

A training session report on
**Semiconductor Device Fabrication and
Characterisation**

Under STUTI program funded by DST



In association with
Indian Institute of Technology, Gandhinagar
(Project Management Unit)



Coordinated by

Dr. Arun Kumar Singh

Semiconductor Research Centre

Department of Electronic and Communication Engineering,

Punjab Engineering College Chandigarh

India

21th to 27th November 2022

Acknowledgement

We convey gratitude for the encouragement and support received from multiple sources during the execution of this training since its beginning. First and foremost, we want to express our sincere appreciation to the IIT Gandhinagar (PMU) and Department of Science and Technology (DST) for entrusting us with this project. The workshop was coordinated by **Dr. Arun Kumar Singh**. The workshop was conducted on the '*Semiconductor Device Fabrication and Characterisation*' on the instrument funded by the FIST program (Sanction No.: SR/FST/ETI-411/2016(C)). Organizing team acknowledge the contributions of the committee, in the implementation and the execution of the program to achieve the objectives of the project.

We also acknowledge all the teaching and non-teaching staff for their contributions, without which these could not have been possible.

Dr. Arun Kumar Singh
Coordinator

Summary

The goal of this training session is to provide a hands-on training on semiconductor device fabrication and characterisation among students, faculty, scientists and industry professionals through a week-long training workshop. The workshop was conducted at Punjab Engineering College (Deemed to be University), Chandigarh from 21th to 27th November, 2022 and comprised of lectures and hands-on training sessions. This initiative is funded by Department of Science & Technology under the program STUTI (Synergistic Training Program Utilizing the Scientific and Technological Infrastructure). This program was designed and focused to “*develops knowledge about various new research areas and fabrication techniques in the field of semiconductor materials, sensors, energy harvesting with hands-on training on state-of-the-art semiconductor fabrication and characterization equipment’s like PECVD, E-Beam cum Thermal Evaporator, RIE, Mask Aligner system, Probe Station, VNA, Impedance Analyser, Spectrum Analyzer etc.*” Practical training to utilize simulation tools like SILVACO TCAD & ANSYS HFSS for design and development of various semiconductor devices. This hands-on training program also includes the synthesis and growth of thin films using various techniques and ability to operate and manage various clean room facilities. During this training program one day visit to nearby esteemed research institutes like INST, SCL and IISER was included to explore the research work and facilities available there.

Introduction

Punjab Engineering College (Deemed to be University), Chandigarh conducted 7-day long hands-on training program on ‘Semiconductor Device Fabrication and Characterisation’ in its campus for participants from various backgrounds such as Post Graduates, Faculties, Scientists, Research Fellows, Ph.D. Fellows and Industry persons were invited (**Annex-1**). The following workshop's activities took place from 21th to 27th November, 2022 (**Annex-2 & 3**). This report provides a quick overview of both the lecture and technical sessions.

- Lecture Sessions:

Dr. Manan Suri (Department of Electrical Engineering, IIT Delhi) delivered expert talk on a topic, *Applications of Emerging Memory Technologies*. **Dr. Dipankar Saha** (Associate Professor, Electrical Engineering IIT, Bombay) gave a talk on ‘*High Performance AlGaIn/GaN-based High Electron Mobility Transistors*’. **Dr. D. S. Rawal** (SSPL-DRDO, Delhi) ‘*Semiconductor Device Fabrication Technology*’. **Dr. S. K. Tomar** (SSPL-DRDO, Delhi) gave an informative on the characterization of high-electron-mobility transistors (HEMT). **Dr. Manish Hooda** (Professor and Head, SCL, Mohali) gave an interactive lecture on the topic ‘*Beyond CMOS Devices*’. **Dr. Krishan Kumar** (SCL, Mohali) delivered a lecture on ‘*Semiconductor device Packaging*’. **Dr. Ananth Venkatesan** (Associate Professor, Physics, IISER Mohali) delivered a talk on ‘*Nanoelectromechanical Systems (NEMS)*’. **Dr. Satinder Sharma** (Professor, Computing and Electrical Engineering IIT Mandi) gave a talk on ‘*Emerging Semiconductor Devices*’. **Dr. Mukesh Kumar** (Associate Professor in the Department of Physics, IIT Ropar) gave a talk on ‘*Large area growth of 2-D Materials for sensor and photodetector application*’. **Dr. Suvankar Chakraverty** (Professor, Scientist-F, INST Mohali) delivered a lecture on ‘*Seeing and Measuring Nano*’. **Dr. Sanjeev Kumar** (Professor & Head, Material Science, PEC Chandigarh) gave an insightful lecture on ‘*Ferroelectrics: Sensing Applications*’. **Dr. Rajendra Singh** (Professor Physics, IIT Delhi) gave a lecture on ‘ *β -Ga₂O₃ grown on sapphire and muscovite mica for deep UV photodetector application*’. **Dr. S.P. Tiwari**

(Associate Professor Electrical Engineering, IIT Jodhpur) gave a talk on ‘*Flexible Devices for Green Electronics*’. **Dr. Brajesh Kaushik** (Professor, Department of Electronics and Communication Engineering IIT Roorkee) gave a talk on *Spintronics- Challenges and Perspectives*’.

- *Technical Session*

From the **first day to sixth day** onwards, all the participants were taken to four different labs, 1. Semiconductor Research centre; 2. Nanotechnology Research Lab; 3. Material Synthesis and 4. PCB Fabrication Lab. Hands-on training sessions were conducted at Semiconductor Research Centre (SRC) on Photo Lithography, Plasma Enhanced Chemical Vapour Deposition (PECVD), Reactive Ion Etching (RIE), E-Beam cum Thermal Evaporation, Probe station, Vector Network Analyser (VNA), Source meter and other electrical characterization using digital Multi-meter. In Nanotechnology Research Lab (NRL) the simulation software was explored by all the participants and they had hand-on on HFSS and Silvaco simulation tool kit. All participants got the hand-on training of PCB design and manufacturing the same in the PCB Fabrication Lab. In addition to these sessions, nanoparticles and nanotube synthesis was also the part of this training program where all the participants got to know about and performed nanoparticle synthesis.

Participants were also taken to one day tour visit, along with few faculty members and technical staff, to INST, SCL and ISSER Mohali.

Outcomes of the Workshop

The STUTI workshop attracted participants from 27 different institutes (**Figure 1**). About 37 participants enrolled and attended the ‘Semiconductor Device Fabrication and Characterisation’. The goal of this training event was to bring together participants from many disciplines and raise awareness of the institute's advanced facilities. Throughout the sessions, participants asked major questions regarding theoretical and practical aspects of semiconductor fabrication process, characterization, PCB making and simulation tools. Finally, the feedback from the participants was considered in the evaluation of the workshop (**Annex 4**). The majority of the participants were pleased with the training session and suggested that more workshops be held in the future. Few participants suggested organizing such a workshop/training session on more troubleshooting techniques of data collection.



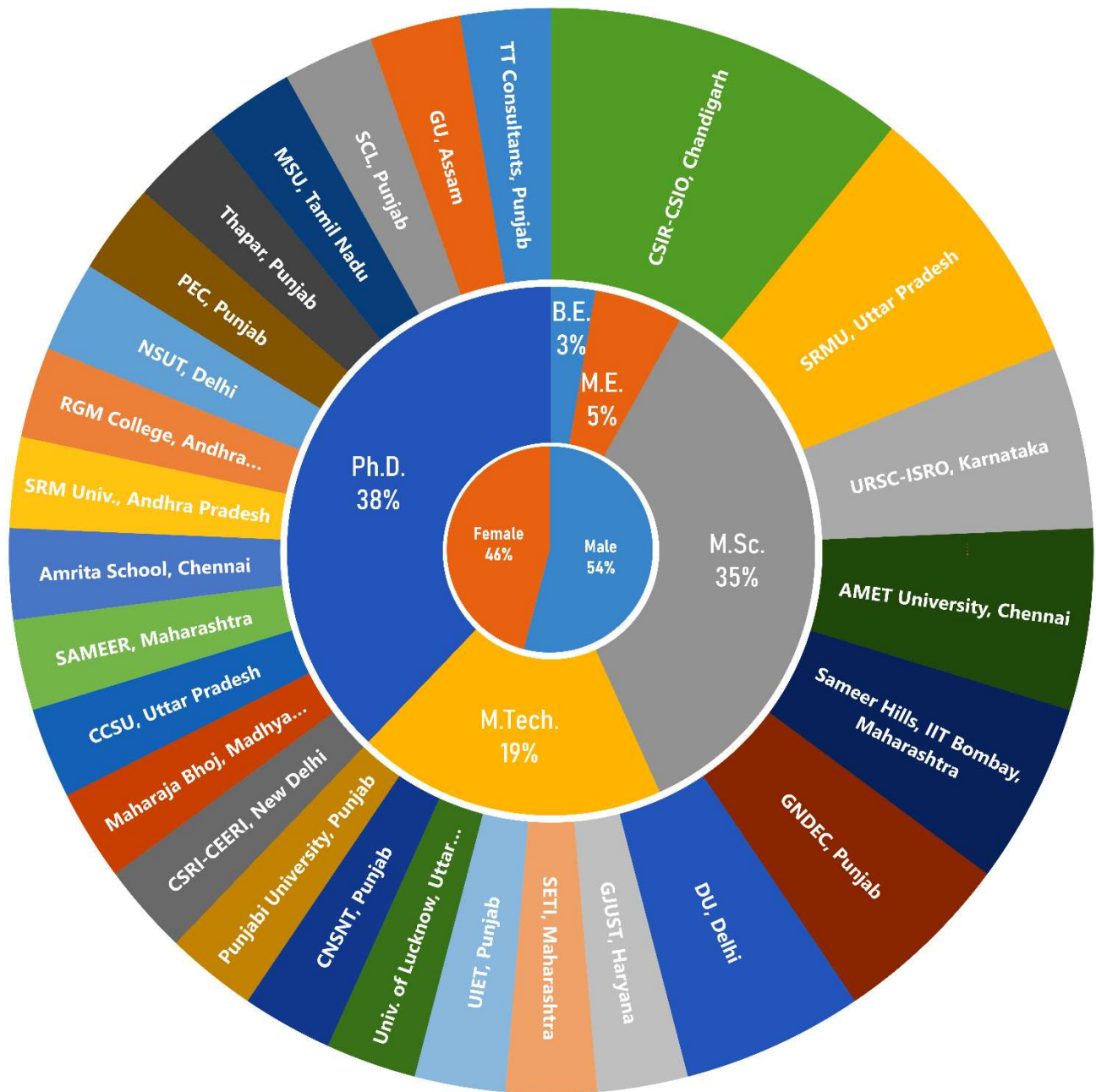



Figure 1. Participants registered workshop from different institutes.

Annexure 1: Brochure for the program.



DST-STUTI HANDS-ON TRAINING PROGRAM ON SEMICONDUCTOR DEVICE FABRICATION AND CHARACTERISATION


JOINTLY ORGANIZED BY:
SEMICONDUCTOR RESEARCH CENTER, DEPT. OF ELECTRONICS AND COMM. ENGG.,
PUNJAB ENGINEERING COLLEGE (DEEMED TO BE UNIVERSITY), CHANDIGARH
&
INDIAN INSTITUTE OF TECHNOLOGY (IIT), GANDHINAGAR

FUNDED BY:
DEPARTMENT OF SCIENCE AND TECHNOLOGY, GOVERNMENT OF INDIA

OBJECTIVES OF THE PROGRAM

The proposed training program is designed in line with the STUTI program of DST. The training program aims to provide hands-on-training on utilizing the unique properties of semiconductor materials for design, fabrication and characterisation of next generation electronic devices using state-of-the-art clean room facilities.


21ST- 27TH NOVEMBER, 2022



HIGHLIGHTS OF THE TRAINING

DEVELOP KNOWLEDGE ABOUT VARIOUS NEW RESEARCH AREAS AND FABRICATION TECHNIQUES IN THE FIELD OF SEMICONDUCTOR MATERIALS, SENSORS, ENERGY HARVESTING, ETC

PROVIDE HANDS-ON TRAINING ON STATE-OF-THE-ART SEMICONDUCTOR FABRICATION AND CHARACTERIZATION EQUIPMENTS LIKE PECVD, MASK ALIGNER SYSTEM ETC.



PRACTICAL TRAINING TO UTILIZE SIMULATION TOOLS LIKE SILVACO TCAD & ANSYS HFSS.

SYNTHESIS AND GROWTH OF THIN FILMS USING VARIOUS TECHNIQUES

ABILITY TO OPERATE AND MANAGE VARIOUS CLEAN ROOM FACILITIES.

WHO CAN ATTEND

- B.Tech. / M.Tech. / M.Sc. / Ph.D Students / JRFs / SRFs (In Relevant Areas)
- Faculty /Scientists / Post-Doc Fellows/ Industry Engineers.
- Not more than 3 people from one institute.

HOW TO REGISTER FOR WORKSHOP

- Interested participants are requested to submit all the details on the following link and upload NOC from institute.
- This event is FREE to attend. Seats are limited. Advance registration is recommended.
- Shortlisted / selected participants will be provided accommodation and food etc. on all the days of Training Program.

LAST DATE TO REGISTER :
31 OCTOBER, 2022

REGISTRATION LINK: <https://forms.gle/VR4QbXxcF16MzvSS7>

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Annexure 2: List of registered participants for the workshop.

Sr. No.	Candidate Name	Gender	Educational Qualification	Email address	University/Institute
1	Aastha Singhal	Female	M.Tech. (Microelectronics)	aasthasinghal90@gmail.com	TT Consultants, Mohali, Punjab
2	Anandita Dey	Female	M.Sc. (Instrumentation & Applied Physics)	ananditadey16@gmail.com	Gauhati University, Assam
3	Annie Puri	Female	M.Tech. (Optoelectronics)	anniepuri@scl.gov.in	Semi-conductor Laboratory, Mohali, Punjab
4	Mritunjay Rai	Male	Ph.D. (Thermal Image)	er.mritunjayrai@gmail.com	SRMU, Lucknow, Uttar Pradesh
5	Alkesh Agrawal	Male	M.Tech. (Digital Comm)	alkesh.agrawal26@gmail.com	
6	Jay Kumar Pandey	Male	Ph.D. (Renewable Energy)	Jay.pandey@srmu.ac.in	
7	Chanchal	Female	M.Sc. (Electronics)	chanchal0210saraswat@gmail.com	Delhi University, Delhi
8	Mohd. Rehan Ansari	Male	M.Sc.(Electronics)	mransari@du.ac.in	
9	Vinod Parmar	Male	Ph.D. (Physics and Biomedical Eng)	vinodparmar@csio.res.in	CSIR-CSIO, Chandigarh
10	Bhargab Das	Male	Ph.D. (Photonics)	bhargab.das@gmail.com	
11	Nalini Pareek	Female	Ph.D. (Study of Surface Plasmonic for THz Generation)	nalinipareek@gmail.com	
12	Dhairya Singh Arya	Male	Ph.D. (Electronics)	dhairya@csio.res.in	
13	Dhilshath Raihana H	Female	M.Sc. (Chemistry)	rosejune97@gmail.com	
14	Hardeepak Singh	Male	M.E. (Computer Science & Engineering)	hardeepakkatron@gmail.com	Thapar Institute of Engineering & Technology, Punjab
15	Jyoti Kedia	Female	Ph.D. (Electronics)	vyotikedia@pec.edu.in	PEC, Punjab
16	Vidula Balkrishna Palekar	Female	M.Sc. (Physics)	pvb001111@gmail.com	SAMEERHILLS IIT Bombay, Maharashtra
17	Kshitij Mittholiya	Male	M.Tech. (Communication System)	kshitij@sameer.gov.in	
18	Anju Subhash	Female	M.Sc. (Physics)	anjusubhash555@gmail.com	AMET University, Chennai
19	Lin Sunil	Male	M.Sc.(Physics)	linsunilsunillin@gmail.com	
20	Manju Kumari	Female	M.Sc.(Physics)	kumarimanju1502@gmail.com	Netaji Subhas University of Technology, Delhi
21	N. Fouzia Sulthana	Female	Ph.D. (VLSI)	fouzia.nfs@gmail.com	Rajeev Gandhi Memorial College of Engineering & Technology, Nandiyal, Andhra Pradesh
22	Gurpurneet Kaur	Female	Ph.D. (E.C.E)	gurpurneetkaur@gmail.com	Guru Nanak Dev Engineering College, Punjab
23	Navneet Kaur	Female	Ph.D. (E.C.E)	navneetkaur@gndec.ac.in	
24	Suma S Lonkadi	Female	B.E. (E.C.E)	lonkadi@urisc.gov.in	URSC-ISRO, Bengaluru, Karnataka
25	Nirupam Sharma	Male	M.Tech. (Microelectronics and VLSI Design)	nirupamsharma855@gmail.com	
26	Nitish Kumar	Male	M.Sc.(Physics)	nitish_k@srmmap.edu.in	SRM University, Andhra Pradesh
27	Ramachandran Ammapet Vijayan	Male	Ph.D. (Optoelectronics)	av_ramachandran@ch.amrita.edu	Amrita School of Engineering, Chennai
28	Rohit Miglani	Male	M.Sc.(Physics)	rohitmiglani0310@gmail.com	Society for Applied Microwave Electronic Engineering and Research
29	Ruchi Bhati	Female	M.Sc.(Physics)	ruchibhati2612@gmail.com	CCS University Meerut, Uttar Pradesh
30	Sagar Sen	Male	Ph.D. (Instrumentation)	sagar.sen@mp.gov.in	Maharaja Bhoj Government PG College, Dhar, Madhya Pradesh
31	Shuvam Gupta	Male	M.Tech. (Nanoscience and Technology)	shuvam5gupta@gmail.com	CSRI-CEERI, New Delhi
32	Simranjit Singh	Male	Ph.D. (E.C.E)	simrankatron@gmail.com	Punjabi University, Patiala, Punjab
33	Sunidhi	Female	M.Sc.(Physics)	sunidhi3525@gmail.com	CNSNT, panjab university, Punjab
34	Vidushi Rajpoot	Female	M.Sc. (Physics)	vidushirajpoot007@gmail.com	University of Lucknow, Uttar Pradesh
35	Vijay Kumar	Male	M.Tech. (VLSI Design)	vijaykumar2594@gmail.com	University Institute Of Engineering and Technology, Panjab University, Punjab
36	Vinod Vasantrao Vanmore	Male	M.E. (Production Engineering)	vinodvanmore@gmail.com	Sanjeevan Engineering & Technology Institute, Maharashtra
37	Vivek Gupta	Male	Ph.D. (Physics)	vivekgupta.skgt@gmail.com	Guru Jambheshwar University of Science & Technology, Hisar, Haryana

Annexure 3: Schedule date and activities during the workshop

21.11.2022 (Monday)	(09.00AM -09:30 AM)	Registration of Participants (Venue: Senate Hall, Administrative Block, Near Helicopter)			
Date/Time	Session-I (09.30AM -11:00 AM)	Session-II (11:30 AM -01:00 PM)	Session-III (02:00 PM -03.30 PM)	Session-IV (03:30 PM -05.00 PM)	
Day-1 21.11.2022 (Monday)	Inauguration	Applications of Emerging Memory Technologies (Manan Suri, IIT Delhi)	High Performance AlGaIn/GaN-based High Electron Mobility Transistors (Dipankar Saha, IIT Bombay)	Material Synthesis & Cleanroom Facilities (Gaurav, Teena, Shonal, Amit, Sandeep, Sunil, Ramdev PEC) (Hands-on-Session-I)	
Day-2 22.11.2022 (Tuesday)	NRL/PCB/Cleanroom (Hands-on-Session-II)	Compound Semiconductor Device Fabrication Technology (D. S. Rawal, SSPL, DRDO)	Characterization of HEMTs (S. K. Tomar, SSPL, DRDO)	NRL/PCB/Cleanroom (Hands-on-Session-III)	
Day-3 23.11.2022 (Wednesday)	Beyond CMOS devices (Manish Hooda, SCL Mohali)	Semiconductor Device Packaging (Krishan Kumar, SCL Mohali)	Nanoelectromechanical Systems (NEMS) (Ananth Venkatesan, IISER Mohali)	Emerging Semiconductor Devices (Satinder Sharma, IIT Mandi)	
Day-4 24.11.2022 (Thursday)	Large area growth of 2-D Materials for sensor and photodetector applications (Mukesh Kumar, IIT Ropar)	Seeing and Measuring Nano (Suvankar Chakraverty, INST Mohali)	NRL/PCB/Cleanroom (Hands-on-Session-IV)	NRL/PCB/Cleanroom (Hands-on-Session-V)	
Day-5 25.11.2022 (Friday)	Visit To SCL Mohali and INST Mohali				
Day-6 26.11.2022 (Saturday)	Ferroelectrics: Sensing Applications (Sanjeev Kumar, PEC Chandigarh)	"β-Ga ₂ O ₃ grown on sapphire and muscovite mica for deep UV photodetector applications (Rajendra Singh, IIT Delhi)	NRL/PCB/Cleanroom (Hands-on-Session-VI)	NRL/PCB/Cleanroom (Hands-on-Session-VII)	
Day-7 27.11.2022 (Sunday)	Flexible Devices for Green Electronics (S. P. Tiwari, IIT Jodhpur)	Spintronics- Challenges and Perspectives (Brajesh Kaushik, IIT Roorkee)	Valedictory & Feedback Session (1.00 PM to 1.30 PM)	Lunch (1.30 PM to 2.30 PM)	

Annexure 4: Feedback summary

S.No.	Content	Rating
1	Overall grading of the Programme with reference to relevance of course, module/content etc.	94% rated above 8 points
2	Overall grading of the facilities provided by the institute, i.e., Hostel, Mess, Class Rooms, Transport/infrastructure etc.	100% rated above 8 points
3	Overall grading of the faculty members conducting the training	97% rated above 8 points
4	How do you rate the overall training methodology	97% rated above 8 points
5	How far the field visit is relevant and related to your research study	88% rated above 8 points
6	Usefulness of this training in your current role	88% rated above 8 points
7	Usefulness of this training in future work/job you may handle	91% rated above 8 points
8	How far have you benefitted from interaction with the fellow participants of the training	94% rated above 8 points
9	How far the course material supplied relevant and related to the training curriculum	85% rated above 8 points
10	Overall grading of the process of training	97% rated above 8 points
11	Your recommendation to your peers/ colleagues for the training Programme	97% rated above 8 points