importance of supportive agricultural management for microbes, the utilization of bio-resources for sustainable agriculture, and microbiome research to improve soil health and crop performance.

Additionally, talks explored the potential of endophytic fungi for increasing plant resilience against stress, the role of rhizosphere and phyllosphere bacteria as bioinoculants for crop protection, and the development of biocontrol agents efficient in tropical regions through collaboration projects. Other sessions focused on the formulation and application aspects of innovative biological products, stress alleviation with arbuscular mycorrhizal fungi, and the application of vermicompost-based bio-stimulants in circular cultivation systems for urban gardening. Overall, the discussions aimed to foster collaboration and innovation in the field of microbial health-based science for sustainable production systems.

Catalysis for circular economy towards sustainable energy (CatCE2)

20–22 September 2023 | Hyderabad, India

Workshop Coordinators

Prof. Sounak Roy

Department of Chemistry BITS Pilani,
Hyderabad Campus

Prof. Jeniffer Strunk

Industrial chemistry and heterogeneous catalysis
Technical University Munich (TUM)

The Indo-German workshop on 'Catalysis for circular economy towards sustainable energy', with the valuable support of IGSTC comprehensively covered a range of catalysis and energy-related topics, fostering lively discussions, networking, and potential collaborations among participants. The workshop was scheduled for September 20 - 23, 2023, at BITS Pilani Hyderabad Campus. The Indian Coordinator was Prof. Sounak Roy from Department of Chemistry, Birla Institute of Technology & Science (BITS) Pilani Hyderabad Campus, Hyderabad, and the German Coordinator was Prof. Jennifer Strunk from Technical University Munich (TUM). The workshop revealed shared interests, innovative problem-solving approaches, and strengthened connections. Attendees included early-career researchers to internationally acclaimed experts, representing diverse institutions and industries from both nations.

The workshop technically covered the fundamental and applied aspects of catalysis and reaction engineering for a wide range of applications, such as alternatives to petrochemical processes, sustainable energy production, and environmental purification. Following are the broad technical areas housed in different sessions of the meeting:

- Homogeneous and Heterogeneous Catalysis
- Biomass Conversion into useful Products
- Green Hydrogen
- CO2 Capture and Utilization
- Emerging Trends in C-H Bond Activation
- Hybrid and Porous Materials
- Single Atom Catalysts

Workshop Inaugural function

A major recommendation of the event was to encourage and support further interdisciplinary collaboration and knowledge exchange among participants. Given the diverse representation of early-career researchers, seasoned experts, and professionals from various institutions and industries, fostering ongoing partnerships could lead to the development of innovative solutions in catalysis and energy-related fields. This collaborative approach can contribute significantly to addressing the challenges associated with achieving the Net Zero Goal and Sustainability Goal.

Carbon management in chemical industry (CMCheI)

27 - 29 February 2024 | Mumbai, India

Workshop Coordinators

Dr. Ojus Mohan
Department of Chemical Engineering
IIT Bombay

Dr. Carlos Lizandara Pueyo
Technology Scouting and Academic Network
BASF SE, Ludwigshafen

To foster collaboration between Indian and German academia and industries, Indian Institute of Technology Bombay (India) and BASF SE (Germany) co-organized a bilateral workshop funded by the Indo-German Science and Technology Centre (IGSTC) on "Carbon management in chemical industry" from 27-29 February 2024 at the BASF Innovation Campus Mumbai. The primary themes of the workshop encompassed areas such as carbon capture and utilization (CCU), green hydrogen production for achieving net-zero emissions, and the utilization of alternative feedstocks in the bio-based value chain. The workshop brought together esteemed experts from academia and industry, both from India and Germany, to share their insights through lectures and engaging panel discussion. The workshop aimed to provide a comprehensive understanding of how digital tools, computational modeling, and data- driven approaches can optimize chemical processes for sustainability.

For the deep dive deliberations, the participants were split into 3 teams, and each team discussed one topic per day: CCU, Clean H2 and Bio-based value chain. The deliberation session comprised of brain dump of ideas, followed by organization of the ideas into a map. At the end of each day, teams presented their idea map to the rest of the participants. All the ideas and idea maps for each of the teams have been consolidated into 8 concrete ideas for each of the topics. Some of the ideas resulting from the deep dive are: hydrogen production from renewable sources and through bio-synthesis, integrated CCU for methanol and integrating CCU with biomass and blue H2, and biomass to biopolymers and Sustainable Aviation Fuels (SAF).

The mutual benefits of the bilateral event have been substantial. German delegation gained exposure to not only the Indian academic experts but also the dynamic Indian chemical industry, its innovative solutions, and its growing market potential. Indian participants, on the other hand, benefited from the technological expertise, research advancements, and sustainability-driven practices of German academia and industry. Additionally, the participants have gained a comprehensive understanding of carbon management strategies and their practical implementation in the chemical industry, and as a result, will explore new horizons in catalytic research by harnessing the power of computational tools and data-driven approaches to accelerate the development of sustainable processes. The workshop has successfully offered a platform for dialogue, collaboration, and innovation, fostering the development of sustainable solutions to address the industry's carbon footprint, and empowered participants with knowledge, networking opportunities, and actionable insights to accelerate the transition towards a low- carbon and sustainable chemical industry.

Engineering for sustainable and resilient development

18 – 20 January 2024 | Mandi, India

Workshop Coordinators

Dr. Deepak Swami
School of Civil and Environmental Engineering,
IIT Mandi

Prof. Regina Nogueira
Institute of Sanitary Engineering and Waste Management
Leibniz University Hannover

The Indo-German workshop titled "Engineering for sustainable and resilient development" was a bilateral interdisciplinary event that brought together experts from both countries to discuss and collaborate on sustainable environment and energy solutions. The event was organized with the purpose of promoting sustainable development and addressing the challenges of climate change. The background of the workshop was about the growing concern towards the impacts of climate change and the need for countries to transition to reduce the energy, carbon, and water footprints. Both India and Germany have shown commitments to ambitious goals in this regard, with India aiming to achieve 40% of its installed power capacity from renewable sources by 2030, and Germany aiming to become climate neutral by 2050. The technical relevance of this workshop bring forth the facts and solutions for the broad challenges both the countries are facing in achieving aforementioned goals. By sharing their knowledge and resources, the workshop was aimed to promote sustainable development and address the challenges of climate change in a mutually beneficial way.

Workshop was organized with following Six technical sub-themes:

- **Sub Theme-1:** Resilient housing for harsh environments and earthquake resistance.
- **Sub Theme-2:** Green chemistry and catalysis for engineering applications
- **Sub Theme-3:** Sustainable Environment
- **Sub Theme-4:** Digital energy transformation for sustainable energy
- **Sub Theme-5:** Energy Systems

- **Sub Theme-6:** Changing people's attitude against climate change: Effect of visualization, feedback, and peer influence?

The main recommendations from the event were the reporting of the emerging areas of research such as sustainable cold region infrastructure, theoretical modelling of diffusion for drug delivery to diseased cells, studying the impact of climate change on human health through agriculture, a sustainable energy solution, microgrid operation and 3D printing for complex systems, and finally the artificial intelligence-based computer simulation to change societal behaviour. Specific groups involved in the respective sub-themes have outlined these recommendations to address the issues faced by both Germany and India for sustainable development goals.

Future energy carriers: Advancing bio-circular economy for clean energy (FACEnergy)

19–20 March 2024 | Braunschweig, Germany

Workshop Coordinators

Prof. Dr. Ravi Fernandes

Department of Physical Chemistry
Physikalisch-Technische Bundesanstalt
Braunschweig

Dr. Sanjukta Subudhi

Microbial Biofuels and Biochemicals Department
The Energy and Resources Institute, Delhi

The growing urgency of transitioning to a sustainable energy model and embracing the circular economy has spurred significant international collaboration. Recognizing this critical need, Physikalisch-Technische Bundesanstalt Braunschweig and The Energy and Resources Institute, Delhi co-hosted a workshop to address energy and environmental challenges and accelerate the adoption of renewable energy sources at Braunshweig from 19-20 March 2024. The workshop brought together 25 stakeholders from both countries, fostering a platform for knowledge exchange and collaborative problem-solving.

During the IGSTC FACEnergy workshop, two dedicated brainstorming sessions were conducted, focusing on bio-based fuels and hydrogen and hydrogen-based fuels spread over 2 days. These sessions provided a platform for stakeholders to engage in insightful discussions, delving into the critical aspects and opportunities within these areas. Participants actively shared their perspectives on the challenges and opportunities, fostering dialogue on potential collaborative efforts to advance clean energy initiatives. The brainstorming sessions served as valuable forums for identifying mutual interests and laying the groundwork for future collaborative endeavors in the pursuit of sustainable energy solutions. The discussions emphasized the importance of developing joint pilot-scale proposals to demonstrate these technologies at a pre-commercial level (TRL 5-7). These proposals can then be submitted to various Indo-German programs for funding opportunities.

As a next step there has been significant progress on collaboration efforts following the workshop. The NIE Mysuru, India team and Technische Hochschule Ostwestfalen-Lippe (TH-OWL) have already initiated a collaboration and submitted a joint proposal for the IGSTC 2+2 call. Building on the workshop's momentum, TERI India and PTB Braunschweig have launched a joint effort to explore green technologies for the port and shipping sector.

Indo-German workshop on frontiers of robot learning (FRL)

4-6 March 2024 | Mumbai, India

Workshop Coordinators

Prof. Arpita Sinha

Department of Systems and Control Engineering
IIT Bombay

Prof. Jan Peters

Department of Computer Science
Technische Universität Darmstadt

Following recent advancements in artificial intelligence (AI), including image, video, and text processing, significant strides have been made. This progress has been paralleled by a notable surge in global adoption of robotic automation. Robotics, crucial for the advancement of AI, offers opportunities to revolutionize various industries. Intelligent robots can assist in surgeries, optimize farming practices, and streamline manufacturing processes. A workshop aimed at fostering collaboration between Indian and German researchers was conducted to explore this intersection of robotics and machine learning by IIT Bombay and TU Darmstadt. The workshop was coordinated by Prof. Arpita Sinha from Indian side and Prof. Jan Peters from German side. The workshop provided a platform to address challenges such as sample efficiency, generalization, transparency in decision-making, continuous learning, safety, human-robot interaction, sensory integration, autonomous learning, and ethical deployment. Through discussions and presentations, attendees delved into practical solutions and explored cutting-edge research at the nexus of robotics and machine learning, paving the way for future collaborations and advancements in the field.

The workshop on robot learning featured keynote talks by leading experts from India and Germany, focusing on cutting-edge research and the integration of robotics and machine learning. Young researchers presented their work, receiving feedback from the experts to refine their ideas. Collaborative brainstorming sessions facilitated in-depth discussions on challenging topics, encouraging collaboration between Indian and German delegates and potentially leading to joint projects and innovative solutions in the field of robot learning.

Recent advances on harnessing green hydrogen and allied areas (GREEN H2)

22-24 November 2023 | Bhilai, India

Workshop Coordinators

Dr Sanjib Banerjee
Department of Chemistry
IIT Bhilai

Dr Prashant Menezes
Department of Chemistry
TU Berlin

Indian Institute of Technology Bhilai along with TU Berlin, Germany organised "GREEN H2: Recent advances on harnessing green hydrogen and allied areas" featured thought-provoking discussions and collaborative initiatives aimed at advancing green hydrogen and related technologies. Esteemed experts, researchers, and industry leaders from JNCASR, IIT Bombay, CSIR-NCL, TIFR, IISc, Reliance Industries Limited, Max Planck Institute for Chemical Energy Conversion, RWTH Aachen University, Helmholtz-Zentrum Berlin, etc united to explore the immense possibilities of green hydrogen in paving the way toward a more sustainable energy landscape. The three-day Workshop included several talks from experts around the world in the field of green hydrogen and allied energy sources. The workshop provided an enriching experience, highlighting the diverse dimensions of green hydrogen and its related domains. Some of the key highlights included:

1. Cutting-edge Green Hydrogen Production Technologies: Through insightful deliberations, experts delved into the emerging developments in green hydrogen production techniques, underscoring the synergistic approach to augment efficacy and minimize expenses. Several methods have been discussed and newer approaches were also elaborated by various speakers. They have also emphasized the importance of these approaches and what must be done in this regard.

2. Leveraging Storage and Distribution Infrastructure: Technical sessions centered around crucial factors concerning storage and distribution of green hydrogen, exploring novel measures and possible collaborations

to surmount present hurdles. These hurdles include production of green hydrogen from a suitable source and utilize it in a proper way. Another hurdle sincerely deliberated was the efficiency of materials.

3. Advancing Sustainable Energy Solutions: During the discussions, the incorporation of green hydrogen production into renewable energy sources was considered, highlighting the importance of a comprehensive approach to tackling sustainability.

4. Exploring the Potential of Hydrogen in Transportation: The workshop also highlighted into the possibilities of utilizing green hydrogen in the transportation industry, with a focus on joint ventures that could lead to the development of hydrogen-fueled vehicles and necessary infrastructure. The industry partners raised the current challenges, possible ways and future aspects for utilizing green hydrogen as a potential fuel.

Information-Centric networks for resilient smart urban infrastructure (INSURE 2024)

22-24 February 2024 | Gwalior, India

Workshop Coordinators

Dr. Kiran Kumar Pattanaik

Department of Information Technology
Atal Bihari Vajpayee Indian Institute of Information Technology and Management, Gwalior

Prof. Dr. Xiaoming Fu

Head of Computer Networks
University of Göttingen

INSURE-2024 workshop was organized jointly between Atal Bihari Vajpayee – Indian Institute of Information Technology and Management and University of Goettingen during 22-23 February 2024. The workshop was coordinated by Prof. K. K. Pattanaik from the Indian side and Prof. Xiaoming Fu from the German side. Industry and academic delegates from India Germany participated in the workshop to discuss a range of issues related to a sustainable smart city and the various efforts initiated by the delegates in their respective organizations. The two-day workshop witnessed 19 sessions of technical talks and discussions.

The workshop was aimed to build a symbiotic relationship among the participating stakeholders and later translate the ideas into a few actionable agendas towards building a societally acceptable public smart city IT infrastructure.

A few possible research directions deliberated among the delegates are as followed.

1. Traffic simulation in the context of smart mobility in a semi-structured society setup where there is a diverse habits and behavioural aspects of navigation.

2. The dimensionality of the smart city problem needs to be carved out.

3. AI across disciplines to model and plan sustainable and climate resilient cities e.g., Flood/natural disaster monitoring, alarming, response considering use cases of Chennai, Hamburg, Rhein/Donau/Elbe, GIFT city etc.

4. Rural/agricultural land use planning: Technical University Braunschweig, University of Göttingen); (agriculture/LUSci), Technical University of Hamburg, crops, insect detection, mobile apps, fertilizer usage and identify the industry partner.

5. Clean energy & Smart Grids: AI-based solutions for utility tunnel safety in case of any hazards (AI anomaly detection, drone-based sensing and surveillance, predictive maintenance, intrusion detection, modelling, cascade effect/complex system analysis, DT and simulations). ABV-IIITM Gwalior, IIT Gandhinagar, GIFT City, University of Gottingen, Industrial partner from Germany to be identified.

6. ICN for disaster management (University of Göttingen); situation sensing and signal analytics (Technical University of Hamburg)

Indo-German workshop on open spatial data infrastructure for sustainable urban development (Open-SDI)

3-4 October 2023 | Ahmedabad, India

Workshop Coordinators

Dr Shaily Gandhi

Centre for Applied Geomatics
CEPT Research & Development Foundation
CEPT University, Ahmedabad

Dr. Mathias Jehling

Spatial Information and Modelling
Leibniz Institute of Ecological Urban and Regional Development, Dresden

In an era marked by unprecedented urbanization and the dynamic evolution of technology, the role of geospatial data in shaping sustainable urban development has become increasingly critical. Recognizing this pivotal intersection, the Indo-German workshop on "Open spatial data infrastructure for sustainable urban development" was held from 3-4 October 2023. This workshop served as a platform for collaboration, knowledge exchange, and exploration of innovative approaches to harnessing geospatial data for the betterment of urban landscapes.

The keynote address, by Prof. Dr. P. G. Diwakar highlighted the significant role of Spatial Data and Geospatial Technology in the country, commending the efforts of ISRO. Despite the challenges posed by a densely populated landscape, he noted the crucial data derived from space, specifically through high resolution Indian satellites which has played a great role in planning and making the Indian cities. Mr. Falk Würriehausen, spoke about 'Federal Agency for Cartography and Geodesy Spatial Data Infrastructure in Germany: Prospects and Challenges.'
Mr. Würriehausen shared insights into the spatial data infrastructure in Germany, outlining both prospects and challenges.

The workshop unfolded as a dynamic platform, delving into pivotal themes Open spatial data infrastructure for sustainable urban development, and collaborative efforts between India and Germany.

The discussions centered around research grant opportunities, collaboration in research data infrastructure, and collaborative data utilization for urban management and policy, fostering an atmosphere of

knowledge exchange and potential collaboration avenues. Special talks, such as the one on Indo-German bilateral cooperation, outlined collaborative initiatives, achievements, and future prospects, setting the stage for deeper engagement between the two nations.

The major outcomes of the workshop for research, industry and government are as below:

1 To deepen the academic debate, themes for special issues in two international academic journals were developed to explore Indo-German partnerships for urban projects, comprehensive overview of advancements, challenges, and potential future directions in spatial data and urban management.

   a Special Issues on Data Driven spatial planning decision support approaches and systems for sustainability modelling in the Journal of Geovisualisation and Spatial Analysis (https://www.springer.com/journal/41651)

   b Special Issues on Indicators, Models, Simulations, and GeoAI-Tools for Cities and Regions of Tomorrow in the Journal of Buildings and Cities (https://journal-buildingscities.org/)

2 To strengthen the links between industry and research, topics and interests for mutual application for Indian and German research grants were identified. In particular, a potential application for a 2+2 project Grant under the IGSTC program was discussed. Also, further options were seen in German Research Foundation and DST Grants for Joint projects and PhD exchange were identified.

3 On an individual level, application for WISER Grant to built expertise between two countries and promote women researchers were also pin pointed.

4 Future plans focus on the joint facilitation of young researcher in PhD projects by Leibniz Institute of Ecological Urban and Regional Development and CEPT University, Ahmedabad.

Resilient Food Systems: AI, remote sensing, and crop models (R-FARM)

21–22 February 2024 | Bonn, Germany

Workshop Coordinators

Dr. Amit Kumar Srivastava
Institute of Crop Science and Resource Conservation (INRES)
University of Bonn

Dr. Adway Mitra
Center of Excellence in Artificial Intelligence
Indian Institute of Technology Kharagpur

As global climate change increasingly disrupts traditional agricultural systems, threatening food security and livelihoods worldwide, the need for innovative solutions becomes imperative. In response to this challenge, agricultural scientists are exploring new scientific ideas to develop resilient practices. The integration of Artificial Intelligence (AI) and Machine Learning (ML) into agricultural sciences has emerged as a promising framework to address these complex issues.

Deliberations: The workshop focused on two main topics:

1. **AI/ML for Crop Modeling and Yield Forecasting:** Participants discussed the potential of AI and ML to enhance crop modeling and yield forecasting. By integrating various data sources such as satellite imagery, weather data, and soil information, ML algorithms can improve model initialization and calibration, leading to more accurate forecasts. Discussions also centered around physics-informed ML models, and the identification of causal relationships between variables.
2. **AI/ML and Remote Sensing for Agriculture:** The workshop explored methodologies and tools in AI and remote sensing for agricultural applications. Remote sensing data, combined with AI algorithms, can provide real-time information on land use, crop health, and environmental conditions, enabling accurate crop yield estimation and effective agricultural planning. Discussions also highlighted the importance of high-resolution spatio-temporal data and tools for mapping crop production and understanding the interconnectedness between crop production, climate, and soil.

Salient Outcomes:

1. **Collaborative Research Initiatives:** The workshop facilitated knowledge exchange and collaboration between researchers from India and Germany. Participants identified common research interests and opportunities for joint projects, leading to the development of innovative solutions for advancing resilience in food systems.

2. **Practical Applications:** Participants discussed the development of tools and methodologies to optimize resource allocation, enhance crop yield predictions, and support evidence-based policy development.

3. **Cultural Exchange and Networking:** The workshop provided a platform for cultural exchange and networking, enabling participants to interact with researchers from diverse backgrounds. Participants benefited from cross-cultural perspectives and established lasting connections for future collaborations.

Next Steps:

1. **Joint Research Projects:** Researchers will explore opportunities for joint research projects, leveraging the expertise and resources of both countries to address common challenges in agriculture.

2. **Tool Development:** Efforts will be made to develop practical tools and methodologies that integrate AI, ML, Process-based models, and remote sensing for agricultural applications, with a focus on enhancing resilience in food systems.

Conclusion:

The workshop served as a platform for interdisciplinary collaboration and knowledge exchange, fostering innovative solutions for advancing resilience in food systems. By harnessing the potential of AI, ML, Hybrid modelling and remote sensing, researchers aim to address the complex challenges posed by climate change and contribute to global food security and sustainable development.

Heat waves: Forestry and agriculture under pressure - A remote sensing perspective (RS-HEAT-2023)

19-21 October 2023 | Dharwad, India

Workshop Coordinators

Dr. Arjun G. Koppad

College of Forestry
University of Agricultural Sciences,
Dharwad Karnataka

Dr. Carsten Montzka

Institute of Bio- and Geosciences:
Agrosphere (IBG-3)
Forschungszentrum Jülich GmbH, Jülich

The Bilateral Workshop on Heat waves: Forestry and agriculture under pressure - a remote sensing perspective (RS-HEAT-2023) was held at University of Agricultural Sciences, Dharwad Karnataka from 19th – 21st October 2023.

The workshop was organized around the following main theme areas:

- Monitoring and understanding climate threats to forestry and agriculture
- Climate extreme mitigation informed by remote sensing
- Automatization in monitoring and mitigation (drones, robotics, and workflows)
- Geo-spatial research conducted in Germany and India.

The participants exchanged potential scientific avenues and business cases for the application of remote sensing not only in the monitoring of heat waves but also in simulating the future status of ecosystems together with optimized mitigation strategies. The application of optical, RADAR, thermal, and LiDAR remote sensing on the impact of heat waves in Agriculture and Forestry was discussed, and mitigation strategies were recommended. In each technical session, one keynote presentation from the Indian and German sides was given, followed by 8-10 research paper presentations. On the third day, a panel discussion was organized to discuss the outcome of the workshop and final recommendations to support policy decisions at the governmental level in India and Germany.

As a result of mutual discussions, participants agreed to initiate bilateral collaborations and established an online platform for easy communication, including posting potential funding sources. A foundation for collaboration was identified, leveraging India's strong

knowledge of local environments, specific in situ measurements, and access to Indian satellite missions, complemented by the methodological expertise of German partners. The overarching aim is to integrate these strengths for future research, particularly focusing on dedicated missions for vegetation and soil moisture monitoring, such as the upcoming NASA-ISRO SAR (NiSAR) mission set to launch in 2024. The availability of S-band radar data exclusively for India presents significant potential for advanced research. Individual discussions have commenced, including collaborations between Jülich and National Remote Sensing Centre on soil moisture and vegetation correction, and between Uni Jena and UASD on forest monitoring.

Indo-German workshop on thermoelectric devices for emerging applications (WTEA)

26-28 February 2024 | Thiruvananthapuram, India

Workshop Coordinators

Dr. Vinayak B. Kamble
School of Physics
IISER Thiruvananthapuram

Dr. Heiko Reith
Institute for Metallic Materials
Leibniz-Institute for Solid State and Materials Research

The Indo-German Workshop on Thermoelectric Devices for Emerging Applications, conducted under the auspices of the IGSTC, convened from 26th-28th February 2024 at IISER Thiruvananthapuram. Spearheaded by Dr. Vinayak B. Kamble, Assistant Professor at IISER TVM, representing India, and Dr. Heiko Reith, from the Leibniz-Institute for Solid State and Material Research, representing Germany, the workshop addressed a diverse array of topics.

The main agenda of the Indo-German workshop was to bring together scientific researchers and industry partners from India and Germany who were interested in thermoelectric (TE) technologies, specifically in TE device design, fabrication, and applications. The workshop comprised presentations by various speakers on their current research activities related to TE fields and discussions on many aspects of TE materials and applications, TE devices, design, fabrication procedures, and practical applications. In this way, the participants had the opportunity to expand their expertise, exchange ideas, and work on cutting-edge thermoelectric research and development. Participants also gained insights into the latest advancements, challenges, and breakthroughs in thermoelectric technology and device fabrication techniques from experts of the other partners. The workshop covered both theoretical concepts and practical applications, providing a comprehensive understanding of thermoelectric devices.

The group of participants had a common research theme i.e. thermoelectric materials and devices. Wherein there were material scientists, physicists, chemists, electronic engineers, modelling scientists (first principles as well as Multiphysics, finite element), researchers

from public and private industry, space and defense related organizations. The truly interdisciplinary group recognized the cross-disciplinary efforts in order to make Thermoelectric technology viable products for sectors like space, automobiles, process industry and wearable technologies. Delegates delivered insightful talks on thermoelectric phenomena in engineered 2D hybrids, alongside discussions on modelling, simulation, recent material developments, and application challenges in thermoelectric devices. Throughout the sessions, participants engaged in fruitful exchanges of ideas, exploring potential industrial ventures, collaborative projects, and research partnerships. The participation of young researchers provided a glimpse into cutting-edge work, while industry and R & D representatives shared insights into current trends and innovations in thermoelectric research. By providing a platform for interdisciplinary dialogue and knowledge exchange, the workshop fostered a deeper understanding of theoretical and instrumental development techniques across various material domains. The connections forged during this event are poised to catalyse future collaborations between India and Germany, promising to advance research and innovation in thermoelectric technology on a global scale.

Crosstalk between cardiovascular disease and chronic inflammation via the routes of metabolite and immunity

7-9 February 2024 | Bhubaneshwar, India

Workshop Coordinators

Prof. Mrutyunjay Suar
School of Biotechnology
Kalinga Institute of Industrial Technology (KIIT University)

Prof. Leon J. Schurgers
AMICARE Institute
RWTH Aachen University

The workshop addressed complex health issues in its diverse range of presentations, which spanned interdisciplinary topics such as microbiology, genetics, immunology, and bioinformatics. Presenters shared cutting-edge research findings and innovative approaches, highlighting recent advancements in areas like vitamin K metabolism, microbiome-host interactions, and molecular diagnostics. A significant focus was on precision medicine, including the identification of biomarkers for targeted interventions, the development of non-invasive diagnostic platforms, and the integration of traditional knowledge for personalized health and wellness.

The discussions also covered novel therapeutic strategies, such as the creation of protein nanocages for toxin adsorption, drug discovery through single-cell analysis, and the development of nano-therapeutics to treat renal inflammation. The advancements in diagnostic technologies were notable, with presentations on point-of-care diagnostics for tuberculosis, cross-platform immunoassays for detecting inflammatory markers, and metabolomics-based methods for identifying biomarkers in patients with chest trauma. These innovations highlight significant progress in disease detection and management.

Furthermore, the integration of technology in healthcare was a recurring theme, particularly in sessions focused on the use of AI, data lakes, and bioinformatics for data-driven innovation and decision-making. The workshop also explored the need for natural immunization strategies against cardiovascular diseases, the investigation of endocrine-disrupting chemicals, and the identification of new therapeutic targets for complex diseases, underscoring the ongoing need for research and collaboration in these critical areas.

Various speakers, including Prof. Monika Stoll and Dr. Tilman Hackeng, highlighted new approaches in cardiovascular research, ranging from novel insights into genetics and metabolism to innovative methods for detecting and repairing cardiovascular damage. These developments contribute to a deeper understanding of cardiovascular diseases and pave the way for more effective interventions.

The event facilitated the signing of MoUs between Indian (KIIT) and German institution (University of Munster), fostering closer collaboration in scientific research and technology development. These MoUs may outline joint research projects, exchange programs for researchers, and knowledge-sharing initiatives, strengthening bilateral S&T cooperation.

Overall, the event likely catalysed Indo-German collaborations in science, technology, and innovation, paving the way for impactful research partnerships and mutual learning opportunities between the two countries.

Deutschland India workshop on integration of sensors with AI hardware (DIWISAH)

15-17 February 2024 | Bhilai, India

Workshop Coordinators

Prof. Rajiv Prakash
Director, IIT Bhilai/Department of Mechanical Engineering IIT Bhilai

Prof. Bhaskar Choubey
Chair of Analog Circuit Technology and Image Level Sensors University of Siegen

The Indo-German workshop aimed to identify and explore the design, construction, and testing of intelligent real-time privacy-enhanced sensory systems. This was achieved by integrating artificial intelligence processing units built through stacks of integrated analogue and digital hardware, along with micro/nano sensors. The workshop explored different integrated circuits for sensing and neural processing in heterogeneous processing technologies. Various approaches to adapt neural network architecture, design, and learning were considered to exploit opportunities from these edge designs of circuits and sensors. The goal was to establish a foundation for future multi-pronged Indo-German projects, with the ambition to integrate sensors directly with brain-type processor-memory systems and dedicated AI models. By doing so, the workshop aimed to eliminate the sensor-processor and sensor-memory bottlenecks present in modern sensor-data processing pipelines, which are bandwidth and energy-intensive. The workshop led to approaches for designing low-power, real-time, compact, and cost-effective solutions for intelligent, adaptable, and efficient AI-enhanced sensory systems, ensuring private and localized sensory information.

A series of 27 presentations were made by leading academics and industrialists during the workshop.
In addition, a research networking event was also organised to identify further research collaborations between individual groups.

The Indo-German workshop featured a diverse range of presentations from experts in academia, industry, and research institutions, focusing on the development and application of intelligent, AI-enhanced sensory systems. Prof. Rajiv Prakash from IIT Bhilai started the session by discussing IoT-enabled sensors for environmental monitoring and biosensors for health, highlighting low-cost diagnostic solutions suitable for the Indian context. This was followed by Prof. Bhaskar Choubey from the University of Siegen, who presented on digital camera design and integrating image sensing with analog AI on-chip for secure edge computations. Further contributions came from Prof. Karsten Seidl of the Fraunhofer Institute, who discussed neurological measurements, and Dr. Lalitha from IGSTC, who detailed funding opportunities for Indo-German collaboration.

Industry insights were provided by Mr. Naresh Kumar from Tektronix, addressing challenges in testing large-scale integrated systems, and Mr. Arvind Dixit from Advance Tech India Pvt Ltd, who explored translating academic research into market-ready products. The workshop also included presentations on cutting-edge research such as Prof. Alex James' work on AI chips with memristors, Prof. Michael Moller's computer vision research, and Prof. Heidemarie Schmidt's study on BFO memristors. The event culminated in a session focused on potential research collaborations, facilitated by a "research networking" event where participants from India and Germany discussed joint activity possibilities, paving the way for future collaborative projects.

From a research perspective, several new lines of investigations were identified and we envision at least 3-5 new proposals to the IGSTC 2+2 call alone. Deliberations were also undertaken for joint DFG-DST international researcher training group. Towards this, it was planned to undertake small projects initially funded locally to create dedicated critical mass required for such large project proposals in future.

Indo-German workshop-2023: Enabling methodologies for rational design of complex systems

11–13 October 2023 | Würzburg, Germany

Group photo in front of the Residence Würzburg

Workshop Coordinators

Prof. Dr. Jürgen Seibel

Institute for Organic Chemistry
Ludwig-Maximilians University
of Würzburg

Prof. Sandeep Verma

Department of Chemistry
Indian Institute of Technology Kanpur

The behaviour of complex systems is based on a multilayered interplay of many processes occurring at the molecular level. Precise knowledge of these processes and how they influence each other is necessary for fundamental understanding and targeted manipulation of these systems. Getting to the bottom of these fundamentals requires collaboration among groups with very different skills. Since such groups often belong to very different scientific communities, assembling suitable consortia is very difficult. The goal of the workshop was to remedy this situation and to bring together German and Indian groups with the necessary complementary research directions and expertise.

Various participating groups encountered each other for the first time, paving the way for the establishment of a new network among German and Indian scientists, potentially reinforced by industrial collaborations. Echoing the conference's theme, 'Enabling Methodologies for Rational Design of Complex Systems,' the subjects spanned from material research in organic semiconductors to bioorganic inquiries into sugar and RNA chemistry, and even medicinal chemistry. To facilitate a comprehensive discourse on these topics, 12 Indian and 12 German scientists were invited.

The symposium highlighted cutting-edge research from India and Germany, showcasing 24 presentations across diverse scientific fields. Key topics included cancer therapy through protein kinase targeting, two-dimensional molecular materials, molecular tweezers for disrupting protein aggregation, and stable cage materials for gas storage. The event also covered advanced topics like singlet fission in molecular design, super-resolution microscopy with genetic code expansion, and unique boron compounds with metal-like properties. Research on molecular ferroelectrics, silafulleranes, and disease diagnostics with nanomaterials was presented, along with studies on neuronal repair, single molecule spectroscopy, and innovative synthetic methodologies. Additionally, there were discussions on transcription and DNA repair mechanisms, and RNA-targeted therapeutics. This diverse array of research underscores the potential for new Indo-German scientific collaborations. In a poster session a wide spectrum of chemistry was presented from theoretical to physical, inorganic to organic, biological and pharmaceutical/medicinal chemistry. This event was ideally suited for the participating students to build networks, receive new impulses and get to know well-known scientists personally who have only been known from publications so far.

IGSTC industrial fellowship

IGSTC Industrial Fellowship programme is aimed at encouraging PhD students/researchers in S&T with an appreciable track record and aptitude for applied research and technology development. The fellowship provides an opportunity for young researchers at PhD or Post-Doc level to gain industrial experience in Germany.

IGSTC Industrial Fellowship

IGSTC awards Industrial Fellowships to encourage young Indian researchers towards applied research in an Industrial setup in Germany. This programme is aimed at encouraging PhD students/researchers in S&T with an appreciable track record and having aptitude for applied research and technology development. This fellowship provides exposure to young researchers from India at German Industrial ecosystems and applied research institutions offering fellowships at two levels - Ph.D. Industrial Exposure Fellowship and Post-Doctoral Industrial Fellowship. The Industrial Fellowships are provided with financial support for subsistence, travel-related, and insurance costs. A total of 10 (ten) researchers from leading academic and research institutions spread across India have been awarded Post-Doctoral Industrial Fellowships (PDIF), and 10 (ten) have been awarded Ph.D. Industrial Exposure Fellowships (PIEF) under the IGSTC Industrial Fellowship Call 2023.
This is the third batch of IGSTC Industrial fellows. They both motivated the young industrial fellows who will be departing shortly for pursuing their research journey in Germany and strongly encouraged the fellowship awardees to experience German culture and facilities in applied research.

IGSTC has organised the award ceremony to felicitate IGSTC Industrial Fellows of Call 2023 on 14th June 2023. The event was graced by Dr Annapurni Subramaniam, Director, Indian Institute of Astrophysics (IIA) as Chief Guest and as the Guest of Honour, Mr Rajesh Nath, Managing Director, Association of Germany's Engineering Industry (VDMA) India, Mr Stephan Grabherr, Charge d'affaires of the German Embassy in Delhi and Mr S. K. Varshney, Adviser & Head, International Division, DST. The young industrial fellows embarking on their research journey to Germany were fervently encouraged to acquire both cross-cultural insights and practical experience within the industrial setup.

PDIF Industrial Fellows 2023

Dr. Yamini Mittal

CSIR-Institute of Minerals & Materials Technology

Host
Ingenieurgesellschaft Janisch & Schulz mbH

Area of Work
Biological wastewater treatment through nature-based sustainable technologies – Piloting of electroactive wetlands and their comparative assessment with conventional constructed wetlands in practice.

Dr. Ashish Sengar

IIT Delhi

Host
Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB

Area of Work
Water and Wastewater Treatment - Development of novel membrane-based renewable technology for the removal of recalcitrant pharmaceuticals present in wastewater while achieving reduction in carbon footprint.

Dr. Bhabagrahi Natha Sharma

IIT Delhi

Host
TESTIA GmbH

Area of Work
Structural Health Monitoring - Investigation into Lamb Wave-Based Structural Health Monitoring (SHM) solution for inspecting structures operating at low temperature environments using the refined time reversal method.

Dr. Mohammed Shariq

Vellore Institute of Technology

Host

Fraunhofer Institute for Manufacturing Engineering and Automation IPA

Area of Work

Dispersion Technology – Digitalization of the dispersion process for the customer slurry recipes that creates the basis for the introduction of numerical solution approaches and new business models in the process industry.

Dr. Amit Kumar Vats

National Institute of Technology, Kurukshetra

Host

Fraunhofer Institute for Manufacturing Engineering and Automation IPA

Area of Work

Recycling and resource recovery - Recycling of Lithium-Ion Battery and rejuvenation of cathode materials for energy storage applications.

Dr. Jaladhi Trivedi

CSIR-Central Salt and Marine Chemicals Research Institute

Host

Fraunhofer Institute for Ceramic Technologies and System IKTS

Area of Work

Polymer Chemistry Membrane Science - Novel dual-layer nanocomposite membrane for the production of fuel-grade alcohols.

Dr. Ramarajan J

Indian Institute of Information Technology, Design and Manufacturing, Kancheepuram

Host

Fraunhofer Institute for Wind Energy Systems IWES

Area of Work

Generation of structured mesh for wind turbines using blade block mesh.

Dr. Harshal Agarwal

CSIR-Central Electrochemical Research Institute

Host
Fraunhofer Institute for Chemical Technology ICT

Area of Work
PEM Electrolysis (Hydrogen Energy)- Developing innovative strategies for enhancing the performance and reliability of proton exchange membrane electrolysis through computational modelling.

Dr. Abhay Mishra

IIT Bombay

Host
Quantum Diamonds GmbH

Area of Work
Quantum sensing – Quantum diamond microscopy with machine learning algorithms for hardware trojan detection.

Dr. Jyotsnamayee Nayak

Sardar Vallabhbhai National Institute of Technology, Surat

Host
DendroPharm GmbH

Area of Work
Nanomedicine – Nano-Solution for Hyperphosphatemia: Iron Oxide Nanoparticles functionalized with Thiolated Chitosan.

PIEF Industrial Fellows 2023

Nabab Khan

CSIR – Institute of Himalayan Bioresource Technology

Host
LIONEX GmbH

Area of Work
Diagnostics and Therapeutics - Development of ultrasensitive Antibody-Gold Nanoparticles (Ab-AuNPs) conjugate based diagnostic kit for sub nanogram level detection of human blood pathogen biomarkers.

Aparna Ramachandran

CSIR – National Chemical Laboratory

Host
UCB Biosciences

Area of Work
Pharmacometrics – Assessment of performance characteristics of Population Pharmacokinetics (PopPK) and Anti-Drug Antibodies (ADA) longitudinal models to inform decision making in drug development.

Kumar Vaibhav Tejan

IIT Mandi

Host
OLI Systems GmbH

Area of Work
Paperless smart charging solution for the real estate sector.

Paladugu Sri Harsha

Indian Institute of Science Bangalore

Host

Fraunhofer Institute for Microengineering and Microsystems IMM

Area of Work

Bioengineering – Advancing Organ-on-Chip (OoC) technology for commercial scale implementation: strategies for effective translation.

Angel Joseph

IIT, Delhi

Host

Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB

Area of Work

Wastewater Treatment – CO2 reduction in oxidation of micro pollutants: energy intensive vs. novel solar based processes.

Ajin Rajan

IIT, Madras

Host

BASF SE

Area of Work

Computational catalysis - Development and application of reactive machine learning force field for complex heterogeneous catalysis.

Nipun Sharma

IIT, Jodhpur

Host

Fraunhofer Institute for Reliability and Microintegration (IZM)

Area of Work

Sensors, implantable electronics, device packaging and product development - Development of non-hermetic thin-film encapsulation for next-generation implantable sensor.

Apurva Sharma

CSIR – Central Scientific Instruments Organisation

Host
K|Lens GmbH

Area of Work
Vision based Industrial Inspection – Unsupervised multiview object detection algorithm for industrial application.

Arunava Kr Kalita

IIIT Guwahati

Host
Fraunhofer Institute for Integrated Circuits IIS

Area of Work
Prosody transfer in voice conversion.

Faridul Hassan

National Institute of Technology Silchar

Host
Fraunhofer Institute for Solar Energy System ISE

Area of Work
Electric Vehicle - Design and development of control for EV charging (G2V) and Vehicle-to-Grid (V2G) mode of operation through VSC in Single-Phase grid-connected PV system and experimental validation.

Women involvement in science and engineering research (WISER)

- Second Batch of Awardees

WISER aims to promote women researchers in Science, Technology, Engineering and Mathematics (STEM) to join an ongoing R&D+I project in the host laboratory.

IGSTC Women Involvement in Science and Engineering Research (WISER) programme aims to promote women researchers in Science, Technology, Engineering and Mathematics (STEM) to create avenues for networking, interaction and long-term research collaboration. Through this scheme, women researchers/entrepreneurs holding regular positions in academic/research institutions/industrial research organisations in India/Germany may apply to be a part of an ongoing R&D project of interest with acceptance from the host team.

WISER is open to all the areas of STEM with a tenure of 3 years or until completion of the project whichever is earlier and will cover one visit per year allowing for a short stay of up to 1 month in the host institute.

The financial assistance under this scheme for Indian awardees is up to 39 lakhs for 3 years and for German awardees, it is up to € 48000 for 3 years.

The following are the brief profiles of 12 successful candidates (10 awardees from India and 2 from Germany) for WISER.

Indian Awardees

Dr. Monika Gupta

IIT Ropar

Host
University of Würzburg

Area of Work
Development of solid-state solar thermal fuels derived from liquid crystalline norbornadiene derivatives

Dr. Medhavi Vishwakarma

IISc Bangalore

Host
RWTH Aachen University

Area of Work
Understanding the role of Idiopathic pulmonary fibrosis in cancer initiation

Dr. Kriti Tyagi

CSIR-National Physical Laboratory

Host

German Aerospace Centre (DLR), Institute of Materials Research Cologne

Area of Work

High Power Factor materials for efficient thermoelectric heat pumping applications

Dr. Kala Sasikumaran

Indian Institute of Information Technology Kottayam

Host

Technische Universitat Dresden

Area of Work

Sparse matrix multiplication co-processor for deep learning applications on RISC V platform

Dr. Greeshma Thrivikraman Nair

IIT Madras

Host

Technische Universitat Dresden

Area of Work

Circumferential cell migration towards a neuropeptide gradient for healing critical-sized cranial defects

Dr. Puja Yadav

Central University of Haryana

Host

University Hospital Ulm

Area of Work

Antibacterial and anti-biofilm activity of the human peptide library against Group B Streptococcus

Dr. Lata Gawade

Goa University

Host

Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research (AWI) Bremerhaven

Area of Work

Understanding and implementing IMTA: An efficient technology towards sustainable mariculture, carbon sequestration, and blue economy boost

Dr. Rita Sharma

BITS Pilani

Host

Max Planck Institute of Molecular Plant Physiology Potsdam

Area of Work

Investigating the role of long non-coding RNAs in phytohormone-mediated autonomous seed development in Arabidopsis

Dr. Ramya Devi Durai

SASTRA Deemed University

Host

Reutlingen University

Area of Work

Exploration of 3D adipose tissue models to study long-acting Statin nanoparticles to assess the efficacy and suitability as an alternative for animal models

Dr. Rik Rani Konerghosh

IIT Mandi

Host

Universitat Leipzig

Area of Work

Engineering hybrid MOF composite materials with rationally designed Ligands for Photocatalytic Hydrogen Evolution

German Awardees

Dr. Mehrnaz Anvari

Fraunhofer-Institute for Algorithms and Scientific Computing (SCAI)

Host
IIT Indore

Area of Work
The role of the higher order and symplectic communications in the power grid stability

Dr. Özlem Günay Eşiyok

Humboldt University of Berlin

Host
BITS Pilani (Hyderabad campus)

Area of Work
Optogenetic modulation of cAMP and cGMP signalling in Toxoplasma gondii

WISER Award Ceremony

IGSTC organised the WISER Award Ceremony on 14th June 2023 to felicitate all the WISER-2023 Awardees. The event was graced by Dr Annapurni Subramaniam, Director, Indian Institute of Astrophysics (IIA), Mr Rajesh Nath, Managing Director, Association of Germany's Engineering Industry (VDMA) India, Mr Stephan Grabherr, Charge d'Affaires of the German Embassy in Delhi and Mr S. K. Varshney, Adviser & Head, International Division, DST & Indian Co-Chair, IGSTC GB.

Dr Annapurni Subramaniam, Director, Indian Institute of Astrophysics (IIA), Bangalore and Chief Guest of the event emphasized the significance of increasing representation of women scientists and ensuring a proportionate number of women-led projects for fostering inclusivity and diversity within the scientific fraternity.

Indian WISER awardees

IGSTC WISER Awardee Dr Ozlem Gunay-Esiyok felicitated by H.E. Parvathaneni Harish, Ambassador of India to Germany in October 2023

Paired early career fellowship in applied research

(PECFAR) 2023 - Awardees

PECFAR fellowship intends to facilitate a pair of Early Career Researchers to have short visits to India/Germany for networking and exploring avenues for collaboration and innovation in Science, Technology, Engineering & Mathematics (STEM).

Paired Early Career Fellowship in Applied Research (PECFAR), a new initiative to facilitate research and networking among early career researchers from India & Germany through a short-term exchange visit up to 2 months. PECFAR provides grants for research stay & networking including monthly fellowship along with international travel support & medical/travel insurance cost for the visit to the host country.

In the second Call, IGSTC awarded the fellowship to 12 pairs of Early Career researchers from various academic institutions in India & Germany. It is envisaged that such engagements through networking would further establish long-term bilateral collaborations and provide an opportunity to explore the Indian and German research landscape for potential collaborations in future.

Pair 1

DBT - National Institute of Animal Biotechnology (NIAB), Hyderabad & University Hospital Knappschaftskrankenhaus Bochum

Janani Radhakrishnan
Scientist-B

Area of Work
Multi-scale porous construct for bone regeneration and in vitro organotypic functional model.

Alexander Sieberath
Postdoctoral researcher

Area of Work
Multi-scale porous construct for bone regeneration and in vitro organotypic functional model.

Pair 2

IIT Jammu & Forschungszentrum Juelich

Harish Pothukuchi
Assistant Professor

Area of Work
Study the boiling phenomena of Liquid Hydrogen (LH2) using Computational Fluid Dynamics modelling.

Khaled Yassin
Research Associate

Area of Work
Study the boiling phenomena of Liquid Hydrogen (LH2) using Computational Fluid Dynamics modelling.

Pair 3

IIT Indore & Chemnitz University of Technology

Pravarthana Dhanapal

Assistant Professor Grade-I

Area of Work

Development and Characterize Solid State Magnetoionic devices for Efficient Magnetic Modulation.

Markus Gößler

Postdoctoral researcher

Area of Work

Development and Characterize Solid State Magnetoionic devices for Efficient Magnetic Modulation.

Pair 4

IISc Bangalore & Johannes Gutenberg University Mainz

Akshay Kumar Singh

Assistant Professor

Area of Work

Investigation of spin functionalities in Hybrid Magnetic 2D Systems.

Angela Wittmann

Junior Professor

Area of Work

Investigation of spin functionalities in Hybrid Magnetic 2D Systems.

Pair 5

IIT Kanpur & Karlsruhe Institute of Technology

Sarvesh Mishra
Assistant Professor

Area of Work
To study the tribological behaviour of micro structured cellular metallic materials through advanced additive manufacturing.

Roxane Lung
Scientific Associate

Area of Work
To study the tribological behaviour of micro structured cellular metallic materials through advanced additive manufacturing.

Pair 6

IISc Bangalore & German Aerospace Center (DLR), Bavaria

Bramha Dutt Vishwakarma
Assistant Professor

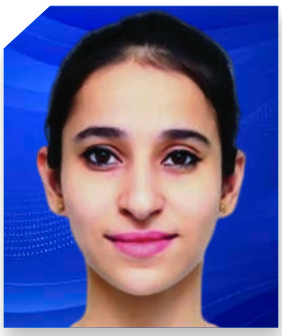
Area of Work
To develop a novel framework using cutting edge ML tools and data from remote sensing and reanalysis for glacier surface mass change estimation.

Codrut-Andrei Diaconu
Doctoral Researcher

Area of Work
To develop a novel framework using cutting edge ML tools and data from remote sensing and reanalysis for glacier surface mass change estimation.

Pair 7

Punjab Engineering College, Chandigarh & RWTH Aachen University



Navneet Kaur
Assistant Professor

Area of Work
To integrate Metallovesicle with Graphene-Based Nanosystems for novel Nanoreactors.

Hesam Amiri
Research Assistant

Area of Work
To integrate Metallovesicle with Graphene-Based Nanosystems for novel Nanoreactors.

Pair 8

BITS Pilani, Hyderabad campus & University Hospital of Cologne

Abhijeet Joshi
Assistant Professor

Area of Work
Central (chemo-brain) and peripheral neuropathy associated with chemotherapy in cancer patients.

Ines Klein
Postdoctoral researcher

Area of Work
Central (chemo-brain) and peripheral neuropathy associated with chemotherapy in cancer patients.

Pair 9

CSIR- National Aerospace Laboratories, Bengaluru & German Aerospace Center (DLR), Braunschweig

Sunil Prasad
Sr Scientist

Area of Work
Study of Integrated Modular Avionics for Unmanned Aerial Vehicle.

Bojan Lukic
Research Scientist

Area of Work
Study of Integrated Modular Avionics for Unmanned Aerial Vehicle.

Pair 10

IISER Berhampur & Technical University of Dortmund

Himanshu Singh
Ramalingaswami Fellow

Area of Work
Significance of Cyclic Dinucleotide Signaling and Spike Protein Dynamics in Bacterial Immunity and SARS-CoV-2 Infection.

Benedikt Söldner
Research Assistant

Area of Work
Significance of Cyclic Dinucleotide Signaling and Spike Protein Dynamics in Bacterial Immunity and SARS-CoV-2 Infection.

Small immediate needs grant

(SING-2023)- Awardees

Small Immediate Need Grants (SING) programme supports proposals with quick turnaround decisions and have the potential to embark on good bilateral Indo-German collaboration.

IGSTC introduced the initiative Small Immediate Need Grants (SING) to support proposals that require modest funding with quick turnaround decisions and have the potential to embark on good bilateral Indo-German collaboration.

SING supports the proposal with at least one of the following objectives:

- Joint initiatives/ideas that have a scope to ignite and open avenues for long term connect/technology development/new areas of collaboration.
- Joint activity towards innovation, rapid prototyping, technology demonstration or industrial R&D.
- Individual proposals that have a high potential of involving industrial sectors.
- Utilizing scientific events to share intellectual thoughts/ideas that can explore avenues for bilateral cooperation.

Dr Ragesh G K

Assistant Professor, IIIT Kottayam

Host

Prof Marlene Harter Director of Institute for Unmanned Aerial Systems (IUAS), University of Applied Sciences, Offenburg

Project Title

Isolation enhancement of CPW fed MIMO array using Substrate Integrated Waveguide (SIW) technique for 5G and beyond.

Mr Fabian Sowieja

Research Staff Member, Hochschule Offenburg

Host

Prof Sameer S M
Professor NIT Calicut

Project Title

IICT- Technology demonstration and expansion of 5G/IoT educational and experimental testbeds in India.

Outreach

The Indo-German Science and Technology Centre (IGSTC) has been increasing its outreach and visibility by conducting events in various tier-2 cities of India. IGSTC organized four successful outreach events in Lucknow, Chandigarh, Nagpur, Dharwad and Bhopal. The events were attended by invitees from different academic and research institutions as well as industries. The one-day interactive events included detailed sessions on IGSTC activities, descriptive sessions for applications, presenting success stories, an address from visiting dignitaries and a panel discussion. The panel discussion which featured panellists from academia, research, industry, and the German consulate, focused on the relevance of international science and technology cooperation in today's context and connecting industry, academia, and research. It generated an excellent response from the audience and was a great experience for all involved. The events were well received and much appreciated by the participants. There were great opportunities for the IGSTC to connect with stakeholders and highlight the centre's mission of fostering collaboration between India and Germany in the field of science and technology.

IGSTC Outreach Event, Lucknow on 18th April 2023

IGSTC Outreach Event, Chandigarh on 16th September 2023

IGSTC Outreach Event, Nagpur on 4th December 2023

IGSTC Outreach Event, Dharwad on 25th January 2024

IGSTC Outreach Event, Bhopal on 4th April 2024

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