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A Quartely e-newsletter of IIT Hyderabad

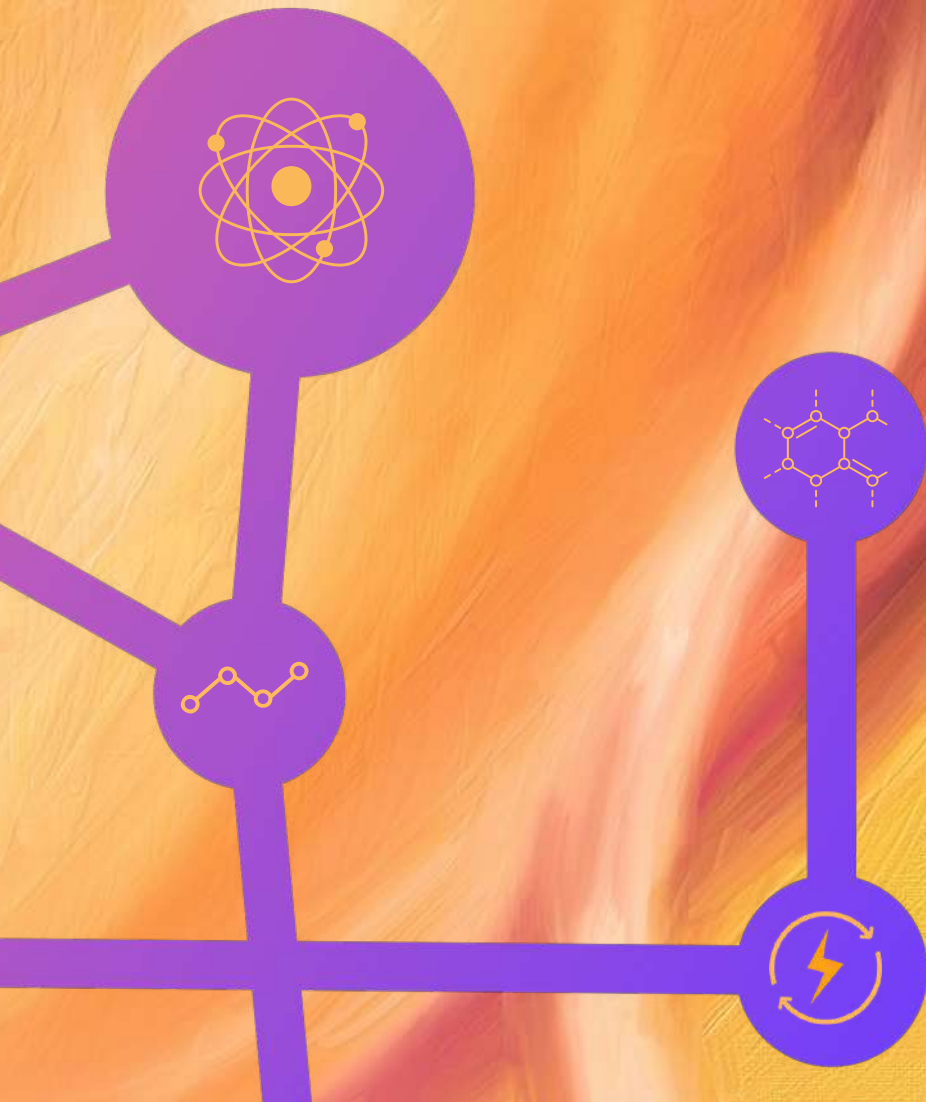
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भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

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Dear Esteemed Readers,
Greetings!!

With great pleasure, we present to you the latest edition of किरIITH. We take this opportunity to express our heartfelt gratitude for your continued support and engagement.

Your sustained interest, thoughtful feedback, and genuine curiosity about the happenings at IIT Hyderabad inspire us to continually raise the bar and curate content that is both insightful and impactful. It is this meaningful connection you share with our publication that makes this endeavour truly fulfilling.

As always, this edition, Vol 7, Issue 1, Jan - Mar 2025 (Issue - 22) is dedicated to one of IITH's key thrust research areas, "Material Characterisation". In today's rapidly evolving world of technology, material characterisation plays a vital role in driving innovation, ensuring reliability, and enhancing performance across industries. As new materials are developed for cutting-edge applications, from semiconductors and renewable energy to biomedical devices & aerospace, understanding their structural, mechanical, electrical, and chemical properties becomes essential.

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Aligned with its motto Inventing and Innovating in Technology for Humanity, IIT Hyderabad is actively advancing research in material characterisation to develop next-generation materials tailored to industrial needs, thereby contributing to technological progress and serving the greater good of society.

This edition offers a carefully curated glimpse into the exciting advancements in material characterisation at IITH, showcasing pioneering research, innovative ideas, and the spirit of collaboration that drives our academic journey. Your continued support motivates us to bring you even more compelling and insightful editions of किरIITH.

We hope you enjoy this read—stay connected and stay inspired!



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Dear Friends,

Wishing you strength, health, and a positive spirit as we step forward together!!

I am delighted to share with you the latest edition of the IITH Newsletter, which captures some of the institute's recent milestones, path-breaking initiatives, and the dynamic spirit that defines our community.

As I step into this edition, I am excited to share that IIT Hyderabad has been ranked among the world's top universities in six subjects in the QS World University Rankings by Subject 2025. This remarkable recognition reflects our growing global presence and the institute's relentless pursuit of academic and research excellence. Notably, three subjects—Materials Science (401–550), Electrical & Electronic Engineering (501–550), and Chemistry (601–700)—have debuted in the rankings, while the other subjects are Mechanical, Aeronautical & Manufacturing Engineering (501–575), Physics & Astronomy (501–550), Computer Science & Information Systems (701–750).

IIT Hyderabad continues to strengthen its position as a hub for cutting-edge research and global collaborations through several significant initiatives. The Marvell® Data Acceleration and Offload Research Facility, inaugurated in partnership with Marvell Technology Inc. In a significant international academic cooperation, IITH has partnered with Heidelberg University, Germany, and TIFR Hyderabad to launch the Heidelberg-Hyderabad Hub in Advanced Chemical Education (H²ACE). This Indo-German initiative aims to promote excellence in chemical education and research. Further expanding its global footprint, IITH and Swinburne University of Technology, Australia, have launched SIMMECT—the Swinburne-IITH Manufacturing, Materials, Energy, and Communication Technologies Joint Research Institute.

IIT Hyderabad continues to foster impactful collaborations across sectors and disciplines, reinforcing its commitment to sustainability.

IITH signed a Memorandum of Understanding (MoU) with Coal India Limited (CIL), a Government of India PSU, to establish the Centre of Clean Coal Energy & Net Zero (CLEANZ). This Centre of Excellence will drive advanced research, technology development, and capacity building for sustainable energy solutions. In a significant international engagement, a 20-member German delegation from DAAD (German Academic Exchange Service) visited IITH, to explore avenues for Indo-German academic and research collaborations.

IITH proudly hosted a series of high-impact events in early 2025, reflecting its growing role in global research and innovation. The Australia-India Critical Minerals Research Hub (AICMRH) Workshop, co-organised with Monash University, focused on sustainable approaches to mineral exploration, extraction, and recycling.

IITH successfully conducted the PIWOT Satellite Conference themed "A Smarter World: AI as the Tool, Industry 5.0 as the Path", fostering dialogue between academia and industry on the future of AI and Industry 5.0. Additionally, IITH became the first second-generation IIT to host the 8th National Finite Element Developers'/FEAST Users' Meet (NAFED08), organised in collaboration with ISRO's Vikram Sarabhai Space Centre (VSSC). The event highlighted the indigenous FEAST software and brought together top minds in structural analysis and engineering.

IITH also launched the Public Humanities Initiative (PHI) under the leadership of the Department of Liberal Arts. This initiative, part of an ICSSR Major Research Project, aims to bridge academic scholarship and public engagement in the humanities. These collaborations reflect IITH's dynamic approach to interdisciplinary partnerships, addressing both national priorities and global challenges.

IIT Hyderabad continues to celebrate its rich cultural spirit through a series of vibrant events. Adding to the festive spirit, the 16th edition of Elan & nVision, IITH's annual techno-cultural extravaganza, embraced the theme "A Space Odyssey." The event buzzed with energy, showcasing creativity, innovation, and cosmic inspiration through competitions, performances, and workshops. A moment of great pride and inspiration was marked by the visit of Hon'ble Vice-President of India, Shri Jagdeep Dhankhar, who addressed the IITH community. His speech highlighted the importance of innovation, technological leadership, and the crucial role of IITs in driving national development. These cheerful and high-spirited activities reflect the dynamic campus life at IITH, where tradition and technology thrive together.

This edition offers a glimpse into IITH's vibrant and ever-evolving research ecosystem, with a special focus on the theme of Material Characterisation. From pioneering investigations to collaborative advancements, the articles within showcase how IITH is contributing meaningfully to the frontiers of materials science and engineering.

~Prof B S Murty

Director
IIT Hyderabad

Facilitating Faculty to Propel Sponsored Research and Consultancy Activities.

A step towards building IITH as a Global Leader

KID: 20250101



IITs have been the pride jewels in the crown of independent India and have produced a phenomenal impact in India and abroad as outstanding centres of nurturing world-class engineers and scientists. Addition of second and third generation IITs is a challenging task, and we are extremely hopeful to see that IITH has emerged as an institute of great strength and very close to reaching the standards of first-generation IITs, which were established in the 1950s. While teaching and creating outstanding human resources continues to be the primary focus of the institute, the importance of shouldering the responsibility to build the research and technological power to make “Aatmanirbhar and Viksit Bharat” is being felt very strongly in recent times. IITH has always been a hub of excellence in research and innovation, and I am committed to further strengthening this ecosystem.

IITH, with about 330 faculty members, 800 running projects (including over 3000 completed projects), with an annual fund from research and consultancy of over 330 crores (in 2024-25 financial year) and 250 crores (in 2023-24 financial year) has become a force to reckon with in any measurable indicator. SRC team efforts are mainly focused on ensuring continuity in research support, launching new initiatives, and fostering a collaborative environment for our faculty and researchers.

I have taken the responsibility of Dean (Sponsored Research & Consultancy) at the Indian Institute of Technology Hyderabad from September 5, 2024, which is both a privilege and responsibility to build upon the strong foundation laid by my predecessors.

On the first day of my tenure, we facilitated the release of the June Seed Grant cycle on September 5, 2024. This prompt action ensured that the funding was disbursed on time, enabling our faculty to continue their research activities seamlessly and aligned with institutional priorities.

We initiated the open call for the next round of Seed Grant proposals, which attracted interest from 12 faculty members. Presentations were organised on December 13, 2024, where faculty shared their project ideas and received valuable feedback. This peer-review mechanism has helped applicants refine and strengthen their proposals, increasing their alignment with IITH's research vision.

An interactive session was held with newly joined faculty members to introduce them to the system of sponsored research and consultancy, emphasising the Seed Grant scheme and the overall functioning of the SRC office. This orientation aimed at demystifying the application process, clarifying expectations, and encouraging them to engage actively in research activities from an early stage.

Our new initiative of granting about 10 Technology Development Grant (TDG) proposals is primarily intended to have a strong industry connection as each scheme has an industry partner, who also funds it and gets involved in developing the technology.

A staff interaction session was also conducted with the SRC office team. It was a warm and engaging experience that helped me understand the operational dynamics and connect with the team on a personal level. Their enthusiasm and support have been truly motivating.

We have significantly expanded the Summer Undergraduate Research Exposure (SURE) program. This year, 250 students will be supported under SURE, out of which 100 positions are reserved exclusively for female students. We have since constituted a new RAC with representation across departments to sustain the momentum and offer strategic input for enhancing the research culture at IITH. With the new Research Advisory Committee in place and our faculty actively engaging with various grant mechanisms, we look forward to scaling greater heights in research and development. Our commitment remains firm: to enable and empower our researchers, streamline processes, and nurture innovation that addresses national and global challenges.

SRC section is there to ensure that the faculty gets the best possible system within the system. We are striving our best to serve the faculty to think big, engage in cutting-edge research, and take up the leadership role. Obviously, transparency in policies, compliance with regulations, and a cooperative approach to amicably solve bottlenecks (if any) are essential to reach greater heights. I am very positive that every member in SRC is committed towards ensuring their best services to strengthen the resolve of the faculty members to give their best for the nation in general, and IITH in particular.

I sign off here on an optimistic note, with the belief that the coming months will see new ideas blossom and the spirit of research grow stronger at IITH.

“Our commitment remains firm to enable and empower our researchers, streamline processes, and nurture innovation that addresses national and global challenges”

Prof G Narahari Sastry
Dean - Sponsored Research & Consultancy
Professor, Dept of BioTechnology

From Atoms to Applications – Our Journey in Materials Characterisation

**KID: 20250102**

It gives me both joy and quiet pride to present this issue of KirIITH, centered on “Materials Characterisation” — a subject that lies at the very heart of our Department’s vision.

In the Department of Materials Science and Metallurgical Engineering, materials characterisation is not simply a branch of our research — it is the very lens through which we engage with the world. It is how we dialogue with matter, engaging it in a quiet conversation across scales and phenomena where each measurement is a question and each signal is an answer. This is how we trace the lyric in the crystal’s symmetry, the whisper of strain in its lattice, and witness the dance of atoms as they transform. Our motto, “Atoms to Applications”, reflects this poetic arc: from the hidden to the harnessed, from signal to solution.

We’ve come a long way. I still remember when we first moved to our new campus — the road to Academic Block A was unpaved and uneven, and we had to set up our first TEM on the ground floor. A colleague rode in the truck transporting the TEM crate, shielding it from every bump and jolt. That care mattered — it was our only TEM, and its safe arrival marked a quiet victory.

Before that, in our ODF makeshift campus, we had just one SEM and a PPMS, both housed in the same corrugated shade where metallography, etching, and sample preparation were done side by side. The air carried the sting of chemical vapours slowly corroding the instruments we couldn’t afford to replace.

And yet, we dreamt big. With no excess space, no safety net — just conviction, collaboration, and a refusal to settle — we built. That indomitable spirit, alive in every student and colleague, has brought us to today: a modern, beautiful campus, equipped with ultra-modern instruments, national-scale facilities, and a thriving research ecosystem. The dream has taken shape — and it grows with each passing year.

Today, the campus is a very different place — physically, yes, but also in spirit. Characterisation is now not just a facility we have; it is a philosophy we live. At MSME, we believe that to characterise is to accompany materials — to walk with them, listen to them, and uncover their inner narratives.

We observe materials through their entire journey. SEM and TEM help us resolve defects and microstructure. *In situ* TEM lets us watch change as it happens. AFM allows us to feel the topography of the invisible, while PFM makes electromechanical interaction audible in its own way. Nanoindentation shows us resilience in numbers. EBSD reads orientation like a topographic map. Every tool not only tells a story — it changes what we choose to ask next.

We began by establishing platforms like SEM–EBSD, PPMS, Raman, AFM/PFM, and XRD — laying the groundwork for advanced materials characterisation at IIT Hyderabad. With XRD, we began decoding the symmetry hidden in structure, setting the stage for deeper insights into phase and orientation.

Today, our faculty, together with colleagues from other departments and partner institutes, have built on that early foundation to secure the prestigious SATHI grant. From this collaboration has grown the SATHI–CISCoM national facility — a vibrant hub for correlative and *in situ* microscopy, and for pushing the frontiers of atom probe tomography (APT). With APT, we now do what once felt like science fiction — mapping matter atom by atom, revealing clusters, segregation, and the chemistry of the infinitesimal.

What began as a modest suite of instruments has evolved into a shared, state-of-the-art infrastructure for cutting-edge research. This transformation has been driven by persistence, foresight, and a conviction that India must lead — not follow — in characterisation science. That belief continues to shape the identity and ambition of our department.

What makes this work truly distinctive is our correlative approach. We refuse to silo observations. Instead, we trace across length, time, and modality — connecting diffraction patterns with microstructural evolution, impedance arcs with thermoelectric behavior, symmetry with properties and performance. We embrace the hierarchy of materials, from atoms to grains, and build the bridges between them.

Our scope extends further: XRD, UV–Vis, Raman, electrical and thermal transport, thermoelectric profiling, and electrochemical impedance spectroscopy allow us to probe the full physical life of a material — not just how it looks, but how it behaves, transforms, and endures.

And then there’s the virtual mirror. Using first-principles calculations, phase-field models, and our in-house MicroSim GPU platform, we simulate microstructures and generate synthetic observables. We don’t just characterise what exists — we explore what could.

At MSME, characterisation is never a full stop. It’s the first sentence of every material’s story. Through this issue, I invite you to explore that story with us — to see, to question, to imagine, and to build.

We do not just observe materials. We accompany them — through microscopes, through models, through minds.

Acronyms: AFM – Atomic Force Microscop(e)y; APT – Atom Probe Tomograph(y); EBSD – Electron Backscatter Diffraction; PFM – Piezoresponse Force Microscop(e)y; PPMS – Physical Property Measurement System; SEM – Scanning Electron Microscop(e)y; TEM – Transmission Electron Microscop(e)y; UV–Vis – Ultraviolet–Visible Spectroscop(e)y; XRD – X-ray Diffraction

Prof Saswata Bhattacharya
Head, Dept of Materials Science and
Metallurgical Engineering

From Bragg to Rietveld: A century of X-Ray Diffraction and 50 years of structural refinement

KID: 20250103



Crystal structures define the properties of the materials, and characterising these structures is key to understanding their properties. X-Ray Diffraction (XRD) technique, often considered simple, is a vital characterization method and a powerful tool to understand a material's structural fingerprint – the crystal system, phases, strain, and defects.

XRD is primarily a coherent scattering of X-rays by electrons due to the ordered arrangement of atoms within a material. This periodicity in the arrangement of atoms gives rise to a phenomenon of diffraction that is unique to certain arrangements/crystallographic structures. This is absent in short-ranged, amorphous materials.

His seminal paper was published on “A Profile Refinement Method for Nuclear and Magnetic Structures” utilising algorithms with computers of that era, which allowed 33 refinement parameters. This program was distributed and was applied to XRD data also. Although it was coined as “Profile refinement method” by Rietveld himself, Terry Sabine and Ray Young proposed the name “Rietveld method” at the Neutron conference in Cracow to prevent confusion of using different terminologies.

Unlike traditional indexing methods that rely on peak positions alone, Rietveld refinement works by fitting an entire calculated diffraction pattern to the observed data—peak by peak, intensity by intensity.

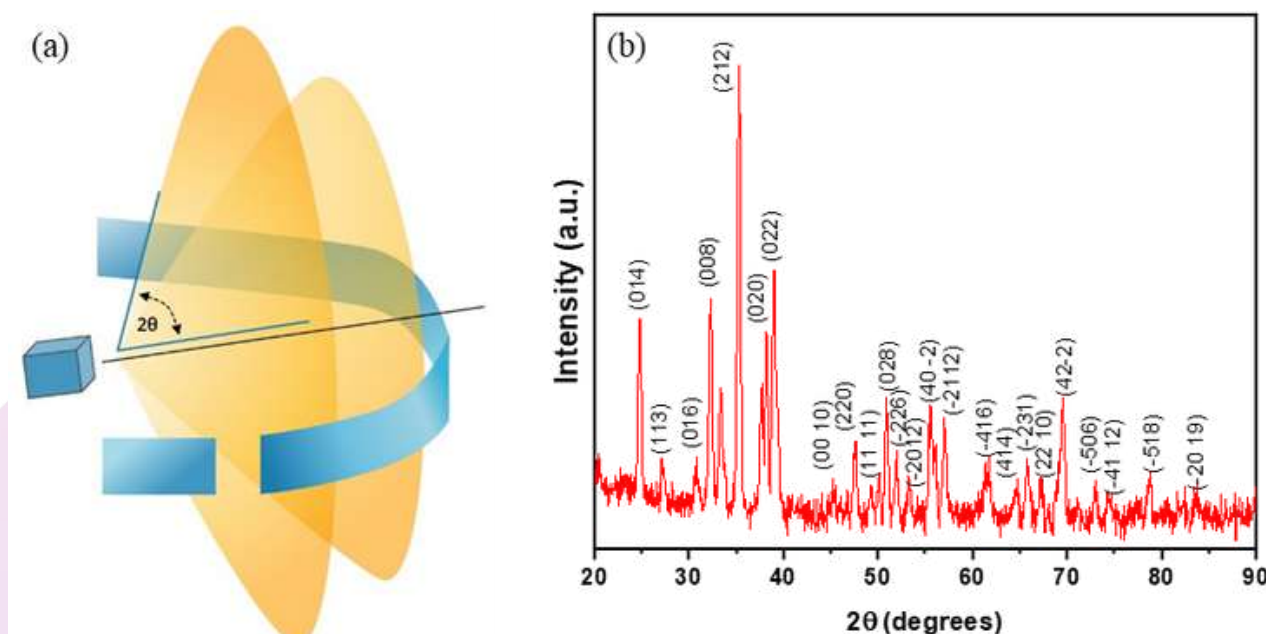


Figure 1. (a) Schematic explaining the Powder XRD (Source – MyScope – Microscopy training) and, (b) a diffractogram of a polycrystalline sample – $\text{Nd}_2\text{Ti}_2\text{O}_7$, of Monoclinic (low symmetry) structure

In powder XRD, all crystallites in a polycrystalline material contribute to the diffraction, and the three-dimensional reciprocal space is contained in one-dimensional data. While it is easier to index peaks for a single crystal, structural analysis studies in the case of polycrystalline samples are limited because of the peak overlap, especially in low-symmetry structures. This challenge highlights the necessity of refinement methods.

The Rietveld refinement method is a least-squares fitting approach to refine crystal structures. It is widely considered the best whole-pattern-fitting method of refinement, which revolutionised the application of powder diffraction in crystallography.

Originally developed by a Dutch scientist, Hugo Rietveld, in the 1960s, the method was designed for the refinement of neutron diffraction data.

The process begins with experimental diffraction data collected from a powdered sample. The next step involves generating a theoretical diffraction pattern based on an initial crystal structure model—usually obtained from database entries. Then, using software like FullProf, GSAS, or TOPAS, the model is refined iteratively.

Parameters such as lattice constants, atomic positions, occupancy factors, and thermal vibrations – as given in the equation below – are adjusted to minimize the difference between the observed and calculated patterns using a least-squares algorithm.

“XRD is primarily a coherent scattering of X-rays by electrons due to the ordered arrangement of atoms within a material.”

$$I_i^{calc} = S_F \sum_{j=1}^{N_{phases}} \frac{f_j}{V_j^2} \sum_{k=1}^{N_{peaks}} L_k |F_{k,j}|^2 S_j(2\theta_i - 2\theta_{k,j}) P_{k,j} A_j + bkg_i$$

Lorentz polarisation factor
Absorption Preferred orientation

Structure factor
Profile shape function
Background function

Scale factor

Rietveld refinement accounts for peak shapes, preferred orientation, background noise, and even microstructural factors like strain and crystallite size. A successful refinement depends on data quality and the initial model. Overfitting is a common pitfall, where the model appears perfect but lacks physical meaning. To avoid this, checking R-factors and residuals is a common practice.

As the pursuit of discovering new materials grows, XRD and refinement techniques will undoubtedly continue to play a crucial role in the field of materials characterization. What began with Laue's insightful realisation at a conference in Cologne, would continue to be an essential tool in the future of this pursuit.

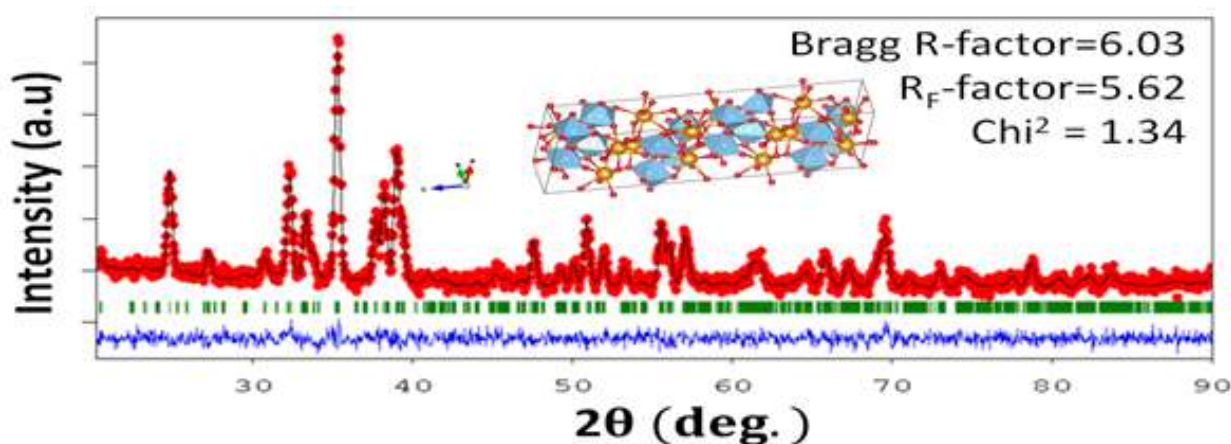


Figure 2. Rietveld refined - calculated data curve - the black line, that closely matches the measured data is fitted. The blue error curve at the bottom of the plot shows how well the calculated data fits the measured data, indicating a good match. Unit cell visualised from the data after the refinement is as an inset.

Alternative fitting approaches like Le Bail and Pawley are also used to do refinements without a need for an initial model focussing on peak positions and intensities. For amorphous materials, where long range order is absent, Pair Distribution Function (PDF) analysis is utilised. These techniques, each unique, offers a different perspective and are also used in tandem.

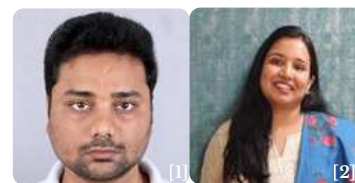
Rietveld method remains standalone, thanks to its flexibility and ability to evolve with the advancements in computational tools. In their commemorative article on half a century of the Rietveld refinement, the authors wrote, "Over the next 50 years, the Rietveld refinement will remain a cornerstone method in crystallographic studies and will provide the basis for understanding materials functions and applications".

Source - The Rietveld Refinement Method: Half of a Century Anniversary, Tomče Runčevski and Craig M. Brown, Crystal Growth & Design 2021 21 (9), 4821-4822

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From learning to living: "Shh... what's happening deep in there"

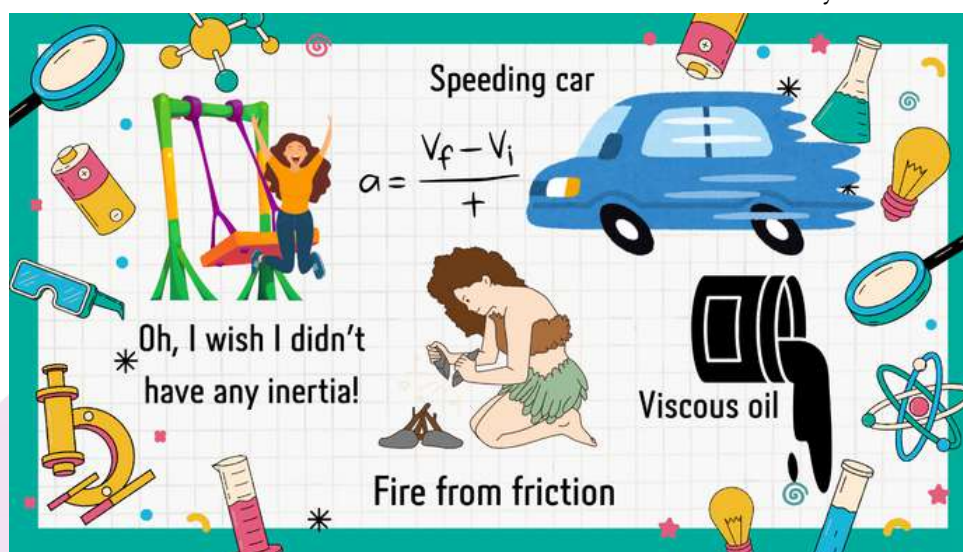
KID: 20250104



We must have experienced “momentum”- when you collide with someone strong, “acceleration” – while driving, “inertia”- when falling from a swing, “friction”- applying brakes, “viscosity”- pouring oil. The physics we learn gives us an understanding of how things work around us, and how nature responds to any actions. However, building an intuition for anything is based on our past experiences. How do we relate to physical terms like “electric field”-unless we carry a strong presence, “drift current”-unless we have boarded a Mumbai local train, “energy structure” – unless you can see beyond the physical, “wave mechanics”- may be if you are a singing maestro, “quantum wavefunction”- unless you are a mystic (as physicist still don’t have an answer to it!).

Even in deterministic systems, practical constraints (e.g., imprecise instruments or chaotic dynamics) prevent exact predictions, necessitating probabilistic descriptions. Thus, this reminds us that probabilistic descriptions are not all that unknown to us, even in the classical domain, and are perceived as extrinsic limitations.

In quantum mechanics, probability is intrinsic to nature. The wavefunction $\psi(x)$ describes a system's state, where $|\psi(x)|^2$ gives the probability density of finding a particle at position x . This isn't due to measurement limitations but a core feature of reality. Now this is hard to logic with! And should we even bother about it? Well, for a material scientist it could be a threat to your “aims and objectives”.



Quantum mechanics phenomenon is quite sneaky; it may appear even if haven't planned for it (e.g., Raman scattering, Quantum capacitance, Tunnelling, plasmonic, diffraction contrast). Especially at smaller dimensions, we are more likely to find some quantum phenomenon either aiding or hindering what we set to achieve. But if we are stuck with quantum mechanics, it's better to make some acquaintance, or at least break some ice.

The point is that we use our daily life experiences to understand most of the classical mechanics physics. However, our perception is largely limited when we talk about physics at the atomic scale, and particularly, quantum mechanics. But this is not all that mind-boggling if approached with some help.

The resistance to accept arises when things do not fit into our logical framework, and it seems as if nature does not care about our logic. “Logic” is “deterministic” in nature; physical laws should give a measurable quantity. How do we know something exists if we cannot measure it? On the other hand, there are probabilistic and indeterministic things, and interestingly, they are important even to derive classical physics. Even to get a simple geometric area, we rely on an irrational number

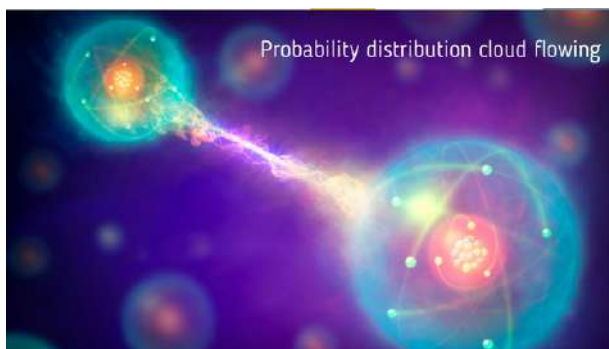
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If we look into the derivations in classical physics (which we often ignore!), probability arises from incomplete information about a system (e.g., not knowing the exact position/momentum of every gas molecule in a container). Thus, probability is epistemic (reflecting ignorance).

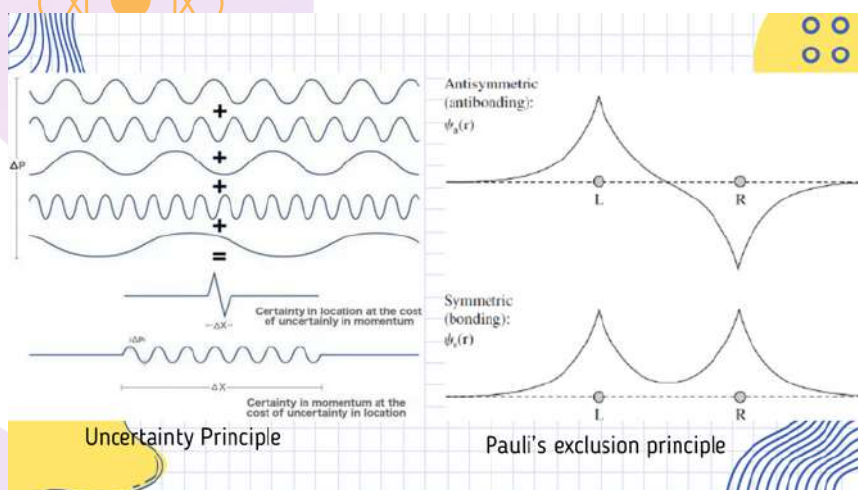
We may think that the material we work with is innate, but try telling that to an electron in that material which got no rest. An analogy would be you on a sail boat deep in an ocean. If you are a lucky electron, you may be in the Pacific (calm) or you can be in the Southern Ocean (Antarctica) struggling to survive. But we want to see this happening in a material, as it is important to solve the problem at hand and put the material to some application.

So, we disturb the already disturbed material and capture the difference when it goes down to its earlier state (Spectroscopy, XRD). Sometimes we disturb it so much that some of the electrons jump out of the material to tell us what was happening to them inside the material (Microscopy, XPS). Other times, we handle it more smartly by making use of “intelligence” about the subtle nature of the material's energy structure (NMR, EPR).

What is it exactly that we are disturbing? Delving further, energy levels or atomic orbitals are a cloud of probability distributions.



When we say a transition for an electron happened from ground state to excited state (e.g., optical transition), in reality, it is changing its probability distribution from a sphere (S-orbital) to maybe a dumbbell shape in space (P-orbital). When you do a UV-VIS spectroscopy of your sample, it would be interesting to visualise the clouds changing shape. What drives this change in shape? Well, the excitation we provided may be by changing the (potential) energies or some other induced interactions. Polarizability is the “squishiness” of these clouds. In Raman spectroscopy, these clouds are coupled with the vibrating nucleus, and they take on shapes (for an infinitesimal time, $\sim 10^{-15}$ sec) corresponding to a different energy level (virtual level). So next time you irradiate your samples with strong lasers, visualize the dynamically changing electron cloud because of the vibrations. A wave is essentially a distribution of any variation in space and time. So, the probability distribution and wave function exhibit wave nature. When we say wave nature, what we mean is that “nature or phenomenon” that any wave may exhibit. Thus, we can use waves on a string or water (for visualization) to build our intuition for quantum waves. What can we say about the position of a wave, which is a spread? At best, we can say a range, and a range leads to uncertainty or error (Heisenberg’s uncertainty principle).



A wave can be a superposition of other waves. If we superimpose waves to reduce uncertainty in position (i.e., narrow down the range), mathematically, we need to add infinite waves with fixed momentum (i.e., increasing the momentum uncertainty). We know what varies in acoustic, mechanical, or electromagnetic waves.

In quantum waves, from the definition, we know that instead of something physical, it is the probability that is varying with space and time. (Try plotting a probability distribution of yourself walking at different speeds: where are you most likely to be?) For example, let's think of a current flow. A current can be a flow of electrons, but electrons will flow to a changing probability distribution due to a change in energies (i.e., voltage).

An analogy would be you sitting in a sparsely filled classroom; the probability of you sitting in the class can be modulated based on your friends entering later. So, we say you moved to adjust to a new probability distribution. Anyway, of course, the probability will carry the object with it. A wave can spread, reflect, and interfere with another wave, which leads to a new wave that incorporates the interactions.

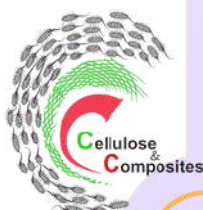
So, when we use a fundamental particle (i.e., single body wavefunction) to make molecules or solids (many-body wavefunction), wave interactions decide the overall wavefunction (The ocean analogy). Pauli's exclusion principle says electrons should have opposite spins to occupy the same orbital (probability distribution). This can be said in another way, that the wavefunction for fermions (electrons) is anti-symmetric. That is, if two fermions occupy the same quantum state (e.g., identical spatial and spin coordinates), swapping them leaves the wavefunction unchanged but also requires a sign change. The only solution is $\psi=0$, meaning such a state cannot exist.

Let us end with one more visualization: imagine yourself opening a refrigerator for a late-night ice cream that you didn't want to share or were not allowed to have, depending on your age. However, by mistake, you dropped your glass bowl (irreversible action), which fell and broke (sound wave).

No matter what you do, can you stop all the subsequent effects? (other than relying on your luck) Waves or quantum mechanics are like that! “A wavefunction collapses upon measurement.”

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Green Steel: Building a cleaner future

KID: 20250105

Steel is the backbone of modern infrastructure—used in everything from buildings/bridges to cars and household appliances. However, traditional steelmaking processes depend heavily on fossil fuels, making the steel industry one of the largest sources of carbon dioxide (CO₂) emissions worldwide. These emissions contribute to global warming by trapping heat in the Earth's atmosphere. Over the last 150 years, human activities—especially burning fossil fuels—have raised CO₂ levels significantly. Today, the iron and steel industry accounts for over 8% of global CO₂ emissions. At present, most of the steel is produced through the Blast Furnace-Basic Oxygen Furnace (BF-BOF) route, which uses coal and emits 2.5 to 2.7 tons of CO₂ per ton of crude steel. Each year, around 2.6 billion tons of iron ore are converted into crude steel, with 70% produced by the BF-BOF route. In contrast, the Electric Arc Furnace (EAF) and Induction Furnace (IF) routes contribute 30% of global production and are generally cleaner.

India produces about 140 million tons (MT) of crude steel per year, with plans to reach 300 MT by 2030. Currently, about 92% of India's steel is made using fossil fuels, contributing to around 11-12% of the country's total greenhouse gas emissions. India's coal-based Direct Reduced Iron (DRI) process, which supplies raw materials for the EAF/IF route, emits even more CO₂ than the BF-BOF route.

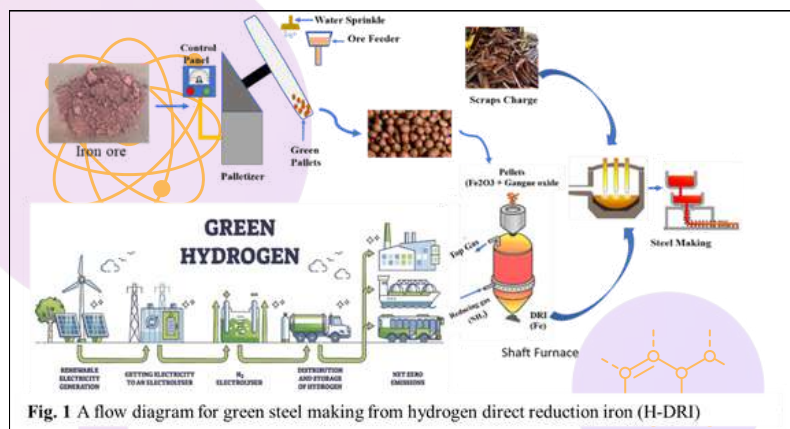
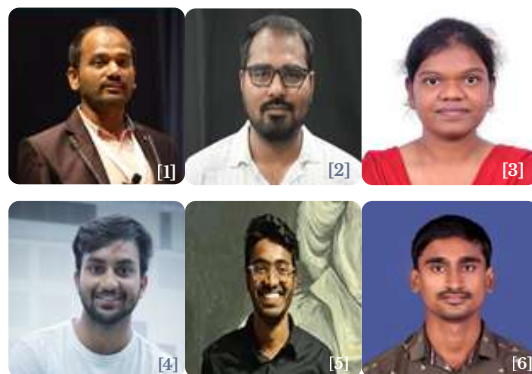


Fig. 1 A flow diagram for green steel making from hydrogen direct reduction iron (H-DRI)

To reduce emissions, the world is now focusing on green steel—steel made using cleaner energy sources like hydrogen, ammonia, biomass, and hydrogen plasma. Recycling scrap steel is another effective method, as it uses far less energy. Therefore, green steel plays a vital role in fighting climate change. As countries aim for net-zero targets, green steel will be key to a sustainable and cleaner future. At the forefront of India's transition to sustainable steelmaking, our Sustainable Metallurgy and Industrial Technologies (SMITH) Research Lab at the Department of Materials Science and Metallurgical Engineering, IIT Hyderabad, is playing a pivotal role in advancing green steel technologies.



Our research group focuses on developing technologies for the reduction of various grades of iron ore using clean reducing agents like hydrogen, ammonia, and biomass/biochar for the green steel production. Through experimental studies and kinetic investigations, we aim to understand and optimize reduction behaviour under controlled atmospheres, exploring process parameters windows for temperature, gas composition, exposure time, etc, for efficient reaction rates.

Our SMITH Lab is currently working on several organization-funded research projects toward green steelmaking, including one supported by the Ministry of Steel on iron ore reduction using ammonia and hydrogen, another in collaboration with CSIRO Australia focusing on CCUS assessment for iron and steelmaking, and a third project funded by TATA Steel on the induration behavior of high-alumina iron ore. Notably, our recent study focused on the reduction of blue dust iron ore using ammonia gas at temperatures ranging from 600°C to 1100°C, with different exposure times.

The results were compared with similar reduction experiments using hydrogen and cracked ammonia (a mixture of hydrogen and nitrogen produced by decomposing ammonia). Encouraging results from the experimental campaigns allow us to establish a green steel complex at IIT Hyderabad with the following state-of-the-art national facilities,

- 10 kg vertical shaft gas-solid reactor.
- 10 kg rotary kiln gas-solid reactor.
- 10 kg induction melting unit

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Greenwashing Alert: Is Your Bamboo Product Truly Sustainable?

KID: 20250106



Greenwashing has emerged as one of sustainability's most persistent challenges. It refers to the practice of presenting products as more environmentally friendly than they truly are. Strategic branding, selective disclosure, and the use of appealing but often unverified claims such as "100% ecofriendly" or "biodegradable" have turned packaging into an effective marketing tool. While these statements may attract consumers who wish to make responsible choices, they can also mislead, creating a polished illusion of sustainability rather than an accurate reflection of a product's environmental footprint. Certain bamboo products illustrate the ways in which greenwashing is taking place today.

Bamboo is often highlighted in sustainability discussions for its environmental credentials. Known for its rapid growth and ability to regenerate without replanting, this versatile grass thrives with minimal fertiliser or pesticide use, absorbs carbon dioxide efficiently, and releases more oxygen than trees. These characteristics have positioned bamboo as a renewable, nature-friendly option and a popular alternative to hardwoods and plastics.

However, the sustainability profile often changes once bamboo is harvested and processed. Many commercially available bamboo goods, ranging from cutlery to flooring, stationery, and textiles, undergo intensive treatments. These can include chemical pulping with strong alkalis, lamination using phenolic resins, or blending with synthetic polymers to improve durability and appearance. While these processes may enhance the product's lifespan or aesthetics, they simultaneously increase energy consumption, raise greenhouse gas emissions, and in some cases compromise biodegradability entirely. A resin-laminated bamboo board or a melamine-reinforced bamboo cup may endure years of use but, when discarded, it can persist in the environment much like conventional plastic.

Despite these realities, many such products are marketed in a way that highlights only bamboo's natural qualities. Labels frequently claim "sustainably sourced" or "compostable in 180 days", but without clear explanation or independent verification. In the absence of reliable disclosure or third-party certification, public have no easy way to confirm whether the claims reflect the entire life-cycle of the product or merely its raw material origin. This lack of clarity can not only deceive buyers but also undermines trust in genuinely sustainable innovations.

Addressing greenwashing requires shared responsibility across all stakeholders. Manufacturers can lead the way by making ethical labelling a standard practice, supported by credible life-cycle assessments that clearly present a product's true environmental impact. Regulators must not only set guidelines for environmental marketing but also ensure that awareness of greenwashing reaches communities across all sections of society, while penalising false or exaggerated statements that distort reality. Consumers, in turn, can play a vital role by questioning green claims, seeking credible certifications, and supporting brands that are transparent about sourcing, processing, and end-of-life disposal.

However, bamboo still holds real potential as a model of sustainability. When cultivated responsibly and processed with minimal chemical intervention, it can deliver both performance and environmental benefits. But real sustainability goes beyond material origin.

Achieving this goal requires integrity at every stage, from sourcing and manufacturing to marketing and disposal. It also calls for a shift towards minimalistic consumption, ensuring that even proven sustainable products are bought mindfully and only when necessary. Protecting consumers from greenwashing demands a united effort of responsible industry conduct, regulatory oversight, and informed choices. Trust, but verify the "green".

“Addressing greenwashing requires shared responsibility across all stakeholders. Manufacturers can lead the way by making ethical labelling a standard practice, supported by credible life-cycle assessments that clearly present a product's true environmental impact.”

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Magnetic Field Controlled Multistate Non-Volatile Random Access Memory

KID: 20250107

Multiferroics are materials that simultaneously possess more than one order parameter, such as magnetization, polarization and/or strain. The magnetic and dipolar interaction gives rise to the magnetoelectric phenomenon, known for induced magnetization or polarization under an external electric or magnetic field, respectively. These materials can be either single-phase materials or composite materials, mostly made of a ferroelectric phase with spontaneous polarization and a magnetically ordered phase coupled via lattice strain. The magnitude of the magnetoelectric coupling coefficient of single-phase materials is weak and rare at room temperature. Hence, in most of the non-volatile memory devices such as RAM, sensors, and energy harvesting applications, magnetoelectric behaviour is achieved by composite materials.

The non-volatile memory technology in the market uses ferro/ferrimagnetic-based tunnelling magnetoresistance, in which low and/or high magnetoresistance is read as 0 and 1 in binary codes. Current RAM research focuses on ferroelectric RAM (Fe-RAM) and resistive RAM (RRAM). Considering the magnetoelectric response of multiferroics, these materials are a potential candidate for a multistate memory device in which “+ve” and “-ve” polarization as one binary state and new memory states will be created under a magnetic field due to magnetostriction-induced polarisation, leading to a multistate non-volatile memory device

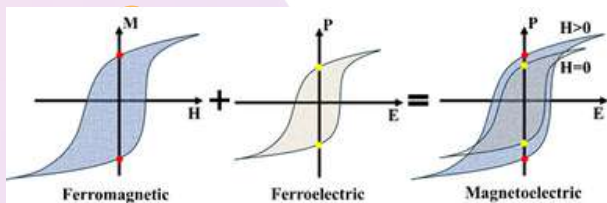


Figure 1. Schematic representation of the multistate polarization in multiferroics.

The most widely used combination of the magnetoelectric composite being the ferromagnetic phase composed of spinel, such as CoFe_2O_4 or NiFe_2O_4 and the ferroelectric perovskites like BaTiO_3 , $\text{Ba}_{1-x}\text{Ca}_x\text{Ti}_{1-y}\text{Zr}_y\text{O}_3$. This combination is advantageous due to the immiscibility of these phases.

Imaging Polarization states under an applied magnetic field:

One of the methods to observe the coupling between FE polarization and magnetic domains is to study the change in the ferroelectric domains under a varying magnetic field using a piezoelectric force microscopy. The underlying sequence of coupling will be strain generated under a magnetic field in the ferromagnetic phase, which is transferred to the ferroelectric layer via the lattice, which in turn induces polarization rotation in the ferroelectric layer due to the piezoelectric effect.

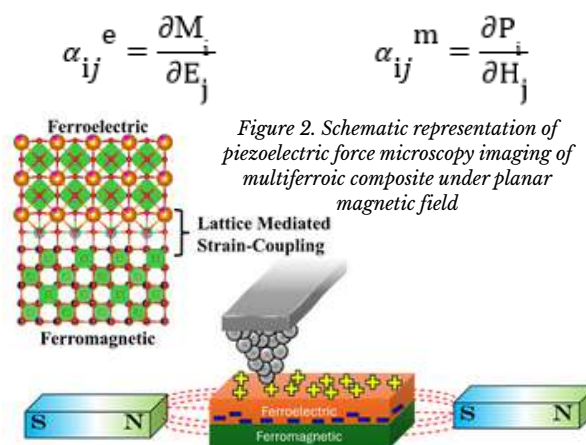


Figure 2. Schematic representation of piezoelectric force microscopy imaging of multiferroic composite under planar magnetic field

Also, since the ferromagnetic layer used has anisotropic magnetostrictive coefficients, new memory states can be created based on the magnetic field direction. The induced polarization rotation need not be always 180° . Instead, it can be gradual. The following figure confirms the magnetic field induced polarisation change and exhibit multistate non-volatile ferroelectric based memory of multiferroics under different magnitude and direction of magnetic field.

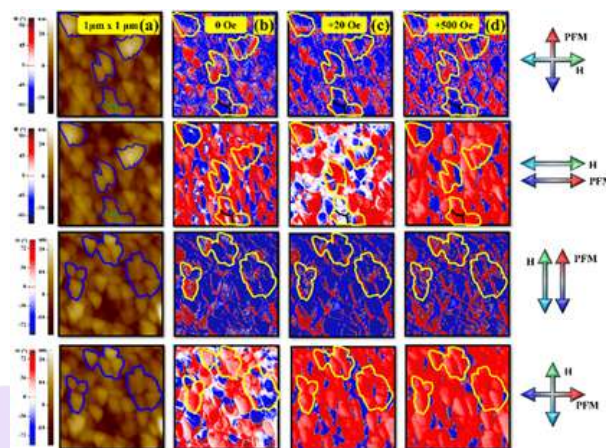


Figure 3 (a). AFM topology and PFM phase mapping of ME nanocomposite under the magnetic field of (b) 0 Oe, (c) 20 Oe, and (d) 500 Oe of different orientations. Horizontal arrows indicate in-plane field & vertical arrows indicate out-of-plane field. Red & blue

Figure 3 shows the change in FE polarization states in the presence of both planar and perpendicular magnetic fields. The studies were carried out in combination with the facilities available at the MSME department and the SATHI-CisCOM centre.

Hence, the observation of ferroelectric polarisation states using piezoelectric force microscopy under a magnetic field facilitates detailed studies on possible multi-state memory devices for memory applications.

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Materials Characterisation of Half-Heusler Compounds

KID: 20250108



Abstract

Half-Heusler (HH) materials have gained significant attention for their unique combination of thermoelectric efficiency, structural versatility, and potential applications in power generation and electronic devices. Characterising these materials at the atomic, electronic, and microstructural levels is essential for optimizing their properties for industrial applications. This article discusses various materials characterisation techniques employed for HH compounds, highlighting structure-property correlations and insights into performance enhancements.

1. Introduction

Half-Heusler (HH) compounds, typically described by the formula XYZ, where X and Y are transition or rare-earth metals and Z is a main-group element.^{1 2} HH compounds are a versatile class of intermetallics showing strong potential in thermoelectrics, spintronics, and power electronics. Despite their relatively simple crystal structure, HH materials can display complex transport behavior, often governed by subtle changes in phase composition, disorder, and grain boundary effects.^{3 4 5} To fully exploit the functional capabilities of HH compounds, comprehensive materials characterisation is indispensable. This includes structural, microstructural, electronic, and thermal analyses, which together inform the design, synthesis, and optimization of high-performance HH materials. In this article, we explore the key techniques used to characterize Half-Heusler materials and discuss their roles in advancing the functionality of these materials.

2. Structural Characterisation

2.1.X-ray Diffraction (XRD)

XRD remains the cornerstone technique for determining crystal structure, phase composition, and phase purity of HH materials. HH crystallizes in the MgAgAs-type structure (space group F-43m), characterised by a cubic unit cell with three interpenetrating face-centred cubic (FCC) sublattices. XRD analysis confirms the formation of the single-phase cubic structure and helps quantify secondary phases, which can severely degrade thermoelectric performance.⁶ Rietveld refinement provides precise lattice parameters and occupancy levels of atomic sites. Rietveld refinement is routinely employed to extract lattice parameters, site occupancies, and atomic displacement parameters, which are critical for assessing structural quality.⁷

3. Microstructural Characterisation

3.1.Electron Microscopy (SEM/TEM)

Scanning electron microscopy (SEM) reveals microstructural details such as surface morphology, grain boundaries, porosity, and secondary inclusions, which are important for understanding the mechanical behaviour of the HH material.⁸

Backscattered electron imaging (BSE) enhances compositional contrast, useful in detecting inhomogeneities or impurity phases.⁹ Transmission electron microscopy (TEM) is employed for atomic-scale imaging, especially in identifying grain boundaries, defect structures, and incoherent nanophases. High-resolution TEM (HRTEM) has revealed embedded secondary phases and stacking faults that affect transport properties in HH materials.⁸

4. Compositional Analysis

4.1.Energy-Dispersive X-ray Spectroscopy (EDS):

EDS provides elemental homogeneity and compositional stoichiometry across the sample and is typically integrated with SEM/TEM platforms.¹⁰ Understanding elemental distribution is critical for HH compounds, as slight deviations (often at the parts-per-thousand level) can lead to antisite defects or the formation of impurity phases. Elemental maps produced via EDS also reveal segregation or phase separation in doped HH systems.

5. Electronic Characterisation

Temperature-dependent measurements of the Seebeck coefficient (S) and electrical conductivity (σ) are essential to evaluate thermoelectric performance. The thermoelectric performance of HH materials is typically expressed using the dimensionless figure of merit: $zT = S^2 \sigma T / \kappa$, where S is the Seebeck coefficient, σ is the electrical conductivity, T is absolute temperature, and κ is total thermal conductivity (electronic + lattice).^{11 12} Seebeck Coefficient (S) indicates the nature (n- or p-type) and magnitude of carrier diffusion. Electrical Conductivity (σ) reflects carrier concentration and mobility, influenced by band structure and defect scattering. Hall measurements yield carrier concentration and mobility, which are key to understanding electronic transport.¹³ In many HHs, degenerate semiconducting behavior is observed, with carrier concentrations in the range of $10^{19} - 10^{21} \text{ cm}^{-3}$.²

6. Phonon and Vibrational Studies

Understanding the phonon behaviour is crucial for engineering the thermal conductivity. Raman spectroscopy and Fourier-transform infrared (FTIR) spectroscopy are used to probe vibrational modes.^{14 15} Shifts or broadening in Raman peaks often reflect disorder, doping, or anharmonicity, and each of which plays a role in phonon scattering. In combination with computational modelling, vibrational spectra can help identify mechanisms of phonon localization and suggest effective strategies for reducing the lattice thermal conductivity.

7. Thermal and Mechanical Characterisation

The advantageous features of HH materials are their mechanical robustness, which makes them a potential candidate for mid to high temperature applications, and also crucial in device integration.

Nanoindentation and Vickers hardness testing assess hardness, elastic modulus, and fracture toughness. These metrics also influence manufacturability and the stability of devices under mechanical stress.⁷

Thermal aging studies and thermogravimetric analysis (TGA) assess the long-term stability of these materials. Laser Flash Analyzer (LFA) is used to measure the thermal diffusivity, which, combined with the material's density and specific heat and gives total thermal conductivity (κ).¹⁶ The total thermal conductivity (κ) includes lattice (κ_l) and electronic (κ_e) contributions.¹¹⁻¹² Decomposing κ into its electronic and lattice components via the Wiedemann-Franz law helps in designing strategies (e.g., nanostructuring or alloying) to selectively suppress lattice thermal conductivity.¹⁷

8. Magnetic Characterisation:

Some HH compounds exhibit magnetic ordering, relevant for spintronic applications. Superconducting quantum interference device (SQUID) magnetometry or vibrating sample magnetometry (VSM) helps to measure the magnetic susceptibility, coercivity, and Curie temperatures. These properties are essential for applications in magnetic sensors and spin valves.¹⁸

9. Chemical and Phase Analysis:

X-ray Photoelectron Spectroscopy (XPS) is essential for probing the chemical states of the constituent elements and detecting surface oxidation, particularly in air-exposed HH materials. It provides insight into bonding environments and valence states, which helps interpret electrical transport properties and catalytic activity and also helps confirm successful doping or detect surface oxidation, especially in air-sensitive HHs. of HH materials.¹⁹ While atom probe tomography (APT) offers 3D compositional mapping at atomic resolution and is increasingly used to detect nanoscale dopant segregation, precipitates, or solute clustering, which influence performance.²⁰

10. Conclusion:

The development of high-performance Half-Heusler materials is intrinsically tied to the depth and precision of their characterisation. These characterisations are inherently multidisciplinary, requiring tools from crystallography, microscopy, spectroscopy, thermoelectric testing, and magnetometry. As characterisation tools evolve, particularly with in situ and operando techniques, the pathway to optimizing HH materials for real-world applications will become increasingly precise and efficient.

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Materials science meets life: Redefining materials for the future

KID: 20250109

People often think of materials as passive, such as steel (metals and alloys), glass (ceramics), and plastic (polymers), but “living materials” challenge that view. They are not passive at all; they are active, evolving, and sometimes even intelligent. From the probiotic bacteria in yogurt to the yeasts that make bread rise and beer bubble, humans have long used living organisms as functional materials. But what’s new today is that we can design and engineer these organisms, embedding them in materials to create active systems that sense, respond, adapt, and sometimes even heal. Living materials are more than just a new chapter in materials science; they are the beginning of a new kind of material logic where biology is not just an application domain for materials, but an integral part of the material itself.

The field of living materials often encompasses several of the systems partially or wholly, such as the biohybrid living materials, bio-engineered living materials, engineered biohybrid materials, living materials with self-generating matrices, living biotherapeutic products, and living therapeutic materials. We can imagine a future where the medications we take, the bands we wear, the sensors that monitor us, and parts of our house and clothing are living things that can heal themselves, react to external stimuli, and even change or evolve over time.

The materials of the future aren’t just durable or smart, but they are alive, and what makes them living is the incorporation of microbial cells or even mammalian cells into a structure or scaffold. These cells aren’t just passengers, but they play a central role, allowing the material to respond to environmental cues, produce chemicals on demand, or even regenerate itself. With modern tools in synthetic biology and materials science, researchers are creating far more advanced and programmable systems. However, the emphasis is always on the holistic view of what it takes to build these systems, where the biocompatibility of the matrix material, cell-matrix interactions, adhesion, and proliferation of the cells, and signaling dynamics of the entire system come into play. Whether embedding cells into polymers or growing cells with their self-generated matrices, the design must balance engineering precision with biological complexity.

The living materials can be categorized in the generation to trace how the field is evolving, much like the way we talk about generations of other technologies. Early “first-generation” materials are largely static, while newer generations (generation 2

and 3) are interactive, self-regulating, and the upcoming generation (generation 4) may even be capable of learning over time. The further developments of living materials on this line aren’t just experimental curiosities, but they are already making inroads into several applied areas: (a) Bioengineered tissues and smart drug-delivery systems that release therapeutics in response to body signals, (b) Engineered microbes embedded in filters to clean up oil spills or heavy metals, (c) Bacteria/fungi/algae-infused concrete that repairs cracks over time, etc. One of the most intriguing aspects of their continuous development can be their application in such areas where living materials are only beginning to be imagined;

such as, living lenses and biofilms that dynamically respond to light, biodegradable films that can self-repair or resist contamination, smart surfaces that respond to microbial threats or environmental stress, biohybrid systems for power generation or storage, and clothings that breathe, adapt, or even grow with us. These domains represent a major leap from the current biomedical and environmental focus of most living material research, and a bold invitation to material scientists, biologists, designers, and investors to explore what’s next.

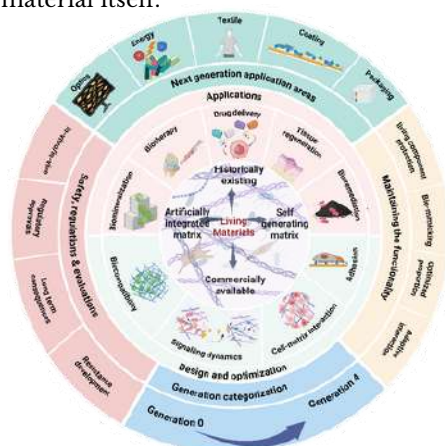


Figure 1: Evolution of living materials, along with design parameters, safety aspects, functionalities, and future advancements

Before living materials become part of everyday life, key challenges remain preserving viability, gaining public acceptance, and understanding long-term impacts on the individual and society. This demands advanced testing models and robust regulatory frameworks, strongly overlapped with materials characterisations. As we increasingly blur the line between user and material, we must ask: are we ready to accept smart, responsive, living materials in our lives? And if so, what are the limits of that acceptance? While in-situ methods, real-time monitoring, and correlative studies are seeing new heights, it becomes indispensable to pursue characterisation of the “living” aspects of these materials. Engaging diverse stakeholders and real-world case studies is essential to guide responsible integration and foster informed, interdisciplinary dialogue.

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Piezo Response Force Microscopy (PFM)

KID: 20250110



Introduction:

The atomic force microscope (AFM) is a powerful thin film characterisation tool; it is also one of the techniques that can produce three-dimensional topography and visualisation. In an AFM, a cantilever with an atomically sharp tip interacts with the surface as shown in Fig. 1, and the topography image is reconstructed with the feedback of these atomic interactions between the tip and surface. Advancements in electronics have given rise to several advanced modes of AFM. For example, if the same tip can be functionalised by coating it with conductive or magnetic materials then we can have conductive AFM or magnetic force microscopy for magnetic domain mapping, among AFM advanced modes Piezo response force microscopy (PFM) is one of the advanced techniques of AFM, which is used for the characterisation of nanoscale ferroelectric domains, for example, materials like lead zirconate titanate (PZT) and barium titanate (BTO)-based lead-free piezoelectric materials are extensively studied using these techniques.

As shown in Fig. 1, an AC voltage of a particular frequency will be applied to a conductive cantilever, interacting with the surface in contact mode. The sample must be grounded to close the circuit. As the AC voltage switches polarity, the sample responds in the same way because of the phenomenon of the inverse piezoelectric effect. As seen in Fig. 1, the applied bias and polarisation are in phase; the material expands or contracts.

This expansion and contraction move the cantilever in a combination of up, down, left, and right directions, which is captured in the photosensitive detector. With advanced electronics, using multiple lock-in amplifiers, we can capture the response of lateral and vertical separately. Apart from mapping the domains, we can also write the domains by altering the polarisation and magnitude. Using voltage-driven lithography, we can create alternating square-shaped ferroelectric domains, common among the epitaxial ferroelectric films, with only monodomain configurations.

In a PZT film, the +10V and -10V domains produce contrasting orientations. Within the +10V domains, the vertical response is strong. In contrast, the -10V domains exhibit an unequal magnitude but opposite phase, resulting in a negative vertical response. The lateral components remain relatively weak in these domains, except near domain walls, where significant in-plane polarisation rotation and shear can occur.

Similarly, PFM can be employed to study the ferroelectric and piezoelectric domain structures in materials like BiFeO₃ (BFO), where multiple phases can be stabilised using strain conditions. Thin films of BFO grown on a LaAlO₃ (001) substrate with a variable thickness La_{0.7}Sr_{0.3}MnO₃ (LSMO) buffer layer can impose different strain conditions on BFO. The PFM images revealed distinct domain morphologies depending on the phase of BFO, which was tuned by the LSMO thickness.

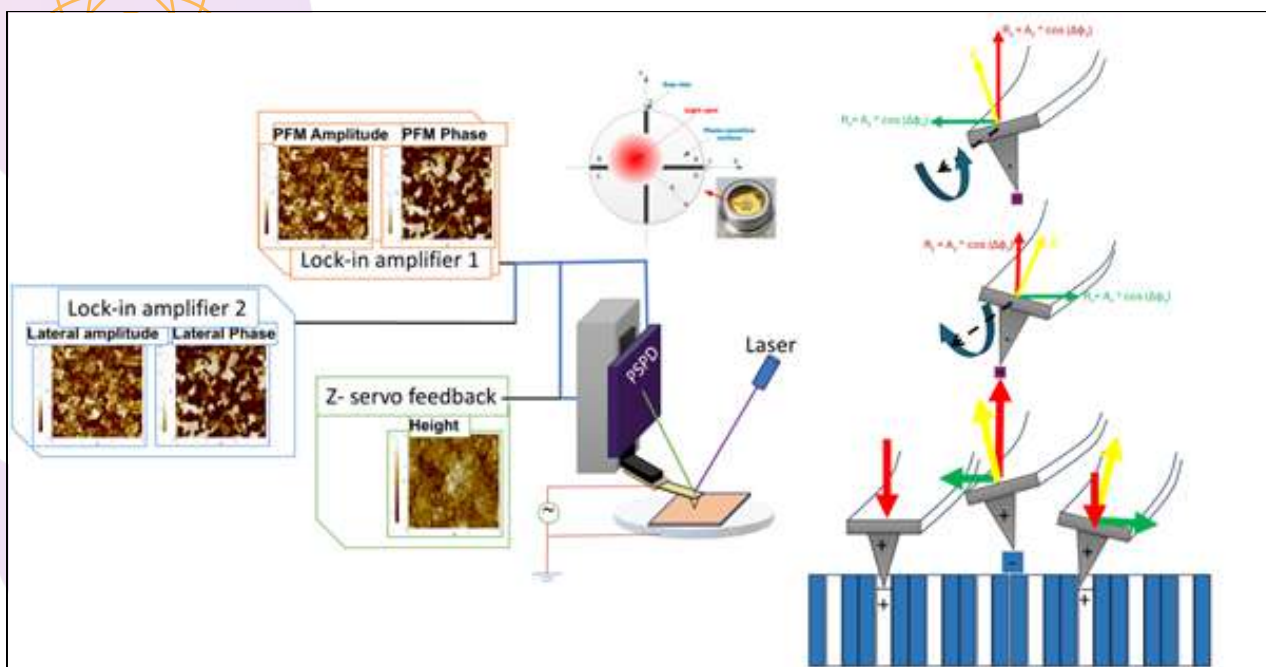


Figure 1. Shows a schematic of PFM, shows how the lock-in amplifier and Z servo work in tandem to capture topography, vertical phase, and amplitude; lateral phase and amplitude; and the right shows the interaction of the tip with a ferroelectric sample and response forces equation in both vertical and lateral.

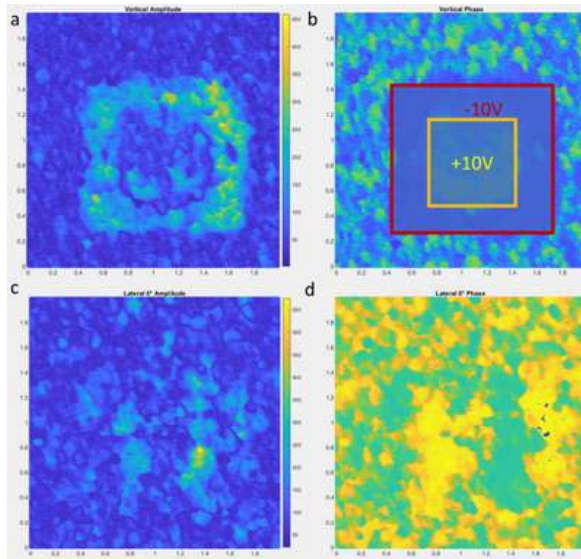


Figure 2. Vertical amplitude (a) and phase (b) of PZT poled domains; the bottom shows lateral PFM amplitude (c) and phase (d) of poled domains.

In the tetragonal-like phase (stabilised by a thin LSMO layer), domains exhibited dominant out-of-plane (OP) polarisation with sharp boundaries and 180° domain walls, indicating polarisation along the $\langle 001 \rangle$ direction. The mixed phase (intermediate LSMO thickness) showed both OP and in-plane (IP) polarisation components, with curved domain boundaries, reflecting the coexistence of tetragonal and rhombohedral domains. The rhombohedral phase (thick LSMO) displayed fractal domain patterns with both OP and IP components, favouring 71° and 109° domain walls. This can be verified correlatively, providing an intriguing way to confirm different phases using PFM to study domain structures.

PFM is a powerful, non-destructive technique for imaging and manipulating ferroelectric domains at the nanoscale. It enables us to study high-resolution mapping of domain structures, local electromechanical properties, and polarization switching behaviour, making it invaluable for both fundamental research and industrial applications. PFM's ability to visualize and control ferroelectric domains supports the development of advanced electronic devices, such as non-volatile memories, sensors, actuators, and energy harvesters.

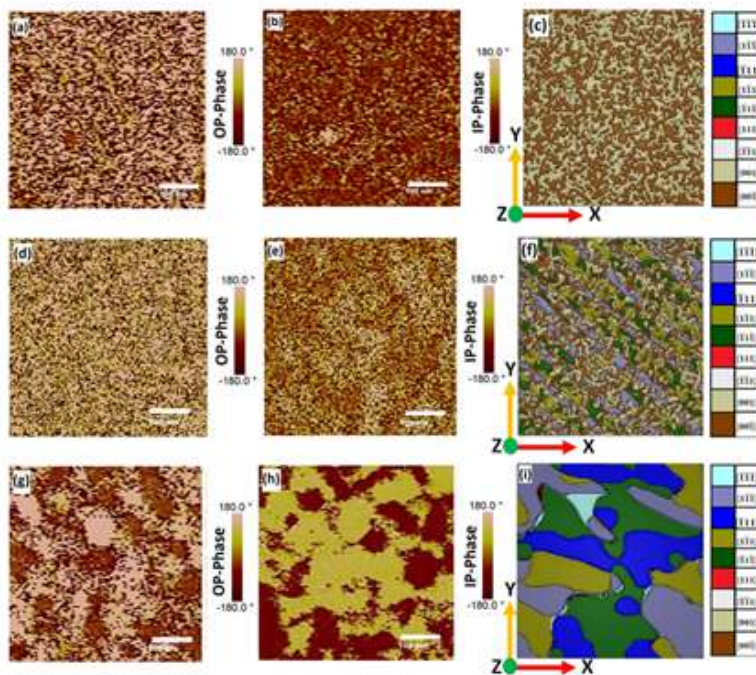


Figure 3. (a) and (b), (d) and (e), and (g) and (h) represent the out-of-plane and in-plane response of tetragonal-like, mixed phase, and rhombohedral phase, respectively, and (c) and (f) (i) are the simulated domain morphologies under these strain conditions.

“PFM is a powerful, non-destructive technique for imaging and manipulating ferroelectric domains at the nanoscale. It enables us to study high-resolution mapping of domain structures, local electromechanical properties, and polarization switching behaviour, making it invaluable for both fundamental research and industrial applications.”

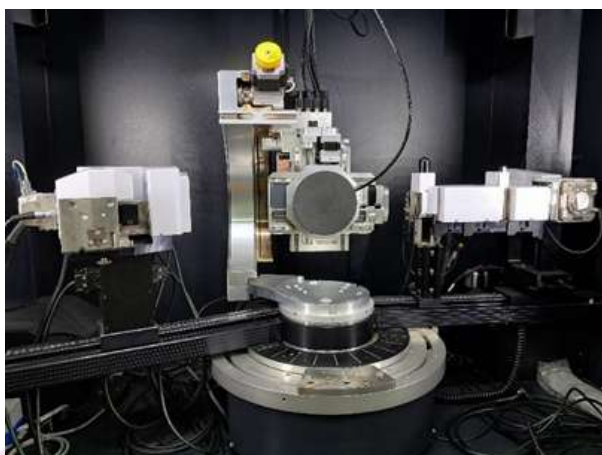
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Reciprocal Space mapping

KID: 20250111

Overview: Reciprocal space mapping is an advanced X-ray diffraction technique essential for characterising epitaxial thin films. It provides insights on lattice spacing, orientation distribution, strain and defects.

This method is especially significant for epitaxial thin films of semiconductors, ferroelectrics and complex oxides where strain-induced effects on crystal structure and properties are widely studied. It enables precise determination of lattice strain and gives more details on the lattice relaxation, composition gradient and dislocation density in the epitaxially grown thin films.



The Technique: The X-ray diffractometer consists of a four-circle (2θ , ω , ψ , ϕ) goniometer that enables precise orientation of the crystal and detector with Cu-K α source of wavelength 0.154nm with a 4-bounce monochromator using parallel beam optics.

Unlike conventional θ - 2θ scans that give information only along the direction normal to surface of the film, reciprocal space map (RSM) provides a two-dimensional view of diffraction intensity in reciprocal space, offering detailed insights on in-plane and out-of-plane lattice parameters, strain, mosaicity, tilt, presence of multiple domains or defects etc.

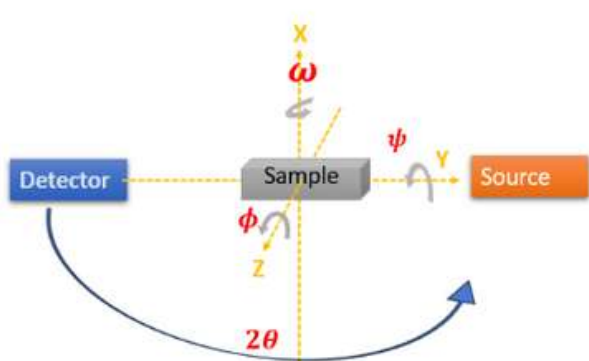


Figure 1. Schematic of four-circle goniometer

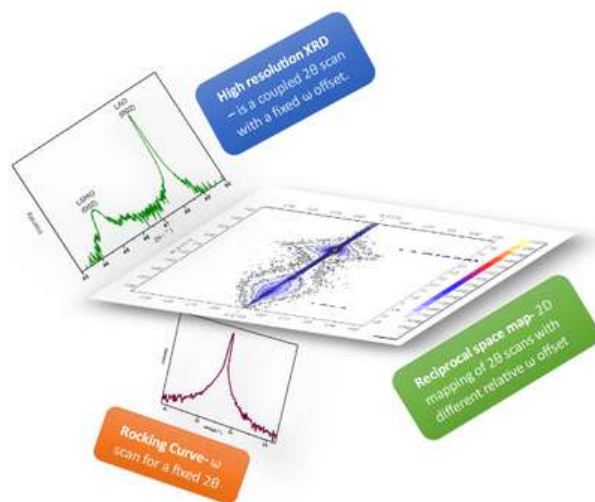
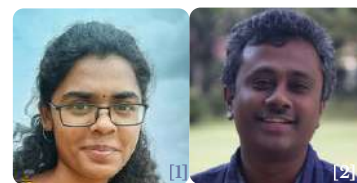


Figure 2. HR-XRD, Rocking curve and Reciprocal Space mapping

In epitaxial films, the arrangement of atoms is in a specific orientation with respect to the substrate, and there would be a substrate-induced strain present in the film. In a typical RSM measurement, the 0D or 1D detector scans both the ω (glancing angle) and 2θ (diffraction angle) axes in small steps around a reflection, allowing one to reconstruct the distribution of diffracted intensity in a plane of reciprocal space.

The scan can be symmetric or asymmetric depending on the alignment. The reconstruction consists of the Y axis corresponding to the out-of-plane (Q_z) component and the X axis to the in-plane (Q_x) component of the scattering vector.

RSM also enables the detection of tilt and mosaic spread present in the film. The elongation or split in certain directions can indicate the presence of tilted domains or dislocations in the film. Rocking curve measurement is performed by fixing the 2θ and sweeping tilting the sample to $\pm \Delta\omega$.

The degree of peak broadening is related to mosaicity and defect densities. In high-quality single-domain films, the peaks are typically sharp and well-defined, whereas broad or streaked peaks suggest a less ordered structure. By fixing the 2θ and ω for a particular reflection, an Azimuth scan (ϕ) gives insights into the crystal symmetry relation of the film with respect to the substrate. Another important application of RSM is in determining lattice distortions and symmetry differences due to substrate-induced strain.

Especially in perovskite oxide films, structural distortions like octahedral tilting or ferroelectric displacements can lead to subtle splitting of reflections or asymmetry in reciprocal space.

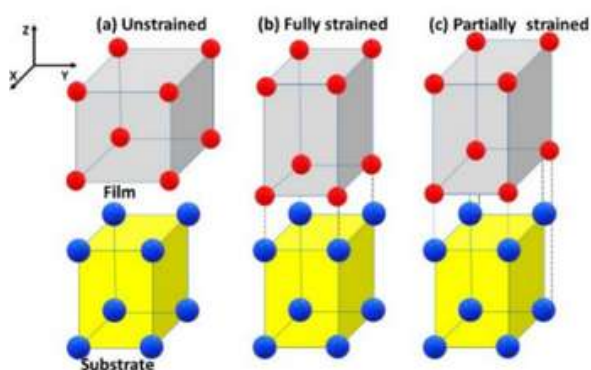


Figure 3. Schematic of (a) unstrained, (b) fully constrained and (d) partially constrained film on the substrate

Also, in heterostructures and superlattices, where there is stacking of multiple layers of different materials stacked in a certain periodicity and different layer thicknesses, which offers varying lattice mismatch, multiple satellite peaks can appear in the RSM, from which layer thicknesses, periodicity, and interface quality can be inferred.

In conclusion, reciprocal space mapping is a substantial technique for characterizing epitaxial thin films where strain engineering of these films serves as an important strategy in tailoring the properties of materials such as ferroelectricity, ferromagnetism, bandgap in semiconductor industry, etc.

It provides a multidimensional perspective on the crystal structure of the film, enabling precise determination of strain, relaxation, crystallographic tilt, and microstructural defects.

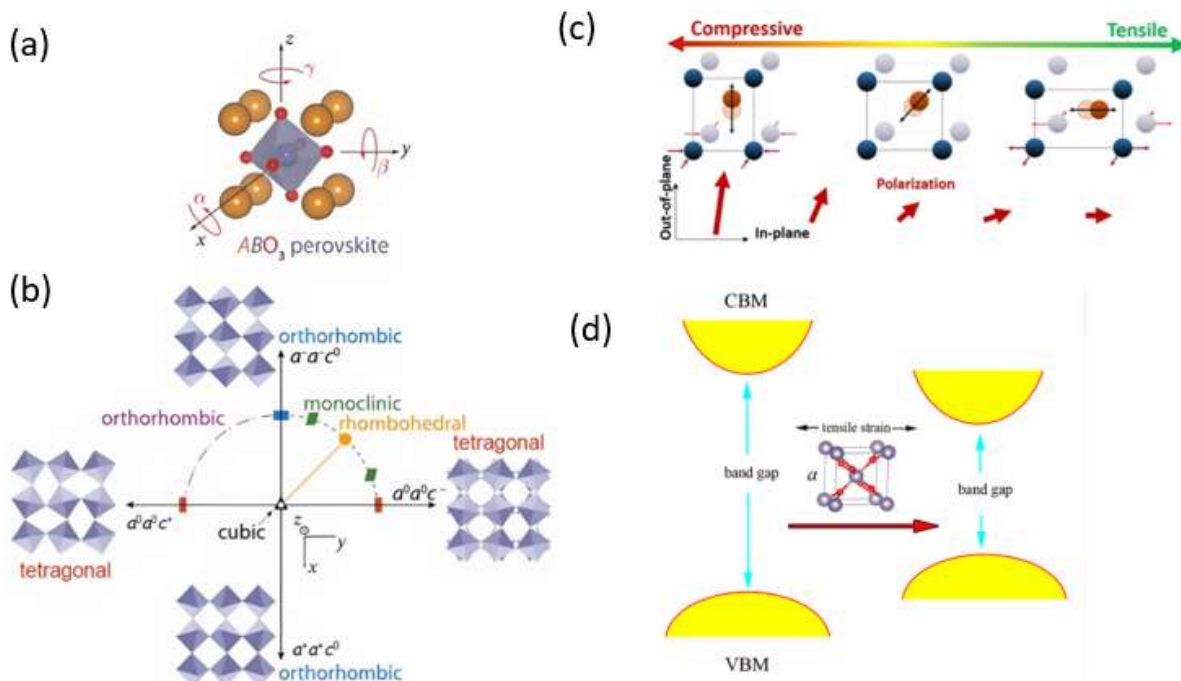


Figure 4. (a) and (b). ABO₃ perovskite structure and distortion of BO₆ Octahedra forming different crystal structures [1] (c) effect of strain on ferroelectric polarisation [2] (d) tuning of bandgap with strain [3]

It provides information about the subtle unit cell distortions, or strain-induced phase transitions in the epitaxially grown thin films which play a crucial role in understanding structure-dependent properties.

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“Reciprocal space mapping is an advanced X-ray diffraction technique essential for characterising epitaxial thin films. It provides insights on lattice spacing, orientation distribution, strain and defects.”

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Scanning Tunneling Microscope

KID: 20250112

Quantum tunneling is a phenomenon in which particles, such as electrons, tunnel through an insulating barrier in the presence of an electric potential that classical physics deems impossible. In 1981, Gerd Binnig and Heinrich Rohrer at IBM Zürich harnessed this phenomenon to create the Scanning Tunneling Microscope (STM), which allows researchers to visualize and study surfaces at the atomic level. This discovery led them to win the Nobel Prize in 1986

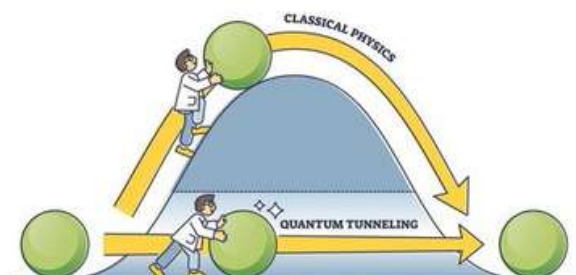


Figure 1. Classical vs Quantum phenomenon

STM operates under high-vacuum conditions ($<10^{-5}$ torr) by bringing a conducting, atomically sharp tip within a few angstroms of a metal or semiconductor sample. When a bias voltage is applied between the tip and the sample, electrons can tunnel through the vacuum gap, generating a tunneling current. By scanning the tip across the sample and maintaining a constant tunneling current through a feedback loop, we can measure the topography and electronic properties of the surface with atomic precision. It also provides information about the local density of states, surface defects, band structure properties, and more. STM is one of the precise imaging techniques available in which we can achieve lateral resolution better than 0.1 nm and vertical resolution as fine as 0.01 nm. As shown in the Figure below, STM measurements were carried out on highly oriented pyrolytic graphite (HOPG) to visualise the unit cell structure. We were able to see the hexagonal unit cell structure, where the unit cell parameter was also observed near the theoretically reported values of 0.26 nm.

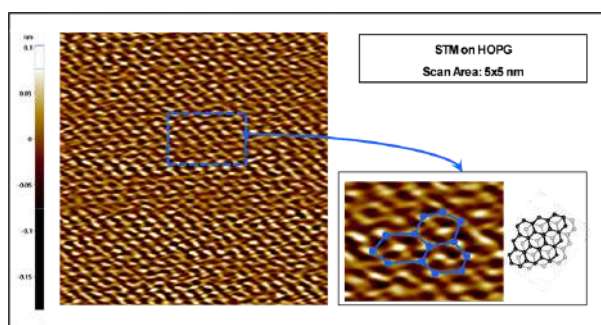


Figure 2. STM image obtained on HOPG

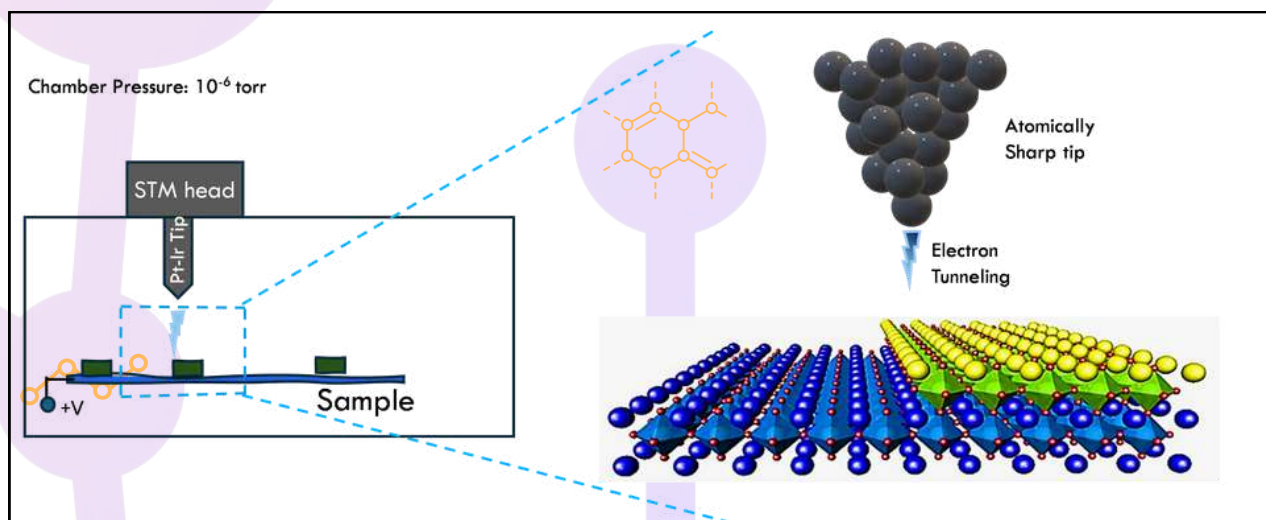


Figure 3. Schematic of how STM works

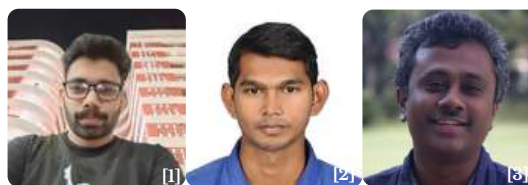




Figure 4. STM at SATHI CisCoM – IITH

A similar type of measurement (2x2 nm scan) was also conducted on highly oriented platinum (111) – Silicon (100) wafers. We were able to identify atomic planes where the d spacing value is close to the previously reported values. The theoretical value for the d-spacing of single crystal Pt (111) is reported as 0.28 nm, and the values we obtained are comparable, considering that the wafer is not single crystal but highly oriented towards (111) in our case.

These measurements were conducted in the Hi-Vac Scanning Probe Microscope (SPM) system (Available at SATHI – IIT Hyderabad), which can achieve high vacuum levels and is suitable for STM measurements. We use Platinum-Iridium wires, which have atomic sharpness, for the measurements.

The instrument is also capable of measuring currents ranging from 10 mA upto 100 fA using current amplifiers like VECA and ULCA.

STM measurement possesses some challenges as it requires extremely clean and stable surfaces, sharp tips, excellent vibration isolation, and sophisticated electronics. Sample selection is also limited to metal or semiconductor, though advanced techniques exist for imaging some non-conductive materials also. Still, Scanning Tunneling Microscopy stands as an advanced tool in modern science, offering deep insights into the atomic and electronic structure of surfaces. Its ability to image and measure properties at the atomic scale continues to drive advances in physics, materials science, and beyond.

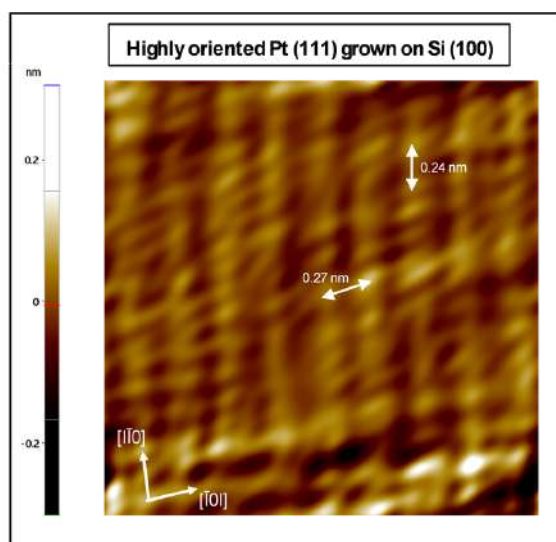


Figure 5. STM image of highly oriented Pt(111)||Si(100)

“Quantum tunneling is a phenomenon in which particles, such as electrons, tunnel through an insulating barrier in the presence of an electric potential that classical physics deems impossible”

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SMITH Lab – Leading the Way in E-Waste Recycling

KID: 20250113

Electronic waste, or e-waste, refers to all items of electrical and electronic equipment and their parts that have been discarded as waste without the intent of re-use. E-waste contains both valuable and hazardous materials that require special handling and recycling methods.

The Global E-waste Monitor finds that by 2022, the world generated 62 billion kg of e-waste, or an average of 7.8 kg per capita. Only 22.3 per cent (13.8 billion kg) of the e-waste generated was documented as properly collected and recycled in an environmentally sound manner. The e-waste generated in 2022 contained 31 billion kg of metals, 17 billion kg of plastics, and 14 billion kg of other materials (minerals, glass, composite materials, etc.). The economic value of the metals contained in the e-waste generated globally in 2022 is estimated at USD 91 billion. Valuable secondary raw materials are copper (USD 19 billion), gold (USD 15 billion), and iron (USD 16 billion). These metals can be efficiently reclaimed with high recycling rates using current e-waste management technologies, implying that improved collection rates could substantially increase current value recovery rates.

India's journey to Viksit Bharat is being powered by a rapid digital transformation, with an increased reliance on electronic devices. From smartphones and laptop computers to modern industrial and medical equipment, technology has become the foundation for economic growth, connectivity, and innovation. However, this rising reliance on electrical devices produces a byproduct – e-waste, which must be properly managed to ensure long-term progress. India, being one of the world's leading e-waste generators (together with China, the United States, Japan, and Germany), faces a serious e-waste management challenge.

The Sustainable Metallurgy and Industrial Technologies (SMITH) Lab at IIT Hyderabad is at the forefront of developing sustainable technologies and circular economy research. Our mission is to develop efficient, eco-friendly, and scalable solutions for managing and recycling e-waste. We develop novel methods to recover critical metals from Printed Circuit Boards (PCBs) using sustainable techniques through critical thermodynamic and sustainability analyses, optimizing environmental factors such as the sustainability index, carbon emission index, and resource utilization efficiency. The SMITH lab also investigates chemical and thermal processes for recycling Liquid Crystal Displays (LCDs), aiming to recover indium, tin, and other valuable metals in an eco-friendly way. Indium concentrations in ore typically range from less than 1 ppm to 100 ppm. At the same time, the LCDs contain approximately 0.24%, which shows a potential for urban mining for these critical metals.

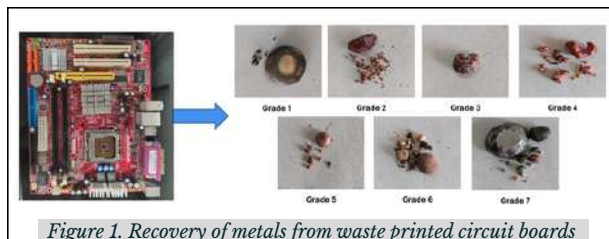
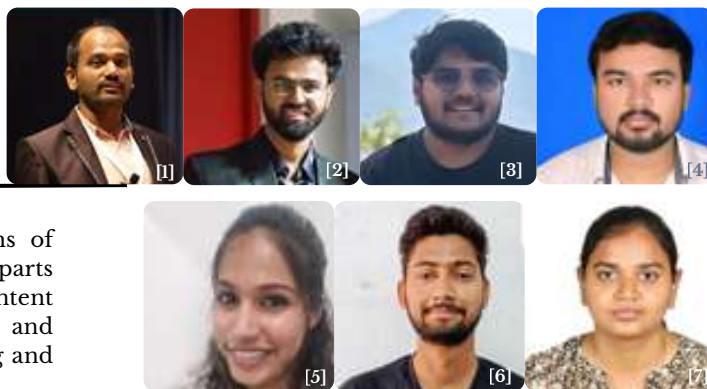


Figure 1. Recovery of metals from waste printed circuit boards from 7 grades.

Also, our lab is working on catalytic membranes to recover platinum and nickel, which are critical metals for our country, through innovative techniques, ensuring safe handling and minimal ecological impact.

Zerava Technologies Pvt Ltd. is a startup originating from the SMITH lab by Mr. Viraj Tank and Mr. Ajay Bachipalli, working on sustainable process development for the recovery of critical metals, rare earth elements, and precious metals from e-waste.

Zerava
Technologies Private Limited



Prof. Veena Sahajwalla (UNSW, Sydney) visit to SMITH Lab



Prof. Akbar Rhamdhani (SUT, Melbourne) visit to SMITH Lab

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Visualizing the complex flows in the reactors for steel sector digitization

KID: 20250114



At the Sustainable Metallurgy and Industrial Technologies (SMITH) Research Lab, we blend engineering insight with practical innovation to tackle real-world challenges in process metallurgy. One of our primary strengths lies in the physical/cold/water modelling of metallurgical processes. This powerful technique uses scaled-down models made up of Perspex or acrylic material to simulate and study industrial metallurgical processes in a safe, cost-effective, industrially relevant, and highly controlled environment. Using similitude techniques, we replicate the complex behavior of molten metals, gas-fluid interactions, and liquid-liquid interactions found in full-scale industrial reactors. These models are usually guided by the dimensionless numbers, such as Reynolds, Froude, and Weber numbers, ensuring that the flow dynamics in our experiments faithfully mirror those in real systems. By doing so, at the SMITH lab, we are committed to pushing the boundaries of process metallurgy, where academic rigor meets industrial relevance.

SMITH lab houses a gas-stirred ladle with a top lance (Refer to Fig 1) to simulate the hot metal desulphurization industry process, in which different process parameters, such as gas flow rate, lance diameter, and immersion depth, can be varied to understand their effects on the jet penetration depth, bubble size, rise velocity, mixing time, etc. Figure 2 depicts the dynamics of bubbles that leave the top lance, thus helping us to visualise, understand, and improve the process effectively.

Similarly, Electric Arc Furnaces (EAFs) are crucial in steel production, utilizing steel scrap and Direct Reduced Iron (DRI) as key inputs. However, slag carryover control during tapping, primarily driven by vortex and drain sink formation, remains a significant challenge. Despite the widespread use of Eccentric Bottom Tapping (EBT) in EAFs, limited research has explored slag carryover mechanisms. We at the SMITH lab conduct experiments using a scaled-down Perspex model presented in Fig. 3 of an industrial EAF, incorporating a bottom purging system to analyze its impact on slag entrainment. The study investigates the factors such as filling flow rates, dwell time, nozzle diameter, initial liquid, purging flow rates, purging duration, etc, that influence vortex and drain sink formation. Critical heights for vortex and drain sink formation were recorded under varying conditions, and dimensional analysis was employed to derive predictive mathematical models. Further, the mathematical formulation of the EAF tapping process, considering the reactor's complex shape, accurately predicts the critical time for vortex formation, offering potential industrial applications to minimize slag carryover and enhance steel quality in EAF operations. In addition to the EAF cold model, SMITH also houses the Basic Oxygen Furnace (BOF) model. We will be exploring ways to decarbonize the

BOF process using this model in the near future in association with the steel sector. In addition to the EAF cold model, SMITH also houses the Basic Oxygen Furnace (BOF) model. We will be exploring ways to decarbonize the BOF process using this model in the near future in association with the steel sector.

It should be noted that physical modelling offers a unique advantage and allows us to understand critical process phenomena such as mixing, vortex formation, bubble dynamics, mass transfer rates, etc, without engaging hazards and costly high-temperature experimentations. This approach determines the optimum process conditions for industrial operations, making them more efficient, economical, and environmentally sustainable.

Our lab also collaborates with industries such as M/s. Jamipol Limited, Jamshedpur, to design better top lance configurations, optimize gas-powder delivery systems, and improve reaction kinetics inside a metallurgical vessel, i.e., hot metal desulphurization unit. From enhancing hot metal quality to liquid steel refining & tapping, our research contributes directly to digitizing the steel sector.



Figure 1. A scaled down Water model setup of an Industrial Desulphurization unit.



Figure 2. Rising air bubbles coming out of a typical T-shaped lance.



Figure 4. A scaled down water model setup of an Industrial DeS ladle



Figure 3. A scaled down cold model setup of an Industrial Electric Arc Furnace.

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Atom Probe Tomography - A Cornerstone in Advanced Materials Characterisation

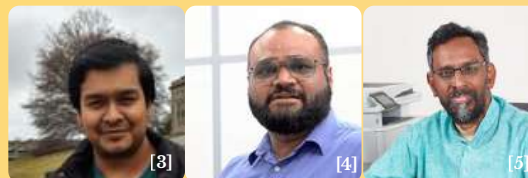
KID: 20250115

There is an increasing number of advanced materials that are tailored at the nanoscale for specific applications, and therefore, it is imperative to understand the relationship between the atom-scale structure of a material system and its properties or performance. Advanced microscopy techniques play a crucial role in the design of these materials and devices. In the past few decades, electron microscopy has made great strides in this direction, such as the continued development of electron tomography and the advent of sensitive elements detection systems [1]. Further, aberration-corrected transmission electron microscopy can provide structural and compositional information in two dimensions with unprecedented atomic resolution [2].

Atom probe tomography (APT) is an effective technique for materials characterization, serving as a complementary tool to electron microscopy while offering distinct microstructural insights. This technique offers both 3-D imaging capability and atomic-scale chemical composition measurements, which make it unique among material analysis techniques. Due to its outstanding spatial resolution ($\Delta x \approx \Delta y \approx 0.3\text{--}0.5$ nm and $\Delta z \approx 0.1\text{--}0.3$ nm) and detection sensitivity element concentrations down to a few ppm can be detected irrespective of elemental mass. The atom probe consists of a time-of-flight mass spectrometer and a point projection microscope capable of imaging at the atomic level.

Fundamentals of atom probe tomography:

The atom probe tomography (APT) technique evolved from field ion microscopy, which was first used to image individual atoms in the 1950s [3]. APT uses the intense electric field, typically on the order of tens of Vnm^{-1} , causing the constituent atoms of a material to be progressively repelled from the surface and ionized, either singly or multiply, through the field evaporation mechanism. The electric field necessary to produce the evaporation of an atom can be called the evaporation field, and it is specific to each element and phase in the material [4]. Conventionally, field evaporation is triggered by DC high voltage, which generates approximately 50-80% of the evaporation field. An electric field ($\sim 10^{10}$ V/m) is created at the apex of a sharp specimen (<100 nm radius) held at cryogenic temperatures when a high voltage (~ 10 kV) is applied. The application of voltage between the specimen and a local electrode facilitates the selective application of the field to a single specimen. By applying either voltage or laser pulses, surface atoms are field ionised and evaporated, atom by atom, layer by layer, towards a position-sensitive detector, where detector collects the ions and records their impact location. The utilization of voltage-pulsing enables the measurement of the time-of-flight for each individually detected ion. Time-of-flight directly correlates to mass-to-charge ratio, thus enabling elemental identification of individual ions.



The evaporation sequence provides information on the depth of the atoms at the specimen's apex, while the hit location on the detector determines their original position on the specimen. Using an inverse projection reconstruction algorithm and the sequence of detected events, the evaporated volume is then reconstructed in three dimensions. Typically, the tomographic data set comprises the spatial coordinates and elemental identities of several millions of atoms with nearly atomic precision, typically spanning tens to hundreds of nanometres in depth. The APT technique has become an indispensable tool in the study of metallic materials, advanced ceramics, semiconductors, biomaterials, and geosciences.

LEAP 6000 XR at the SATHI-CISCoM at IIT Hyderabad:

At SATHI-CISCoM, the atom probe lab houses the state-of-the-art LEAP (Cameca, LEAP 6000 XR) along with a focused ion beam (JEOL, JIB 4700F) for atom probe specimen preparation. The SATHI Centre for In-Situ and Correlative Microscopy (SATHI-CISCoM) at IIT Hyderabad is set up by a consortium of 18 partner institutes and with the support of DST through the SATHI program.

SATHI-CISCoM is the first centre in the country to enable real-time characterisation across multiple length scales for fundamental and industrial R&D purposes. Through this initiative, scientists from a variety of scientific disciplines, including metallurgy, materials sciences, physical sciences, and chemistry, will come together to address common scientific goals that can only be addressed through the use of sophisticated microscopy techniques. Designated students/scientists/technical staff of each partner institution have been trained on the operation of the LEAP, data acquisition and data analysis.

“Atom probe tomography (APT) is an effective technique for materials characterization, serving as a complementary tool to electron microscopy while offering distinct microstructural insights.”





Figure 1: Photographs of LEAP 6000 XR and demonstration to delegates at the SATHI-CISCoM, IIT Hyderabad.

Characterisation of precipitates and ordered phases in a high entropy super alloy:

The atom probe characterisation of $\text{Ni}_{39.7}\text{Co}_{32.2}\text{Cr}_{16.1}\text{Al}_6\text{Ti}_6$ medium entropy alloy was carried out using LEAP 6000 XR. APT studies were conducted using a laser with a wavelength of 257.5 nm (UV). To mitigate preferential evaporation of different elements and errors resulting from thermal vibrations, the specimen temperature was maintained at 60 K. Pulsed laser energy, pulse frequency, and data collection rate were 40 pJ, 200 kHz, and 0.5% per field evaporation pulse, respectively [5].

Atom maps (Fig. 2(a)) reveal that the γ' precipitates are enriched in Ni, Al, and Ti, whereas the γ matrix is rich in Co and Cr. The corresponding APT reconstruction (Fig. 2(b)), with blue atoms representing element Ti and yellow atoms representing element Al, further illustrates this elemental partitioning.

The γ/γ' interfaces are delineated by 6.65% iso-concentration surfaces, encompassing regions of $\geq 6.65\%$ Al and Ti. A 1-D concentration profile across the γ/γ' interfaces in the as-cast Al_7Ti_7 MEA (Fig. 2(c)) demonstrates distinct partitioning behaviour, with the γ matrix enriched in Cr (~29%) and Co (~16%), and the γ' phase enriched in Ni (~68%), Al (11%), and Ti (12%). These findings indicate that Co and Cr preferentially partition to the γ phase, while Al and Ti partition to the γ' phase, consistent with recent observations [6]. Similar elemental partitioning trends have been observed in other HEAs [7].

The partitioning coefficient ($K_i = C_i^{\gamma'}/C_i^{\gamma}$) characterises the preferential partition of element i between the γ and γ' phases, where $C_i^{\gamma'}$ and C_i^{γ} represent the elemental concentrations in the γ' and γ phases, respectively. Elements with $K_i > 1$ preferentially partition to the γ' phase, while those with $K_i < 1$ tend to partition to the γ phase, providing a quantitative assessment of elemental partitioning in complex alloys [8]. Notably, the Ni concentration is lower in the matrix (~51%) compared to the γ' precipitates (~68%).

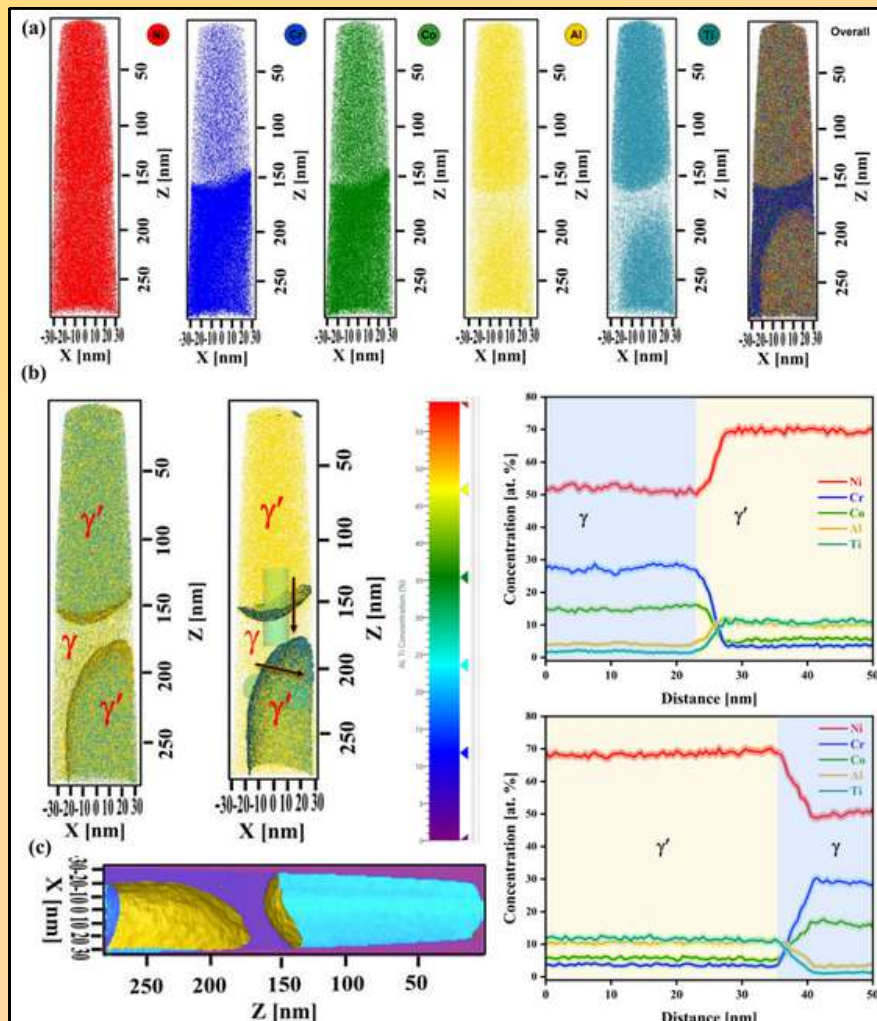


Figure 2: (a) Elemental distribution of Ni, Co, Cr, Al and Ti, (b) Ti delineated using 6.29% Ti iso-concentration surface and distribution Al and Ti with Ti iso-concentration surfaces, (c) one-dimensional concentration profile (0.5 nm bin width) obtained using a 20 nm diameter cylindrical region of interest shown in (b) and (d) 2d concentration plot showing the enrichment of Ti and Al in γ' phase.

Technique used	Phases	Ni	Co	Cr	Al	Ti	Partition coefficients ($C_{i\gamma'}/C_{i\gamma}$)				
							K_{Ni}	K_{Co}	K_{Cr}	K_{Al}	K_{Ti}
APT	γ' -dendritic	67.12 ± 0.21	6.06 ± 0.18	3.34 ± 0.08	10.32 ± 0.13	13.17 ± 0.16	1.29	0.39	0.12	3.85	9.14
	γ -dendritic	51.66 ± 0.21	15.49 ± 0.17	28.74 ± 0.21	2.68 ± 0.08	1.44 ± 0.07					

Table 1: Average chemical compositions of the γ and γ' phases (at. %) and corresponding partitioning coefficients (K_i), obtained from APT proxigram data.

Precise delineation of individual γ and γ' phase regions from APT datasets allowed for accurate determination of their phase compositions (Table 1) from the corresponding mass spectra and the calculation of elemental partitioning coefficients. The γ' phase primarily comprises Ni, Al, and Ti (~ 91%), with the remaining elements accounting for ~ 9%. Among the elements partitioning to γ' ($K_i > 1$), Ti exhibits the highest partitioning coefficient, followed by Al and Ni, indicating the strongest preference for the γ' phase. Conversely, Cr and Co preferentially partition to the γ matrix ($K_i < 1$), with Co showing the most significant partitioning coefficient among these elements (Table 1).

The strong partitioning of Ti to γ' precipitates ($K_{Ti} > 9$) with respect to γ matrix suggests its role as a strong γ' stabiliser in the alloy. Overall, Ti strongly partitions to γ' , while Cr partitions to the matrix. The total concentration of Co, Cr, and Ni in the γ' phase approaches ~ 75%, aligning with the stoichiometry of the A_3B-Ll_2 structure, wherein Co and Ni preferentially occupy the A-sites, and Al and Ti occupy the B-sites. Consequently, the γ' precipitates in the present alloy can be nominally represented as $(Ni, Co, Cr)_3(Al, Ti)$, which is consistent with the measured composition.

Conclusions:

The APT technique is increasingly recognized as an essential tool for advanced materials characterization. The growing interest in this technique is attributed to its exceptional ability to collect individual ions from nanoscopic volumes, even within complex morphologies, while maintaining single-ion sensitivity and high mass-resolving power.

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“SATHI-CISCoM is the first centre in the country to enable real-time characterisation across multiple length scales for fundamental and industrial R&D purposes. Through this initiative, scientists from a variety of scientific disciplines, including metallurgy, materials sciences, physical sciences, and chemistry, will come together to address common scientific goals that can only be addressed through the use of sophisticated microscopy techniques.”

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Confocal microscopy for understanding fluorescently labelled biological samples

KID: 20250116

Optical microscopy has been extensively used for studying samples from various fields, ranging from geology to life sciences [1]. In particular, advances in optics, electronics, light sources and digital imaging have increased the scope of microscopy remarkably for observing samples in actual conditions. In case of biological samples, various cellular and tissue entities can be labelled with fluorescent molecules, and this label can be used to monitor any changes that they might be undergoing. From an application standpoint, it is now possible to achieve diffraction-limited images with visible light [1]. In recent times, researchers have developed imaging techniques that can beat the diffraction limit of light using unique illumination and collection strategies [2]. In particular, the improvement in the z-axis resolution using the confocal geometry opens avenues for optical sectioning of a sample with sub-200 nm resolution, wherein we can obtain the 3D image of the object. Confocal microscopy is a fast, laser-scanning fluorescence imaging technique that provides high-resolution and high-contrast images by eliminating out-of-focus light.

About the system in SATHI-CISCoM

At SATHI CISCoM at IIT Hyderabad, we have the Nikon Ti2-E confocal microscope equipped with NSPARC (Nikon Spatial Array Confocal) for super-resolution imaging and a TIRF (Total Internal Reflection Fluorescence) module for studying samples labelled with fluorescent dyes. This is achieved using point illumination and a pinhole aperture that allows only in-focus light to reach the detector. The Ti2-E confocal microscope features a large field of view (FOV) of 25 mm. The objective lenses used in this confocal microscope are 4x, 10x, 20x, 40x, 60x(oil) and 100x(oil). Chromatic aberration is reduced in confocal microscopy by using a nanocrystal coating on the objective lens. Equipped with the AIR HD laser-scanning confocal unit, the system offers six excitation lines (405, 445, 488, 514, 561, 640 nm), enabling a broad array of common fluorophores (DAPI, CFP, FITC, YFP, TRITC, Cy5). A hybrid scanning mechanism—combining high-speed resonant scanning (up to 30 fps at 512×512) with Galvano scanning (10 fps at 512×512; 4096×4096 spatial resolution)—provides flexibility in imaging speed and resolution. The detector assembly uses two traditional PMTs and two GaAsP detectors. The Perfect Focus System (PFS) is integrated into Nikon confocal microscopy systems. This PFS (Perfect Focus System) is an autofocus mechanism that automatically compensates for focus drift caused by temperature fluctuations or mechanical instability. It is especially useful during long-term time-lapse imaging in confocal microscopy (uses infrared tracking to maintain Z position). Ti2 E supports live-cell imaging with controlled temperature and CO₂, for prolonged experiments. It also supports various imaging modes, including large-area imaging, Z-stacking, time-lapse

imaging, multipoint acquisition, multichannel imaging, and live-cell studies. Advanced techniques such as FRAP (Fluorescence Recovery After Photobleaching) and FRET (Förster Resonance Energy Transfer) can also be utilized for functional imaging and molecular interaction studies.

Imaging fluorescently labelled samples using the confocal system

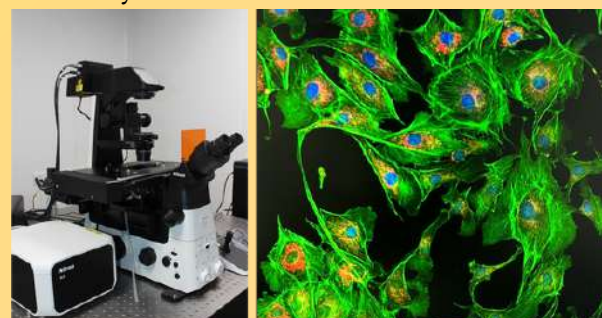


Figure 1. Shows the Ti2E microscope along with the image of a human cell line stained with three different dyes. Each of the dyes labels the nucleus, the mitochondria and the cytoskeleton of the cells. From this, we can easily observe the morphology of the different organelles and calculate the area of each of them.

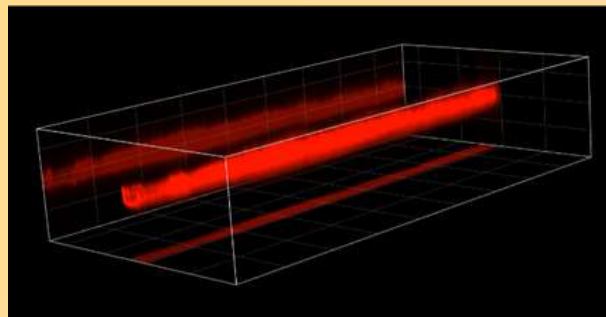


Figure 2. Shows the z-stack image of a tubular structure stained with Nile Red dye, wherein the dye only attaches to the surface of the structure. Using this it is possible to map the 3D surface topography of the sample.

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Characterization of Materials

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SATHI – Centre for In-Situ and Correlative Microscopy, IITH

DST-SATHI Centre on In-situ and Correlative Microscopy: a cornerstone to cutting-edge characterisation across multiple length scales

KID: 20250117

Since its advent, Microscopy has been used extensively to characterise materials across all disciplines, from physical to life sciences. In these areas, information from various length scales was obtained using optical, surface probe, or electron microscopy. With most of the research these days being interdisciplinary, it is essential to establish facilities that can promote and nurture this form of research. Currently, in-situ electron, optical and scanning probe microscopy techniques are at the helm of interdisciplinary research. To realise this latest paradigm in microscopy, it is essential to have a platform that enables the acquisition of information from materials using complementary techniques at different length scales. At the same time, the sample is subject to external stimuli. This will be the first such centre in India to cater to advanced sample analysis in real-time across multiple length scales using complementary imaging and spectroscopic techniques while the sample is subjected to a stimulus.

To realise this, IIT Hyderabad and five other partner organisations, namely University of Hyderabad, ARCI, CCMB, IICT and CBIT, submitted a proposal in September 2022. In April 2023, the cluster from IIT Hyderabad was shortlisted for a presentation at JNCASR Bengaluru and in the meeting, IIT Hyderabad was advised to identify more partner organisations, particularly industrial partners and suggested expanding the cluster beyond the local Telangana region and making this a national facility. This led to several discussions with industrial partners and R&D labs across the country, and today, the IIT Hyderabad cluster has 10 academic partners, 4 R&D labs and 4 Industrial partners[1]. This effort of bringing together people across multiple disciplines and raising a financial contribution of 20 Cr INR from the cluster has paved the way for the success of the SATHI proposal. In December 2023, the IIT Hyderabad cluster was awarded the SATHI grant to set up a Centre on In-situ and Correlative Microscopy (CISCoM).

While much pioneering work has been done in India in Electron Microscopy, Surface Probe Microscopy, and Optical Microscopy, correlating these three fields and extracting complementary information to gain a complete understanding of a specimen at different length scales and in real time has been very limited. Even globally, very few centres of excellence focus on in situ correlative microscopy. To sustain cutting-edge interdisciplinary research at IITH and establish ourselves as a centre of excellence locally and globally. In line with this vision, along with our partner institutions, pertinent scientific topics which are of mutual interest and can potentially be tackled by carrying out correlative in-situ microscopy studies have been identified and categorised into three broad verticals, namely structural, functional, biomedical & pharmaceutical applications, as summarised in Table 1.



Among these, we have defined twelve research themes that foster interdisciplinary research among the partner institutes and the local industries and institutions.

[1] A complete list of partners institutes is given at the end of this article.

Verticals	Themes	Techniques
SATHI CISCoM R&D Activities	Novel Processing Routes	
	Phase Transformations in Advanced Steels	S/TEM
	Mechanical Behaviour of Advanced Alloys	APT
	Assessment of Cements and Concrete Mixtures	SPM TERS FTIR
Functional Applications	Energy Storage Materials	S/TEM
	2D Materials	SPM
	Neuromorphic Computing	TERS
	Magnetic Materials & Devices	FTIR MOKE
Biological applications	Transplantation Therapies	Super-resolution optical microscopy
	Insights into Infectious Diseases	
	Cellular Dynamics	S/TEM
	Rheological Paradigms for Materials Design	TERS FTIR

Table 1: Proposed R&D Activities at the SATHI Centre on In-Situ and Correlative Microscopy (CISCoM) at IIT Hyderabad

This centre will house nine state-of-the-art facilities and sample preparation facilities in a class 100000 cleanroom. The details and specifications of the equipment procured and installed are given in Table 2. This centre at IITH on “In-situ & Correlative Microscopy (CISCoM)” will be the cornerstone to cater to cutting-edge sample analysis.

By enabling such a centre, we are bringing people across various scientific disciplines ranging from materials science and metallurgical engineering, physics and chemistry, biology, biomedical and pharmaceutical studies, and geology as well as expertise in computational techniques, artificial intelligence and machine learning together to address common scientific goals which can only be solved using such sophisticated techniques.

“To sustain cutting-edge interdisciplinary research at IITH and establish ourselves as a centre of excellence locally and globally. In line with this vision, along with our partner institutions, pertinent scientific topics which are of mutual interest and can potentially be tackled by carrying out correlative in-situ microscopy studies have been identified and categorised into three broad verticals, namely structural, functional, biomedical & pharmaceutical applications.”

Table 2: Proposed R&D Activities at the SATHI Centre on In-Situ and Correlative Microscopy (CISCoM) at IIT Hyderabad

SNO	Facility	Technical Details	Key Specification	Photograph
1.	Cameca LEAP 6000XR (installed & functioning)	An advanced microscopy and spectroscopy tool that delivers atomic-scale, 3D reconstructions of metals and inorganic solids. It combines time-of-flight mass spectrometry	spatial resolution $\Delta x \approx \Delta y \approx 0.3\text{--}0.5\text{ nm}$; $\Delta z \approx 0.1\text{--}0.3\text{ nm}$ ppm-level element sensitivity	
2.	JEOL NEOARM 200F – Probe Corrected TEM (installed & training due)	Aberration-corrected Scanning Transmission Electron Microscope with Energy Filtering and Imaging to enable atomic resolution EDS and EELS, making this a state-of-the-art Analytical TEM	30 – 200 kV STEM 0.82 Å spatial resolution 160 mm ² EDS detector STEM-SAAF detector 4d-STEM CEFID EELS	
3.	JEOL NEOARM 200F – Image Corrected TEM (installed & training due)	Aberration Corrected High Resolution Transmission Electron microscope equipped with an electric biprism to perform electron holography	30 – 200 kV HRTEM 0.7 Å spatial resolution STEM-HAADF/ABF Electron Holography	
4.	JEOL JIB-4700F (yet to be installed)	Focused-ion-beam/Scanning Electron Microscope for site-specific specimen preparation for APT and TEM analysis	1.6 nm resolution @ 1kV In-lens Schottky-emission Max probe current (SEM): 300 nA, Ga-ion source: 90 nA probe current	
5.	Park NX-Hivac AFM (installed & functioning)	A high vacuum multimode AFM for precise semiconductor failure analysis and highly sensitive nanomaterials science research in ambient & vacuum	Multimode AFM with LFM, EFM, DC-EFM, KPM, EFM, IV Spectroscopy	
6.	NTMDT – NTEGRA Spectra II, AFM with Tip-Enhanced Raman Scattering (installed & functioning)	AFM with confocal Raman spectroscopy, enabling simultaneous topographical and chemical analysis at the nanoscale, supporting a wide range of AFM modes	mechanical, thermal, SECM, and electrical measurements combined with high-resolution Raman mapping with spatial resolution of 20 nm and spectral resolution of 0.1 cm ⁻¹	
7.	Nikon AXR with NSPARC High resolution confocal imaging system (installed & functioning)	Confocal microscope equipped with Nikon Spatial Array Confocal detector for super-resolution fluorescence imaging	100 nm lateral and 300 nm axial resolution 25 mm field of view with 8k x 8k scanning 6 laser lines: 405, 445, 488, 514, 561, 640 nm sCMOS detector	
8.	ThermoFisher Scientific RaptIR+ with iS50	An FTIR spectrometer for bulk measurements and a microscopy platform for detailed micro-analysis for a wide range of sample types	Spectral range: 350–7800 cm ⁻¹ Spectral resolution: 0.09 cm ⁻¹ ATR crystals: Monolithic diamond (main compartment), germanium tip (microscope)	

9.	Anton Paar MCR 302e – Modular Compact Rheometer	A versatile rheometer designed to characterise viscoelastic properties in complex fluids and soft materials precisely.	Storage modulus, loss modulus and viscosity across varying frequencies, strain, shear rate and temperature Rotational & oscillatory modes Digital microscope with glass Peltier plate	
10.	10. Vertis Magvision Kerr Microscopy System	Designed for spintronics and magnetic materials research, the Magvision 18001 enables fast, non-destructive imaging of magnetisation through polarisation rotation detection.	400 nm resolution 6MP 60 FPS camera with >80% QE >10 electrical contact sample stage with high precision piezo control 400 mT electromagnet in two axes Liquid nitrogen cooled stage down to 90K	
11.	11. Specimen preparation facilities	Preparation techniques for inorganic and organic materials tailored for multiple length-scale microscopic studies.		

Annexure: List of partners at SATHI-CISCoM:

Academic Institutions:

1. Indian Institute of Technology Hyderabad (Host Institute)
2. University of Hyderabad
3. Visvesvaraya National Institute of Technology, Nagpur
4. National Institute of Technology, Raipur
5. National Institute of Technology, Warangal
6. National Institute of Technology Andhra Pradesh, Tadepalligudem
7. Telangana State Council for Higher Education
8. Chaitanya Bharati Institute of Technology (CBIT), Hyderabad
9. Sri Vishnu Educational Society, Hyderabad
10. Veltech University, Chennai

R&D Labs:

1. International Advanced Research Centre for Powder Metallurgy and New Materials (ARCI), Hyderabad
2. Centre for Cellular & Molecular Biology (CCMB), Hyderabad
3. Indian Institute of Chemical Technology (IICT), Hyderabad
4. LV Prasad Eye Institute, Hyderabad

Industries:

1. Dr. Reddy's Labs, Hyderabad
2. Bharat Biotech, Hyderabad
3. Amara Raja Group, Tirupati
4. TATA Steel, Jamshedpur



Transmission Electron Microscopy

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FTIR micro-spectroscopy for analyzing chemical groups in materials

KID: 20250118



Fourier Transform Infra-Red (FTIR) spectroscopy is one of analytical techniques commonly used for analyzing the chemical bonds present in the material [1-3]. This is especially useful for organic materials and their modifications, as the bond formation and its quantification can be carried out by analysis of the FTIR spectrum. These measurements can be done in reflection, transmission and ATR geometries, with each having its own advantages and disadvantages. For example, ATR uses a diamond prism for improving the S/N ratio via increasing the effective volume from which the IR signal is measured. In most cases, a FTIR system acquires a single spectrum from the whole sample and provides the average chemical composition of the sample. Recently, there has been a significant interest towards micro-FTIR based approach wherein a IR microscope is coupled to the FTIR spectrometer enabling the spectral mapping of a sample. This approach can be used for studying samples where the chemical composition distribution is inhomogeneous. Such analysis can provide greater insights into the sample, the chemical composition distribution and also detect the presence of minor inclusions/impurities which might be missed in the macroscopic FTIR measurements.

At the SATHI-CISCoM centre we have a RaptIR+ microscope along with the iS50 spectrometer from TFS. In the spectrometer, we can analyze the chemical composition of both solid and liquid samples. The spectrometer can be operated in both transmission and ATR modes by replacing different compartment modules (these are user switchable). The spectrometer provides a high spectral resolution spectrum of the sample with high S/N. The DLaTGS (Deuterated Lanthanum Alanine-doped Triglycine Sulfate) detector used in the spectrometer which does not require cryogenic cooling, simplifying its use in FTIR instruments. Both the spectrometer and the microscope have a humidity indicator which allows the user to monitor the level of humidity inside the spectrometer.

Equipment in SATHI-CISCoM: TFS Nicolet iS50 with RaptIR+



Figure 1. MicroFTIR system in SATHI-CISCoM at IITH



Figure 2. The RaptIR+ microscope with its different components.

The system has the following specifications:

Spectral range– 600-4000 cm^{-1} for the microscope (450 – 6000 cm^{-1} on the spectrometer)

Spectral resolution – 4 cm^{-1} (microscope); 0.09 cm^{-1} (Spectrometer)

Detector – DLaTGS for FTIR; MCT for Microscope
ATR Crystal – Monolithic Diamond (bulk ATR); Germanium tip (microATR)

This system has the following features:

- **Dual Visualisation Modes:** Optical Brightfield (for visual inspection) and Infrared Visualisation (spectral measurement).
- **High Spatial Resolution:** The system provides near-diffraction-limited resolution and is capable of analysing particles as small as 10–20 μm .
- **Minimal Sample Prep Needed:** The stage can accommodate large samples, and the samples typically require minimal sample preparation (eg, Wet samples need to be dried, etc.). A variety of sample types, including filters (silver membrane, cellulose nitrate), can be mounted directly for analysis.
- Can operate in both reflectance and transmission modes
- Automated mapping of the sample is possible with a designated spatial resolution and step size.
- The software for the system can be used for post-processing of the data, especially library-based spectral matching.
- Introduction of Micro-FTIR (TFS Nicolet iS50 with RaptIR+)

Some examples of systems where microFTIR can be employed:

- Microplastics in environmental samples
- Unknown particles in materials (like pharmaceuticals, etc.)
- Defects or inclusions in polymers and coatings
- Contaminants in food, cosmetics, and industrial materials
- Chemical modification of organic samples through reactions
- Material identification and characterisation
- Polymer analysis
- Pharmaceutical and Biopharmaceutical Analysis
- Soil Analysis
- Biomaterials Research
- Hydrogen Bonding Studies
- Forensic Science
- Clinical Diagnostics
- IR response of functional devices

“ Fourier Transform Infra-Red (FTIR) spectroscopy is one of analytical techniques commonly used for analyzing the chemical bonds present in the material ”

Application of FTIR analysis for liquid samples in flow conditions:

In most cases, the FTIR analysis is carried out in dry conditions, especially to avoid the strong spectral signatures of solvents. However, in order to use FTIR for monitoring chemical reactions in-situ, it becomes pertinent to carry out the analysis in liquid conditions wherein the contribution of the solvents to the FTIR spectrum becomes extremely crucial [3]. Figure 3(a) shows the design of a homemade liquid which can be used for measuring the IR spectrum using either a gold mirror on CaF₂ substrate or with IR metasurfaces. Using this system, it is possible to measure the IR spectrum of solvents (water, acetone and ethanol) as shown in Figure 3(b). We can clearly observe distinct peaks for each of the solvents. In converse, by measuring the spectrum we are able to infer about the composition of the solvent in question. Figure 3(c) shows the timeline of an experiment, wherein the flow cell is first filled with PBS (water based buffer) and then after a certain time point, ethanol is introduced. Using FTIR spectroscopy in real-time, we can observe the replacement of water with ethanol from the IR spectrum as shown in Figure 3(d) and (e). Please note that the measurement volume in this case is extremely low due to the use of metasurfaces required for enhancing the IR signature.

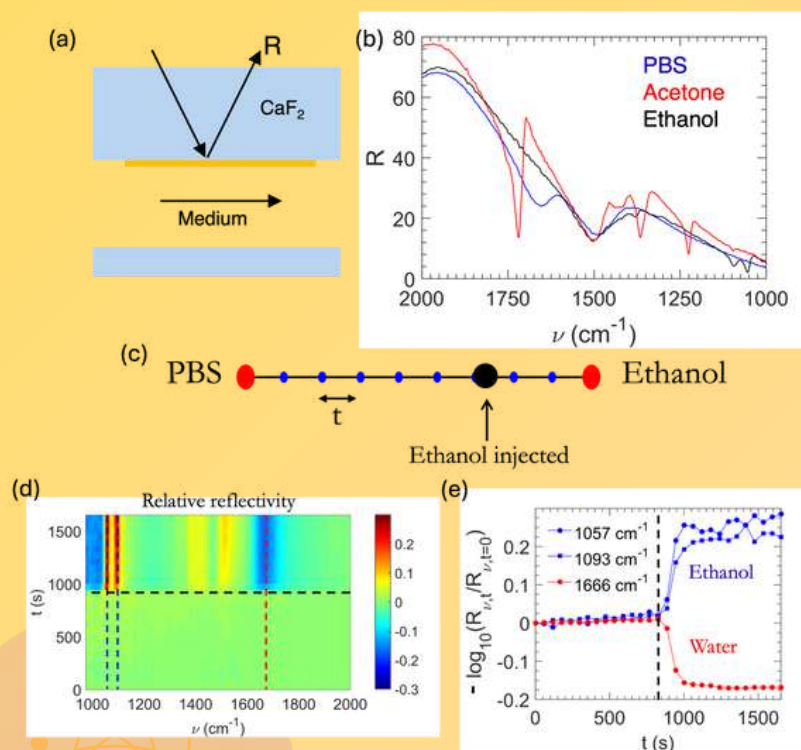


Figure 3. Identification of chemicals in various liquid mixtures. (a) Home made flow cell design wherein a liquid can be injected in to the IR measurement area. (b) FTIR reflection spectrum for three solvents (water, ethanol and acetone). (c) Time line showing the monitoring the exchange of solvents within the flow cell. After a certain time, ethanol is injected in to the flow cell and the FTIR spectrum is monitored in real time. (d) Colormap of change in reflection intensity as a function of wavenumber and time showing the displacement of water. (e) Reflection intensity change as a function of time at three different wavenumbers.

In conclusion, FTIR microspectroscopy is a powerful tool that can be used for analyzing the chemical composition of various materials especially at the microscopic scale. Additionally, combining the microFTIR system with flow cells (with IR transparent windows) allows us to monitor the IR spectrum of samples in in-situ conditions in real-time.

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Date : 15/02/2025 EditionName : TELANGANA(SANGAREDDY) PageNo : 02

NDSA urged to
act on safety of
Grisailam dam

Source : Gambar eddy Mardak (Sangar - Jay Mardak Elitistik) / Page
<http://www.sangarandanjyrdak.com>

- MoU signed in the presence of Union Minister Kishan Reddy
- IIT Hyderabad is to set up a Centre of Clean Coal Energy & Net Zero (CLEAN2) with Rs 98 crore

విద్యాభివృద్ధికి అంతర్జాతీయ సహకారం



IITH had the privilege of hosting the Hon'ble Vice-President of India, Shri Jagdeep Dhankhar who visited the campus and interacted with students and faculty members



IITH proudly hosted The PAN IIT Satellite Session with the theme "A Smarter World: AI as the Tool, Industry 5.0 as the Path"



Reminiscence of a Remarkable iCoRD'25 Journey held at IITH



IITH and Marvell Technology Co-hosted MLNetSec Workshop at ICDCN 2025



iTIC, IITH hosted the International SPARC Workshop on Translational Bio-Nano Medical Systems



IITH hosted an engaging Road User Safety Event





IITH proudly honoured Shri K S Ravindra Babu, for his unwavering dedication and exemplary service, celebrating his lasting legacy

IITH hosted the Australia-India Critical Minerals Research Hub (AICMRH) two-day workshop in collaboration with Monash University



ISRO unravelled latest version of "FEAST" analysis software with more features towards Athmanirbharath at the 8th NAFED08 hosted by IITH



IITH Successfully conducted Plantation Drive the first quarter of the year



January month of Plantation Drive



February month of Plantation Drive



March month of Plantation Drive

School Visits



Meru International school students visit to IITH



District welfare Department students visit to IITH



Deeksha organized by RDC and Prayas, inspired students to pursue education and strive for excellence, providing guidance and exposure for a brighter future!



**11TH ANNUAL MEETING OF THE INDIAN CHAPTER OF
INTERNATIONAL SOCIETY FOR MAGNETIC
RESONANCE IN MEDICINE (ISMRM)**
27 FEBRUARY - 01 MARCH 2025 | IIT HYDERABAD



*The 11th Annual
Meeting
of the Indian Chapter
of
the International
Society
for
Magnetic Resonance
in Medicine (ISMRM)
held at
IIT Hyderabad*



76th Republic Day Celebrations at IITH

Elan & nVision 2025 – A Spectacular Success!
IIT Hyderabad's annual techno-cultural fest, A Space Odyssey, lit up the campus from 21st to 23rd February 2025, leaving behind unforgettable memories of innovation, creativity, and celebration!





The spectacular performance by Miracle on Wheels India's first Wheelchair Dance Theatre was successfully held at IIT Hyderabad



An enchanting evening of soulful music unfolded at IIT Hyderabad with a mesmerizing Qawwali performance by the renowned Warsi Brothers



SPICMACAY IITH organized a curtain-raiser event with a mesmerising Pandavani performance by Smt Ritu Verma bringing the Mahabharata to life



IITH hosted the curtain raiser event of the 10th International Convention of SPIC MACAY with a mesmerizing shower of music by Shri Ustad Amjad Ali Khan



Family Get-Together 2025 at IIT Hyderabad! A joyful day filled with fun, laughter, and bonding as the IITH family came together to create unforgettable memories



*IIT Hyderabad Celebrated "Diesta'25"
The Inter Departmental Sports and Cultural fest*



Yoga and Meditation session and an interaction session on "Vedic way of life" by Sri Swami Parmarthdev ji, Patanjali Yogpeeth Haridwar



Glimpses of Ottan Thullal at IITH by Kalamandalam Mohan Krishnan, Kalamandalam Suresh Kaliyath & Kalamandalam Anirudh from SPICMACAY



IIT Hyderabad hosted a mesmerizing "Classical Piano Concert" featuring Martin Helmchen



Dean ITS Office along with IIC organized "Start Up & Innovation Ecosystem" at IITH on the occasion of "National Startup Day"



A lecture series by subject experts from the UK on "Challenges and Opportunities in the Application of Extended Reality (XR) in Sport and Exercise"



Workshop on "Empowering Startups in the 5th Industrial Revolution: Opportunities, Challenges, and the Digital Mindset"



IITH Secures an Overall 7th Rank at InterIIT Tech Meet 13.0



Workshop on "Disruptions in Entrepreneurship" by Mr Indraneel Ganguli, Global Head: Brand and communications at Sutherland



Tinkerer's Lab & IIC conducted a workshop on Problem Solving, Troubleshooting in AIML and Deep Learning in IITH by Mr Aayush Adlakha



Prof. Murty, Director of IITH, felicitated the winners of the Road Safety Quiz



IITH Expands its Innovation Hub! TRP Extension Facility was inaugurated at IITH Technology Research Park



An Indo-German initiative, "Heidelberg-Hyderabad Hub in Advanced Chemical Education" (H-3ACE) at IIT Hyderabad



SIMMECT – Swinburne-IITH Manufacturing, Materials, Energy, and Communication Technologies an IITH-Swinburne University Joint Research Institute



The Vision Viksit Bharat @2047 international conference was held at IITH, focusing on gender dynamics and empowerment through CCTs and Beti Bachao-Beti Padhao



Health talk on General awareness of Cancer by Dr Vindhya Vasini Andra, Consultant Medical Oncologist, Omega Hospitals, in observance of World Cancer Day



Entrepreneurship lecture on "IP Commercialization & Opportunities" by Dr Amaresh Panda Lead RTTO



IITH in collaboration with Marvell Technology, has inaugurated India's first Data Acceleration and Offload Lab at the Dept of Computer Science & Engineering



IIT Hyderabad hosted Safer Internet Day on February 2025, bringing together experts, students, and faculty to discuss online safety, data privacy, and responsible digital habits



IIT Hyderabad Team Met JST President, Dr Kazuhito Hashimoto to strengthen the research collaborations between IITH and Japan



IISAA - Hyderabad Chapter was launched at IIT Hyderabad, celebrating IISc Founder's Day with alumni, networking, and inspiring conversations



IITH in association with INYAS, inaugurated SCOPE a 5-day workshop on Science Communication for STEM faculty under



IIT Hyderabad hosted a fruitful meeting with delegates from various German Universities and the DAAD team to foster academic collaboration



The PMRF Annual Symposium was successfully conducted at IIT Hyderabad



On the Occasion of "International Women's Day, Half-Day Seminar" was organized by Dr Srividya Ramakrishnan, Global Head



Workshop on How to plan a start-up and legal and Ethical steps at IIT Hyderabad



Prof Murty, Director of IITH, felicitated the winners of the Road Safety Quiz



IIT Hyderabad Team Met JICA President Dr TANAKA Akihiko to strengthen the research collaboration between IITH and Japan



*Workshop on "Business Model Canvoas"
at IIT Hyderabad*



*Workshop on "Proteting Intellectual Property Rights and IP
Management for Startups"
at IIT Hyderabad*



*Workshop on "Prototype/Process Design and Development" at
IIT Hyderabad*



*Workshop on "Raising Capitaland Managing Financefor
Startups" at IIT Hyderabad*



*Workshop on Mastering ChatGPT and AI Tools" at IIT
Hyderabad*



*Session on
"Hackathon - Partnered with BOSCH"
at IIT Hyderabad*



*AutoExpo at IIT Hyderabad, organized under the banner of
IIC, brought innovation to life — quite literally*



*Session on "Robotics Expo"by Mr Aurobindo Maharana
Professional Robotics Demonstrators &
Event Organizers*



IIT Hyderabad has signed an MoU with Energy Efficiency Services Limited (EESL) a PSU under the Ministry of Power, Govt. of India, to drive Energy Efficiency and foster innovation through knowledge & technology exchange



IIT Hyderabad signed an MoU with Nara Women's University



IIT Hyderabad signed student Exchange Agreement with Kyoto University



IIT Hyderabad & Coal India Limited joined Forces to establish Centre of Excellence on Clean Coal Energy & Net Zero



IIT Hyderabad and Spanda.ai (USA) signed an MoU to develop AI-powered Sustainable Digital Twin Cloud Services for the Built Environment



IIT Hyderabad Team visited the Institute of Science Tokyo, Japan to discuss the mutual Research Collaboration



IIT Hyderabad Team visited AGC, Japan and discussed mutual Research Collaborations



Prof C Malla Reddy
Department of Chemistry
Elected as Fellow of Indian Academy of Sciences (FASc)



Prof Mahendrakumar Madhavan
Department of Civil Engineering
Elected as a fellow of the Institution of Structural Engineers (FIStructE), UK and a Chartered Structural Engineer (CEng)



Prof Sai Santosh Kumar Raavi
Department of Physics
Selected for the prestigious JSPS Invitational Fellowship for FY 2025 to conduct research collaborative work with Kyushu University, Japan



Dr Nithyanandan Kanagaraj
Assistant Professor, Department of Physics
Was awarded Senior Membership by the International Society for Optics and Photonics (SPIE)



Dr Debaditya Roy
IITH Alumnus, Department of Science and Engineering
Joined as an Assistant Professor at IIT Kharagpur



Mr Daideep Kumar
PhD Scholar, Department of Physics
*Received the Best Poster prizes at two international conferences
(a): AAPPS-DPP 2024 plasma physics conference held in Malaysia
(b): ASILS-13 conference held in Udaipur, Rajasthan*



Dr Anjishnu Choudhury
IITH Alumnus, Department of Mechanical and Aerospace Engineering
Appointed as an Assistant Professor at IIT Bombay



Mr Vineet Gairola
PhD Scholar, Department of Liberal Arts
Received the International Relations Committee (IRC) of the Society for Psychoanalysis and Psychoanalytic Psychology (Div. 39) of APA 2025-2026 IRC Scholar Award



Mr Daideep Kumar Balusu
PhD Scholar, Department of MSME
Received Best Poster Prize Award at the AAPPS-DPP conference (8th Asia-Pacific Conference on Plasma Physics) held at Malaysia



Mr Sahil Dhiman
IITH-Deakin JDP student, Department of Mechanical & Aerospace Engineering
Received the Best Poster Award in 30th International Conference on Processing of Advanced Materials and Fabrication of Products



Mr Shubham Bhoi
Research scholar, Department of Chemistry
Received Best Poster Presentation Award at International Conference on Next Generation Sustainable Materials for Water and Energy Solutions (SuWatE' 24)



Ms Shruti Moorthy
PhD Scholar, Department of Chemistry
Received Best Poster Presentation Award at "MTMM-SiMS 2024" held at the Indian Institute of Science, Bangalore



Mr Vaibhav S Marde
Research Scholar, Department of Chemistry
Received the Best Poster Presentation Award at the conference entitled "New Approaches in Material Fabrication for Environmental Clean-up & Impacts on Human Health"



Mr Subha P
Research Scholar, Department of Chemistry
Received the Best Oral Presentation Award along with a cash prize of Rs.1000 at the 43rd Annual National Conference organized by the Indian Council of Chemists (Analytical and Environmental Chemistry Section),"



Mr Soumyaranjan Behera
Research Scholar, Department of Chemistry

Received the Best Poster Presentation Award at the International Conference on Next Generation Sustainable Materials for Water and Energy Solutions (SuWatE' 24)



Ms Utkarsha Mahanta
PhD Scholar, Department of Biotechnology

Secured Second Position for the Poster Presentation at the INBIX-ADNAT 2024 international scientific conference Titled: "Integrating Archaeogenetics, Forensics & Multi-omics for Human Health Breakthrough" organized by Banaras Hindu University



Mr Pravat Kumar Sahu
PhD Scholar, Department of Chemistry

Received RSC Analyst poster presentation award at a conference entitled "DAE-BRNS Conference on Electrochemistry for Industry, Health, and Environment (EIHE-2025)"



Mr Saibal Saha
PhD Scholar, Department of Biotechnology

Received the 2nd Prize in Poster Presentation at the European Molecular Biology Organization (EMBO)



Ms Sakshi Manekar
PhD scholar, Department of Chemical Engineering

Received the Best Oral Presentation in DST-PURSE supported 24th National Symposium on Catalysis (CATSYMP-24) on "Catalysis for Sustainable Chemicals, Materials & Energy (CSCME-2025)"



Ms Monica Gunasingh
PhD Scholar, Department of Biomedical Engineering

Received the Best Oral Presentation Award at 11th Annual Scientific Meeting of the Indian Chapter of the International Society of Magnetic Resonance in Medicine, hosted at IIT Hyderabad



Ms Saanya Yadav
PhD scholar, Department of Biotechnology

Received the Best Poster Award at the 47th Indian Biophysical Society meeting held at IIT Madras from 6-9 March 2025



Mr Amitkumar Girbide
PhD Scholar, Department of Chemistry

Received the Best Poster Presentation Award & cash prize at the International Conference on the Main Group Molecule to Materials (MMM-4, 2025) held at IIT Bombay from 9th to 12th February 2025



Ms Swapna Bhattu
PhD Scholar, Department of Chemistry

Received the Best Oral Presentation Award at the 2nd International Conference on Impending Inquisitions in Humanities and Science (ICIHS)



Mr Vishnu K
MTech student, Department of Mechanical & Aerospace Engineering

Received the Best Oral Presentation Award at the International Conference on Laser and Other Deposition Techniques (iCOLD25)



Mr Mudavath Arun Kumar
Research scholar, Department of Chemistry

Received the Best Oral Presentation Award at the "VALORIZATION 2025: International Conference on Science & Technology Integration for Circular Economy."



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