Global Initiative on Academic Network (GIAN), Course

Advanced Electron Microscopy for Materials Science

Invited Faculty: Prof. Dr. Benjamin Butz, University of Siegen, Germany

Duration: 13-22 March 2018 at Jawaharlal Nehru University (JNU)

Objectives

- Providing an overview of **state-of-the-art electron microscopy** (EM) and its applications in materials science
- Introducing the physical principles of electron(/ion)-sample interaction to understand image formation and spectroscopy in scanning and (scanning) transmission EM (SEM, (S)TEM)
- Explaining the functional principles and practices of alignment of such microscopes for SEM and (S)TEM
- Explaining and comparing important imaging, diffraction and spectroscopic SEM & (S)TEM techniques for materials characterization
- Introducting state-of-the-art *in situ* capabilites
- Explaining simulation and interpretation of SEM and TEM data
- Providing practical insight of TEM sample preparation

Course Content

Lecture Topics

Overview of SEM, (S)TEM techniques, applications	1
Functional principle and alignment of SEM	1
Electron-sample interaction, interaction volume, back-scattered (BSE)/secondary electron(SE) generation, SEM image formation, contrast mechanism (topography/chemistry by SE/BSE imaging, STEM, back-scatter diffraction (EBSD)), quantitative interpretation	2
Focussed-ion beam (FIB) instrumentation, ion-beam microscopy	2
Functional principle and alignment of TEM	1
Electron diffraction (ED) in TEM (single crystal vs. powder): reciprocal space, Kikuchi/HOLZ lines, selected-area ED (SAED), convergent-beam ED (CBED)	3
Diffraction-contrast (bright-/dark-field) imaging: crystal orientation, thickness fringes, bend contours, dislocation/stacking-fault imaging	2
High-resolution TEM (HRTEM): weak-phase object, exit-wave function, contrast-transfer function, aberration correction (AC)	3
(High-resolution) STEM: ronchigram alignment, Rutherford/thermal diffuse scattering, Z-contrast imaging, aberration correction	3
S(TEM) & FIB tomography	2
Energy-dispersive X-ray spectroscopy (EDXS) in SEM and TEM: detectors, quantification methods, atomic-resolution EDXS	2
Electron energy-loss spectroscopy (EELS) in TEM: detector, alignment, quantification, atomic-resolution EELS	2
Advanced *in situ* electron microscopy (SEM, TEM): Equipment/capabilities, applications	3
Application of advanced EM on graphene, batteries, fuel cells, etc.	1
Total lecture hrs	**28**

Demo/Tutorial Topics

Demonstration of SEM techniques: alignments, SE, BSE, EDX, FIB	3
TEM sample preparation using ion milling and ultramicrotomy	2
Demonstration of TEM techniques: alignment, SAED/CBED, BF/DF imaging, HRTEM	2
Demonstration of STEM techniques: alignment, Z-contrast imaging, EDXS	1
Indexing of diffraction patterns	3
Simulation of TEM images and diffraction patterns, EELS data analysis	4
Total demo/tutorial hrs	**15**

Who can attend:

- Students at all levels (BTech/MSc/MTech/PhD) or faculty from reputed academic institutions and technical institutions
- Engineers, researchers and executives, from industry, service and government organizations including R&D laboratories

Registration, Venue & Course Fees**:

- JNU M.Sc. / M.Tech. students: free
- JNU research students (M. Phil & Ph.D): Rs 1000; JNU Faculty : Rs 2000

Other educational institutes

- Research students: Rs 2000; Faculty : Rs 4000
- government institutes: Rs 10000 ; Industry and private institutes: Rs 15000
- Participants from outside India: US$ 500

Registration: for pre-registration please apply online at http://www.gian.iitkgp.ac.in & https://www.jnu.ac.in/GIAN/

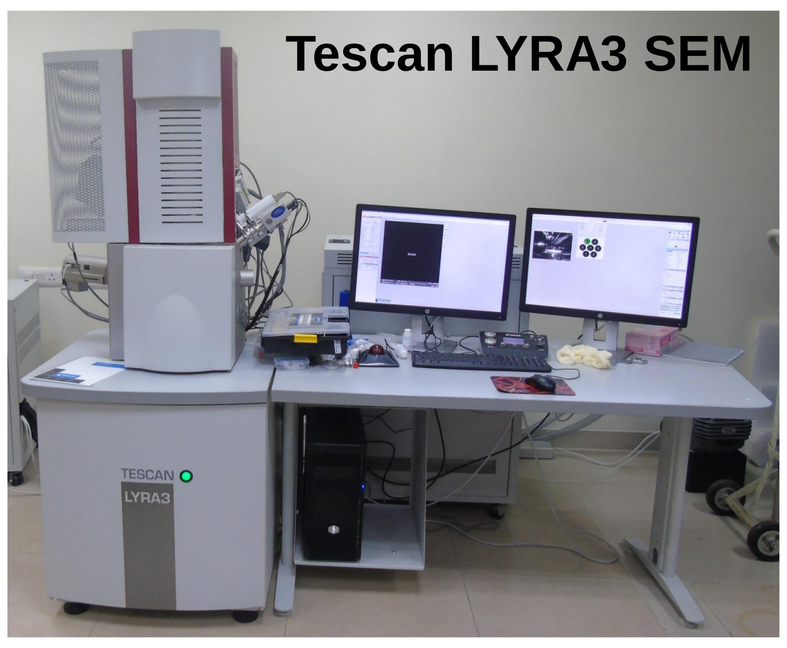
Number of participants: will be shortlisted to 40 + waiting list of ~15

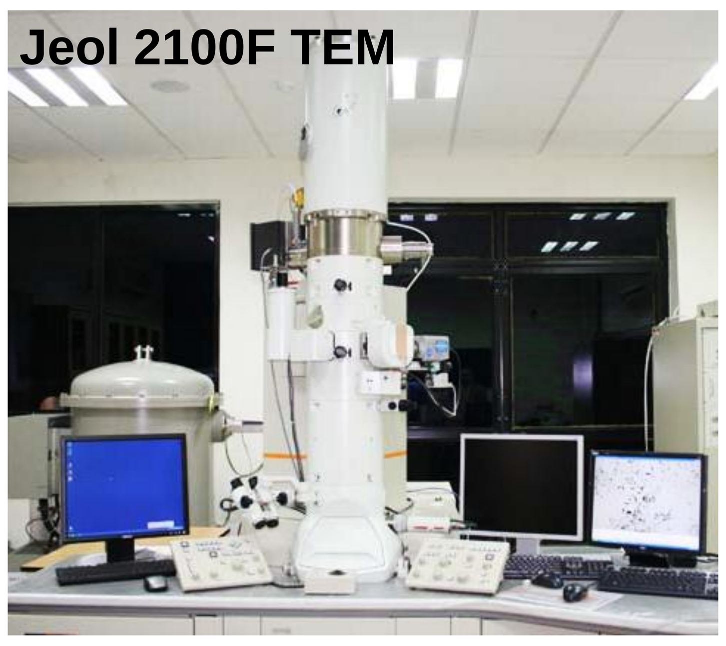
Venue: Special Centre for Nanoscience and AIRF, JNU

Accommodation: We will facilitate in finding accommodation in JNU guest houses and hostels upon request, subject to payment rules and availability.

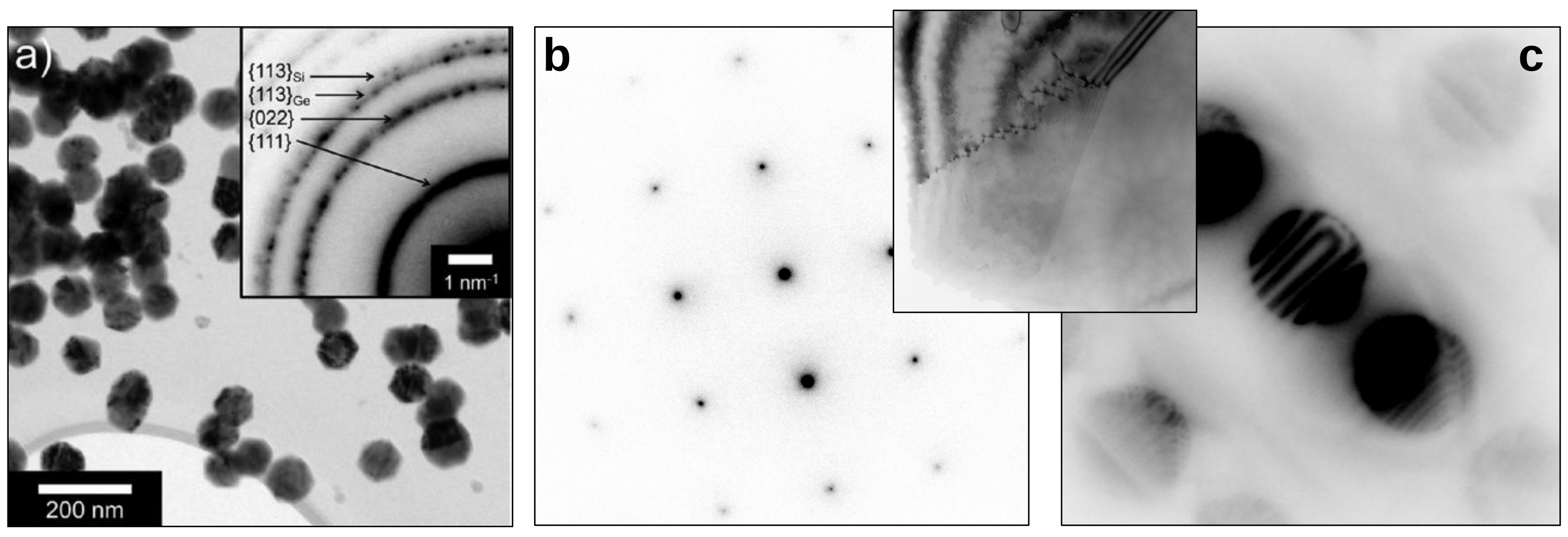
** does not include boarding and lodging charges (birajdar@mail.jnu.ac.in)

Tools at Advanced Instrumentation & Research Facility/JNU

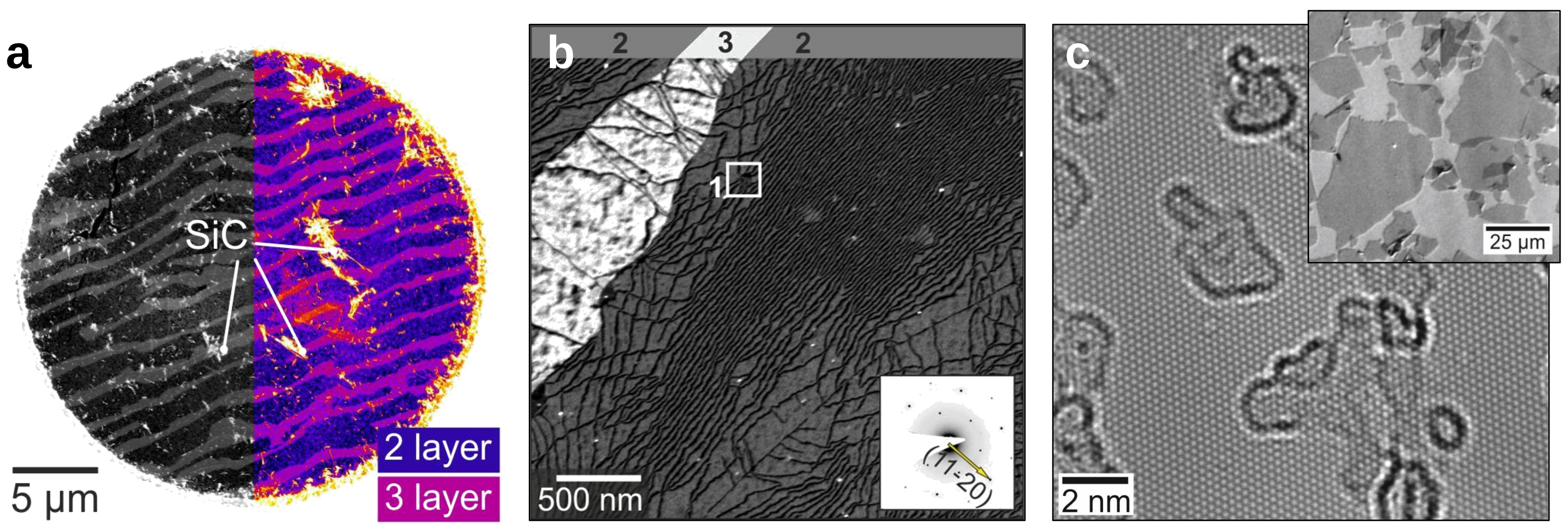




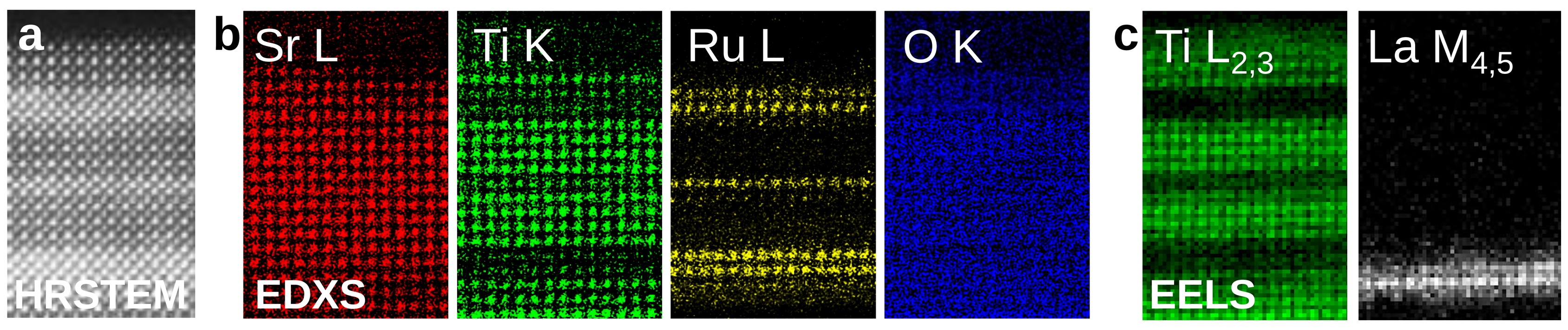
Research Examples



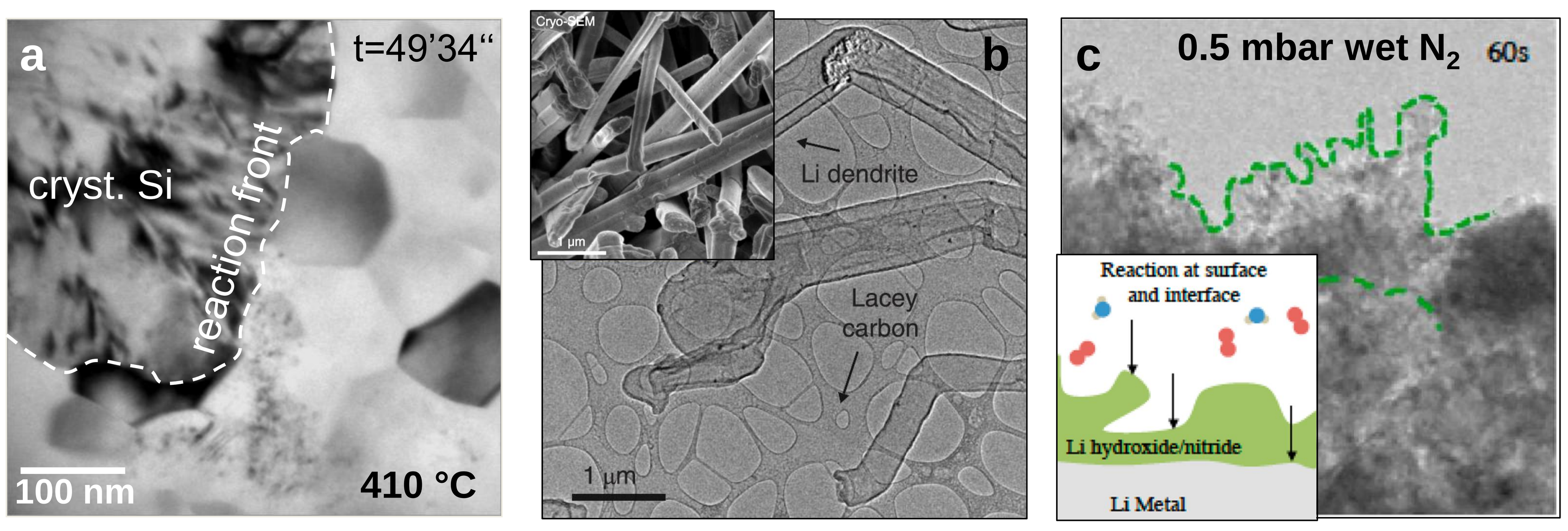
a) Debye SAED pattern of SiGe nanoparticles[1], b) <001> SAED pattern of single grain of commercial Al foil (inset shows polycrystals), c) CBED pattern of same Al foil



a) Quantitative SEM of few-layer graphene membrane[2], b) DF-TEM of dislocations in bilayer graphene (dark lines)[3], c) AC-HRTEM of monolayer graphene oxide[4]



a) Probe-corrected HRSTEM of La-STO-SRO heterostructure (1 La monolayer & 2-1-2 unit cells of SRO on STO wafer) with atomic-resolution b) EDXS and c) EELS mappings



a) Thermally induced layer exchange by *in situ* TEM heating (ALILE)[5], b) cryo-EM of Li battery materials[6], c) environmental TEM (ETEM) study of Li corrosion at RT[7]

[1]*Nanoscale* 7 (2015) 5186 [2]**ACS Nano** 7 (2013) 4441 [3]**Nature** 505 (2014) 533 [4]**Angew Chem** 128 (2016) 16003 [5]**Scripta Mater** 66 (2012) 550 [6]**Science** 358 (2017) 506 [7]**Nano Lett** 17 (2017) 5171

Invited Faculty: Prof. Benjamin Butz, Univ. of Siegen, Germany

Materials physicist and expert in advanced EM at the interface of material characterization and development. To clarify structure-property relations, he utilizes state-of-the-art aberration-corrected TEM and FIB/SEM in combination with modern *in situ* capabilities. His work, in particular on graphene, is published in renowned journals like Nature and Nat. Physics.

Host Faculty: Dr. Balaji Birajdar, Asst. Prof. SCNS, JNU

Solid-state physicist and an expert in structure-property correlations of functional materials using advanced EM. His research fields cover novel ferroelectric, superconducting, and semiconducting thin films and bulk materials. He also synthesizes novel functional materials for photocatalytic, photovoltaic and capacitor applications.