

September 16th-19th, 2025
Valencia / Spain
Marie Curie Auditorium
Scientific Park



Website

EU-FIB.net
WORKSHOP 2025

Organised by

eufn
EUROPEAN FIB NETWORK

ICMOL

VNIVERSITAT
ID VALÈNCIA

EXCELENCIA
MARIA
DE MAEZTU

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Scientific Committee



Dr. Gregor Hlawacek
Helmholtz Zentrum
Dresden. Rossendorf
e.V., Germany



Dr. Petr Bábor
CEITEC, IPE Brno
University of Technology,
Czech Republic



Prof. Philip Moll
Max Planck Institute
for the Structure and
Dynamics of Matter,
Germany



Dr. Aleksander B. Mosberg
NTNU NanoLab,
Norway



Dr. Rosa Córdoba
Institute of Molecular
Science (ICMol),
University of Valencia,
Spain



Dr. Katja Höflich
Ferdinand-Braun-Institut
Humboldt, Universität zu
Berlin, Germany



Prof. Gerhard Hobler
TU Wien,
Austria



Dr. Gregor Weiss
ETH Zürich,
Switzerland



Dr. Alexandra Frackiewicz
CEA leti, France



Dr. Jack Donoghue
University of Manchester
England, UK



Scientific Committee

Local Committee



Dr. Rosa Córdoba
Institute of Molecular
Science (ICMol),
University of Valencia,
Spain



Alba Arroyo Fructuoso
Institute of Molecular
Science (ICMol),
University of Valencia,
Spain



**Dr. Alejandra Soriano
Portillo**
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**Juan José Munafo
Horta**
Institute of Molecular
Science (ICMol),
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**Francisco Escrig
Escrig**
Institute of Molecular
Science (ICMol),
University of Valencia,
Spain



Dr. Ana Galet Domingo
Institute of Molecular
Science (ICMol),
University of Valencia,
Spain



Local Committee

Instructions for Presenters

Instructions for Presenters – 2025 EU-FIB.net Workshop

To ensure a smooth and timely program, please read and follow the guidelines below carefully.

General Information

- A laptop will be available in the conference room for presentations.
- All presenters must upload their presentation onto the provided laptop and check that it runs correctly before their session.
- If a presenter prefers to use their own laptop, they must:
 - Bring all necessary adapters/connectors (e.g. HDMI, USB-C, VGA, etc.)
 - Test their setup before the start of the session to ensure compatibility and smooth functioning.

Talk Duration

- Invited Speakers:
 - Presentation time: 25 minutes
 - Q&A: 5 minutes
- Tutorial Speakers:
 - Presentation time: 25 minutes
 - Q&A: 5 minutes
- Industrial Communications:
 - Presentation time: 15 minutes
 - Q&A: 5 minutes
- Oral Communications:
 - Presentation time: 15 minutes
 - Q&A: 5 minutes

Please respect the allocated time to help us keep the program on schedule.

Poster Presentations

- Posters must be printed in A0 size (84.1 x 118.9 cm, portrait orientation).
- Posters should be mounted on Tuesday during the coffee break, so they are ready and visible at the beginning of the poster session.

Final Note

We kindly ask all participants to adhere strictly to these guidelines. The program is tightly scheduled, and delays cannot be accommodated.

Thank you for your cooperation!

Instructions for Social Activities

Instructions for Social Activities – 2025 EU-FIB.net Workshop

We are delighted to share the schedule of social activities planned throughout the workshop. These events are intended to foster networking, informal discussions, and to give you the opportunity to enjoy the city of Valencia in a relaxed atmosphere.

Tuesday, 16 September – Welcome Cocktail & Poster Session

- Time: 18:00
- Location: Garden area outside

The Welcome Cocktail will take place at 18:00, in parallel with the Poster Session. This format will allow all participants to engage with the posters in a friendly and informal setting. After the cocktail, participants will have free time to return to their hotel or explore the city of Valencia at their own pace.

Wednesday, 17 September – Guided Tour of the City of Arts and Sciences

- Bus departure: 18:10 from the main entrance of the Scientific Park.
- Tour start: 18:30 (approx. 2 hours) at CaixaForum (starting point of the tour).

We will enjoy a guided walking tour of the City of Arts and Sciences, one of Valencia's most iconic landmarks.

If you wish to use the bus service, please indicate this during your registration on Tuesday September 16th.

Participants who prefer to go on their own can meet directly at the CaixaForum at 18:30.

After the tour, you may wish to take a relaxing walk along the old Turia riverbed.

Thursday, 18 September – Workshop Dinner

- Time: 20:30
- Venue: Ateneo Restaurant, 6th floor, Ateneo Mercantil Building (Plaza del Ayuntamiento 18, Valencia).
- Bus departure:
 - 18:30 from the main entrance of the Scientific Park
 - 19:45 from Hotel Por Fera
 - 20:00 from Hotel Novotel Valencia

Buses will drop participants as close as possible to the restaurant.

The Workshop Dinner will be held at the Ateneo Restaurant, located in the heart of the city, offering wonderful views over Town Hall Square.

After dinner, you are welcome to return to your hotel or take advantage of the central location to enjoy Valencia's historic center.

Important Notes

- The bus service is provided only for the outbound trip. Return transportation is the responsibility of each participant.
- The tram stop Santa Gema – Parc Científic is located just a few meters from the main entrance of the Scientific Park
- Punctuality is essential: the schedule is tight, and buses will depart on time.

We very much look forward to sharing these special moments with you and we hope you enjoy both the scientific program, and the social experiences that Valencia has to offer.

Thank you for your cooperation!



Venue & Contact

The workshop and welcome cocktail will take place in the Marie Curie Auditorium, located at Catedrático Agustín Escardino Benlloch 9 in the 1 SC building (2nd floor) of the Scientific Park in Paterna.

Marie Curie Auditorium
Scientific Park
Catedrático Agustín Escardino Benlloch 9
46980 Paterna
Valencia
Spain



Scan the QR code and
access the map

How to arrive:

By car:

From Valencia take CV-35 towards Avinguda de l'Universitat in Burjassot.
Take exit 4AB from CV-35. Follow Avinguda de l'Universitat to the Parc Científic de la Universitat de València (gray buildings).

By public transport:

The tram line that will take you to the Parc Científic de la Universitat de València is (Line 4)
The nearest tram stop is Santa Gemma - Parc Científic UV (Trains to Mas del Rosari).
Alternatively, the À Punt stop on the same line 4 will leave you less than 5 minutes away on foot.

Venue for the workshop dinner:
Ateneo Restaurant



Plaça de l'Ajuntament, 18, Sexta
Planta, 46002 València, Valencia



Guided tour of the City of Arts and Sciences – 2h
September 17th



Invited Speakers



ADAMSKI, FRÉDÉRIC

Safran Tech
Paris, France



ALLEN, FRANCES

University of California
Berkeley, USA



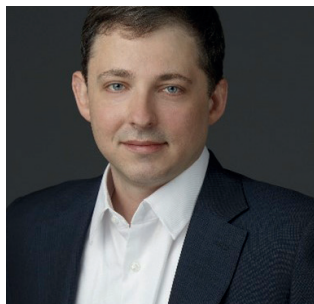
BELIANINOV, ALEX

Sandia National
Laboratories
Albuquerque, USA



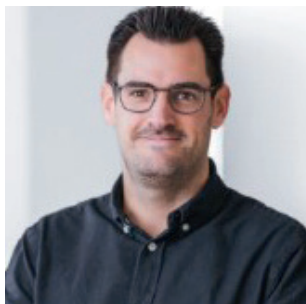
BOTHNER, DANIEL

Universität Tübingen
Tübingen, Germany



CYBART, SHANE

University of California
Riverside, USA



DE CASTRO, OLIVIER

Luxembourg Institute of
Science and Technology
(LIST), Luxembourg



**FRACZKIEWICZ,
ALEXANDRA**

CEA-Leti
Grenoble, France



HOUËL, ARNAUD

Orsay Physics
Fuveau, France



KASTL, CHRISTOPH

Walter-Schottky-
Institute (Technical
University of Munich)
Munich, Germany



**PICCIRILLO,
JONATHAN GABRIEL**

CNB-CSIC
CryoEM Facility
Madrid, Spain



RAGUIN, EMELINE

Max Plank Institute for
Colloids and Interfaces
Golm, Germany



ZHAKINA, ELINA

Max Plank Institute
Dresden, Germany

Tutorial Speakers



DONOGHUE, JACK

University of Manchester
Greater Manchester,
England



OSENBERG, MARKUS

Helmholtz-Zentrum
Berlin für Materialien und
Energie (HZB)
Berlin, Germany



Invited Speakers



Tutorial Speakers

Scientific Program

Tuesday, 16 September



Invited Talk



Industry Talk



Tutorial Talk



Oral Talk

11:00 - 18:00	Registration	
14:00 - 14:30	Welcome	
14:30 - 15:00	30 min	Arnaud Houël
15:00 - 15:20	20 min	Amina Zid
15:20 - 15:40	20 min	Ashwini Vaishnav
15:40 - 16:00	20 min	Janos Metzger
16:00 - 16:30	Coffee Break	
16:30 - 17:00	30 min	Olivier De Castro
17:00 - 17:20	20 min	Alix Tatiana Escalante
17:20 - 17:40	20 min	Laurencich Marine
17:40 - 18:00	20 min	Peter Gnauck
18:00 - 19:30	Poster Session	
18:00 - 20:00	Welcome Cocktail	

Wednesday, 17 September

9:00 - 9:30	30 min	Shane Cybart
9:30 - 9:50	20 min	José María De Teresa
9:50 - 10:10	20 min	Alba Arroyo-Fructuoso
10:10 - 10:30	20 min	Min Wu
10:30 - 11:00	Coffee Break	
11:00 - 11:30	30 min	Elina Zhakina
11:30 - 11:50	20 min	Andreas Johansson
11:50 - 12:10	20 min	Elyas Khairi
12:10 - 12:30	20 min	Lucía Herrer
12:30 - 13:00	30 min	Jack Donoghue
13:00 - 14:30	Lunch Break	
14:30 - 15:00	30 min	Christoph Kastl
15:00 - 15:20	20 min	Urszula Nawrot
15:20 - 15:40	20 min	Ewelina Gacka
15:40 - 16:00	20 min	Alessandro Cian
16:00 - 16:20	20 min	Milos Hrabovsky
16:20 - 16:50	Coffee Break	
16:50 - 17:20	30 min	Alex Belianinov
17:20 - 17:40	20 min	Elia Scattolo
17:40 - 18:00	20 min	Valentine Riedo
18:30 - 20:30	Cultural visit	
21:00	EU-FIB.net Steering Committee Meeting (on invitation only)	

Scientific Program

Thursday, 18 September

9:00 - 9:30	30 min	Emeline Raguin
9:30 - 9:50	20 min	Till Leissner
9:50 - 10:10	20 min	Jean-Nicolas Audinot
10:10 - 10:30	20 min	Andrew Jonathan Smith
10:30 - 11:00	Coffee Break	
11:00 - 11:30	30 min	Alexandra Fraczekiewicz
11:30 - 11:50	20 min	Amaia Sáenz-Hernández
11:50 - 12:10	20 min	Bailiang Li
12:10 - 12:30	20 min	Umutcan Bektas
12:30 - 13:00	30 min	Markus Osenberg
13:00 - 14:30	Lunch Break	
14:30 - 15:00	30 min	Daniel Bother
15:00 - 15:20	20 min	Katja Höflich
15:20 - 15:40	20 min	David Jamieson
15:40 - 16:00	20 min	Maddison Coke
16:00 - 16:20	20 min	Tanguy Roche
16:20 - 16:50	Coffee Break	
16:50 - 17:20	30 min	Jonathan Gabriel Piccirillo
17:20 - 17:40	20 min	Ayanesh Maiti
17:40 - 18:00	20 min	James Douglas
20:30	Workshop Dinner	

Friday, 19 September

9:00 - 9:30	30 min	Frédéric Adamski
9:30 - 9:50	20 min	Kevin Fuchs
9:50 - 10:10	20 min	Adrien Delga
10:10 - 10:30	20 min	Kirill Atlasov
10:30 - 11:00	Coffee Break	
11:00 - 11:30	30 min	Frances Allen
11:30 - 11:50	20 min	Aydin Sabouri
11:50 - 12:10	20 min	Marie Jose Saleh Afif
12:10 - 12:30	Awards Ceremony	
12:30 - 13:00	Closure	



Program

DetailedScientific Program

Tuesday, 16 September		
11:00 - 18:00		Registration
14:00 - 14:30		Welcome
14:30 - 15:00	Invited	Arnaud Houël - Development of a Molten Salt Ion Source For Sims Applications
15:00 - 15:20	Oral	Amina Zid - Development of Heavy Noble Gas Field Ion Sources Using An Iridium Coated Single Crystalline Tungsten Emitter
15:20 - 15:40	Oral	Ashwini Vaishnav - Controlling The Motion Of Charged Species With Chirped Optical Lattices
15:40 - 16:00	Industry	Janos Metzger- TOFWERK: A Global Leader in TOF Mass Spectrometry
16:00 - 16:30		Coffee Break
16:30 - 17:00	Invited	Olivier De Castro - Implementing Time-of-Flight Capability for Scanning Transmission Ion Microscopy – Towards Ion Energy Loss Spectroscopy
17:00 - 17:20	Oral	Alix Tatiana Escalante Quiceno - Magnetic Force Microscopy Probe Enhancement and Magnetic Multilayer Irradiation using Focused He ⁺ and Ga ⁺ Beam
17:20 - 17:40	Oral	Laurencich Marine - Study of Iridium Tips for the Coaxial Ion Source (CIS)
17:40 - 18:00	Industry	Peter Gnauck - High-Resolution Nano-Analytics using a Liquid Metal Alloy Ion Source LMAIS
18:00 - 19:30		Poster Session
18:00 - 20:00		Welcome Cocktail

Wednesday, 17 September		
9:00 - 9:30	Invited	Shane Cybart - Direct-Write Nanofabrication of Superconducting Devices with Focused Helium Ion Beams
9:30 - 9:50	Oral	José María De Teresa - Hybrid Josephson Junctions and Nanodevices Based on Micro-Crystals and FIBID-Grown Superconductors
9:50 - 10:10	Oral	Alba Arroyo-Fructuoso - Observation of Superconducting Diode Effect in 3D W-C Nanohelix
10:10 - 10:30	Industry	Min Wu - The History And Latest Advancement In FIB Technology
10:30 - 11:00		Coffee Break
11:00 - 11:30	Invited	Elina Zhakina - Superconducting Three-Dimensional Nanoarchitectures Using FEBID
11:30 - 11:50	Oral	Andreas Johansson - 2.5 Dimensional Graphene From Sculpting The Catalytic CVD Surface
11:50 - 12:10	Oral	Elyas Khairi - Optimizing Helium Ion Beam Milling to Minimize Beam Damage in the Patterning of Suspended hBN
12:10 - 12:30	Oral	Lucía Herrero - Precursor Film Thickness as a Determinant of Functional Properties in He-FIB-Fabricated Pd Nanostructures
12:30 - 13:00	Tutorial	Jack Donoghue - How To Destroy Your Sample And Learn Everything You Can While Doing So. 3D FIB-SEM: A Tutorial
13:00 - 14:30		Lunch Break
14:30 - 15:00	Invited	Christoph Kastl - Creation Of Functional Defects In Van Der Waals Materials By Focused He-Ion Beam Irradiation
15:00 - 15:20	Oral	Urszula Nawrot - Application of Focused Ion Beam Technology in the Fabrication of D-Shaped Optical Fiber Sensors
15:20 - 15:40	Oral	Ewelina Gacka - Prototyping of Field Emission MEMS Components using FIB Techniques
15:40 - 16:00	Oral	Alessandro Cian - Overcoming Fabrication Challenges Of Color Centers In Diamond With A Focused Ion Beam
16:00 - 16:20	Industry	Milos Hrabovsky - Robust FIB-SEM Automation for TEM Sample Preparation and Cross-Sectioning, with API-Enabled Support for User-Defined Workflows
16:20 - 16:50		Coffee Break

Detailed Scientific Program

16:50 - 17:20	Invited	Alex Belianinov - Low Energy Implantation with Focused Ion Beams
17:20 - 17:40	Oral	Elia Scattolo - Diamond Graphitization By Ion Implantation: Nano-Patterning And Electrical Circuit
17:40 - 18:00	Oral	Valentine Riedo-Grimaudo - Next Generation fibTOF For Faster FIB-SIMS
18:30 - 20:30	Cultural Visit	
21:00	EU-FIB.net Steering Committee Meeting (On invitation only)	

Thursday, 18 September		
9:00 - 9:30	Invited	Emeline Raguin - Correlative Cryogenic Imaging Approach For High-Resolution 3D Visualization Of Biological Samples
9:30 - 9:50	Oral	Till Leissner - Tuning the Optoelectronic Properties of ALD-Grown MoS ₂ Monolayers via Helium Ion Beam Irradiation
9:50 - 10:10	Oral	Jean-Nicolas Audinot - FIB meets Mass Spectrometry: Full-spectrum Imaging at the Nanoscale
10:10 - 10:30	Industry	Andrew Jonathan Smith - FIB Add-Ons for Enhancing and Expanding Workflows
10:30 - 11:00	Coffee Break	
11:00 - 11:30	Invited	Alexandra Fraczkiwicz - Selecting, Preparing, And Analysing A Needle In A Haystack : ECCI-Assisted TEM Sample Preparation
11:30 - 11:50	Oral	Amaia Sáenz-Hernández - Studying Bismuth Magnetotransport Properties In Different Crystallographic Directions Using FIB
11:50 - 12:10	Oral	Bailiang Li - Simulation of Plastic Flow and Diffusion in FIB Milling
12:10 - 12:30	Oral	Umutcan Bektas - Spatially Resolved Phase Transition and Characterization in Gallium Oxide
12:30 - 13:00	Tutorial	Markus Osenberg - Correlated Machine Learning Assisted FIB Tomography On Functional Materials
13:00 - 14:30	Lunch Break	
14:30 - 15:00	Invited	Daniel Bother - Josephson Microwave Circuits Enabled By A Focused Ion Beam
15:00 - 15:20	Oral	Katja Höflich - Advanced Fabrication and Characterization of Solid Immersion Lenses in Diamond
15:20 - 15:40	Oral	David Jamieson - Towards A Large-Scale Donor Qubit Array In Enriched Silicon Fabricated With A Focused Ion Beam System
15:40 - 16:00	Oral	Maddison Coke - Advances in Focused Ion Beam Materials Engineering
16:00 - 16:20	Industry	Tanguy Roche - New FIB-SEM by JEOL
16:20 - 16:50	Coffee Break	
16:50 - 17:20	Invited	Jonathan Gabriel Piccirillo - Reducing Artifacts in Cryo-FIB-SEM: Challenges in Processing Biological Samples
17:20 - 17:40	Oral	Ayanesh Maiti - Why Cryo-FIB Cuprates?
17:40 - 18:00	Oral	James Douglas - Applications Of Cryogenic Plasma Focused Ion Beam With High Vacuum Cryogenic Sample Transfers
18:30 - 20:00	Workshop Dinner	

Detailed Scientific Program

Friday, 19 September		
9:00 - 9:30	Invited	Frédéric Adamski - Industrial Applications of FIB-SEM in Material Science
9:30 - 9:50	Oral	Kevin Fuchs - Accelerating Material Characterization: Femtosecond Laser as a Complement to Correlative FIB and SEM Workflows
9:50 - 10:10	Oral	Adrien Delga - FIB Assisted Circuit Modification: A Nano-Surgery Tool For IC Designers
10:10 - 10:30	Industry	Kirill Atlasov - ZEISS Crossbeam for High-End Microscopy, Analytics and Sample Prep
10:30 - 11:00		Coffee Break
11:00 - 11:30	Invited	Frances Allen - Advancing FIB Beyond the Cut with Helium Ion Microscopy
11:30 - 11:50	Oral	Aydin Sabouri - Optimisation of charged particle optics with the differential algebra method
11:50 - 12:10	Oral	Marie Jose Saleh Afif - FIB-SEM: Challenges in Industrial Applications
12:10 - 12:30		Awards Ceremony
12:30 - 13:00		Closure

**You can access the
Scientific Program by
scanning the QR-code**



Poster Contribution

Poster presentations:

If your abstract was accepted as a poster, please prepare a vertical A0 poster; fixing material will be provided by the organizers.

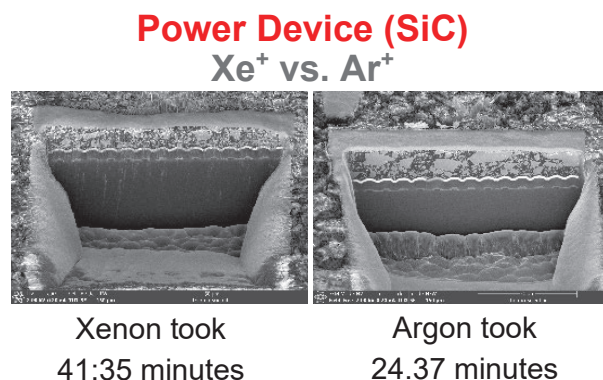
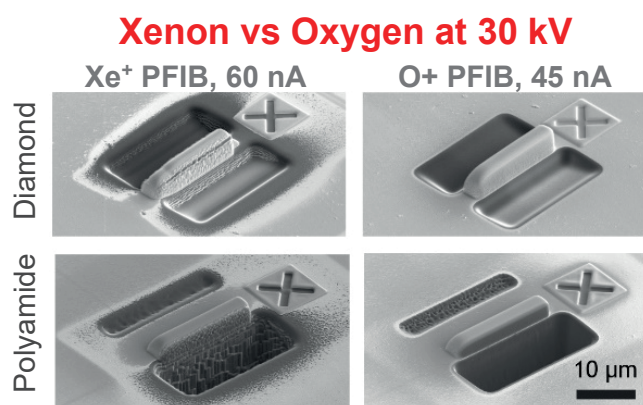
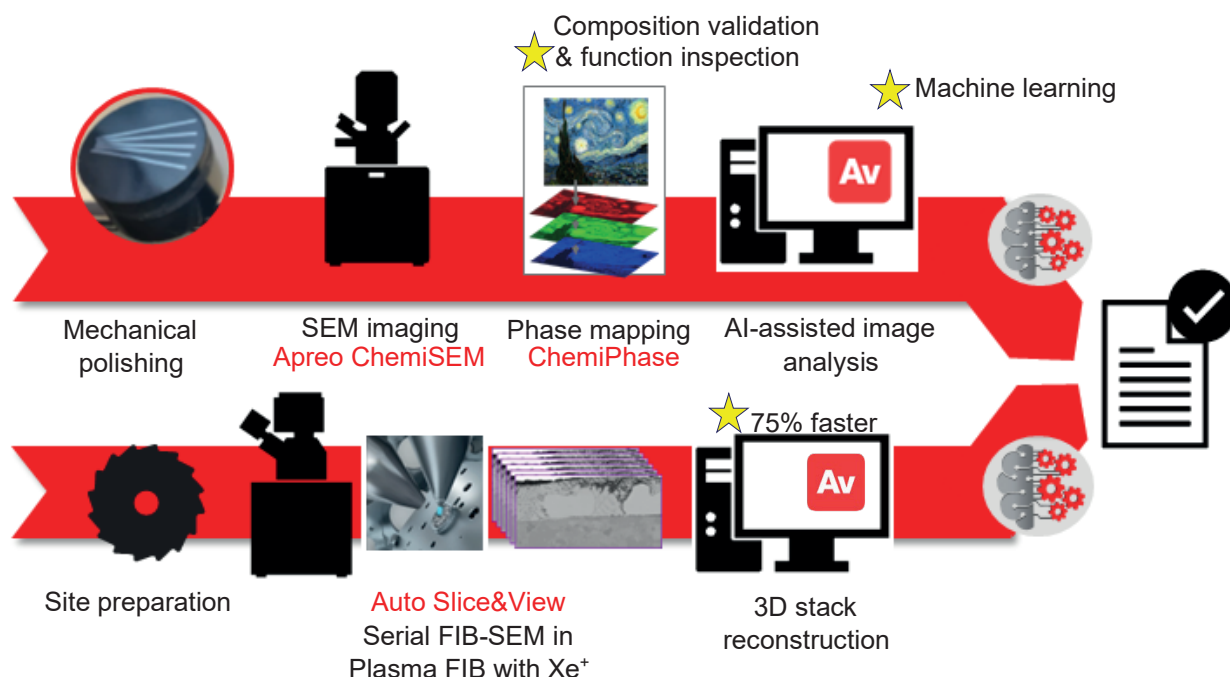
Nº	Author	Title of contribution	Affiliation
1	Alexander Spyrantis	Creation of quantum emitters in silicon carbide	Ferdinand-Braun-Institut (FBH), Berlin, Germany
2	Ana Galet	Investigating 3D nanostructures with diverse geometries for AFM Tip Development	ICMol (Institute of Molecular Science)
3	Andreu Estrela	3D nano-superconductors grown by He+ FIBID: a brief introduction	ICMol (Institute of Molecular Science)
4	Brandon Torrigino	Streamlining and Automation of Cryo-FIB Workflows with “EasyCryo”	Max Planck Institute For The Structure And Dynamics of Matter
5	Daniel Vasquez	Multi-Ion Plasma FIB for Advanced TEM Lamella Preparation	TU Darmstadt
6	JING WANG	Focused Ion Beam-based patterning of topological-insulator Bi ₂ Te ₃ thin films	Departamento de Física de la Materia Condensada, Zaragoza
7	Juan Ignacio Ocaña Parral	Direct-Write Fabrication of Silver Microstructures via FIB Irradiation of Organometallic Films	Instituto de Nanociencia y Materiales de Aragón (INMA)
8	Jyoti Verma	Radiation behaviour in coarse-grained and nanostructured Tungsten under He irradiation	Helmholtz Zentrum Dresden Rossendorf
9	Michal Moravec	Focused ion beam microstructuring for mesoscopic transport experiments	Max Planck Institute for Chemical Physics of Solids
10	Nico Klingner	Enabling Scalable Donor Spin Qubits in Silicon via Focused Ion Beam Implantation in TIBUSSII	Helmholtz-Zentrum Dresden-Rossendorf
11	Pilz Wolfgang	Comparison of imaging and milling using ion beams from Li-containing LMAISs FIBs and He and Ne ion beams provided by a GFIS based HIM system	Raith GmbH
12	Ryan Yang	Research Infrastructure Access in NANoscience & nanotechnology (RIANA)	Helmholtz Zentrum Dresden-Rossendorf
13	Shaun Boodram	Ion Implantation into Semiconductors using Ionic Liquid Ion Sources	University College London
14	Topeswar Meher	Effect of ion irradiation on the crystallization of Ge via AIILE process	Department of Pure and Applied Physics, India
15	Warres Clementine	Comparative Analysis of TOF-SIMS Depth Profiling and Mapping on TEM Lamellae for Solar Cell Characterization	NMI Natural and Medical Sciences Institute at the University of Tübingen
16	Zejun Shi	Fabrication of Pd nanostructures by focused ion beam irradiation of palladium acetate films	Departamento de Física de la Materia Condensada, Zaragoza

Sponsors



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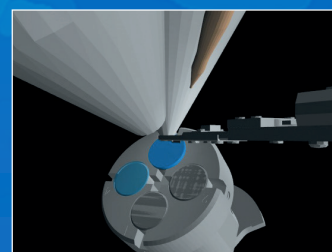
JIB-PS500i

High Performance FIB-SEM from JEOL technologies

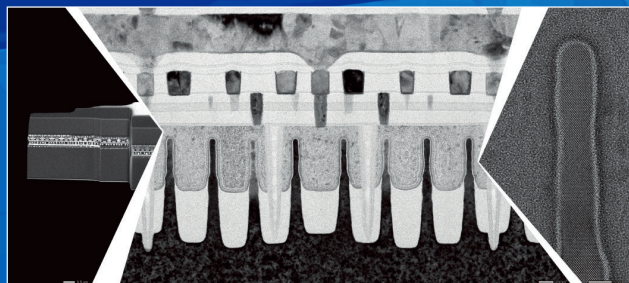
- Automatic TEM sample preparation
- 3D acquisition (imaging, EDS, EBSD)
- New EOS design with dual mode operation
- Check & Go directly from FIB to TEM
- Omniprobe integrated inside GUI



STEMPLING 2



New stage design



Check & Go directly from FIB to TEM



Large specimen chamber

www.jeol.com



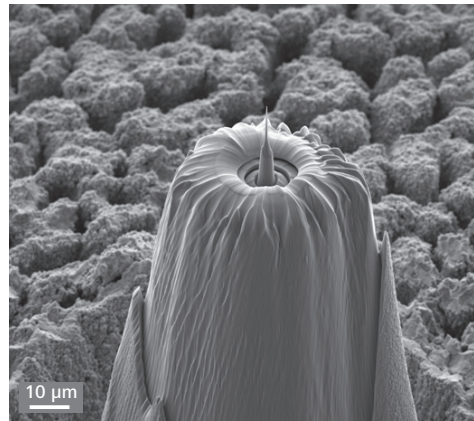
ZEISS Crossbeam

FIB-SEM for High Throughput 3D Analysis and Sample Preparation

Combine imaging and analytical performance of a high resolution field emission scanning electron microscope (FE-SEM) with the processing ability of a next-generation focused ion beam (FIB). You may be working in a multi-user facility, as an academic or in an industrial lab. Take advantage of the modular platform concept of ZEISS Crossbeam and upgrade your system with your growing needs, e.g. with the LaserFIB for massive material ablation. During milling, imaging or when performing 3D analytics Crossbeam will speed up your FIB applications.



- Maximize your SEM insights
- Increase your FIB sample throughput
- Experience best 3D resolution in your FIB-SEM analysis

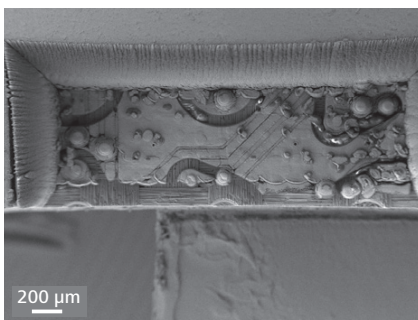


Preparation of an atom probe tomography (APT) sample using ZEISS Crossbeam laser

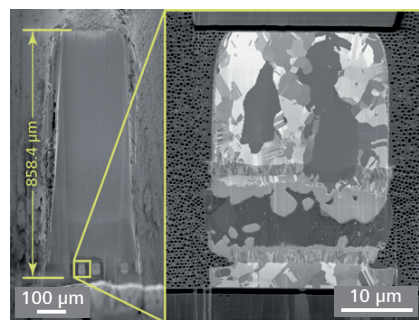
ZEISS Correlative Workflow with XRM and Crossbeam

Transform Your Sample Prep and Site-specific Analysis with Efficient Workflows

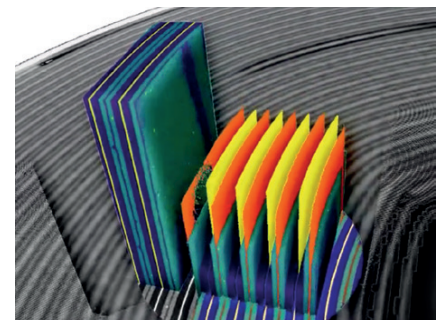
Micro- and nanomaterials are critical for improving the performance and reducing the energy consumption of electronic circuits and packages. Continued miniaturization creates new packaging requirements and enters the nanometer range. Advances in FIB-SEM and 3D X-ray microscopy have radically changed sample preparation and analysis. These advances open new possibilities for semiconductor research, development, and failure analysis.



Access using ZEISS Crossbeam laser FIB-SEM



Cu-pillar microbumps milled by fs-laser and polished by ion-beam using ZEISS Crossbeam laser



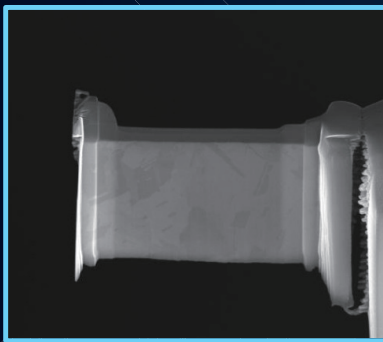
Li ion battery imaged by ZEISS Xradia Versa 3D X-ray microscope



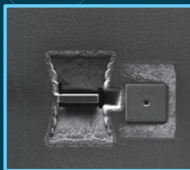
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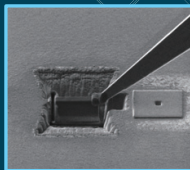
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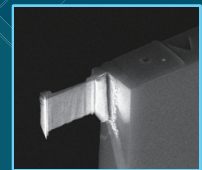
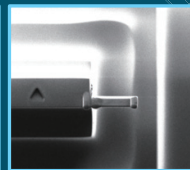
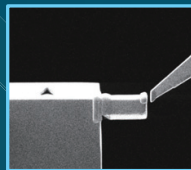
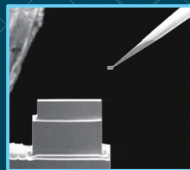
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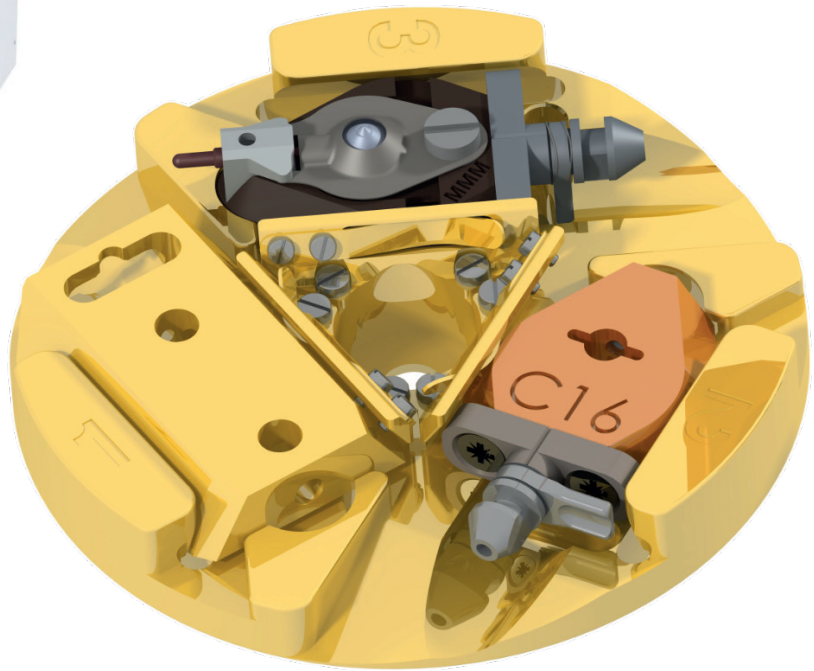
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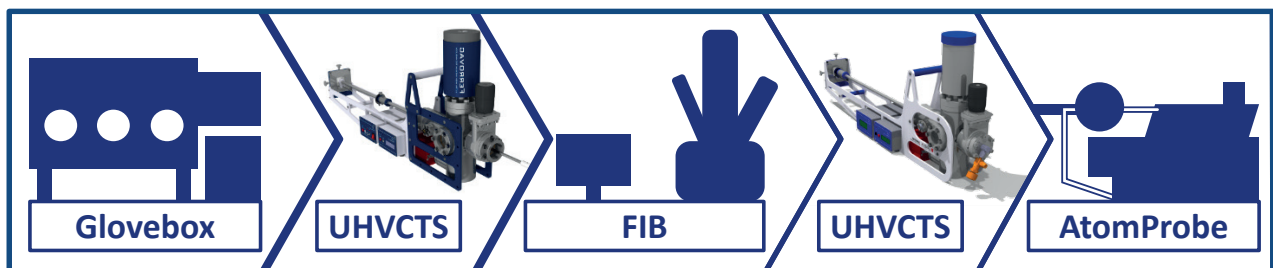
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Abstracts

Tuesday, 16th

DEVELOPMENT OF A MOLTEN SALT ION SOURCE FOR SIMS APPLICATIONS

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I will talk about results coming from our joint laboratory CICLOP, a collaboration between Orsay Physics and the CIMAP laboratory. The objective is to develop an ion source specifically tailored to the needs of SIMS (Secondary Ion Mass Spectrometry).

An ideal primary ion source for Secondary Ion Mass Spectrometry (SIMS), would combine the brightness and low energy spread of a Liquid Metal Ion Source (LMIS), with the availability of reactive elements as primary ions like Cs⁺ beam or non-metallic ones like Oxygen or reactive clusters. Instead of pure liquid metals, Liquid Metal Alloy Ion Sources (LMAIS) use liquid alloys based, for example, on gold-silicon eutectics to produce ion beams of different species, see L. Bischoff et al. for an extensive review [1]. While LMAIS sources are able to emit numerous ions like Li, Be, Ge. . . , Cs emitting LMAIS sources have to our knowledges not been reported, probably because they are as challenging to operate.

Since several years, Ionic liquid Ion Sources (ILIS) have been investigated as alternatives to LMIAS due to their low vapor pressure, chemical stability, low operating temperature and tunability via selection of cation/anion pairs and more recent works and results have been performed [2].

We present a proof of concept of an ILIS source using a molten salt mixture to produce a beam of desired alkali ions like Cs⁺ when polarized positively or oxygen complexes like NO₃⁻ when polarized negatively. Similar to liquid metal ion sources, the ions of the salt are emitted by field evaporation from a Taylor cone formed under the influence of an intense electric field, but unlike liquid metal sources, the meniscus of the Taylor cone is not anchored on the tip of a metal tip but rather on the tip of a conical glass capillary containing the molten salt. We succeeded in producing a stable ion beam emission in DC mode of several μ A for more than 200 μ A.h in both polarities. We will present the behavior of the source's operation and address some properties of ionic emissivity.

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Development of heavy noble gas field ion sources using an iridium coated single crystalline tungsten emitter

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Gas Field Ion Sources (GFIS) have already demonstrated their efficiency in nano imaging and patterning due to their high brightness, high current density and superior spatial resolution [1]. This type of ion source typically employs light noble gases such as helium and neon. In the first case negligible sputtering and fast diffusion enables image resolution as low as 0.5nm, while the latter allows high resolution milling of small nanostructures with resolutions better than conventional Liquid Metal Ion Source (LMIS). GFIS suffers from limitation in terms of material removal rate due to low current. Another limitation comes from the light ion species used, as well as bubble formation due to deep implantation making GFIS less efficient than LMIS for larger volume or high aspect ratio milling application with only shallow end of range defects. To overcome those limitations, we investigated GFIS performance in a Focused Ion Beam (FIB) using heavier noble gases, namely argon and xenon.

In addition, we consider an alternative emitter configuration. Historically, GFIS emitters are based on single-crystal tungsten tips while, we employed an iridium coated tungsten tip. Among noble metals, iridium confers the strongest bond with tungsten [2]. That particularity would allow the overall tip structure to withstand higher electric field than with any other noble metal coating. As a result, iridium coated tip enable higher beam currents without endangering the emitter stability. We also work with a single emission point (see Fig.1) opposed to the typically trimer configuration traditionally used in Helium Ion Microscope (HIM).

In this work we will present the first FIB evaluation and performances of this particular emitter using argon and xenon. Comparison to helium and neon based GFIS used in the HIM will also be covered.

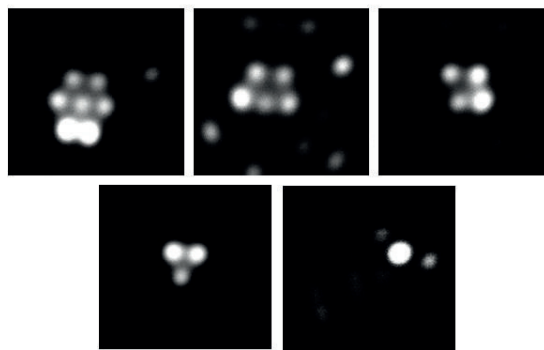


Figure 1 : Typical SFIM images following the formation of a single emission point using helium.

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Controlling the motion of charged species with chirped optical lattices

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Focused ion beam (FIB) instrumentation is a well-established and essential tool in applied research and industry applications. The diverse range of applications includes FIB based imaging, analysis, manipulation, and fabrication. The transfer of ions in FIB instrumentation is based on charged particle optics (CPO), a framework to study charged particle trajectories as they pass through electric fields, magnetic fields or a combination of both. CPO principles could also be used to tailor fields required to guide and focus ion beams. A persistent challenge in ion beam-based systems is to focus the beam into a narrower probe size at the sample to enhance the lateral resolution. The smallest achievable probe diameter is limited by a few factors including the randomness in ion energies originating inherently from the ionization process [1]. Ions having different energies are focused at different distances on the optical axis limiting the ultimate resolution, precision and efficiency. This effect named chromatic aberration is a function of the relative energy spread ($\Delta E/E_0$) of ions [2]. The chromatic aberration effect strongly affects the performance of low energy ($< 2\text{keV}$) ion beams systems [1] used for applications requiring low ion penetration depths or treating sensitive materials (i.e., 2D, soft or tissue samples). Efforts have been made to improve ionization methods and ion sources to reduce $\Delta E/E_0$ however, these are source or species specific. Ion columns in commercial FIB instruments usually do not correct for chromatic aberration post ionization [1].

We propose a novel approach to mitigate the energy spread post ionization by coupling the ion beam with two intense ($\sim 10^{14}\text{W/m}^2$), chirped, nanosecond pulsed laser beams. The intersecting laser beams create spatially moving interference pattern if they have a relative frequency difference between them. The velocity of the interference pattern depends on the relative frequency difference and the laser intersection angle. Polarizable ions interact with the laser fields via dipole interaction, resulting in a periodically varying polarizability-dependent interaction potential known as an optical lattice. The lattice could be accelerated/decelerated by varying the frequency difference over time (i. e., chirp). Such lattice can trap the ions via the interaction potential and drag (accelerate/decelerate) them as it moves [2, 3]. By designing a specific chirping scheme over time, the ion population could be transferred from the periphery of the initial velocity distribution function (VDF) to near its centre, resulting ultimately in a reduction of both, the width of the VDF and the relative energy spread.

We present the progress towards the development of a working prototype demonstrating VDF modulation via chirped optical lattices. The discussion includes lattice-ion interaction modelling, simulation results, the proposed design and operation scheme for the prototype, the laser system capable of delivering laser beams of required intensity and frequency chirp.

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TOFWERK: A Global Leader in TOF Mass Spectrometry

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Implementing Time-of-Flight Capability for Scanning Transmission Ion Microscopy – Towards Ion Energy Loss Spectroscopy

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Built on a focused ion beam (FIB) platform with a gas field ion source (GFIS), the combination of secondary electron (SE) imaging coupled with scanning transmission ion microscopy (STIM) has proven to be very useful for advanced studies in materials science and beyond [1, 2, 3]. Furthermore, implementing Time-of-Flight (ToF) measurements within the STIM setup will extend the analytical capabilities of the platform towards ion energy-loss spectroscopy (IELS), with the potential to provide complementary information to more standard techniques like electron energy-loss spectroscopy (EELS). During transmission, the ions interact with the sample and are capable of both charge loss or gain, leading to charge exchange processes and neutralization [4]. Moreover, during the interaction, sample atoms' electron orbitals can temporarily merge with those of the incoming ions (possibly leading to ion-induced Auger electron emission), as well as sample atoms being ejected (detectable with mass spectrometry [1]). These processes, many not being accessible to primary electrons, lead to an energy loss of the primary ions measurable as an increased ToF from sample to transmission detector. Furthermore, the recorded scattering pattern not only contains detailed information about the crystal structure, but also the internal particle trajectories within the sample [5]. By combining scattering (2D detector position) with spatially resolved (2D sample position) ion energy-loss (ToF) information thus a rich 5D dataset is obtained and can be explored.

The work presented here focuses on highly laterally resolved STIM investigations coupled to ToF measurements. Sub-50 keV He⁺ ions are used, which are particularly well suited for this purpose due to their relatively small scattering cross section (allowing thicker samples) and low induced sample damage. The capabilities and limitations of the employed setup for these kinds of studies will be explored by analysing the angular and energy-loss distributions of the transmitted helium ions and neutrals for initial proof-of-concept samples (starting with materials-science related samples).

The authors acknowledge funding from the Luxembourg National Research Fund (FNR) AIMSTHIM2 (C21/MS/16215748).

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Magnetic Force Microscopy Probe Enhancement and Magnetic Multilayer Irradiation using Focused He⁺ and Ga⁺ Beam.

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Advanced lithographic techniques are fundamental to semiconductor technology and the miniaturization of electronic devices. Among these, focused ion beam (FIB) processing has emerged as a versatile tool for both material modification and nanostructure fabrication, enabling high-resolution patterning, localized milling, and controlled ion implantation [1]. In this context, the processing of magnetic materials by FIB techniques, especially using light ions such as He⁺, is attracting growing attention due to the possibility of tailoring magnetic properties at the nanoscale with minimal damage and superior spatial precision [2,3]. Here, we present recent developments in the optimization of FEBID-grown magnetic tips and their post-processing by He⁺ ion irradiation. This approach leads to significant improvements in spatial resolution while maintaining their good magnetic performance [4,5], making them suitable for the study of nanoscale spin textures. In parallel, we investigate the effects of localized He⁺ and Ga⁺ ion irradiation on Fe₈₀Ni₂₀/NdCo₅ magnetic multilayers. These systems exhibit rich spin textures, including vortex-antivortex pairs and skyrmions, which arise from the imprinting of perpendicular magnetic anisotropy and interlayer coupling [6,7]. Finally, we demonstrate the synergy between both lines of research by using the sharpened MFM probes to characterize the magnetic textures induced by ion irradiation in these multilayers, for their application in devices with high data storage densities.

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Study and development of a focused ion beam column (FIB) integrating a coaxial ion source (CIS)

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To optimize the size of the ion probes used in a FIB, one option is to develop and optimize the properties of the source, such as brightness and energy spread. In practice, high stability and lifetime are also required. In addition, even if the brightness is high, it is preferable to have a wide range of currents to be able to work at different speeds. One potentially promising source is the GFIS (Gas Field Ion Source), based on the field ionization process and using noble gases. This type of ion source is used in the helium microscope (HIM). The brightness is high, $10^9 \text{ A.cm}^{-2}.\text{sr}^{-1}$, the energy spread is low, 0.5 eV [1], and the resolution limit reached is of the order of 0.5 nm at 30 kV. However, the maximum current of the ion probe is less than 35 pA, which limits the amount of work that can be done on the sample because of the slow speed. What's more, the source operates at low temperature (70-80K), which adds to the technical constraints.

One way of increasing this current is the coaxial ion source (CIS). This structure consists of an ultrafine tungsten tip emerging of 170 μm from a capillary, through which gas is injected. The design enables it to deliver a current 300 times greater than that of a conventional GFIS [2] and to operate at ambient temperature, which makes this source of interest for FIB technology.

The problem is that under vacuum and intense field conditions, the tungsten tip corrodes [3]. Studies to characterize ionization efficiency were carried out on palladium-coated tips to avoid corrosion. However, the complexity and instability of the deposit led us to consider a new metallic emitter based on ultrafine iridium tips. Characterization is in progress. I will present the first results obtained in field emission with Fowler-Nordheim characteristics, lifetime and stability, as well as the field ionization scheme obtained with these tips.

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High-Resolution Nano-Analytics using a Liquid Metal Alloy Ion Source LMAIS

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High-resolution material characterization is essential for exploring the structure and composition of nanoscale systems. Techniques that combine spatial precision with analytical sensitivity are particularly valuable in fields such as materials science, semiconductor research, and geosciences. Focused Ion Beam (FIB) systems coupled with Secondary Ion Mass Spectrometry (SIMS) offer a powerful approach for 2D and 3D nano-analytics by enabling the visualization and chemical analysis of surfaces and sub-surfaces with nanometer-scale resolution.

The IONMASTER magSIMS system integrates a Liquid Metal Alloy Ion Source (LMAIS) [1] with a high sensitivity magnetic sector SIMS unit to deliver enhanced capabilities in nano-scale imaging and analytics. Unlike traditional ion sources, LMAIS enables the simultaneous emission of multiple ion species. This provides users with the flexibility to optimize analysis conditions based on specific material properties or analytical goals. For example, switching between light and heavy ion species allows users to tailor imaging resolution or sputtering depth, significantly enhancing both surface sensitivity and structural detail.

In addition the system incorporates a high-precision laser interferometer stage, ensuring stable, nanometer-accurate positioning throughout complex measurement routines. The tool is capable of navigating using industry-standard KLARF and GDS files, facilitating seamless integration into semiconductor workflows and enabling precise targeting of features of interest.

Key system advantages include rapid switching between positive and negative SIMS modes, application-specific primary ion beam selection, and automation features that support complex analytical workflows. With an analytical spot size better than 20 nm using light ions, the system is well-suited for advanced applications requiring both high-resolution imaging and precise chemical characterization.

This contribution outlines the operating principles of the IONMASTER platform and demonstrates its performance through selected applications. Case studies include the analysis of CIGS (Copper Indium Gallium Selenide) solar cells biological and geological samples, where the system reveals detailed 3D compositional information and structural features that are not accessible with conventional techniques. The combined use of a high-precision sample stage with a highly sensitive SIMS detector extends the system's applicability across a wide range of samples.

In summary, the IONMASTER magSIMS system represents a next-generation solution for nanoscale material analysis, offering an unmatched combination of flexibility, resolution, and analytical depth. Its innovative design and performance characteristics position it as a key tool for researchers seeking deeper insights into complex material systems.

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Abstracts

Wednesday, 17th

Direct-Write Nanofabrication of Superconducting Devices with Focused Helium Ion Beams

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Focused helium ion beam (He^+ FIB) lithography is a transformative nanofabrication approach for patterning high-transition-temperature superconducting (HTS) materials with unprecedented spatial resolution. Utilizing a 0.5 nm diameter, 40 kV helium ion beam generated by a gas field ion source (GFIS), we directly engineer superconducting devices by locally inducing disorder in $\text{YBa}_2\text{Cu}_3\text{O}_{7-\delta}$ (YBCO) thin films. This direct-write process allows fabrication of superconducting-insulating-superconducting (SIS) and superconductor-normal-superconductor (SNS) Josephson junctions with insulating widths below 2 nm — without masks or resists. We systematically explore how ion dose modifies electrical transport, revealing a clear transition from SNS to SIS behavior as fluence exceeds 300 ions/nm. Monte Carlo simulations of ion implantation are employed to correlate the spatial disorder profile with junction properties. Our technique enables highly reproducible nanoscale patterning and integration of multiple functional devices on a single chip. We present applications of this fabrication method including: (1) ultra-compact nanoSQUIDs with integrated control lines operating as superconducting transimpedance amplifiers (Figure 1), and (2) cryogenic digital logic based on quantum flux parametrons (QFPs), demonstrating energy dissipation over $10^5\times$ lower than CMOS. These results highlight the utility of focused helium ion beams not only for materials modification, but as a precision nanofabrication tool for next-generation superconducting and quantum electronic circuits. The high spatial resolution, minimal collateral damage, and material selectivity of He^+ FIB make it uniquely suited for device prototyping at the sub-10 nm scale.

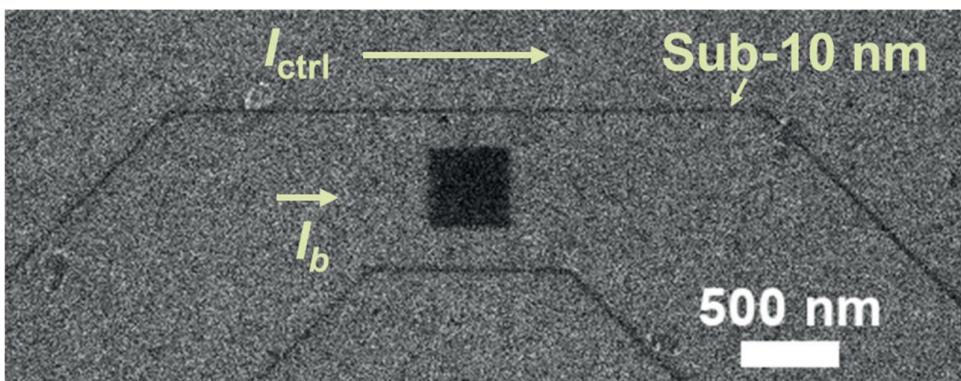


Figure 1. Focused helium ion image of a nanoSQUID patterned into a thin YBCO film. The dark contrast regions show where the material has been rendered insulating from interaction with the beam [1].

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Hybrid Josephson Junctions and Nanodevices Based on Micro-Crystals and FIBID-Grown Superconductors

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Recent advances in quantum technologies are highly influencing the current technological scenario. Hybrid devices combining superconductors and topological insulators represent an excellent opportunity to study the topological superconducting phase, which offers interesting features that might have significant implications in the development of quantum sensing and quantum computing [1]. Furthermore, focused ion beam techniques such as focused ion beam induced deposition (FIBID), whose versatility enables to create sophisticated devices with high degree of customization, can enhance the creation of complex devices [2]. Here, we present novel approaches for creating micro-crystal devices based on FIBID superconductors and topological-insulator Bi_2Se_3 crystals [3, 4]. Characterization of devices such as that shown in Figure 1 reveals that superconductivity can be induced in the microcrystal and the supercurrent is modulated by applying an external magnetic field. These results open the way to tailoring the response of hybrid devices that combine superconductors and topological insulators by focused ion beam techniques.

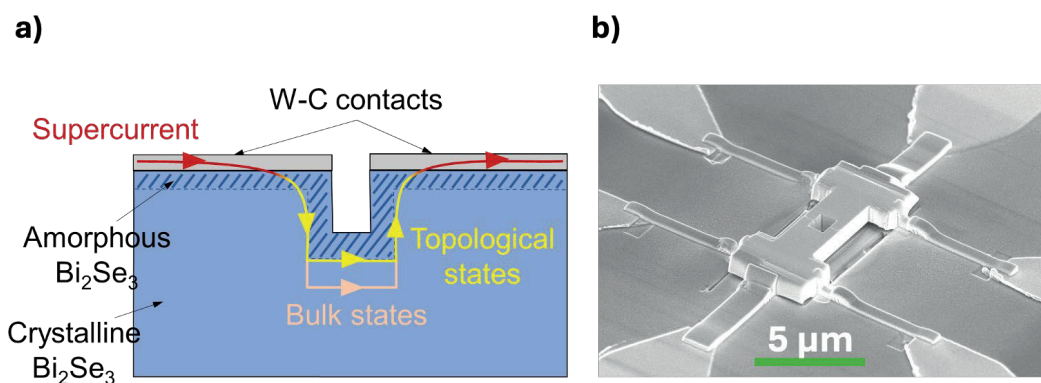


Fig. 1: a) Sketch showing the possible supercurrent paths; b) SEM micrograph of one of the microcrystals fabricated with W-C superconducting contacts in the geometry of a nanoSQUID.

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Observation of superconducting diode effect in 3D W-C nanohelix

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The superconducting diode effect (SDE) consists in the appearance of a supercurrent that flows preferably in a one direction, without dissipation, breaking the transport symmetry typical of conventional superconductors. This phenomenon has been observed in 2D devices with asymmetric geometries^[1,2].

Here, we report the first observation of the SDE in a 3D W-C complex nanohelix structure grown via He⁺ FIBID^[3] (Fig.1a). The intrinsic spatial asymmetry of the nanohelix enables the emergence of a non-reciprocal supercurrent in the absence of an external magnetic field, while the application of a magnetic field further enhances the magnitude of the SDE (Fig.2b-c). This discovery demonstrates that the SDE can also occur in 3D architectures, expanding and the range of geometries capable of hosting the effect. Moreover, it positions the FIBID technique as a promising tool for designing nonlinear and functional superconducting devices, with potential applications in 3D quantum technologies and active superconducting circuits.

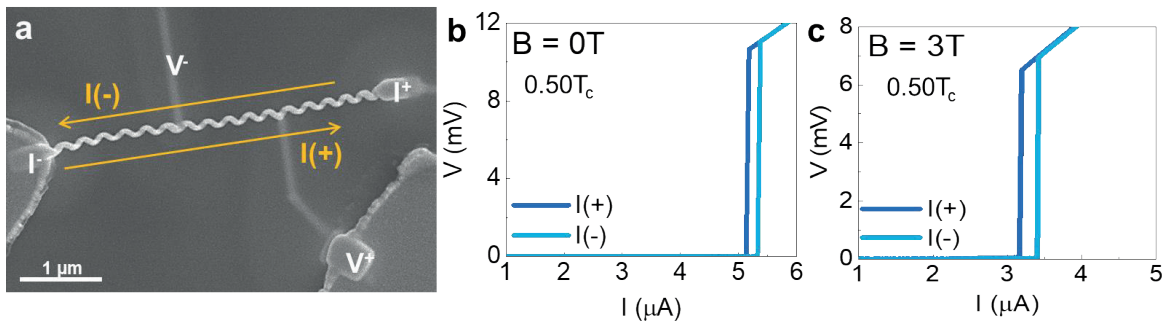


Figure 1. **a** SEM image of the WC nanohelix, showing the four-probe contacts and the direction of the driving current, with polarity changing as indicated by I⁽⁺⁾ or I⁽⁻⁾. **b-c** Voltage-current characteristics 3.30 K (0.50 T_c), at 0 T and 3 T respectively representing the direct change between I⁽⁺⁾ and I⁽⁻⁾.

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The history and latest advancement in FIB technology

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This presentation will focus on the history of focused ion beam technology including ion source development from the early days and ion column design evolution at FEI company and Thermo Fisher Scientific.

It will also cover the overview of the latest advancement in both hardware and software perspective for FIB technology. The recent application development in focused plasma ion beam field will be shared including special usecases using oxygen ion beam and argon ion beam. In addition, this presentation will discuss the latest software innovation including automated TEM lamellae fabrication software AutoTEM5, automated serial sectioning software Auto Slice & View 5 featuring unique spin mill technology, rocking mill technology and 3D TOF-SIMS capability. It will also present python-based scripting software AutoScript 4 for users to obtain full scripting possibility of the microscope.

Superconducting three-dimensional nanoarchitectures using FEBID

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Introducing three-dimensional (3D) nanoconfinement into the superconducting system can open a path for local geometrical control and the possibility of going beyond intrinsic properties [1]. However, the fabrication of such intricate nanoarchitectures remains challenging [2, 3]. In this context, we present an approach to realise 3D superconducting nanoarchitectures with focused electron-beam-induced deposition of tungsten [4]. This method allows for the fabrication of 3D superconducting nanostructures with arbitrary geometries within a wide range of critical temperatures, providing local geometrical control of critical fields and, for example, for the realisation of reconfigurable weak links [5]. Moreover, we demonstrate the possibility of pre-designing superconducting parameters, such as the critical temperature, by controlling the deposition parameters. The realisation of 3D superconducting nanostructures using FEBID opens the possibility for the prototyping of 3D nanosuperconductors immediately available to the wider community. The increase in density, complexity and interconnectivity offers new horizons for non-standard computing architectures, such as neuromorphic and quantum computing.

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2.5 dimensional graphene from sculpting the catalytic CVD surface

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Most of the emerging two-dimensional materials (2DMs) can be synthesized by chemical vapor deposition (CVD) [1]. The quality of the resulting 2DMs depend among other things on the choice and quality of the catalytic surface it is grown upon. The trend in the field has been to optimize the catalytic surface towards promoting better crystallinity of the 2DM. Here we investigate the opposite route, the use of intentional deviation from the optimized catalytic surface to impart local functionality to the 2DM.

The system we chose to study is the most common one - graphene grown on a copper surface. The choice was easy, based on the well advanced methods already developed to prepare high quality graphene [2]. We utilize Cu(111) surfaces with large grain size, giving us a good starting point [3]. These surfaces are then milled with Ne ions to create surface topography, after which graphene is synthesized on the surface through CVD. The outcome is then studied with atomic force microscope to evaluate how well the graphene follows surface features of different radius. Raman spectra are collected to characterize the quality of the graphene along the milled topography.

We find that there is a specific feature size beyond which CVD grown graphene adheres to the milled topography and in those areas graphene start to show an increase of lattice defects. We will discuss the potential of Ne FIB sculpting and how this approach gives a new processing path towards integration of local functionality into 2DM devices.

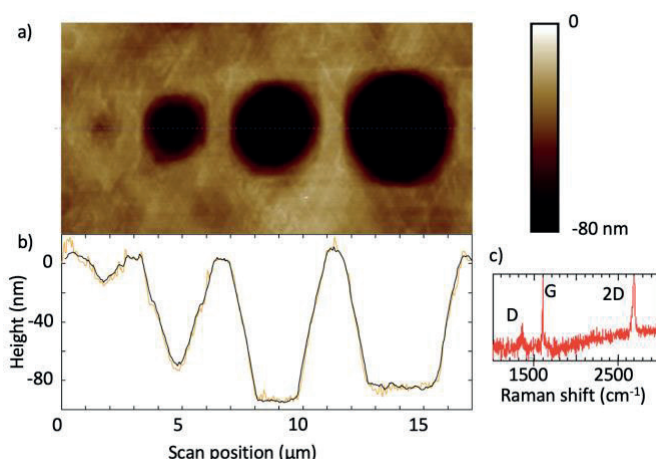


Figure 1: CVD grown graphene on sculpted Cu surface. a) Top view AFM image of Cu surface with milled pits after which graphene was synthesised. b) Cross sections from before (orange) and after (black) CVD growth of graphene. c) Raman spectrum of graphene on the Cu surface.

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Optimizing Helium Ion Beam Milling to Minimize Beam Damage in the Patterning of Suspended hBN

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Polaritons in two-dimensional (2D) materials can lead to a significantly enhanced light-matter interaction [1] making them interesting for highly-confined and low-loss light transport. A polariton is defined as a quasiparticle that couples a photon to a dipole-carrying excitation in matter, with this process being strongly dependent on the material type and geometry. Hexagonal boron nitride (hBN) is a non-metallic insulator that has been shown to support phonon polaritons, resulting from strong coupling between infrared photons and lattice vibrations (phonons). Tailoring the geometry of hBN structures is critical to advanced photonic quantum applications, which e.g. rely on enhanced radiative emission of defect-based single-photon emitters [2]. Due to its extreme spatial resolution, helium (He) ion beam patterning is well-suited for structuring 2D materials at the nanoscale [3, 4]. In order to preserve the unique properties of these crystalline materials, it is crucial to minimise beam-induced damage in such 2D materials.

Samples were produced by dry transfer using polydimethylsiloxane (PDMS) and poly(propylene) carbonate (PPC) films due to their favorable viscoelastic and thermoplastic properties. By cutting through suspended layers of hBN with focused He ion beams, we manipulate the geometry to modify and study the arising polaritons.

Optimizing the He ion beam patterning involves fine-tuning both, the geometrical pattern routine itself and the beam parameters that affect the ion beam profile. Variations in parameters such as beam current, spot control, acceleration voltage and beam scanning velocity result in distinct beam profiles and local sputter/damage distributions, each exerting different effects on the final structure.

In the aim of systematically optimizing He ion-induced patterning of hBN, a study of line cuts for optimized beam profiles at varying beam velocities for different hBN thicknesses was performed to obtain information from damage profiling [5]. This is based on low-dose diffraction line scans. Line scans are performed along the direction perpendicular to the cuts to obtain the microstructural information from the diffraction patterns in correlation with the real-space detector signal indicating the crystallinity, defectivity or degree of amorphization of material. The resulting diffraction line scans data shows a clear beam velocity dependent behaviour in both defect creation and amorphization.

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Precursor Film Thickness as a Determinant of Functional Properties in He-FIB-Fabricated Pd Nanostructures

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The direct ion beam writing of metallic nano- and microstructures is an emerging technique with a wide range of potential applications, largely influenced by the choice of both the precursors and the ion or electron beams. Until now, most studies involving the fabrication of metallic structures from spin-coated palladium acetate thin films have focused on film thicknesses greater than 200 nm and have utilized the four most common beams: Ga⁺, Ne⁺, He⁺, and focused electron beams [1]. Additionally, the smallest gap achieved between large metallic pads in such systems has been approximately 40 nm.

However, many advanced technologies demand much smaller gap widths for optimal performance [2]. Given its superior resolution capabilities, He-FIB appears to be the most promising tool for achieving such fine features. In this study, we investigate the effect of reducing the initial thickness of the organometallic film and it is aimed to determine the minimum lateral resolution attainable using this material and this focused beam.

This work presents the results of direct He-FIB writing on palladium-based thin films with a thickness of approximately 100 nm, comparing the resulting nano- and microstructures to those obtained in our previous experiments.

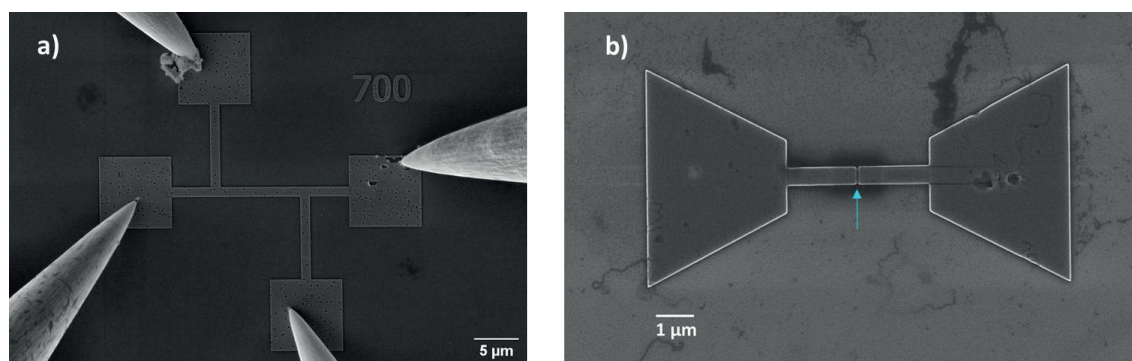


Figure 1. Example of He-FIB direct written Pd structures to: **a)** Determine the electrical properties. **b)** Determine the minimal lateral resolution.

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How to destroy your sample and learn everything you can while doing so. 3D FIB-SEM: A Tutorial

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In this tutorial I will be covering considerations and capabilities when it comes to FIB-SEM tomography by serial sectioning. Particular attention is paid to the various ways to prepare a volume of interest ahead of sectioning, and how to mount the volume for both analysis and easy manipulation. Considerations for setup of various analyses are covered, including both secondary and backscatter electron imaging, chemical analysis through energy dispersive spectroscopy (EDS), and orientation and phase analysis through electron backscatter diffraction (EBSD). The majority of examples presented are prepared with a fs-laser Xe⁺ PFIB tribeam system (using either the laser or FIB for sectioning) and on metallic samples, however many of the pointers given are equally applicable to other ion species and a wide range of sample types.

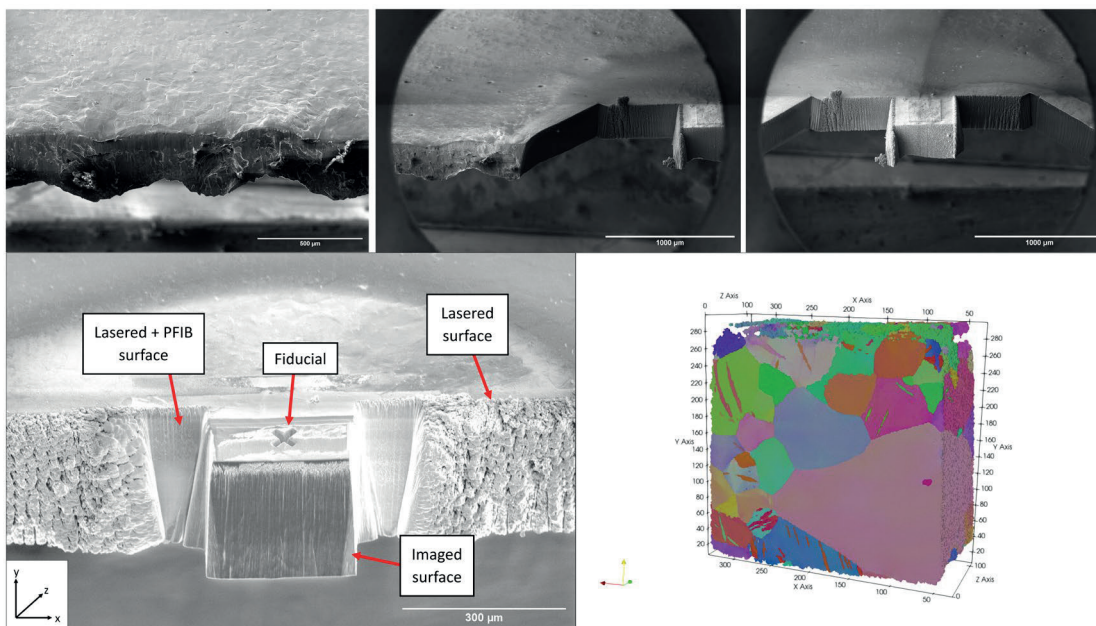


Figure 1: Preparation of a volume for serial sectioning using a combination of fs-laser and X⁺ PFIB and the subsequent 3D-EBSD volume.

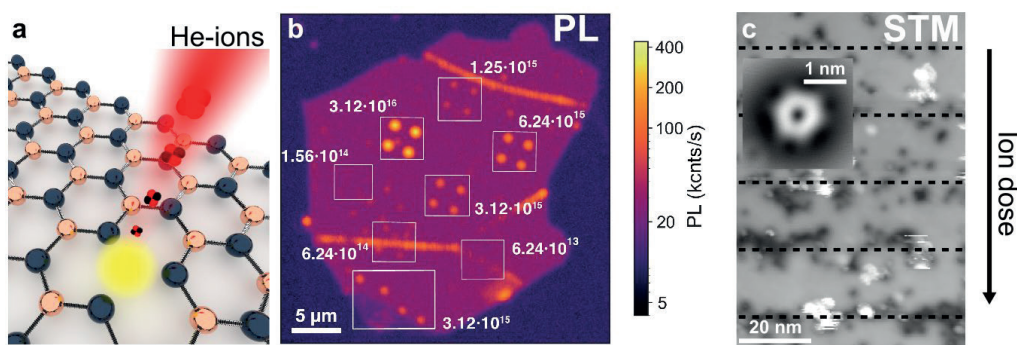
Creation of functional defects in van der Waals materials by focused He-ion beam irradiation

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a Defect creation in hBN using a focused He-ion beam. **b** PL image of positioned boron vacancies in multilayer hBN. **c** STM images of patterned defect lines in monolayer MoS₂ on graphene.

The helium ion microscope is a versatile tool for both nanoanalytics and nanoscale fabrication of atomically thin van der Waals materials. Focused He-ion beam exposure can create functional defects, such as single photon emitters [1], with a spatial resolution well below 10 nm [2]. For monolayer MoS₂, I will discuss the optical properties of He-ion beam creation of sulfur site defects. For sulfur vacancies, the defect excitons are predicted to exhibit a mixed localized-delocalized character resulting in hybridized electron-hole transitions, which manifest as a varying exciton g-factor [3], a broadband sub-gap absorption [4,5], and characteristic dipole emission pattern [6]. For multilayer hBN, I will discuss spin defect creation using focused He-ions and, in particular, the quantification of optically active, negatively charged boron vacancies [7].

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Application of Focused Ion Beam Technology in the Fabrication of D-Shaped Optical Fiber Sensors

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Refractive index measurements serve as a fundamental analytical tool, offering valuable insights into the density, concentration, and overall chemical composition of various materials. This parameter finds applications in basic research, chemical analyses of food, environmental monitoring, and medical diagnostics. However, the accurate and localized measurement of refractive index poses significant challenges. To address this, focused ion beam (FIB) technology has emerged as a powerful technique for fabricating microstructures on optical fibers, enabling the precise modification of optical fiber geometry.

In this study, we present the development of a refractive index sensor based on a D-shaped multimode optical fiber, modified using FIB milling. The sensor design integrates the D-shaped optical fiber with Optical Time Domain Reflectometry (OTDR), offering a compact, cost-effective, and scalable solution for multi-point sensing. Unlike conventional refractive index sensors, which rely on transmission-based measurement techniques and require separate light sources and detectors, the proposed system uses the Fresnel reflection detected by the OTDR, thus combining the sensing mechanism into one device. The fabrication process involved precise exposure of the optical fiber using FIB, enabling the fabrication of a well-defined sensor surface for interaction with the external environment. A comparative analysis was conducted using two types of optical fibers with different core diameters (50 μm and 62.5 μm) to assess the impact of core size on sensor sensitivity and signal quality. The integration of OTDR in the proposed sensing system not only simplifies the measurement setup but also enables the simultaneous monitoring of multiple sensors along a single optical fiber.

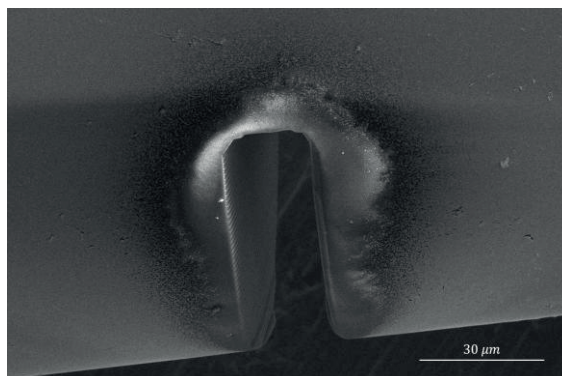


Figure 1. D-Shaped multimode optical fiber milled with focused ion beam.

Prototyping of Field Emission MEMS Components using FIB Techniques

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The development of microelectromechanical systems (MEMS) for nanometrology poses significant challenges, particularly in the fabrication of functional components using conventional microfabrication methods. This work explores alternative prototyping techniques based on focused electron/ion beam induced deposition (FEBID/FIBID) processes, combined with a scanning electron microscope with a gallium focused ion beam (SEM with Ga-FIB) and a helium ion microscope (HIM). These tools enable direct-write modification and additive fabrication of nanostructures with high precision. The research is part of the LabInSEM approach, which integrates in situ electrical characterization with nanostructure fabrication. The primary objective was to investigate field emission from nanowire-like structures fabricated on MEMS cantilevers.

First, Pt(C) nanowire tips were created using Ga-FIB [1]. The structures were evaluated using atomic force microscopy (AFM) to assess their mechanical durability and electrical conductivity. Material composition and the effects of post-processing on electrical properties were also studied.

In the final phase, FEBID/FIBID was used to fabricate Pt(C) and W(C) nanowire cathodes directly onto MEMS cantilevers (figure 1). The optimised geometry of the field emitters with a radius of approximately 25 nm and inter-electrode gaps of ~120 nm reduced the threshold voltage for field emission to 45-70 V. Fowler–Nordheim analysis enabled the extraction of key emission parameters. Cantilever deflection detection tests demonstrated that reducing the tip-anode gap by 20 nm led to a 328 nA increase in the emission current.

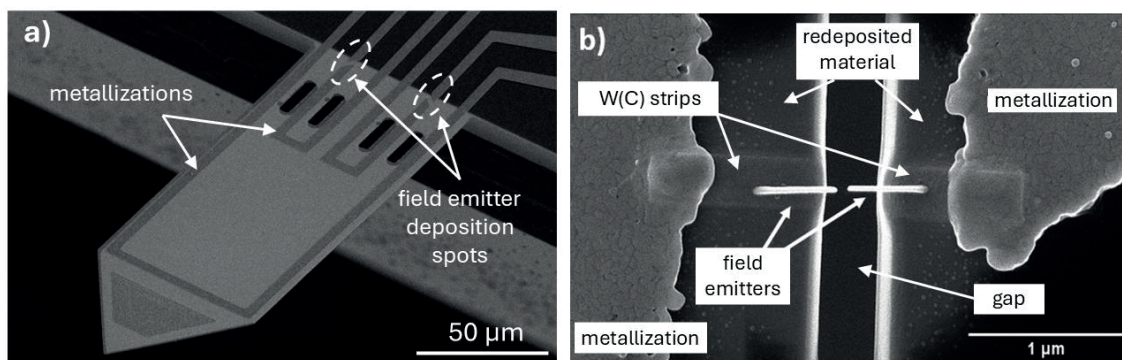


Figure 1. Images of: a) a MEMS-type microcantilever; b) a nanowire field emitter integrated with the microcantilever.

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Overcoming fabrication challenges of color centers in diamond with a focused ion beam

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Defects in diamonds such as nitrogen-vacancy (NV), silicon-vacancy (SiV), and germanium-vacancy (GeV) color centers have become extremely important in quantum sensing, quantum communication, and quantum computing technologies [1] [2], for their remarkable optical and spin properties.

This work is focused on the deterministic color center fabrication technique based on ion implantation using a FIB system with a Liquid Metal Alloy Ion Source (LMAIS) [3]. This method enables the accurate implantation of several ions (such as Si and Ge) down to the nanometer scale, thus facilitating the precise engineering of color centers without the necessity of elaborate lithographic techniques [4].

Regardless of its benefits, this method offers several challenges in fabrication. One significant challenge is the local amorphization, which occurs when high local ion fluence, resulting from concentrating ions into small regions, damage the diamond lattice and induce amorphization and then graphitization after a thermal annealing process [5]. The damaged areas compromise the quality of the crystal but also leads to additional undesired emitting sources of photons.

Furthermore, the mass resolution of the Wien filter can lead to ion cross-contamination, especially when using large or degraded apertures. For instance, Ge and Si cross-contamination may occur, unintentionally forming mixed color center types, as shown in figure 1. Another concern is the implantation of neutral atomic species [6], which, in systems without dedicated hardware to handle them, can travel undisturbed down the column to the substrate, introducing defects at the center of the writing field. To overcome these issues, we investigate approaches like layout modification, a few guidelines about beam, and a post-implantation protocol to treat the substrates. All these strategies seek to improve the control of defect formation, background noise reduction, and operational dependability of quantum devices that take advantage of diamond color centers.

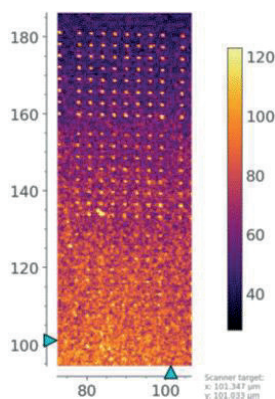


Figure 1 – Photoluminescence map of a Ge-implanted region acquired at SiV wavelength.

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Robust FIB-SEM Automation for TEM Sample Preparation and Cross-Sectioning, with API-Enabled Support for User-Defined Workflows

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Automated workflows in FIB-SEM systems are essential for increasing throughput, improving reproducibility, and minimizing operator workload. The AMBER X2 platform integrates robust, application-specific automation modules to streamline key sample preparation tasks. For TEM lamella preparation, the system features AutoPrep PRO, a high-reliability solution delivering consistent results across a broad range of materials and geometries. For cross-sectioning, the AutoSection module provides efficient, high-quality trenching and imaging with minimal user intervention.

In addition to these standardized workflows, AMBER X2 supports advanced user-defined automation through the FIB-SEM Expert PI, a Python-based programming interface that enables direct control over system functions. This API allows users to develop and deploy custom milling, imaging, and acquisition routines, tailored to unique sample types, experimental protocols, or integration with external systems. Example use cases include automated multi-site processing, adaptive feedback loops, and correlative imaging sequences.

For users without programming experience, the VisualCoder environment offers a no-code approach to automation. VisualCoder enables users to create complex workflows using an intuitive, drag-and-drop interface based on modular code blocks. This empowers a broader range of users—from application specialists to lab technicians—to build, test, and run custom sequences without writing a single line of code.

By combining field-proven automation modules with an open, scriptable interface, AMBER X2 offers both out-of-the-box productivity and the flexibility required for advanced, application-specific workflows.

Low Energy Implantation with Focused Ion Beams (1 blank line)

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Ion implantation is a key capability for a variety of industries. As devices continue to shrink, novel materials enter the manufacturing line, and quantum technologies become more mainstream, traditional implantation methods fall short in delivering energies, ion species, and positional precision necessary. Specifically, lowering the implantation energy while maintaining nanometer scale spot size is a technological challenge. This presentation will show an overview of techniques at Sandia National Laboratories Ion Beam Facility that allow focused ion implants 1-200 keV range for quantum relevant applications.

Additionally new developments in sub-1 keV focused ion implants into Si and 2D devices, using a focused ion beam system, validated by atom probe tomography will be shown. We illustrate that identical results for low energy ion implants can be achieved by either lowering the column voltage, or decelerating ions using bias – while maintaining good spatial resolution. Furthermore, our data reveal that standard implant modelling approaches overestimates experimental depth by a significant margin. Finally, we discuss how our results pave a way to maintaining high spatial resolution with low implantation energies.

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Diamond graphitization by ion implantation: nano-patterning and electrical circuit

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Irradiation of diamond surfaces with energetic ion beams is a versatile and effective technique for modifying the material properties to meet the demands of quantum technology. Ion implantation is a reliable method to create color centers in diamond, offering precise control over their concentration and three-dimensional location [1,2]. In addition to this, ion implantation can permanently alter the crystallographic phase of diamond, by damaging its lattice structure. Subsequent thermal annealing can convert the irradiated regions into graphite [3], enabling the formation of conductive graphitic paths in an insulating diamond matrix. Furthermore, the diamond graphitization via ion implantation combined with a selective etching [4] provides a promising approach for nano-patterning the diamond surface [5], enabled by a lower fluence than direct milling, achieving a high lateral resolution if a focused ion beam (FIB) system is used.

In this work, we report a systematic study on nano-patterning the surface of (100) diamond (CVD grown) inducing first graphitization using a multi-species FIB implantation combined with a thermal annealing process (3h at 1000°C) and then removing the graphite by wet etching. The installed liquid metal alloy ion source (LMAIS) [6] allows for implantation of Au⁺⁺, Ge⁺⁺ and Si⁺⁺ species with maximum energy of 70 keV, enabling the control over the graphitic thicknesses and thus the depth of the nanostructures. For instance, for 70 keV irradiations the graphite layer thicknesses ranged from 40-125 nm depending on the ion used. The graphitization process window was defined for each ion species in terms of ion fluence and thermal annealing, identifying the carbon phases by Raman spectroscopy and measuring by atomic force microscopy the swelling after ion irradiation, the etched thicknesses, and the minimum lateral resolution after the wet etching. Additionally, we report electrical resistivity values obtained from I-V measurements on graphite pads induced by Au, Ge, and Si implantation. Finally, these pads were directly bonded to a printed circuit board, see Figure 1.

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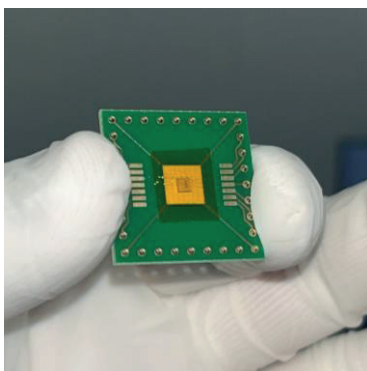


Figure 1 – Diamond glued on a PCB and the graphitic pads induced by FIB implantation;

Next generation fibTOF for faster FIB-SIMS

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Secondary Ion Mass Spectrometry (SIMS) is a technique used to study the local chemical composition of solid materials. When using a FIB as the primary ion beam it allows spatially accurate imaging of elemental and isotopic composition with nanometer resolution [1-3].

The *next generation fibTOF*, based on the time-of-flight principle, allows the simultaneous measurement of all elements present in the sputtered material, including hydrogen and other light mass elements with higher signal intensities. The improvement of the data acquisition system allows for a higher linear dynamic range of secondary ion current. Thus the maximum acceptable secondary ion signal intensity has been increased by orders of magnitude. The acceptance of higher signals allows for higher sputtering rates with the FIB beam and so for faster milling and measurement time.

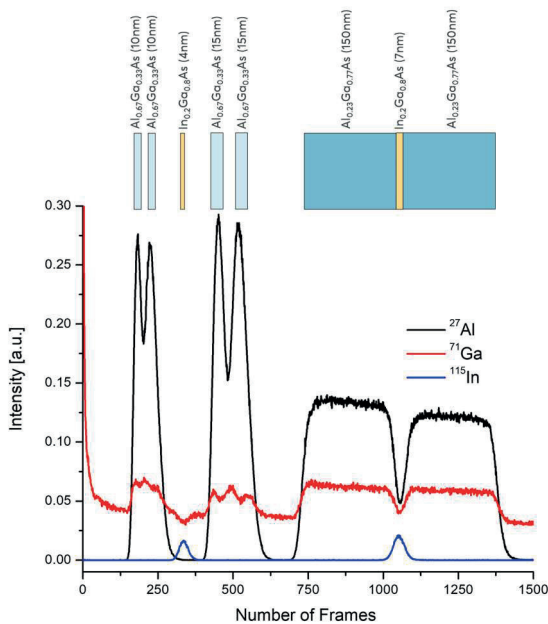


Fig. 1. FIB-SIMS measurement of a multilayer sample consisting of different AlGaAs layers and two different InGaAs quantum wells. The measurement was recorded using a 69Ga ion beam, adjusted to 5 keV energy and 48 pA, and probing a 10 μ m HVF.

The faster measuring rate allows for a smoother integration and workflow of fibTOF measurements with other analytical techniques, as demonstrated by 3D FIB-SIMS tomography experiments.

The potential to combine the local chemical information with other local material properties such as topography, crystal orientation or strain, to name a few, by overlaying sequential maps from various depths is highly valuable as it helps to locate contaminants, weaknesses and chemical inconsistencies. Nevertheless, such larger volume scale analysis requires increased sputtering (faster than can be accommodated by the current commercial FIB-SIMS product from TOFWERK).

We will demonstrate the performance of our *next-generation fibTOF* on our new custom-made multilayer reference sample consisting of alternating AlGaAs/InGaAs layers of different thicknesses and compositions (see Fig. 1), and show the applicability of the instrument in the semiconductor industry. Together with the new data acquisition software TOFexplore a more precise analysis of the specimen is ensured.

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Abstracts Thursday, 18th

Correlative cryogenic imaging approach for high-resolution 3D visualization of biological samples

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Cryogenic imaging techniques are essential for preserving the native ultrastructure of hydrated biological samples. However, locating precise regions of interest within these samples remains a significant challenge. Unlike conventional room-temperature methods—where dehydration, fixation, and staining enhance contrast and structural clarity—cryo-electron microscopy must rely on intrinsic contrast, which is often low. Additionally, the complex and irregular surfaces produced by freeze-fracture further hinder the recognition of specific cellular or extracellular features within the heterogeneous biological environment. To address these challenges, we implemented a cryogenic correlative light and electron microscopy (cryo-CLEM) workflow that combines cryo-fluorescence imaging with focused ion beam scanning electron microscopy (FIBSEM) volume imaging. Samples are prepared by high-pressure freezing to preserve their native, hydrated state, using a specific carrier configuration with fiducial markers positioned on the rim to support precise spatial correlation between imaging modalities. Fluorescence targeting—either through specific antibody labeling or by leveraging the sample's intrinsic autofluorescence—is employed to localize regions of interest prior to high-resolution imaging. Accurate correlation between cryo-fluorescence and cryo-SEM images is achieved using alignment based on these fiducial markers, enabling targeted FIB milling and 3D reconstruction of ultrastructural features. Volumetric data from the two modalities are further aligned computationally to refine the match between structural and fluorescence signals in three dimensions. This integrated approach allows for high-resolution visualization of biological architecture while maintaining the spatial context of labeled structures. The workflow has proven highly effective across a wide range of biological samples, from plant tissues to mineralized bone structures.

Tuning the Optoelectronic Properties of ALD-Grown MoS₂ Monolayers via Helium Ion Beam Irradiation

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Transition metal dichalcogenides (TMDCs) have created significant attention as promising materials for next-generation electronics and optoelectronics due to their two-dimensional nature, pronounced layer-dependent properties, and favourable semiconducting characteristics [1]. MoS₂ when fabricated as a single monolayer displays remarkable enhancements in its optoelectronic attributes [2,3]. Despite these advantages, realizing TMDC films with precisely tailored properties remains a formidable challenge. Post-growth modification techniques, such as helium-ion beam irradiation, offer a versatile route to engineer the electrical and optical properties of TMDCs by introducing controlled defects [4,5]. In this study, we employ focused helium-ion beam irradiation to systematically modify MoS₂ monolayers grown by atomic layer deposition (ALD). The influence of different ion doses on the monolayers is examined through Kelvin probe force microscopy (KPFM), which provides insights into work function shifts indicative of changes in the surface electronic structure. Concurrently, photoluminescence (PL) measurements reveal shifts in excitonic transitions, reflecting modifications to the optical response. By correlating these observations, we demonstrate that helium-ion beam irradiation can effectively steer the optoelectronic behaviour of MoS₂ toward specific performance targets, thereby bridging the gap between the intrinsic properties of as-grown films and the demands of advanced device applications. Our findings highlight the promise of helium-ion irradiation as a strategic tool for post-growth tuning of 2D TMDC materials. This approach paves the way for fabricating MoS₂-based devices with optimized electronic and optical functionalities, aiding in the development of more efficient and versatile nanoscale technologies.

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FIB meets Mass Spectrometry: Full-spectrum imaging at the nanoscale

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Focused Ion Beam (FIB) and FIB–Scanning Electron Microscope (FIB-SEM) platforms are versatile and powerful tools employed across a wide range of scientific and engineering disciplines. Imaging can be conducted using either the FIB column—primarily detecting secondary electrons (SE) - or the SEM column, which supports multiple imaging modes, including SE, backscattered electrons (BSE), electron backscatter diffraction (EBSD), and scanning transmission electron microscopy (STEM). Complementary chemical characterization is possible through wavelength-dispersive X-ray spectroscopy (WDS) and energy-dispersive X-ray spectroscopy (EDX). However, electron-based analyses probe relatively large interaction volumes (up to several micrometres), and EDX suffers from limitations such as low sensitivity to light elements (e.g., H, Li), inability to detect trace elements (<1 at.%), and incapacity to resolve isotopic compositions. Modern platforms now support a variety of primary ion species, including Ga⁺, Li⁺, He⁺, Ne⁺, Bi⁺, Au⁺ and Cs⁺. This allows selecting the most suitable primary ion species for a given application, which, in combination with finely focused probes and high ion currents, makes these FIB platforms highly effective for both high-resolution imaging and precision nanofabrication applications [1].

To combine high spatial resolution imaging with highly sensitive chemical and isotopic analysis, a compact secondary ion mass spectrometry (SIMS) system based on a magnetic sector analyzer was developed at LIST [1–2], optimized for integration with state-of-the-art FIB platforms. These FIB-(SEM)-SIMS instruments are capable of delivering elemental and isotopic information with lateral resolutions down to 15 nm. A key innovation in this setup is the development of a continuous focal plane detector (FPD), which overcomes the limitations of conventional magnetic sector SIMS instruments that detect only a few preselected ion species. The FPD, based on a microchannel plate coupled with a delay line detector, enables simultaneous acquisition of the full mass spectrum at every pixel of the SIMS image, for ions up to 500 amu. This allows for rapid and comprehensive data acquisition—providing full-spectrum analysis in as little as 1 second, or high-resolution chemical images (512 × 512 pixels) within 2 minutes, with excellent dynamic range and signal-to-noise ratio.

Here, we review recent developments in FIB-(SEM)-SIMS instrumentation and methodology, with a focus on high-resolution 2D and 3D chemical imaging, as well as give an outlook on emerging strategies to manage and interpret the large data volumes generated during such acquisitions. These aspects will be illustrated through applications involving the detection of elements at low concentrations and isotopic measurements, with particular emphasis on precision and accuracy.

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FIB Add-Ons for Enhancing and Expanding Workflows

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Modern Focused Ion Beam / Scanning Electron Microscope's (FIB/SEMs) are highly complex, but generally reliable and accessible tools used in wide array of research and development contexts. They offer the ability to investigate materials but also modify or fabricate micro and nano structures. The addition of specialized detectors and other add-ons further enhance the range of applications that these microscopes can be used for. Most FIB/SEM systems in the field are equipped with Gas Injection Systems (GIS) and a micromanipulator. These two tools are commonly used e.g. for preparing and extracting TEM lamella from bulk samples.

Going beyond the 'default' list of equipment, various tools can further expand the system's capabilities. For example, a customized GIS that allows using (gaseous, liquid, or solid) precursor material, provided by the user, can open up new possibilities in the fields of material fabrication, corrosion studies, elemental analysis, etc. An easy to use heating and cooling stage can further enhance gas assisted processes but also be used to suppress FIB milling artefacts by cooling samples to minimize beam induced damage to the materials being processed.

Micromanipulators can be used as "hands" that can be used to pick-up and precisely place objects at a desired location while arranging these into desired patterns. Equipping these "hands" with plug-ins such as grippers or force sensors yields additional capabilities.

In addition, substages can be added to the FIB/SEM's typically five- or six-axis sample stage in order to yield even more flexibility in positioning and processing samples using the FIB. These processing steps go from generating cross sections to milling complex patterns and assembling components, among others.

Selecting, preparing, and analysing a needle in a haystack : ECCI-assisted TEM sample preparation

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As new substrates are being investigated beyond silicon ones in the semiconductor field, advanced characterization of crystalline defects (stacking faults, dislocations) becomes critical. The characterisation of these defects can be done using several reference techniques, as cathodoluminescence (CL), photoluminescence (PL), or transmission electron microscopy (TEM). CL and PL offer large fields of view but limited resolution, while TEM offers a resolution down to the atom, but with a highly limited field of view (several micrometer), and requires a specific sample preparation.

For materials featuring a high and homogenous density of defects, the TEM lamella preparation is straightforward, as the probability to encounter a defect in a several micron large lamella is high. Unfortunately, in materials containing less defects or more specific ones, an additional localization step is necessary in order to ensure a given defect will be present inside the observed TEM lamella.

In this study, we present a SEM-based technique for crystalline defects imaging, possible to implement inside a FIB/SEM instrument, and exploit it to design a full workflow leading to the identification, isolation, and TEM observation of a crystalline defect.

Electron Channeling Contrast Imaging (ECCI) exploits the link existing between the angle formed by a primary electron beam on a crystalline material, and the obtained backscattered electrons (BSE) contrast: when this angle is close to the Bragg angle, any local variation of crystallographic properties (typically a misorientation or stacking fault) will appear as a change in contrast in the BSE image. In its simplest implementation, the technique only requires a BSE detector. It can therefore be applied inside a FIB/SEM instrument, and combines the resolution and the field of view reachable by an SEM. By applying this imaging method to a sample featuring a low defect density, we were able to identify a specific stacking fault. Using carbon deposition, we created fiducials enabling the isolation of the stacking fault inside a TEM lamella and the thinning of the lamella around the defect. This workflow allows a full characterization of the defect via TEM imaging. Possibilities and limits of the ECCI technique for semiconductor samples observation and TEM lamellae preparation will be addressed.

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Studying bismuth magnetotransport properties in different crystallographic directions using FIB

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Electrical magnetotransport properties of quantum materials are anisotropic, which becomes evident in single crystals, where resistivity under an applied magnetic field depends on the relative orientation of the crystallographic axes, the magnetic field, and the current [1]. Focused Ion Beam (FIB) technology has gained interest for device fabrication for studying these effects, as it is a direct-write nanolithography technique that avoids the use of chemical resists and enables real-time fabrication with nanometric precision.

Our research group has developed an *in situ* fabrication method using FIB exclusively, enabling the study of anisotropic magnetotransport in single crystals. Two types of samples are produced: Horizontal (H) and Vertical (V). In H-type devices, the current flows perpendicular to both the crystallographic *c*-axis and the magnetic field, while in V-type devices, it flows parallel to the *c*-axis and perpendicular to the field (see Figure) [2].

We present magnetotransport measurements on single-crystal bismuth devices of both types, observing differences in longitudinal and transversal (Hall) resistivity when comparing V and H samples. Additionally, Subnikov-De Haas oscillations with different periodicities are observed in the longitudinal resistivity for both device types.

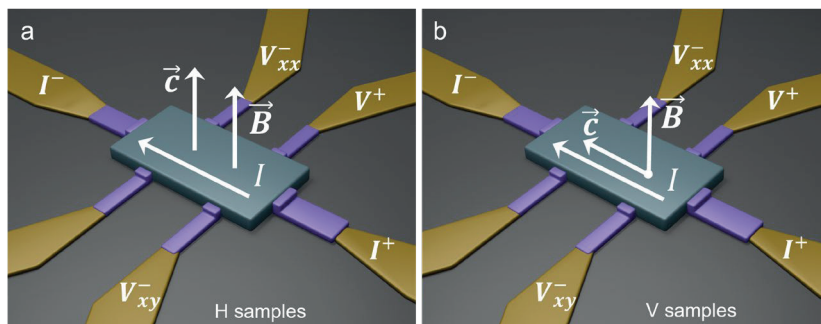


Figure: Schematic image of (a) H devices and (b) V devices showing the direction of the application of the current with respect to the *c* axis and the applied magnetic field *B*.

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Simulation of Plastic Flow and Diffusion in FIB Milling

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Simulations based on the binary collision approximation (BCA) are well suited for the prediction of topography and compositional changes during FIB milling. One problem that occurs in these simulations is to relax the density changes, which result from the implantation of the ions and the relocation of the target atoms. In most cases, such as in TRI3DYN [1], this is done in a heuristic way. One of us has previously proposed to combine BCA simulation of the collision cascades with continuum mechanics simulation of the relaxation process [2]. In this approach, the BCA simulations provides a spatially dependent mass source and a spatially dependent radiation induced fluidity, and the continuum model relaxes excess and deficit atom densities by plastic flow.

In this work, we go beyond our previous model by also including surface tension and diffusion of the implanted species. The effect of surface tension on the milling of a fin is illustrated in Fig. 1: While a sharp peak ("shock") forms when surface tension is neglected, a half-cylinder-like shape forms as a result of surface tension. We have also implemented a radiation-induced diffusion model in order to predict the outgassing of noble gas atoms. Like the radiation induced fluidity, the radiation induced diffusivity is modeled to be proportional to the displacement rate of target atoms. We will show results of simulations including Xe diffusion versus assuming Xe to be volatile or immobile.

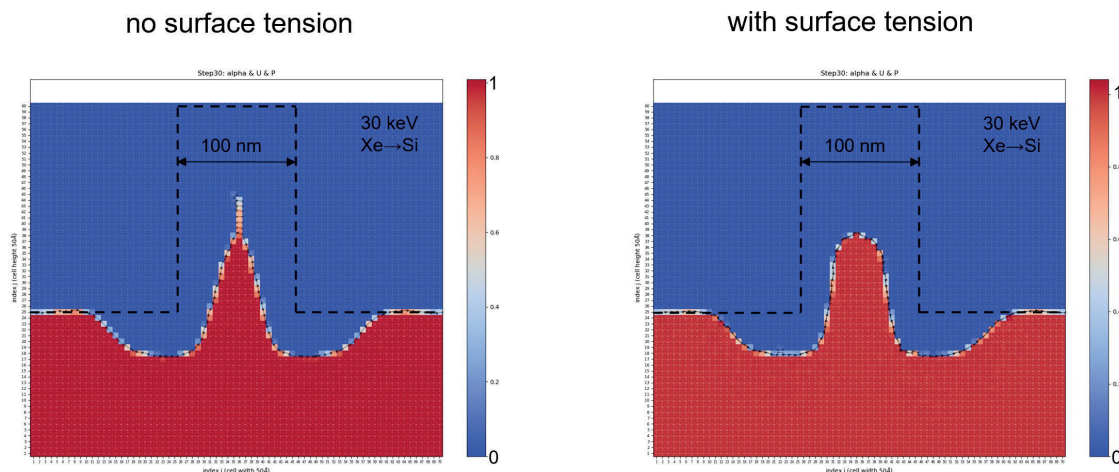


Fig.1: influence of surface tension on the milling of a Si fin by a Xe FIB as simulated with IMSIL.

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Spatially Resolved Phase Transition and Characterization in Gallium Oxide

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Gallium Oxide (Ga_2O_3) is a promising ultra-wide bandgap semiconductor material that has garnered significant attention due to its ease of large-scale production through melt growth and its high breakdown voltage. $\beta\text{-Ga}_2\text{O}_3$ is the most thermally and chemically stable polymorph among the various forms of Ga_2O_3 . Unfortunately, the control and manufacturing of other phases on the nanoscale remain immature due to the metastable nature of those phases.

Azarov et al. demonstrated that a β to $\gamma\text{-Ga}_2\text{O}_3$ phase transition is possible after reaching a certain critical damage level (dpa) induced by ion irradiation [1]. Various ion implantation experiments have shown that the phase transition is independent of the chemical nature of the implanted ion. Interestingly, the structure retains its crystal order up to 260 dpa before amorphization, which is higher than most radiation-tolerant materials (AlN, SiC). The stability of the oxygen lattice against ion irradiation is the main reason for the high radiation tolerance of Ga_2O_3 [2].

In this study, we investigate ion-irradiated $\beta\text{-Ga}_2\text{O}_3$ samples (varying ions and fluences) alongside α - and $\kappa\text{-Ga}_2\text{O}_3$ thin films. Using focused ion beam (FIB) irradiation, we locally modified the samples under controlled conditions by tuning beam current, size, spacing, scan type, and ion species. Structural changes in the irradiated regions were characterized via electron backscatter diffraction (EBSD) and transmission electron microscopy (TEM) as shown in Figure 1. Our results demonstrate that polymorph transitions can be achieved through FIB irradiation. Furthermore, time-domain thermoreflectance (TDTR) measurements further revealed the thermal conductivity of irradiated regions, highlighting opportunities to optimize heat transport in Ga_2O_3 power electronic devices. This research is supported by the tax funds on the basis of the budget passed by the Saxonian state parliament in Germany.

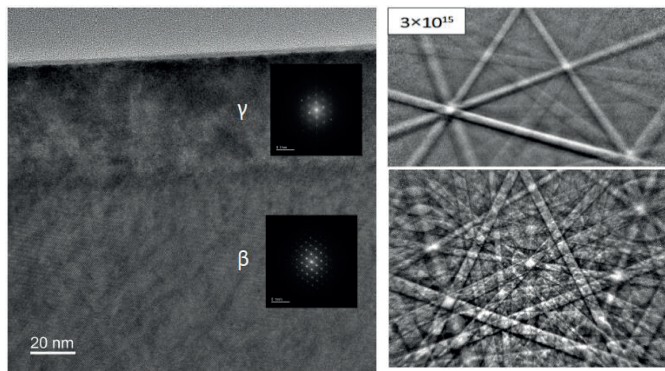


Figure 1: TEM images and corresponding EBSD patterns after 25 keV $3 \times 10^{15} \text{ Ne}^+/\text{cm}^2$ FIB irradiation.

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Correlated machine learning assisted FIB tomography on functional materials

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Focused Ion Beam Scanning Electron Microscopy (FIB-SEM) tomography is a critical technique for high-resolution, three-dimensional structural analysis of functional materials. In the field of energy storage and conversion, where micro- and nano structural properties govern performance, FIB tomography plays a key role in revealing pore structures, particle networks, and interface characteristics that are otherwise inaccessible through conventional imaging. However, segmentation and classification of multi-phase, porous materials remain challenging due to limited contrast, complex geometries, and the presence of imaging artifacts.

This talk presents a correlative and machine learning (ML)-assisted approach to FIB tomography tailored to functional materials. By combining multiple SEM signals and ML-based classification algorithms, we significantly enhance material phase segmentation [1]. This approach enables robust, quantitative reconstruction of multi-component systems e.g. Li-ion battery cathodes and fuel cell electrodes, without the need for invasive pore infiltration or extensive manual annotation.

We demonstrate how this methodology captures critical features such as porosity, tortuosity, particle connectivity, and transport pathways, which are key to understanding and optimizing structure–property relationships in hierarchical electrodes. The improved segmentation fidelity allows for accurate extraction of geometrical descriptors like constrictivity and shortest path lengths, which directly relate to ionic and electronic transport behaviour.

Furthermore, this correlative approach facilitates the integration of FIB-SEM tomography with complementary imaging modalities such as synchrotron X-ray tomography, enabling multiscale analysis from micrometre down to nanometre resolution [2]. This combined strategy supports the development of digital twins for predictive modelling, materials design, and performance diagnostics [3].

The flexibility and robustness of this ML-enhanced pipeline have proven general enough to extend beyond energy materials, enabling, for example, the analysis of preserved biological nanostructures in fossilized bone [4]. This underscores its potential as a universal tool for 3D nano tomographic analysis across diverse scientific domains.

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Josephson microwave circuits enabled by a focused ion beam

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Superconducting microwave circuits with integrated Josephson junctions and superconducting quantum interference devices (SQUIDs) are the essential ingredient for many groundbreaking superconducting quantum technologies, such as circuit quantum electrodynamics, quantum computing, quantum-limited amplifiers and quantum sensors for e.g. axion dark matter, micromechanical oscillators or single spins. The vast majority of microwave circuits today is fabricated from the superconductor aluminum and the most commonly used Josephson junction technology is that of a trilayer superconductor-insulator-superconductor tunnel sandwich. Unfortunately, these standard devices are not compatible with large magnetic fields and higher temperatures, and therefore cannot be considered for many exciting applications, that would require these operation conditions. In this talk, I will present an overview of both, the exciting high-field hybrid systems we want to develop, and our approaches to realize suitable Josephson circuits based on alternative superconducting materials and novel junction fabrication methods. As materials, we operate with niobium and the high-temperature superconductor $\text{YBa}_2\text{Cu}_3\text{O}_7$ (YBCO), and for the junctions we integrate neon-ion-beam (Ne-FIB) patterned nano-constrictions in Nb circuits [1, 2] and helium-ion-beam (He-FIB) patterned barrier Josephson junctions in YBCO devices [3]. In the second part of the talk, I will discuss two nanoconstriction-based recent experiments in more detail. In the first, we investigate how a nanoconstriction microwave-SQUID-circuit responds to external magnetic fields up to 300 mT, and observe a highly unusual behaviour of the resonance frequency tuning with flux through the SQUID. We interpret our findings as a subcritical superconducting diode effect, that is induced by the inhomogeneous constriction properties as a result from the Ne-FIB process. In the second experiment, we realize a niobium-based photon-pressure system, the circuit QED implementation of the optomechanical Hamiltonian. Due to the device being based on niobium nano-constrictions, it can be operated in the so far unexplored highly thermal and dissipative regime at 4.2 K. We demonstrate, that in this regime we obtain both a dispersive and a dissipative photon-pressure interaction with comparable strengths, which leads to interference of the two processes and to significant modifications of photon-pressure induced transparency, dynamical backaction and sideband-cooling.

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Advanced Fabrication and Characterization of Solid Immersion Lenses in Diamond

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Color centers in diamond are one of the promising platforms for realizing efficient quantum networks. Solid immersion lenses (SILs) are microstructures that significantly increase the light collection efficiency of defect-based quantum emitters in high refractive index materials. Although previous attempts [1,2] improved the photonic properties and readout efficiency of individual quantum defects, they lacked reproducibility and suffered from losses due to redeposited material at the side walls. We propose a fabrication technique offering a flexible and reproducible route to integrate high-performance optical components with quantum defects in diamond. Using a continuous spiral pattern, we have achieved SILs with optimal curvature without carbon redeposition and with minimal surface roughness directly above the quantum defect site. In addition, our milling strategy minimizes unwanted carbon redeposition, which typically results in scattering and absorption losses. Interestingly, depending on the acceleration voltages, step edges of different sizes form at the bottom of the side walls of the lens [3] (see Fig. 1). The size of the steps can be reduced by lowering the acceleration voltage. This will be further investigated using numerical modeling of the material reorganization, supported by transmission electron microscopy data indicating the presence of only a very thin amorphization layer and otherwise mostly intact crystalline material. The corresponding milling routines were implemented into the Python-based toolbox Fib-o-Mat [4].

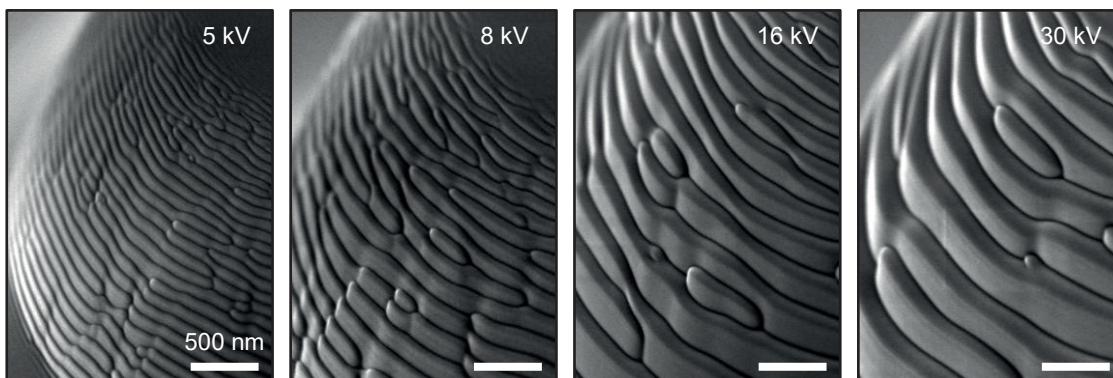


Figure 1 - SE micrographs of typical SILs with radius 4.9 μm fabricated in diamond. The step size decreases as the primary energy of the ion is reduced.

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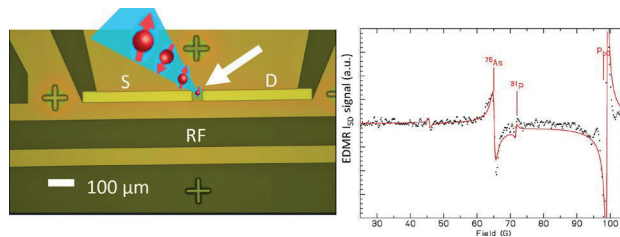
Towards a large-scale donor qubit array in enriched silicon fabricated with a focused ion beam system

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Qubits in a large-scale quantum computer using an architecture based on ion implanted dopants in silicon require a low background spin bath to prolong coherent quantum states programmed into the qubits. We have developed a method employing high fluence ^{28}Si ion irradiation of natural silicon to deplete the problematic nuclear spin $I = 1/2$ ^{29}Si isotope from 47,000 parts per million (ppm) to around 2 ppm. At this extreme depletion there is, on average, less than one ^{29}Si atom within the Bohr radius of the donor electron qubit. A FIB with a LMIS offers several advantages over a conventional ion implanter: a very clean vacuum system that minimises isobar contamination; a high intensity beam that minimises the time to reach the very high fluence required for the extreme depletion process; and the ability to selectively enrich areas that house qubits and not waste time on areas that house classical nanocircuitry. We have demonstrated 2.3 ppm residual ^{29}Si by employing focused 45 keV ^{28}Si ion beams with a fluence of $\sim 1 \times 10^{19}/\text{cm}^2$ [1]. We have also found by using a broad negative ion beam in a conventional implanter that raising the beam energy can achieve the same depletion with much less fluence [2] suggesting further optimisation of the FIB process is possible. We have built Electrically Detected Magnetic Resonance (EDMR) devices to measure the donor spin resonances of ion implanted two million donor ensembles and have demonstrated clock transitions that are insensitive to magnetic noise in ^{75}As [3]. The next step is to repeat this experiment in FIB enriched silicon with the ^{123}Sb donor in which highly complex robust logical quantum states can be encoded on the $I = 7/2$ nuclear spin donor states. The AuSbSi LMIS offers the potential to enrich the silicon substrate and to direct the ^{123}Sb qubits into ordered arrays with deterministic implantation without breaking vacuum. This presentation addresses the construction of a large-scale million qubit array to demonstrate that a useful quantum computer device could employ a FIB system as the first stage of the construction process.



(left) An EDMR device configured with a FIB-enriched island arrowed and (right) an EDMR spectrum at $f=280$ MHz for a P implanted device. From the work of R. Acharya, PhD 2025.

Acknowledgements: We acknowledge the contributions of Experimental Condensed Matter Physics group at the University of Melbourne, the Photon Science Institute of the University of Manchester, and support from Australian and UK funding agencies.

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Advances in Focused Ion Beam Materials Engineering

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The utilisation of focused ion beam (FIB) technologies allows for the nanoscale doping and modification of devices for advanced materials. Combined with high isotopic mass selection and spatial resolution [1], this technique, in the form of the P-NAME tool, provides a novel way to engineer materials on the nanoscale. Coupled with high-gain secondary electron detectors it also allows for deterministic doping of single ions. With single ion implantation providing of active area of interest in both solid-state qubit generation and single photon emitters.

This work represents an update on the work of the P-NAME tool at the University of Manchester, where focused ion beam doping has been used for the creation of isotopically pure Si [2], single photon emitters in diamond [3] and modification to the emission of lithium niobate in the last year. The work presented will focus on the expansion of the library of ion species available and their verification, including species such as phosphorus, and the identification of novel clusters such as Sb₂. Such clusters could for example, be an ideal candidate for solid-state qudit generation with access to 14-dimensional Hilbert space operation. It will also update on the deterministic single ion implantation approach, looking at the work done on a range of ion and material combinations, demonstrating the versatility of the system and detection efficiencies approaching up to 100% for cluster implantation. Finally, we report the utilisation of localised hyper-alloying for metallic nanoparticle generation, including Au and Pt, with initial studies verifying their catalytic properties.

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New FIB-SEM by JEOL

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Keywords: FIB-SEM, TEM lamella preparation, 3D analysis, EDS, EBSD

Since 1949, JEOL's legacy has been one of the most remarkable innovations in the development of instruments used to advance scientific research and technology. JEOL has 75 years of expertise in the field of electron.

This year, JEOL introduces a new generation of FIB-SEM the JIB-PS500i.

The JIB-PS500i has been designed to prepare various specimens of high quality for superior atomic-resolution transmission electron microscopy (TEM) observations. This instrument provides three solutions to assist TEM specimen preparation.

- TEM-LINKAGE: The use of JEOL's double tilt cartridge and TEM holder facilitates linkage between the TEM and the FIB. The cartridge can be attached to the dedicated TEM specimen holder with a single touch.
- CHECK-AND-GO: To precisely and efficiently prepare a TEM specimen, it is essential to quickly check the preparation progress. With its high-tilt stage and detector scheme, the JIB-PS500i allows for seamless transition from FIB milling to scanning transmission electron microscope (STEM) imaging. Fast transitions between lamella processing and STEM imaging lead to efficient specimen preparation.
- AUTOMATIC PREPARATION: The JIB-PS500i automates specimen preparation using the STEMLING2 automatic TEM specimen preparation system. This automatic system enables any operator to smoothly prepare specimens for TEM.

Other features will be also introduced during the presentation:

- High-resolution & High-contrast SEM Imaging
- High-power & High-quality FIB processing
- New Chamber & Stage Design



Reducing Artifacts in Cryo-FIB-SEM: Challenges in Processing Biological Samples

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Preserving the native conditions and environment of our biological samples is essential to fully understand the complexity of living systems while maintaining accurate localization of target structures [1]. Traditional high-resolution techniques for studying biological complexes often lack the ability to target structures without disrupting the cellular context. To address this limitation, it is crucial to integrate light microscopy with cryo-techniques, enabling the precise targeting of protein complexes and resolving their structure within their native environment.

The Valpuesta group, in partnership with the Cryo-Electron Microscopy Facility at CNB-CSIC, is pioneering in Spain cryo-correlative light and electron microscopy (cryo-CLEM) approaches. One possible approach is tomographic and involves preparing ultra-thin cell sections (lamellae, <300 nm) via FIB milling, enabling near-atomic resolution. The second is a serial sectioning method (cryo-FIBSEM tomography) for reconstructing entire cell volumes at approximately 10 nm resolution. This process iteratively combines scanning electron microscopy (SEM) imaging with focused ion beam (FIB) surface milling to generate a complete stack of cellular images.

Serial sectioning, while powerful, can introduce technique-specific artifacts that compromise image quality [2]. To address this, we're developing an open-source, user-friendly software package specifically designed for processing cryo-FIBSEM volumes and improving data accuracy (Fig. 1).

Our processing pipeline tackles several key issues:

Stripe Artifact Removal, Charging Artifact Mitigation, Stack Alignment, Deep Learning Segmentation [3]

This advanced processing pipeline significantly reduces artifacts in cryo-FIBSEM data, leading to more reliable and accurate structural insights from native cellular environments.

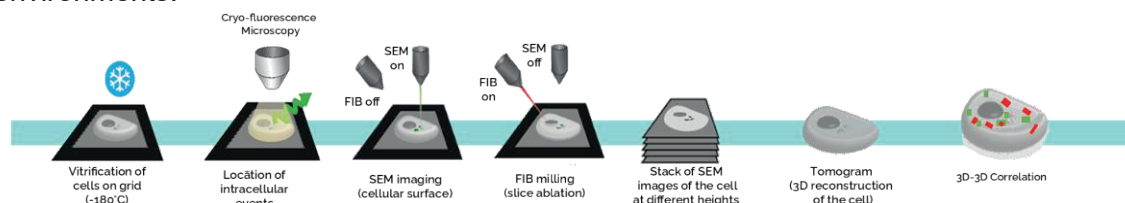


Fig. 1 Postprocessing workflow for CryoFIBSEM volume imaging

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Why cryoFIB for cuprates?

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Cuprate superconductors exhibit the highest known critical temperatures under ambient pressure, but their extreme sensitivity to ion beam damage and difficulty in contacting small samples have long hindered FIB-based device fabrication [1].

Here, we demonstrate a robust microstructuring workflow using cryogenic FIB milling combined with optimized cleanroom processes, enabling high-quality electrical transport devices from fragile, beam-sensitive cuprate crystals. This approach preserves the superconducting properties and enables sub-micron level of precision, unlocking new possibilities for mesoscale studies of high-T_c physics.

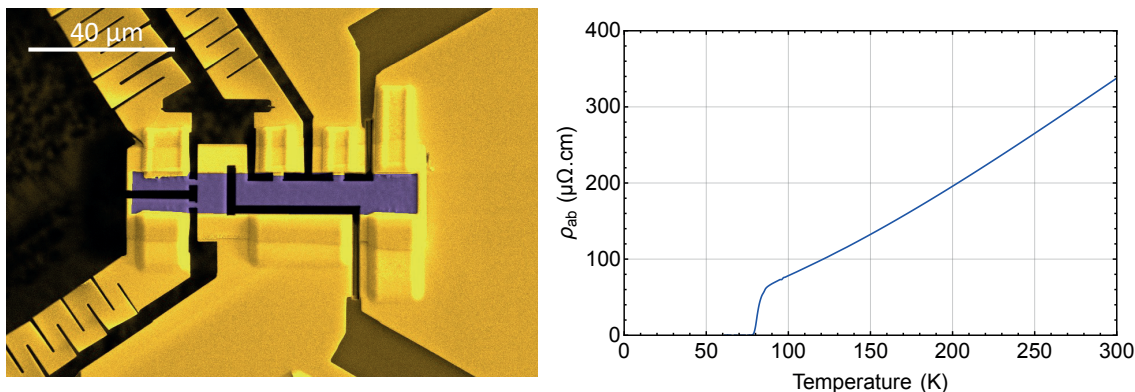


Figure: Strain-free microstructured device for electrical transport measurements, fabricated from the cuprate superconductor $\text{Ti}_2\text{Ba}_2\text{CuO}_{6+x}$ (left), and superconducting transition observed in the sample resistance (right).

Our results highlight how advanced cryo-FIB techniques can push the boundaries of what is possible in superconducting device fabrication, with relevance to other delicate material systems as well.

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Applications of cryogenic Plasma Focused Ion Beam with high vacuum cryogenic sample transfers

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Cryogenic Scanning Electron Microscopy (SEM) sample imaging, Focused Ion Beam (FIB) milling and sample preparation for techniques such as Transmission Electron Microscopy (TEM) [1] and Atom Probe Tomography [2] have advanced considerably in recent years.

A large amount of technique development has been based upon the more widespread applications in the life sciences [3] but there have been specific advances, specifically in high vacuum cryogenic sample transfers [4] and cryogenic sample preparation, that have allowed direct movement of samples between FIB and complementary high resolution techniques such as TEM and APT [5]

In this presentation, we demonstrate the advances in cryogenic sample preparation and cryogenic sample preparation using plasma FIB at the Imperial Centre for Cryo Microscopy of Materials at Imperial College London. We discuss the challenges in developing robust workflows for environmentally controlled transfers between instruments and give examples of material systems which benefit from such analysis.

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Abstracts

Friday, 19th

C2 - Confidential

Industrial applications of FIB-SEM in materials science

Safran Tech is the research center of Safran, an international high-technology group operating in the aerospace, defense and aerospace sectors. In 2023, the Materials and Processes division invested in the CrossBeam 550 SEM-FIB (Zeiss) to greatly improve the microstructural characterizations carried out in the laboratory.

This presentation illustrates the new contribution made by the installation of the FIB-SEM, focusing on three concrete examples of use, highlighting the practical tips that have been implemented for each:

- Imaging and EDS on cross-sections of thin films (< 100 nm),
- Machining of geometrically controlled defects at the bottom of notches in bending fatigue specimens,
- 3D EBSD characterization of the microstructure around a crack initiation in a nickel-based superalloy.

It will conclude with the prospects for new uses that we expect to see in the coming months.

Accelerating Material Characterization: Femtosecond Laser as a Complement to Correlative FIB and SEM Workflows

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Recent advancements in material design have demonstrated the significant role of femtosecond laser technology in enhancing SEM analyses, particularly when integrated with Focused Ion Beam (FIB) processes. In 2017, Pfeifenberger et al. utilised the Zeiss Crossbeam system to fabricate 100 tungsten cantilevers for material testing within a span of merely 30 minutes [1]. Furthermore, there is a significant demand for research in the field of battery materials. In 2025, Peng et al. utilised a FIB to analyse the battery active material [2].

FIB analyses are central to precise material characterisation, offering unparalleled capabilities in defect identification and sample preparation. Nevertheless, it should be noted that the processes in question can be time-consuming. The integration of a femtosecond laser with the Zeiss Crossbeam SEM introduces a complementary enhancement that significantly accelerates workflow without compromising the integrity of traditional FIB processes. This synergy exploits correlative capabilities between X-ray Microscopy (XRM) and SEM, facilitating efficient manipulation and analysis of areas of interest using 3D volumetric data for localisation.

The femtosecond laser which is situated in an external chamber, serves to prevent contamination in the main chamber during the process of ablation and serves as a powerful adjunct to FIB processes, offering substantial time savings and expanded analytical capabilities.

This presentation will provide a detailed exposition of the analysis of energy materials, with particular reference to the examination of battery samples for foreign particle and defect analysis, and the preparation of pillar samples in novel hard metals for mechanical testing and characterisation. The laser has been demonstrated to be capable of producing high-quality surfaces on metals and ceramics for conventional phase analyses and even for electron backscatter diffraction (EBSD) analyses. This integration enhances analytical precision and optimises time efficiency, rendering it an invaluable tool in the realm of material analysis.

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FIB assisted circuit modification: a nano-surgery tool for IC designers

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In the microelectronics industry, the conception of new prototypes requires a complex combination of semiconductor intellectual property cores put together. This development has always been a challenge that often needs several steps with fine-tuning and testing between the first conception and the mass production of an Integrated Circuit (IC). This fine-tuning requires to test different layouts of the circuit in order to optimize or fix the electrical functions inside the die. This can be done by a complete overhaul of the production process by changing the lithography masks. This solution is very costly and time consuming, therefore not a good solution to consider when multiple small modifications need to be tested one after the other. In this regard, the Focused Ion Beam (FIB) has greatly enhanced this process flow between designers and testers by providing a tool that can act like nano-surgery at the die level for a moderate cost and time. [1] The techniques of circuit modifications have evolved at the same time as the gate process technology, the metal tracks density, and the increasing complexity of the devices available in the market (3D integration, flip chip, etc.). [2] [3] FIB edit is also a powerful tool for failure analysis as it can help localize a defect or probe the device at several electrical nodes inside the die in order to follow the evolution of an electrical signal inside the circuitry. This contribution offers an overview of the strengths and limits of circuit modification, by presenting its basics and some more advanced cases.

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ZEISS Crossbeam for High-End Microscopy, Analytics and Sample Prep

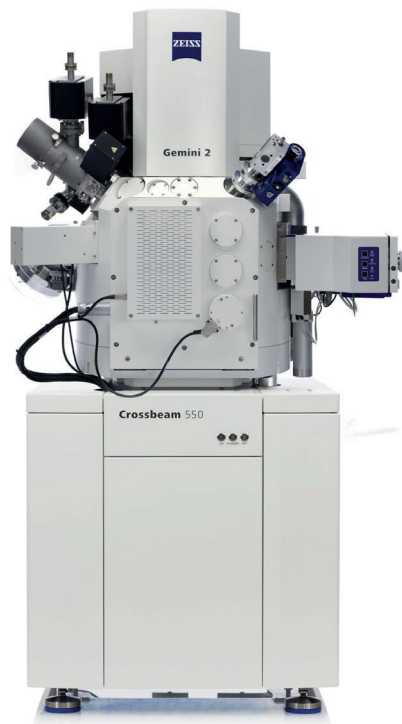
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In this talk we will present several important technical aspects of the ZEISS Crossbeam FIB-SEM tool and its recent development. We will illustrate the following topics:

- Correlative 3D multimodal microscopy with Cut-2-ROI workflow that implements X-ray microscopy (XRM) and Crossbeam Laser tools for identification of regions of interest (ROI) and respective sample preparation for structures hidden below the surface
- Automation with recently introduced to market Automated TEM lamella Prep (Crossbeam Samplefab)
- Visual workflow builder for automated FE-SEM control; automated cross-section for multisite milling, imaging and EDS using a workflow descriptor/scheduler
- ATLAS 3D most important features for reliable high-resolution 3D tomography with isometric resolution below 5 nm



Advancing FIB Beyond the Cut with Helium Ion Microscopy

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Focused ion beams (FIBs) today have many foci. Once primarily used for circuit edit and cross-sectioning, FIB techniques now underpin a range of advanced applications, including direct-write nanostructuring, precise tuning of material properties through the controlled introduction of defects, and ultra-sensitive analytics. This growing versatility has been accelerated by the development of novel ion sources that offer a broad selection of ion species from across the periodic table [1]. At the highest end of spatial resolution is the helium ion microscope, which delivers a sub-nanometer probe of light ions enabling nanofabrication with exceptional precision [2].

In this talk, I will highlight the unique contributions of helium ion microscopy in propelling FIB technology beyond its traditional use. In particular, I will explore nanofabrication strategies using helium-ion-induced near-surface swelling [3], helium-ion-induced deposition [4], and hybrid workflows that combine atomic-level defect engineering with high-resolution electron microscopy [5]. Together, these approaches demonstrate how the helium FIB is unlocking new possibilities in nanofabrication and functional material design.

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Optimisation of charged particle optics with the differential algebra method

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Genetic algorithms (GA) and Particle Swarm Optimisation (PSO) have been used in conjunction with the Differential Algebra (DA) method for Einzel lens design [1]. The GA and PSO algorithms both start with initial populations of lenses with random geometrical configurations. These starting populations are then altered for a set number of iterations according to the performance of the existing designs. To evaluate the performance of each test lens geometry, the spot size is calculated from the aberration coefficients obtained using the DA method. The DA technique uses nonstandard analysis for ray tracing a particle as it is subjected to the field generated by an optics element. The crucial advantage of the DA method is that it provides higher-order aberration coefficients from a single ray trace, and thus reduces the computational cost of calculating the spot size over the many iterations required by the intelligent algorithms, when compared to other ways of calculating the spot size (aberration integrals, direct ray tracing). This approach has been demonstrated on both the design of an Einzel lens (see Figure 1) as well as in the design of a focusing column with two lenses and a Wien filter.

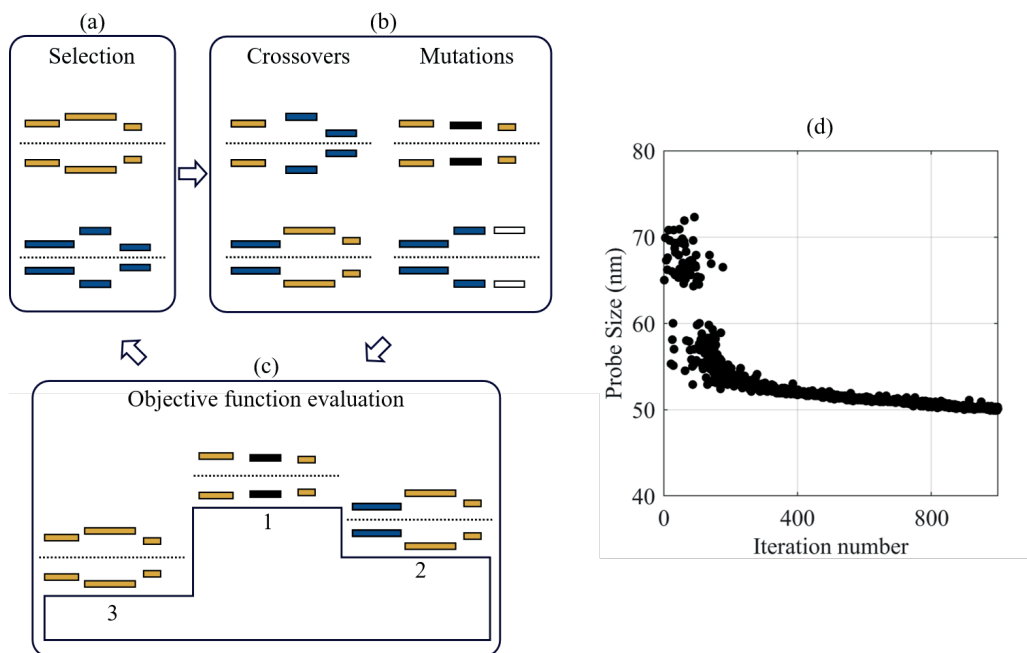


Figure 1. Genetic Algorithm applied to Einzel lens optimisation (a) Cross-sections of two random three-electrode Einzel lenses, with different electrode radii and lengths. These selected lenses serve as the starting population for the genetic algorithm. (b) Crossover and mutation produce four new configurations (c) evaluation of the objective function (spot size) for the six lenses, with lenses with a smaller spot size ranked with preference. The top two performers are used as parents for the next generation. (d) Example showing the spot size getting progressively smaller as the algorithm searches the parameter space for better performers.

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FIB-SEM: Challenges in Industrial Applications

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The rapid advancement of technology has brought significant challenges to the microelectronics and materials industries. Among the most pressing are the ongoing miniaturization of devices. As devices become smaller, the need for ultra-thin lamellae complicates analysis processes and characterization, while economic pressures demand more efficient production methods. To tackle these issues, the Focused Ion Beam (FIB) technique has emerged as a widely adopted and powerful tool in industrial applications. Its versatility enables precise failure analysis, process monitoring, and defect detection. This technique supports as well the development of novel materials across diverse sectors including metallurgy, glass, and horology. This contribution highlights the four main modes of FIB use, i.e. TEM sample preparation and other applications, cross-sectioning and circuit editing, in addition to their practical applications in microelectronics and materials science. It also focuses on real-world applications and effective solutions to common technical challenges.

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Abstracts Poster

Creation of quantum emitters in silicon carbide

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Besides its mechanical and electronic properties, that lead to applications in numerous devices, silicon carbide hosts a variety of color centers ranging from UV even to telecom wavelengths [1]. The quantum emitters originate from point defects that can be created by the impact of energetic ions [2]. The most studied defects so far are silicon or carbon vacancies, especially the negatively charged silicon vacancy V_{Si}^- found in both 4H-SiC and 6H-SiC polytypes [3]. It has been shown that especially helium ions combine a high creation yield [4] with the possibility to achieve highly precise and spatially resolved placement of the emitters by using helium ion microscopy (HIM) [5].

In the present study HIM patterning is used for the site-selective creation of silicon vacancies. Since silicon carbide has a high refractive index ($n = 2.6$) total internal reflection severely limits the light collection efficiency [5]. In this regard the depth of the generated defects is critical. Accordingly, the expected depth distribution was simulated using Monte Carlo simulations implemented in the code: stopping and range of ions in matter (SRIM), indicating a typical depth of these defects for helium ions far below the surface, for example 180 nm at 30 keV.

Focused helium ions were used to generate emitters in 4H-SiC (0001) on-axis samples with epitaxial graphene on the surface by direct ion beam writing and a specialized pattern design, that creates spot arrays with varying ion dose between 10 and 5000 ions/spot. To modify the depth of the generated emitters, the microscope is tuned to different accelerations voltages between 5 and 30 kV. The irradiated samples are then characterised in a home-built confocal epifluorescence setup, which allows for spectroscopy and second-order autocorrelation measurements of the emitters through a Hanbury Brown and Twiss setup. An additional Montana closed cycle helium cryostat integrated in this setup enables the investigation of the emitters at cryogenic temperatures below 4 K for spectral resolution of the involved transitions, the zero-phonon lines (ZPLs) of which are expected to reach their lifetime-limited linewidth at these temperatures [3].

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Investigating 3D nanostructures with diverse geometries for AFM Tip Development

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Atomic Force Microscopy (AFM) enables nanoscale surface characterization with exceptional precision, where the geometry and robustness of the probe play a key role in measurement quality. While focused ion beam induced deposition (FIBID) has been widely employed for fabricating AFM tips—mostly limited to nanopillar^[1-3] geometries—recent advances in 3D nanoprinting allow the direct^[4] creation of complex structures with high resolution.

In this study, we explore the fabrication and evaluation of AFM probes with diverse 3D geometries using helium ion FIBID. Three different tip designs—nanopillar, nanohelix, and nanospiral—were produced with varying dimensions from a W-C precursor. Each probe was tested through multiple AFM topography scans on two distinct instruments. The results demonstrated comparable resolution and measurement quality to commercial probes. However, post-measurement SEM imaging revealed structural degradation in all fabricated tips, indicating limitations in mechanical stability. This systematic evaluation highlights the potential of geometrically tailored FIBID tips for AFM, while also underlining the need for improved material and design strategies to ensure tip durability under operating conditions.

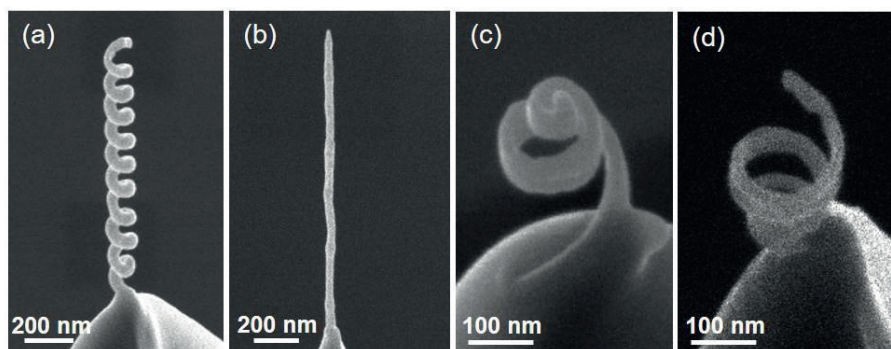


Figure 1: HIM images of 3D nanostructured AFM tip geometries fabricated using He⁺ FIBID: (a) Nanohelix, (b) Nanopillar, (c) Inward Archimedean nanospiral, and (d) Outward Archimedean nanospiral

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3D nano-superconductors grown by He⁺ FIBID: a brief introduction

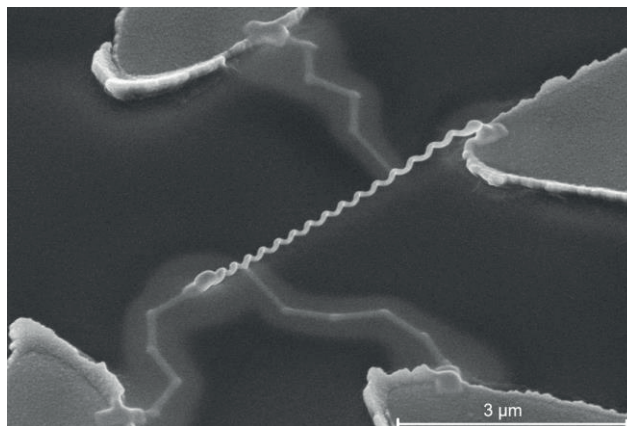
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3D nano-superconductors are positioning themselves as new smart materials with the ability to solve electronic and energy problems that our society must face. Although their manufacturing is still far from optimal, new growth techniques are increasingly enabling the production of more complex three-dimensional nanostructures [1-4]. In this way, *He⁺ FIBID* provides us the opportunity to develop W-C nanohelices with more than 10 loops, whose transition to a superconducting state is measured at $T_C = 6.6$ K and we determine a value of the critical magnetic field, B_{C2} ($T = 1.9$ K) = 9.3 T. After characterising the superconductor state, we further studied the influence of the temperature on the B_{C2} or the external magnetic field on T_C .



SEM image of the analysed W-C nanohelices, which is connected by four tips with *Pt-Ga⁺ FIBID*-grown contacts for magnetotransport measurements.

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Streamlining and Automation of Cryo-FIB Workflows with “EasyCryo”

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Cryo-FIB is playing an increasingly important role in materials research, often enabling sensitive materials to be prepared with higher quality than ever before. Yet it brings an added workflow complexity as users must not only learn how their unique materials behave when structured at cryogenic conditions, but they must also master a complex heating and cooling system to precisely dictate those conditions. This complexity significantly prolongs required training times, increases the risk of sample loss or even hardware damage and ultimately acts as a barrier to entry to a promising sample preparation strategy.

“EasyCryo” helps make this burgeoning technique more approachable by consolidating control of several complex sub-systems into a single intuitive general user interface (GUI), designed to greatly simplify the user experience. Pre-configured functions plot temperature, drive the stage to base temperature, or even prepare the system for unloading, letting researchers focus on micro-structuring rather than hardware management. Standard users can easily target setpoints to ~80K with the click of a button and maintain thermal stability of $\pm 0.01\text{K}$ for several hours at a time. Optional safeguards—such as aborting patterns upon detection of thermal drift—further protects sample quality. Meanwhile advanced users can embed control of the heating and cooling systems into their Thermo Fisher AutoScript routines, via an API, allowing ‘temperature-aware’ automation for advanced FIB operations.

The development of EasyCryo provides an approachable, yet robust platform, for managing a cryogenic environment during FIB experiments. By contributing to improved operational efficiency, reduced training time, and expanding the capability of automated procedures, it highlights how thoughtful engineering efforts can significantly improve productivity in a lab environment.

Multi-Ion Plasma FIB for Advanced TEM Lamella Preparation

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Ga⁺ focused ion beam (FIB) systems have enabled site-specific transmission-electron-microscopy lamella preparation for decades [1]. Nonetheless, Ga implantation degrades electrical and structural integrity, hampering functional studies. Novel multi-ion plasma FIB (PFIB) instruments allow to switch between Xe⁺ and Ar⁺ ions, but the optimal sequence of gases for protection, bulk removal and final polish is still debated [2,3]. We present a single-lift-out workflow that combines the use of Xe⁺ for protection-layer deposition and Ar⁺ for rough milling and final thinning. In this test, a TiN/HfO₂/Pt metal–insulator–metal stack on c-cut sapphire (Al₂O₃) was prepared in a Helios Hydra CX. A Xe⁺-assisted Pt-C deposition (30 keV, 1 μA) resulted in a dense protection layer reducing the effect of curtaining (unlike Ar⁺-assisted deposition). Trench milling and polishing however was performed with Ar⁺ due to increased speed and precision despite the lower ion mass compared to Xe⁺. The Xe/Ar procedure halves total preparation time compared with Ga FIB while delivering lamellae suitable for correlative structural and electrical characterisation of beam-sensitive oxides. The protocol offers a generic route for high-throughput, Ga-free sample preparation in next-generation PFIB laboratories.

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Focused Ion Beam-based patterning of topological-insulator Bi_2Te_3 thin films

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Focused Ion Beam (FIB) is versatile in device fabrication with high spatial resolution. However, the lateral damage induced by ion irradiation is cumbersome, especially for materials relying on pristine crystallinity. For example, the electrical resistance of topological insulator (TI) Bi_2Se_3 thin film is severely affected by Ga^+ ion irradiation [1]. To reduce the FIB-induced damage, some strategies have been employed, including annealing [2], coating with a sacrificial layer [3], milling under cryogenic condition [4], etc.

Building on previous work with Bi_2Se_3 , we aim to develop a method to pattern precise lines in Bi_2Te_3 by Ga -FIB milling, minimizing damage spread. Our Bi_2Te_3 thin films were grown by metal-organic chemical vapor deposition [5]. The figure shows how penetration depth and width depend on the ion dose, revealing the minimum dose required to pattern the full film with a narrow width below 100 nm. These results represent a first step for defining hybrid devices of Bi_2Te_3 and superconducting materials by FIB techniques.

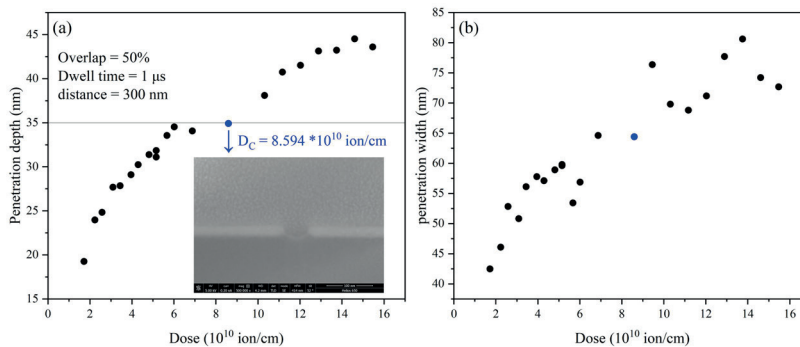


Figure: The Ga^+ dose vs. penetration (a) depth and (b) width under 30 kV and 1.1 pA milling voltage and current. The inset in (a) is a scanning electron micrograph of the sample area irradiated with D_c .

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Direct-Write Fabrication of Silver Microstructures via FIB Irradiation of Organometallic Films

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Metallic nanopatterns are intricate structures fabricated at the nanometer scale using metals. These patterns possess unique properties due to their size and composition, making them highly relevant in the development of new advancements in nanoelectronics, photonics, and sensor technologies. Existing methods for creating these structures often face limitations in precision, efficiency, and cost-effectiveness [1]. This opens up possibilities for developing novel fabrication techniques that achieve high efficiency and throughput without compromising resolution. This study introduces such a novel method for fabricating metallic nanopatterns based on the direct decomposition of silver butyrate organometallic films through Focused Ion Beam (FIB) irradiation, which has been previously used with high success in palladium acetate films [2]. The technique involves: 1) spread a solution containing the organometallic precursor onto the chosen substrate by spin coating, 2) FIB irradiation, and 3) revealing the metallic microstructure by dissolving the non-irradiated areas. This method eliminates the need for a sacrificial resist layer [3]. Using this approach, metallic micro-structures with a thickness of 40nm, a high degree of homogeneity, a silver content up to 60%, and a resistivity as low as 210 $\mu\Omega\cdot\text{cm}$ at a dose of 100 $\mu\text{C}/\text{cm}^2$ have been successfully fabricated.

These results pave the way for customizing the design and fabrication of silver-based micro- and nanostructures by FIB irradiation of organometallic films, making the method and results highly relevant for the themes of the conference.

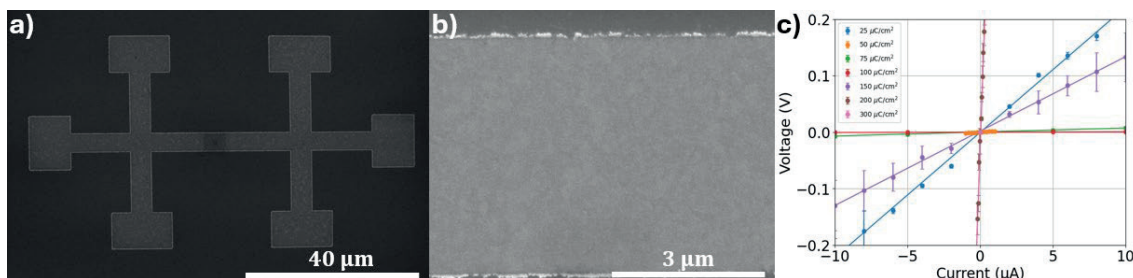


Figure 1: a) SEM micrograph of one metallic pattern. b) HR-SEM of the surface of the pattern. c) Electrical measurements taken by four-point probing.

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Radiation behaviour in coarse-grained and nanostructured Tungsten under He irradiation

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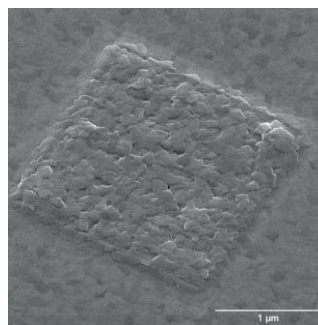
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Nuclear fusion is a promising alternative for producing clean energy, and it has the potential to meet the world's expanding energy needs. However, several challenges must be addressed before fusion can become a reality. Among other things, new materials should be introduced that are capable of surviving the reactor's environment (primarily high heat load and radiation flux).

In fusion reactors, plasma-facing materials (PFMs) are directly exposed to the operation plasma. They protect the structural material from irradiation and excessive heat. Thus, a PFM must possess excellent structural stability since severe cracking or mass loss would reduce its protective role and potentially poison the reactor. It must also have: (I) high thermal shock resistance, (II) high thermal conductivity, (III) high melting point, (IV) low physical and chemical sputtering, and (V) good compatibility with the coolant. Nowadays, tungsten (W) is the best candidate for plasma-facing materials applications, in both magnetic confinement (MC) and inertial (laser) confinement nuclear fusion reactors (IC) [1].

In this contribution, we compare the capabilities of two different types of W samples, coarse-grained (CGW) and nanostructured (NW), with a large density of grain boundaries (GBs), to act as PFMs. To do this, the samples were irradiated with helium at an energy of 30 keV, well above the displacement damage threshold (90 eV), at room temperature (RT) and high temperature (450 °C). The latter will lead to an increased mobility of vacancies in the material. The changes of the morphology of the plasma-facing surface of the samples were characterized in situ during irradiation, up to fluences larger than the point at which damage is observed, using a helium ion microscope (HIM). These studies (damage accumulated in the sample surface and He bubbles) are complemented with transmission electron microscope (TEM) observations, which provides an accurate characterization of the radiation-induced defects in samples irradiated slightly below and above the fluence damage threshold.



The differences in damage mechanisms will be discussed in terms of intrinsic (vacancies and interstitials) and extrinsic defects (helium) behaviour by combining HIM and TEM images.

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Focused ion beam microstructuring for mesoscopic transport experiments

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Mesoscopic transport occurs in systems where multiple length scales important for the physics of the system become comparable. An example of a mesoscopic transport regime is the ballistic regime, in which the average distance between the scattering events, the momentum-relaxing mean free path L_{MR} , becomes large relative to the characteristic device dimension. Mesoscopic transport regime can be accessed in highly clean materials with long L_{MR} . Delafossite metals, with L_{MR} in excess of 10 μm , are examples of such materials and display isotropic in-plane resistivity in bulk due to their triangular lattice symmetry. However, in the mesoscopic regime, pronounced anisotropic transport behavior emerges [1], reflecting the material's underlying electronic properties that remain hidden in bulk measurements.

Here we used the focused ion beam (FIB) milling to fabricate mesoscopic channels in delafossite metals PdCoO_2 and PtCoO_2 with sub-micrometer precision. Single crystals were sculpted into long, narrow channels in two distinct crystal orientations. The channels were iteratively narrowed, and after each modification, we measured the temperature and magnetic field dependence of the electrical resistivity of the channels. Our results demonstrate how FIB-based microfabrication enables systematic tuning between transport regimes through geometric confinement, allowing selective probing of different parts of the electronic structure and revealing intrinsic anisotropies not observable in bulk measurements.

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Enabling Scalable Donor Spin Qubits in Silicon via Focused Ion Beam Implantation in TIBUSSII

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The recently started EIC Pathfinder project **EquSpace** aims to establish a scalable, silicon-based quantum information platform using **donor spin qubits**. A key technological requirement is the controlled placement of single dopant atoms and the engineering of a low-noise host environment. Focused ion beam (FIB) technology is the central enabler, and within the project it will serve three core purposes:

1. **Deterministic Single-Ion Implantation:**

We will develop FIB-based methods for the precise placement of individual dopant atoms (e.g., Bi) with high spatial resolution. This includes isotopic ion selection, energy and current tuning and the implementation of a novel detection scheme to confirm successful implantation events.

2. **Local Isotopic Purification:**

FIB will be used for site-selective enrichment of ²⁸Si by reducing or removing ²⁹Si nuclear spins, which are a major source of decoherence for electron spins [1,2]. This approach will enable the creation of localized quantum-coherent regions within standard silicon wafers, making the platform compatible with industrial fabrication and independent of gas-centrifuged ²⁸Si sources.

3. **Local Strain Engineering:**

Ion beam modification will be employed for precise local strain engineering, which allows individual tuning of donor coupling frequencies.

To carry out these demanding tasks, we are using a unique and specialized setup: **TIBUSSII**—our new "**Triple Ion Beam UHV Setup for Single Ion Implantation**." This is a one-of-a-kind multi-column FIB platform operating under real ultra-high vacuum, perfectly suited for the fabrication of advanced quantum devices as envisioned in EquSpace.

In the poster, we will present the core concepts of the project, demonstrate how TIBUSSII meets the technical challenges, and provide an update on our initial progress.



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Comparison of imaging and milling using ion beams from Li-containing LMAISs FIBs and He and Ne ion beams provided by a GFIS based HIM system

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Focused Ion Beam (FIB) processing is a well-established technique for nanoscale patterning and prototyping. This study compares Helium and Neon ion beams generated by a Gas Field Ion Source (GFIS) in a Helium Ion Microscope (HIM) with ion beams of the very light element Lithium and the very heavy element Bismuth. These latter beams are produced using a mass-separated FIB system equipped with a GaBiLi liquid metal alloy ion source (LMAIS) [1]. The comparison focuses on imaging performance and sputtering behavior [2]. While HIM systems provide excellent imaging and nanometer-scale patterning capabilities with Helium and Neon ions, there is a growing demand for alternative ion species that offer similar or improved performance. Mass-separated FIB systems, which typically lack integrated scanning electron microscopes (SEMs), require rapid patterning control with the highest possible resolution.

A 2 nm imaging resolution was achieved with a 35 keV ⁷Li ion beam using a GaBiLi LMAIS. In comparison, a 30 keV Helium ion beam from a HIM system reached 0.5 nm resolution, while a 25 keV Neon ion beam achieved 1.8 nm [2]. Regarding sputtering performance, the theoretical sputter yields (Y) on silicon were as follows: Helium ions – 0.02, Lithium ions – 0.07, Neon ions – 0.84, and Bismuth ions – 3.3 [2]. To demonstrate the high-resolution capabilities, for instance of a 35 keV ⁷Li ion beam, images of biological test samples are presented (Fig. 1).

Overall, the imaging performance of light-ion beams from LMAIS-based FIBs is comparable to that of GFIS-based HIMs. Moreover, the ability to rapidly switch between Lithium and Bismuth ions in mass-filtered FIB systems enables high-rate Bismuth ion milling [3].

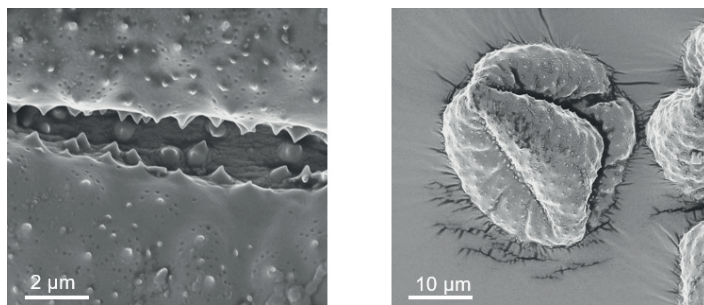


Fig. 1: Lithium ion images of Bio samples (red poppy).

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Research Infrastructure Access in NANoscience & nanotechnology (RIANA)

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Abstract body:

RIANA is a Horizon Europe-funded consortium of seven Analytical Research Infrastructures in Europe (ARIE) comprising of 69 research facilities that offer open, curiosity-driven research in nanoscience and nanotechnology. By integrating advanced capabilities within Europe in simulation, material synthesis, nanofabrication, characterization, and analysis, RIANA provides a single-point entry for users to perform targeted and impact-orientated investigations. The 7 ARIE are:

1. LEAPS (League of European Accelerator-based Photon Sources) – Allows access to synchrotron and free-electron laser-based photon sources.
2. LaserLab (Integrated Initiative of European Laser Research Infrastructures) – Allows access to laser sources.
3. e-DREAM (European Distributed Research Infrastructure for Advanced Electron Microscopy) – access to electron microscopy.
4. RADIATE (Research and Development with Ion Beams – Advancing Technology in Europe) – access to ion sources.
5. LENS (League of Advanced European Neutron Sources) – access to neutron sources.
6. EUROnanoLab – access to cleanrooms.
7. EUSMI (European Soft Matter Infrastructure) – access to soft matter research.

Users can simply submit a single application to access any of the nanoscience infrastructures within RIANA.

A comprehensive service, anchored by 21 Junior Scientists and supported by a panel of senior facility experts will guide users through technique selection, experimental operation, data analysis and publication. Parallel Innovation Services tailor access for industry—especially SMEs—helping mature technologies, raise TRLs, and scale production processes. The Smart Science Cluster (SSC) network of on-site Junior Scientists ensures hands-on support at every research stage, from experiment design to result interpretation.

Specifically, users requiring beam-time among other methods of research can take advantage of RIANA and the FIB aspects of their projects will be delegated to the RADIATE network such as the HZDR's Ion Beam Center.

References

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Ion Implantation into Semiconductors using Ionic Liquid Ion Sources

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Ionic liquids are salts comprised purely of ions that exist in the liquid phase at temperatures below 100°C. An Ionic Liquid Ion Source (ILIS) utilises field evaporation to produce a beam of ions from this novel type of liquid. ILIS consist of a sharp emitter needle and an extractor. A potential difference is applied between the emitter and the extractor, deforming the liquid into a sharp meniscus from which ions are evaporated.

ILIS can provide positively or negatively charged beams for material processing and focused ion beam (FIB) applications [1]. ILIS has been shown to reactively etch silicon [2], producing competitive sputtering yields and smoothness compared to Liquid Metal Ion Sources (LMIS). For example, an incoming BF_4^- ion disassociates upon impact with a surface into highly reactive fluorine radicals, which facilitate chemical etching processes.

This work will present atom probe tomography (APT) data showing ion implantation into semiconductor substrates caused by irradiation with ILIS beams. APT is a characterisation technique which produces three-dimensional atomic composition maps with sub-nanometer spatial resolution. APT has been used to characterise ion implantation from other ion sources, such as Xe into Si [3].

APT data will be presented from irradiations of Si, SiC and GaAs substrates using filtered and unfiltered beams from 1-ethyl-3-methylimidazolium tris(pentafluoroethyl)trifluorophosphate (EMI-FAP) in both positive and negative modes at beam energies of up to 20 keV. An APT reconstruction of a Si substrate irradiated with a filtered beam of EMI^+ ions at 4.2 keV is shown in Figure 1, displaying the implantation of carbon at depths of up to 10 nm.

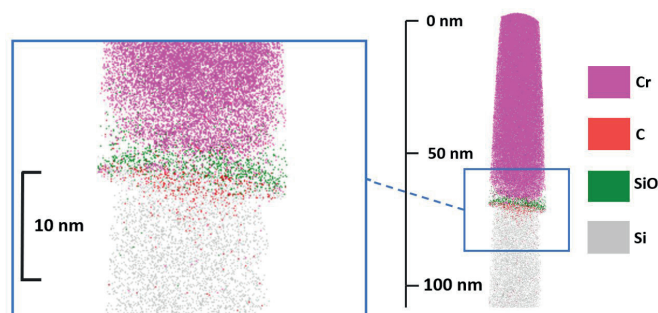


Figure 1: An atom probe reconstruction of a specimen prepared from Si sample irradiated with a pure EMI^+ beam. The grey points represent Si atoms, green points represent SiO, red points represent C, and pink points represent Cr, which was added as a sacrificial coating layer. The magnified image on the left shows some C atoms implanted within the first 10 nm of the Si.

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Effect of ion irradiation on the crystallization of Ge via AILLE process

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To achieve crystallization of amorphous semiconductors at low temperatures, metal contact is made with which the semiconductor forms a eutectic phase known as metal induced crystallization (MIC). In recent, ion beam irradiation have been used as a tool to reduce the crystallization temperature of Si and Ge [1-5]. The ion beam irradiation, athermal process, has several advantages over thermal annealing such as spatial selectivity of samples, high precision, and lower processing time. In the present paper, the polycrystalline (*p*-) Al (50 nm)/ amorphous (*a*-) Ge (50 nm) is irradiated using 1000 keV Xe⁺ ions with fluences of 7×10^{14} ions/cm², 3×10^{15} ions/cm² and 1×10^{16} ions/cm² followed by post thermal annealing at 200 °C. The pristine (i.e., as-prepared) sample is also thermally annealed for comparison purposes. The X-ray diffraction measurement confirms the crystallization of Ge after thermal annealing in both pristine and ion irradiated samples whereas only ion irradiation does not show any crystallization of Ge. The optical micrograph and field emission scanning electron microscopy (FE-SEM) images show dotted like structures on the surface of the film which are found to increase with increasing ion fluence. The Rutherford backscattering spectrometry confirms the interface mixing and the energy dispersive X-ray spectroscopy confirms the layer exchange phenomena at the interface in the *c*-Al/*a*-Ge bilayer system. The produced polycrystalline Ge may be used as IR sensors or thermoelectric power generation application in future.

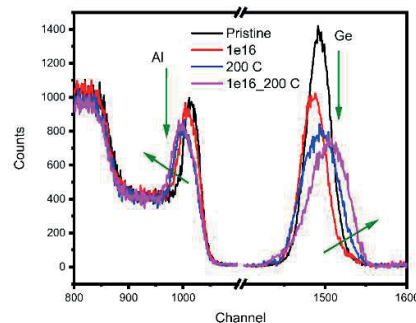


Figure 1: RBS spectra of *p*-Al/*a*-Ge (pristine), irradiated with 1000 keV Xe⁺ ion at a fluence of 1×10^{16} ions/cm², annealed at 200 °C and irradiated at a fluence of 1×10^{16} ions/cm² followed by annealing at 200 °C

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Comparative Analysis of TOF-SIMS Depth Profiling and Mapping on TEM Lamellae for Solar Cell Characterization

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Abstract

In this study, we present a comparative evaluation of secondary ion mass spectrometry (SIMS) techniques applied to solar cell analysis. We focus on two complementary approaches:

(1) Depth profiling with a Iontof TOF-SIMS⁵ to obtain chemical information across the sample depth and (2) TOF-SIMS mapping using a Zeiss Crossbeam 350 equipped with a fibTOF mass analyzer, applied to a slightly thicker TEM lamellae. The mapping approach permits high-resolution lateral imaging of elemental and molecular distributions, while post-acquisition further thinning of the lamella enables correlation with high resolution TEM imaging and morphological characterization. Our results demonstrate the strengths and limitations of both techniques in resolving depth-specific chemical signatures and structural features, providing insights for optimized interface analysis in photovoltaic materials. These findings underscore the benefit of integrating high-resolution SIMS mapping with conventional depth profiles to fully elucidate the multi-scale phenomena in solar cell structures.

Fabrication of Pd nanostructures by focused ion beam irradiation of palladium acetate films

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Focused Ion Beam (FIB) technology is an advanced technique that enables precise modification, patterning, and analysis of materials at micro- and nanoscales [1]. When combined with a suitable precursor, this technique can be used to directly grow nanostructures through Focused Ion Beam Induced Deposition (FIBID) [2]. In contrast to traditional photolithography, which involves multiple steps and the use of resists and masks, FIBID offers several advantages, including a simplified process, higher spatial resolution, and greater flexibility, especially for rapid prototyping and fabrication of complex structures [3].

In this study, we use palladium acetate ($\text{Pd}(\text{OAc})_2$) as a solid precursor material. A thin film of $\text{Pd}(\text{OAc})_2$ is deposited onto a silicon substrate via spin-coating and subsequently irradiated with a focused gallium ion (Ga^+) beam at 30 keV. The irradiation induces local decomposition and reduction of the precursor, forming metallic palladium. The conductivity of the resulting structures is further enhanced by adjusting the ion dose and applying post-irradiation annealing in a nitrogen atmosphere. The morphology and composition of the irradiated films are characterized using scanning electron microscopy (SEM) and energy-dispersive X-ray spectroscopy (EDX). Electrical measurements confirm a notable increase in conductivity after irradiation and annealing, demonstrating the effectiveness of this method for creating conductive palladium-based microstructures for potential electronic and nanoscale device applications.

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