4 EXPERIMENTAL FACILITIES IN BEAM HALL

4.1 SCATTERING CHAMBER AND NEUTRON ARRAY

N. Saneesh, K. S. Golda, Mohit Kumar, A. Jhingan and P. Sugathan

4.1.1 Operation and maintenance activities

Problems related to the vacuum systems of the General Purpose Scattering Chamber (GPSC) facility had been encountered quite often during experiments in the recent past. The most likely cause of the problems is ageing of components of the vacuum systems. One such problem was leakage in the Gate Valve, caused by misalignment of the cylinder controlling operation of the valve. The problem was temporarily resolved by aligning the cylinder. Two other problems were a leak in the foreline side of the diffusion pump and malfunctioning of a Penning Gauge. All these problems were resolved with technical support from the Vacuum Laboratory of IUAC.

In the NAND data room, as part of the routine maintenance work, the performance test of signal processing electronics was carried out. The NIM bins housing the Pulse Shape Discrimination (PSD) moduels and the cooling fans were cleaned with compressed air and tested to ensure their proper functioning after completion of cleaning. During previous experiments, it was observed that the jitter in the timing signal, used in Time of Flight (TOF), broadened the time width of γ-ray peak in the TOF spectrum. On detailed examination, it was found that the delayed signal from constant fraction discriminator (CFD) circuit, integrated into the PSD module had a large time jitter as compared to the prompt CFD signal. It was, therefore, decided to use the prompt CFD signal for extracting the TOF information in experiments and run the acquisition in common STOP mode for all time digitizers. Necessary changes were incorporated in the data acquisition system modifying the setup for common STOP configuration of VME TDCs. To further improve the performance of the CFD delay circuit, electronics of the PSD module is being modified.

The air-conditioning of the NAND data room has been upgraded to localized air-conditioning system which can meet cooling requirements of the electronics for full detector array along with auxiliary detectors. After failure of the centralized air-conditioning in this area, two window air conditioners (ACs) were fixed temporarily to cool the data room electronics. The arrangement was found to be insufficient to keep the temperature cool enough for operating all the modules required for the full array during the peak of summer. The upgraded system now consists of three split-ACs (each of 3 ton capacity) directly cooling the electronics rack.

Thin mylar foils of large area are used as entrance windows of Multi Wire Proportional Counters (MWPCs) to isolate the gas from high vacuum region in fusion-fission experiments. The entrance window is made of 0.9 µm thick mylar foil which allows the heavy ions to enter the detection medium with minimal energy loss. The foil is required to maintain the target chamber pressure at lower than 5×10^{-6} mbar when isobutane gas is circulated through the MWPC at a pressure of ~4 mbar. The large pressure gradient causes bulging of the thin entrance foil towards the low-pressure region and is protected by nylon support wires wound on the window frame. On prolonged operations, minor damages on the foil surfaces (wrinkles, scratches, etc.) may develop which can lead to vacuum leaks. A leak was detected in one of the MWPCs (20 cm × 10 cm) during a routine test prior to an experiment. The window foil was replaced with a new piece of mylar of the same thickness and subsequently performance of the detector was found to be satisfactory.

4.1.2 User experiments in GPSC and NAND

The following experiments were carried out in GPSC and NAND beam-lines during the last year. The GPSC experiments were performed with beams from the Pelletron whereas NAND experiments used beams from the Pelletron and superconducting linac.

User / Affiliation	*Experiment*	*Beam*	*No of shifts*
Ms. Malika Kaushik IIT Roper	Understanding the interplay of different nuclear reactions at low incident energies	^{12}C	16
Dr. Md. Sabir Ali MANU University, Bihar	Study of fusion suppression in heavy ion induced reactions above the barrier energy	^{16}O	15
Dr. Rahbar Ali	Disentangling the incomplete fusion dynamics in heavy ion induced reaction at energies 3-8 MeV/A	^{16}O	15
Mr. Sunil Prajapati Bareilly College, Bareilly	Study of some heavy ion induced reactions at Pelletron energies.	^{16}O	21
Ms. Divya Arora IUAC	Probing fission dynamics with neutron clock	^{28}Si	18
Ms. Shruti Punjab University	Fragmentation dynamics and neutron multiplicity measurements for super-heavy nuclei	^{28}Si	18

User / Affiliation	*Experiment*	*Beam*	*No of shifts*
Mr. Amit Punjab University	Study of fission dynamics of neutron-rich nuclei	^{28}Si	30
Ms. Kajol Chakraborty Delhi University	Fission time scale measurements around mass ~ 200 region	^{19}F	30
Mr. N. Saneesh, Calicut University / IUAC	Role of neutron emission in the fission of actinide nuclei	^{19}F	30
Ms. Divya Arora IUAC	Probing fission dynamics with neutron clock	^{12}C	18
Ms. Honey Arora Punjab University	Anomalous light particle spectra in heavy ion induced fusion reactions	^{48}Ti	18
Mr. Chetan Sharma Punjab University	Study of the entrance channel effect in fission reaction dynamics measuring the light particle multiplicities	^{12}C	18
Prof. Sandhya Kamat ISRO	Test for Single event effect	^{28}Si	12
Mr. Gurvinder Singh SCL, Mohali	Test for Single event effect	Si, Ti, Ni	9

4.1.3 Simulation of neutron scattering by materials in NAND

In a recent publication [1], the results of FLUKA simulation on estimation of neutron scattering from materials in the target chamber and cross talk probability of the NAND array were reported. Though the facility had been constructed with minimal use of materials between the target and neutron detectors, walls of the vacuum chamber, detector coverings etc. remained as sources of scattering. FLUKA-based simulations were performed to calculate the loss of flux due to scattering and the subsequent generation of neutron background in other detectors of the array. The simulation was carried out with two commonly used vacuum chamber materials, aluminum (Al) and stainless steel (SS) in the form of 4 mm thick blocks, mounted on the flight path of neutrons 50 cm away from the source position.

The geometrical setup for the simulation consisted of three organic liquid scintillators, situated at 175 cm from the source position at an angular separation of 18^{o} from each other. A beam of neutrons with Maxwellian energy distribution was bombarded on the sample materials (Al or SS) and the scattered beam flux was recorded in the detectors. The table below shows the incident neutron flux in the detector at 0^{o} (ϕ_{direct}) and the background produced by the scattered beam to the detector mounted at 18^{o} ($\phi_{scattered}$). The loss of flux due to scattering and the associated neutron background were minimal for Al as compared to SS. The measured cross-talk probability, defined as the probability of detecting the same neutron in two or more neighboring detectors after scattering, was found to be comparable with the background caused by the chamber walls made of SS.

Table 4.1.3: Percentage of incident neutron flux (direct and scattered) on detectors, after interactions with 4 mm thick materials (Al and SS) placed in the path of neutrons.

Scattering material	*Φ_{direct} at 0^{0} (%)*	*$\Phi_{scattered}$ at 18^{0} (%)*	*Cross-talk probability (%)*
Aluminium	91.7	5.6×10^{-3}	$4.6 \pm 0.28 \times 10^{-2}$
Stainless steel	88.1	3.8×10^{-2}	

References:

[1] N. Saneesh *et al*., Nucl. Instrum. Methods A **986**, 164754 (2021).

4.2 GAMMA DETECTOR ARRAYS: GDA and INGA

S. Muralithar, R. P. Singh, R. Kumar, Indu Bala and Yashraj

4.2.1 User experiments

Ten user experiments were carried out using GDA and INGA experimental facilities in the last academic year. The experiments comprised of study of lifetime of excited nuclear states using the plunger device and Doppler-shift attenuation method along with high spin spectroscopy in INGA. Coulomb excitation and incomplete fusion studies were performed using Clover Ge detectors in GDA. A total of about 150 shifts of beam time was utilized for these studies.

4.2.2 Servicing of Clover detectors

Clover detector annealing setup was moved to beam hall II and about 10 Clover detectors were annealed and serviced for good vacuum using the setup.

4.2.3 VME data acquisition system in INGA

Yashraj, Mamta Jain, Kusum Rani, E. T. Subramanium, R. P. Singh and S. Muralithar

VME-based data acquisition system (DAS) was implemented in INGA last year. After test of various characteristics, *e.g.*, stability, non-linearity and time correlations with radioactive sources, an in-beam test run was carried out with ^{16}O beam on ^{94}Zr target. The beam energy was varied from 104 MeV to 80 MeV. During the test run the coincidence data throughput was measured for the new DAS. The same is shown in Fig. 4.2.1. Fourteen Compton-suppressed Clover detectors were used in the test run. It can be seen from the figure that for 10k trigger rate received, about 80% triggers were accepted by the system.

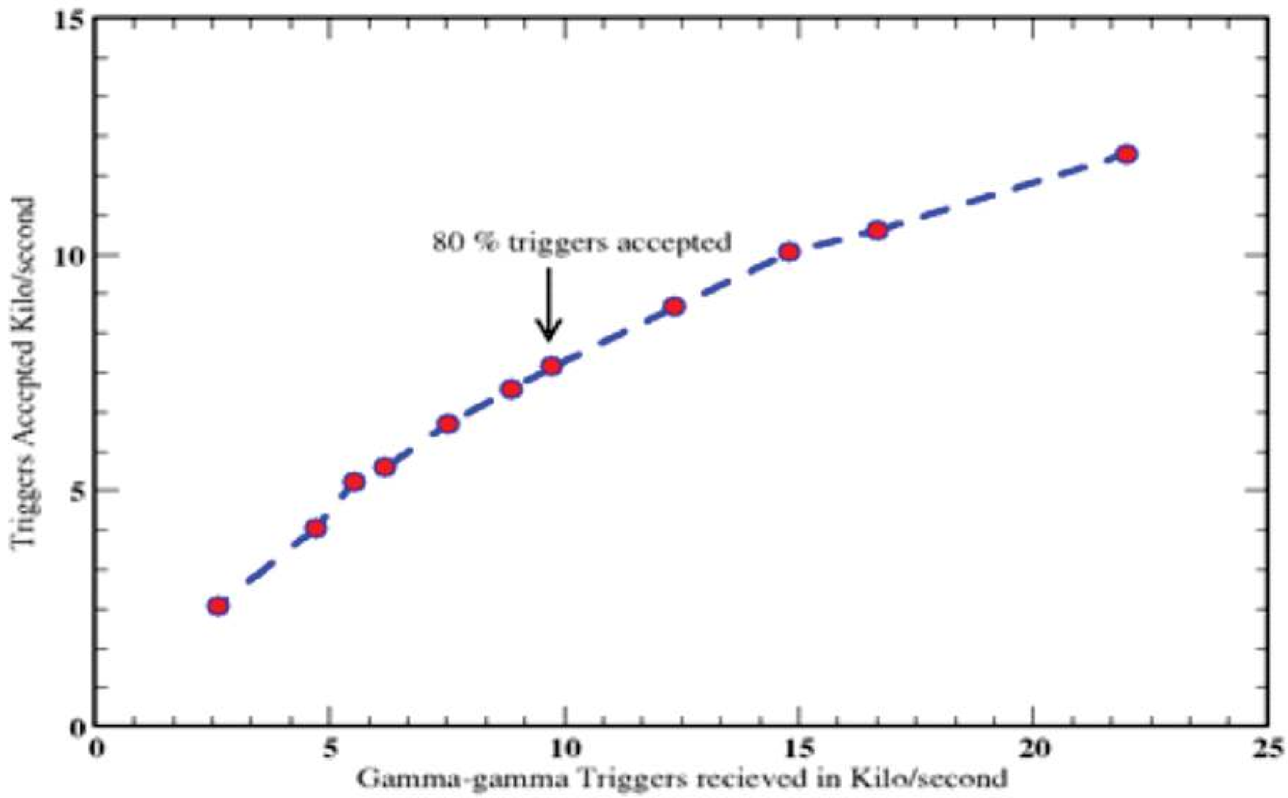


Fig. 4.2.1: Triggers received versus triggers accepted for the new VME-based DAS in INGA.

The DAS writes the data in the ROOT format. Detailed analysis for γ-γ coincidences and time analysis of the TDC were also performed for the acquired data. In the new DAS, 13-bit VME ADCs from Mesytec and 12-bit TDC from CAEN were used with home-made VME crate controller and Global Event trigger Module (GEM). The home-made modules were developed by the Data Support Laboratory of IUAC.

4.2.4 Clover enhancer module

Arti Gupta, S. Venkataramanan, E. T. Subramanium, Mamta Jain, R. P. Singh and S. Muralithar

A prototype enhancer module was developed by the Electronics and RF Group of IUAC to enable collection of Compton-suppressed time information from individual Clover crystals. The time spectra from this module were compared with the time spectra from the Clover module using radioactive sources. Both were found to have same time resolution. The module was also tested for stability.

4.3 RECOIL MASS SPECTROMETERS

4.3.1 Heavy Ion Reaction Analyzer (HIRA)

S. Nath, J. Gehlot, Gonika, T. Varughese and N. Madhavan

HIRA facility was used in five experimental runs all of which were part of student thesis proposals. A facility test with beam was taken up to test the newly installed VME-based Data Acquisition System (DAS).

A. $^{16}O+^{107,109}Ag$ systems leading to $^{123,125}Cs^*$ compound nuclei (Thesis experiment of A. Vinayak, Karnatak University, Dharwad) – Sub-barrier transfer and fusion, quasielastic back-scattering.

B. $^{19}F+^{191,193}Ir$ systems leading to $^{210,212}Rn^*$ compound nuclei (Thesis experiment of Amritraj Mahato, Central University of Jharkhand, Ranchi) – Sub-barrier fusion and quasielastic back-scattering.

C. $^{16}O+^{116}Cd,^{140,142}Ce$ leading to $^{132}Ba^*$ and $^{156,158}Dy^*$ compound nuclei (Thesis experiment of Rohan Biswas, IUAC/JNU, New Delhi) – Sub-barrier fusion and quasielastic back-scattering.

D. $^{28}Si+^{158}Gd$ and $^{30}Si+^{156}Gd$ both leading to the compound nucleus $^{186}Pt^*$ (Thesis experiment of Rinku Prajapat, IIT Roorkee, Roorkee) – Sub- and near-barrier fusion and quasielastic back-scattering.

E. $^{19}F+^{64,68}Zn$ leading to $^{83,87}Y^*$ compound nuclei (Thesis experiment of Shoaib Noor, Thapar University, Patiala) – Near barrier transfer studies by detecting the target-like nuclei at zero degree (ie. direction of primary beam) and quasielastic back-scattering.

As can be observed, in each experiment, more than one aspect of the reaction dynamics was studied simultaneously by appropriate choice of detection systems, thereby, optimally making use of the beam time.

Anjali Rani (Research Scholar from University of Delhi, Delhi) who used HIRA for her thesis experiment won one of the best poster awards in DAE Symposium on Nuclear Physics 2021 organized by BARC, Mumbai in a hybrid mode.

The focal plane detector window foil (0.5 μm thick, 150×50 mm^2 cross section), which had a minor leak prior to an experiment, was replaced. VME-based DAS was tested with pulser, using an α-particle source and later with beam in a facility test. The requirement of different strobes for the ADCs and TDC was discussed with the DAS group and the same was implemented by them with modifications in both the hardware and software.

4.3.2 HYbrid Recoil mass Analyzer (HYRA)

N. Madhavan, S. Nath, J. Gehlot, Gonika, T. Varughese

SC-LINAC operated for a few months in 2021-2022 and the following thesis experiment was scheduled and successfully carried out using the HYRA.

$^{32}S+^{208}Pb$ leading to $^{240}Cf^*$ compound nucleus (Thesis experiment of Ranjan Sariyal, Punjab University, Chandigarh) – evaporation residue (ER) cross sections and ER-tagged angular momentum distributions were measured for highly fissile compound nucleus to extract nuclear viscosity; $^{32}S+^{154}Sm$ leading to $^{186}Pt^*$ compound nucleus was used for calibration.

The combined measurements of ER cross sections and ER-gated angular momentum distributions using γ-ray multiplicity method is very effective in understanding fusion-fission dynamics and in identifying the most appropriate theoretical model. HYRA – TIFR 4π Spin Spectrometer combined facility was used in this experiment. The TIFR 4π array was biased, tuned and calibrated prior to the experiment. HYRA was operated in gas-filled mode to separate the heavy ERs from the primary beam at 0^o. $^{240}Cf^*$ is the heaviest CN whose ERs were measured with HYRA so far, due to limitations in the beam intensity (~ 0.25 pnA). Once the High Current Injector (HCI) starts operating, the higher intensity beams from HCI+SC-LINAC will help in extending the study to heavier CN.

VME-based DAS has been implemented in the HYRA facility and tested with pulser. Further tests with α-particles and beam are to be carried out before using the same in user experiments.

4.4 MATERIALS SCIENCE FACILITIES

A. Tripathi, D. Kabiraj, K. Asokan, F. Singh, V.V. Sivakumar, S.A. Khan, P. K. Kulriya, I. Sulania, R.C. Meena, and A. Mishra

The materials science facilities are supporting research programmes of a large number of users from different universities and research institutions. Even though there were disruptions during second Covid wave, extra efforts were made to complete user runs by getting their samples whenever physical visits were not possible due to various restrictions. A total of 28 user experiments spread over 108 shifts were performed this year. During this period there were no major breakdown of facilities resulting in beam time loss in materials science beamline in beamhall I. BTA experiments associated with students' Ph.D. programmes continued to get priority with special emphasis being given to scholar's in fifth year of Ph.D and 17 scholar's runs spread over 61 shifts were completed. Though the swift heavy ion (SHI) irradiation and related experiments mostly utilize irradiation chamber in the materials science beamlines in beamhall-I, three special runs from URSC Bangalore, SAC Ahmedabad and SCL involving low fluence irradiation was performed in the GPSC. 2 runs of 7 shifts including a run in BH II for facility testing also took place. The details of the experiments being done in areas of SHI induced materials modification and characterization are given in Section 5.2 and related publication are given in sec 6.7. Besides irradiation facilities, materials science group is also providing many materials synthesis and characterization facilities and this year limited off line characterizations were undertaken keeping Covid protocols in place.

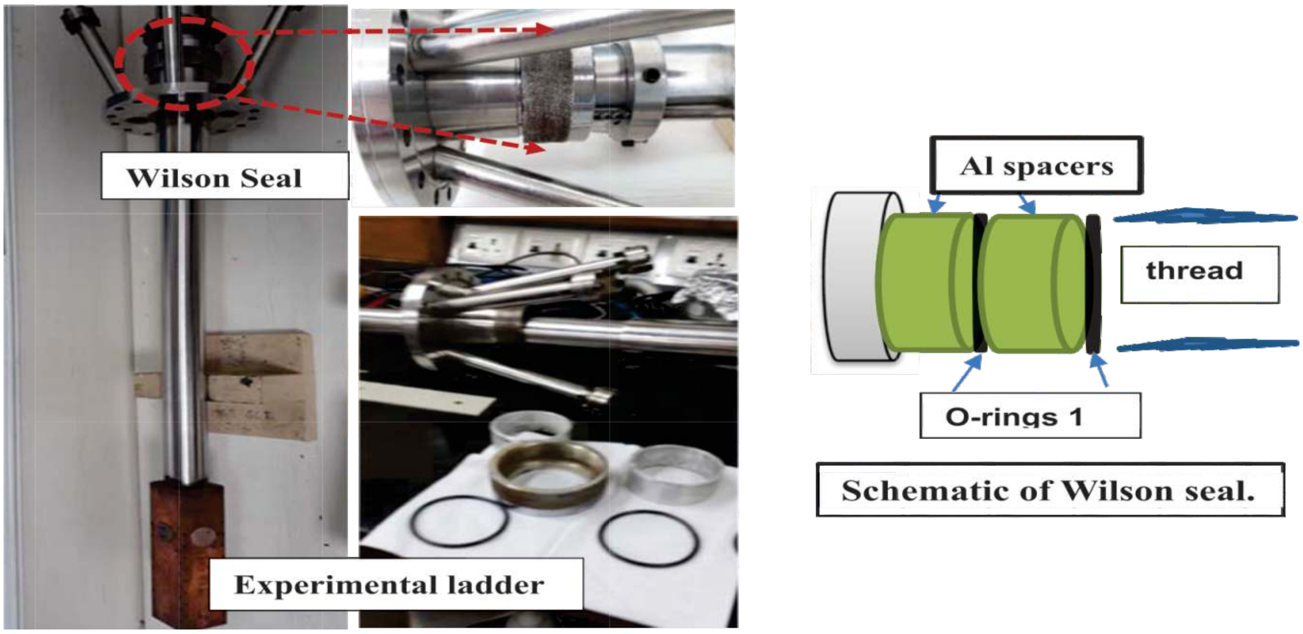
Efforts in organizing workshops, schools and conferences on specialized topics continued this year also so that the users are familiar with state of art experiments and facilities. Due to COVID situation the activities were undertaken in an online mode. 6th International Conference on Nanostructuring with Ion Beamss (Oct 5-8, 2021), Online school/workshop on Ion Beams in Sensors and Developments (Sept 7-8, 2021) and Virtual School on Microscopic Techniques (Nov 9-12, 2021) were organized this year and details are given in section 6.

4.4.1 Irradiation chamber in Beam Hall I

I. Sulania, S. A. Khan and A. Tripathi

The HV irradiation chamber in Materials Science beamline in BH1 is used by a large number of materials science users for their experiments. In total, 23 user experiments have been carried out utilizing 92 shifts in BH1 experimental chamber. There are regular maintenance activities undertaken for trouble free operation of the systems and some of them are described below:

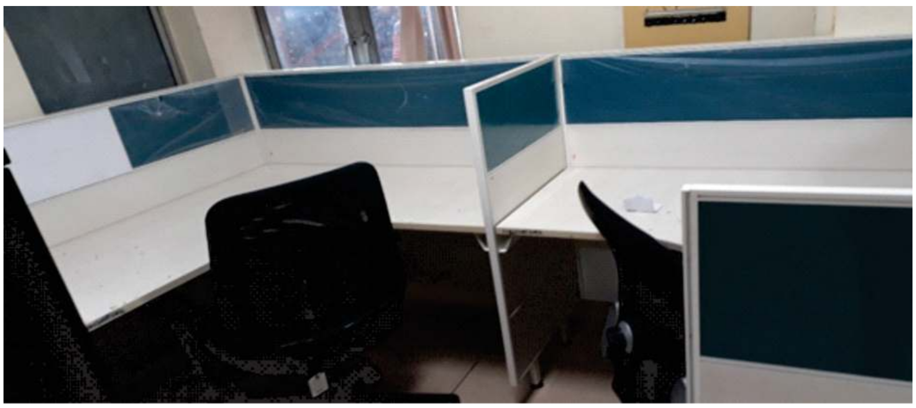
(i) It was observed that one of the sample ladders was taking unusually longer time to reach the operating vacuum and it was checked for possible leaks.



(i) The problem was attributed to Wilson seal of the ladder and the problem was resolved by replacing the Viton O-rings (50mm ID) used in the seal.

(ii) The penning gauge problem was resolved by replacing the same in the HV irradiation chamber by Vacuum laboratory Group.

(iii) The sample handling room was shifted to Data room for the easy handling of the samples. There is an almirah to keep the ladders safely when the experiments are not scheduled. Few cables were also made for facilitating the beam time experiments.



4.4.2 Materials Synthesis and Microscopy laboratory

I. Sulania, S.A. Khan and V V Sivakumar

The laboratory has facilities for the synthesis of thin films and nano-powders and many characterization facilities which are extensively used by users. Most of the facilities are in proper working condition.

4.4.2.1 Scanning Electron Microscopy

S.A. Khan

The scanning electron microscope, TESCAN's MIRA II LMH FE-SEM, was utilized for charactering 260 samples of about 55 users from 21 different universities/institutes. In this period, 301 samples were characterized for composition estimates using attached energy dispersive x-ray spectroscopy system (Oxford's INCA PentaFET3). Conducting thin film deposition on the surface using coater was required for about 9 users to reduce the charging problem in insulating samples. The electron emitter of SEM reached end of its life towards the end of the academic year which need to be replaced in coming months.

4.4.2.2 Scanning Probe Microscope

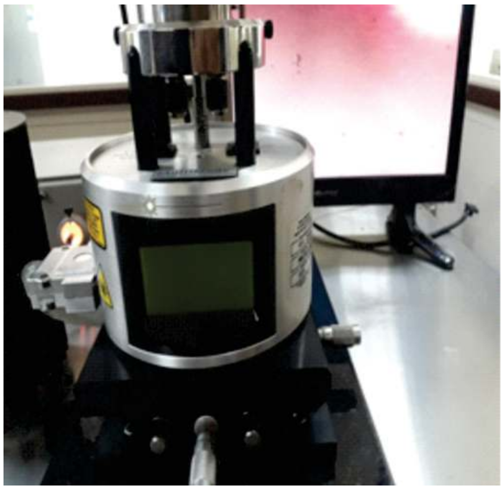
I. Sulania and A. Tripathi

Most of the Scanning Probe Microscope modes such as AFM, MFM, C-AFM, STM, STS and F-d mode etc are available at IUAC and used in user experiments. The facility remained operational for most of the time with Covid protocols and this year a total of 113 samples were characterized for 15 users in AFM/MFM mode. A major software glitch happened in August 2021 which was resolved with the help received from Bruker.

4.4.2.2.1 Maintenance related to Scanning Probe Microscope

I. Sulania and S. A. Khan

This year, there was a major problem faced with the Scanning Probe Microscope (Nanoscope IIIA, 2003). In August 2021, the IDE hard disk of the SPM Computer crashed. It was replaced with SATA hard disk and Windows XP and SPM software were installed from backup files and files provided by Company engineer. But few drivers could not be found and hence, real-time interfacing couldn't be achieved with the Instrument's head. However, Bruker supplied the software for driver support and after installing them, the Realtime imaging could be achieved even though few glitches are observed in readout of AFM head module. The system was checked with few calibration samples and User support was restarted. The system has since been working satisfactorily.



4.4.2.3 Optical Microscope

I. Sulania and A. Tripathi

The laboratory has a high-end Optical Microscope from Zeiss, which can magnify the images up to 100x. It is mostly used as a tool to predetermine the sample's area before performing the SPM measurements. It is especially useful to track the single or multilayer flakes in 2D materials such as Graphene. The Optical Microscope system was utilized for characterizing 23 samples from 6 users.

4.4.2.4 UV-Vis Spectrophotometer

I. Sulania and A. Tripathi

UV-Vis Spectrophotometer, which was procured from Hitachi, is capable of doing measurements in Absorbance/Transmission mode. The UV-Vis spectrophotometer was used to characterize 100 samples of 15 users

4.4.2.5 Contact angle measurement facility

I. Sulania

The laboratory has a Drop Shape Analyzer, DSA100, from Kruss GmbH – Germany for contact angle measurement setup. The system is used for studying wetting and adhesion of solid surfaces with water drop as the contact angle (wetting angle) is a measure of the wettability of a solid by a liquid. This year, it was utilized by 2 users scanning 28 samples. The set-up is working satisfactorily and no major maintenance was required.

4.4.3 Transport Lab

Ramcharan Meena, K. Asokan and A. Tripathi

To characterize the electrical transport properties of the materials, various facilities are available in the transport lab like resistivity, dielectric, Hall effect and IV-CV measurements. The resistivity measurements can be performed either in two probe or four probe mode. For low resistive samples, the resistivity measurements are performed in four probe mode using Keithley source meter or current source and nanovoltmeter. The resistivity of high resistance samples is measured using a Keithley electrometer in two probe mode. The resistivity is measured in two different temperature ranges (i) 20K-300 K using Cryocooler and (ii) 80K-400 K using liquid nitrogen. The resistivity helps us to find the nature (metal, semiconductor or insulator) of the material.

To find the charge storage ability of a material, the dielectric measurements are performed in the frequency range of 20Hz-2MHz using an Agilent LCR meter. Various parameters like Capacitance (C), Inductance (L), Dielectric loss (D), Impedance (Z) and Phase angle (θ) can be measured in the temperature range of 20K-300 K and 80K-400K in capacitance mode. The carrier concentration, mobility and sign of the carriers can be found using the Hall effect measurements at two different temperatures (a) Room temperature and (b) Liquid nitrogen temperature. The magnetic field used is 0.57T.

To characterize a semiconductor device like a diode, and transistors at room temperature, we use an Agilent B1500 semiconductor analyzer. Different types of measurements like I-V and C-V are performed to characterize the sample. Here the devices are characterized using W-metal probes. To know the Seebeck coefficient of thermoelectric material, thermoelectric materials are also characterized using the homemade thermoelectric measurement setup within the temperature range of 90K-450K. The measurement is performed in the differential method. To synthesize the samples there are three types of furnaces available for users: air, vacuum and rapid thermal-annealing set-up. These furnaces work up to the temperature range of 1200ºC. Annealing can be done on both types of samples (bulk and thin films). To characterize the device during ion irradiation by in-situ measurements various experiments are performed on the samples like I-V, C-V and resistivity measurements. These characterizations are done at various ion fluences and different temperatures using the homemade in-situ ladder. Over 50 users from various universities and institutes have used the above-mentioned facilities in the year 2021-2022.

4.4.4 High-Resolution Transmission Electron Microscopy (HRTEM) Lab Activities

Ambuj Mishra, Abhilash S.R. and Debdulal Kabiraj

4.4.4.1 Introduction

Energetic ion beams play a crucial role in modifications of the materials and can change their physical properties. TEM is a state-of-the-art technique that is used to investigate morphological, structural, and compositional modifications in a material. The IUAC TEM and TEM sample preparation facilities are being utilized by various users of different universities.

4.4.4.2 TEM Specimen Preparation Facility

TEM specimen preparation facility is equipped with an Ultrasonic bath, Hot Plate, Traditional Lapping/Grinding Tools, Dimple Grinder, Diamond Wire Saw, and Precision Ion Polishing System (PIPS). All these instruments are regularly used for TEM sample preparation. Planar TEM, Cross-sectional TEM (XTEM), and Powder samples on TEM Grids are prepared for TEM characterization. TEM specimen preparation facility has been utilized to prepare more than 82 TEM samples including 23 XTEM and 5 planar samples by various users during this academic year 2021-2022.

XTEM specimen preparation by Strip Method has been introduced. In this technique, a strip of the desired sample is used in place of a standard Stacking Method. Sample preparation by this method requires relatively less time and also eliminates the uncertainty of placing the region of interest at the center of the sample. A glimpse of sample preparation is shown in Fig. 4.4.4.2.

Fig. 4.4.4.2: *Glimpse of XTEM sample preparation using a strip of the sample*

4.4.4.3 High-Resolution Transmission Electron Microscope (HRTEM) Facility

Maintenance of TEM is very important for smooth operation and is done as and when required. Some of the regular TEM maintenance activities undertaken are the Bake-out process followed by HT conditioning, ACD heating, Camera warmup, etc. TEM Bake-out cycle has been performed in the month of April, August, and December 2021. Around 140 samples of various users have been characterized for TEM, HRTEM, and Selected Area Electron Diffraction (SAED).

Some of the research works which have been published during 2021-2022 in the peer-reviewed journals where the IUAC TEM facility is used are listed below:

4.4.4.3.1 Morphological, structural, and elemental characterization of amorphization/ crystallization at the interfaces of thin films

G. Maity et al. have studied the effect of Ni film thickness on Nickel mono-silicide (NiSi) phase formation using low energy ion irradiation at room temperature [1]. To investigate the NiSi phase and its crystallographic orientation, XTEM measurements of the pristine and irradiated samples have been performed. In Fig. 4.4.4.3.1.1(a), a sharp interface of Ni and Si without any mixing has been observed and the crystallinity of Ni and Si has been confirmed by HRTEM and SAED images, as is shown in the inset of Fig. 4.4.4.3.1.1(a). In Fig. 4.4.4.3.1.1(b), the combined elemental mapping of Ni (red) and Si (green) atoms has been shown which has been obtained by collecting Si-L x-rays and Ni-M x-rays in EDS measurement [1].

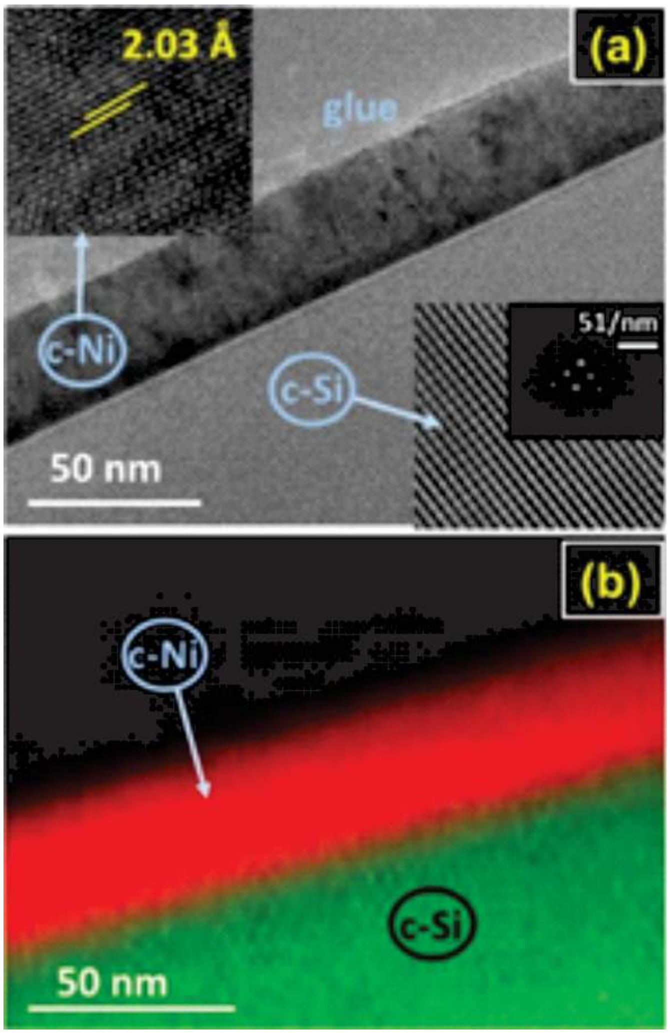


Fig. 4.4.4.3.1.1: *(a) The cross-sectional transmission electron microscopy (XTEM) image of pristine Ni (30 nm)/Si and (b) the corresponding elemental mapping of Ni (red) and Si (green) obtained by collecting Ni-M and Si-L x-rays in EDS measurement [1].*

In Fig. 4.4.4.3.1.2(a), the XTEM images of the sample irradiated at a fluence of 1×10^{15} ions/cm^2 has shown the ion irradiation-induced amorphization of the Si region which has also been observed in the SAED pattern shown in the inset of Fig. 4.4.4.3.1.2 (a). The mixing of Ni and Si at the interface has been clearly observed in the XTEM images and the width of the mixed layer has been measured to be around ~38 nm. The inset HRTEM image of the unreacted Ni region (~17 nm) has confirmed the crystalline nature of Ni after irradiation. The NiSi phase has been identified with inter-planer spacing (i.e. d spacing) of 1.77 Å in the HRTEM image of a selected region as shown in Fig. 4.4.4.3.1.2(b). The SAED pattern has confirmed the presence of the NiSi phase by showing rings corresponding to (103) and (002) planes [1].