Skill India
कौशल भारत-कुशल भारत

Directorate General of Training

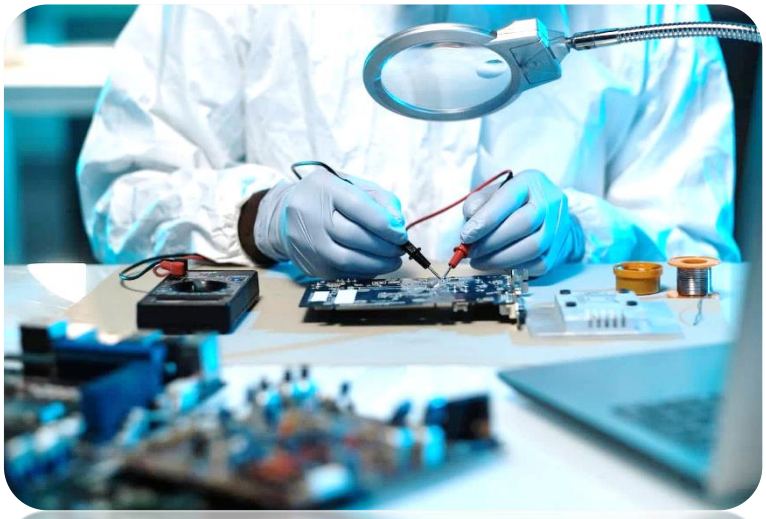
सत्यमेव जयते

GOVERNMENT OF INDIA
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP
DIRECTORATE GENERAL OF TRAINING

COMPETENCY BASED CURRICULUM

CERTIFICATE COURSE ON

FUNDAMENTALS OF SEMICONDUCTOR TECHNOLOGY



NSQF LEVEL- 3.5

SECTOR: ELECTRONICS & HARDWARE

FUNDAMENTALS OF SEMICONDUCTOR TECHNOLOGY

Duration: 240 Hours

NSQF LEVEL- 3.5

(Version: 1.0)

Designed in 2024

Developed By

Ministry of Skill Development and Entrepreneurship

Directorate General of Training

&

CENTRAL STAFF TRAINING AND RESEARCH INSTITUTE

EN-81, Sector-V, Salt Lake City,

Kolkata – 700 091

CONTENTS

1. COURSE INFORMATION

1.1 GENERAL

This course has been developed for CTS/CITS trainees to take up as optional courses during course of study for technical and behavioural upgradation of trainees to meet industry related job roles. During the 240 hours duration of FUNDAMENTALS OF SEMICONDUCTOR TECHNOLOGY course, a candidate is trained on professional skills & knowledge related to job role. The Broad components covered during the course are given below:

During the course, students will understand semiconductor technology and its application. It covers a wide range of topics, including the exploration of passive and active electronic components, semiconductor materials, cleanroom processes, assembly and packaging techniques, device physics, and semiconductor device applications.

1.2 COURSE STRUCTURE

Table below depicts the distribution of training hours across various course elements during a period of 6 weeks: -

S No.	Course Element	Notional Training Hours
1.	Professional Skill (Trade Practical)	180
2.	Professional Knowledge (Trade Theory)	60
	Total	**240**

1.3 ASSESSMENT & CERTIFICATION

The trainee will be tested for his skill, knowledge and attitude during the period of course through assessment at the end of the course through skill testing at Training Center & CBT through examination conducted by DGT.

The minimum pass percentage for skill test is 60% and for theory will be 33% as in main CTS examination.

2. JOB ROLE

FUNDAMENTALS OF SEMICONDUCTOR TECHNOLOGY; is responsible for assisting in assembly, testing, and maintenance of semiconductor components and devices. Their role involves assisting in operating specialized equipment, conducting quality control checks, troubleshooting issues, and following safety protocols in cleanroom environments.

Electronics Technicians, Other; include all other Electronics Technicians engaged in research and testing in various fields of electronic engineering, not elsewhere classified

Reference NCO-2015: -

(a) 3114.9900 - Electronics and Telecommunications Engineering Technicians, Other

Mapped NOS:

i) ELE/N9511
ii) ELE/N9512
iii) ELE/N9513
iv) ELE/N9514
v) ELE/N9515

3. GENERAL INFORMATION

Name of the Trade	**FUNDAMENTALS OF SEMICONDUCTOR TECHNOLOGY**
Reference NCO - 2015	3114.9900
NOS Covered	ELE/N9511, ELE/N9512, ELE/N9513, ELE/N9514, ELE/N9515
NSQF Level	3.5
Duration of Craftsmen Training	240 Hours
Entry Qualification	10th Class passed and pursuing/ passed out Electronic Mechanic, Instrument Mechanic under CTS and Electronic Mechanic, Instrument Mechanic under CITS.
Unit Strength (No. of Student), Space & Power Norms	As per affiliated mapped trade of Semiconductor Technician CTS
Instructors Qualification	B.Voc/Degree in Electronics/ Electronics and Telecommunication/ Electronics and communication/Electronics and Instrumentation Engineering from AICTE/UGC recognized Engineering College/ university with one-year experience in the relevant field. **OR** Diploma (Minimum 2 years) in Electronics/ Electronics and telecommunication/ Electronics and communication/Electronics and Instrumentation from AICTE/recognized board of technical education or relevant Advanced Diploma (Vocational) from DGT with two years' experience in the relevant field. **OR** NTC/NAC passed in the Trade of "Electronics Mechanic" or "Semiconductor Technician" With three years' experience in the relevant field. **Essential Qualification:** Relevant Regular / RPL variants of National Craft Instructor Certificate (NCIC) under DGT.
List of Tools and Equipment	As per Annexure – I

4. LEARNING OUTCOME

Learning outcomes are a reflection of total competencies of a trainee and assessment will be carried out as per the assessment criteria.

LEARNING OUTCOMES

1. Describe the fundamental properties, characteristics and applications of semiconductor materials, including crystal structures, energy bands and carrier behaviour. (NOS: ELE/N9511)
2. Familiarize with passive and active electronic components built with semiconductor technology and Exposure to various semiconductor component, devices, sensors, small circuits. (NOS: ELE/N9512)
3. Identify semiconductor Materials and Process management. (Simulation) (NOS: ELE/N9513)
4. Demonstrate assembly and packaging of semiconductor technology and Attain exposure to do assembly and packaging tools and operations. (NOS: ELE/N9514)
5. Demonstrate Semiconductor Device Applications. (NOS: ELE/N9515)

5. SYLLABUS

SYLLABUS – FUNDAMENTALS OF SEMICONDUCTOR TECHNOLOGY			
Duration: 240 Hours			
Duration Weeks	**Reference Learning outcome**	**Professional Skills (Trade Practical)**	**Professional Knowledge (Trade Theory)**
Professional skills 10 Hrs. Professional Knowledge 05 Hrs.	Describe the fundamental properties, characteristics and applications of semiconductor materials, including crystal structures, energy bands and carrier behaviour.	1. Testing and characterization of diodes in different configurations (rectifiers, voltage regulators, etc.). 2. Measuring diode characteristics, including forward and reverse biasing. 3. Practical testing of semiconductor material properties such as Band Gap of Diode and of wafer by using Four Probe method. 4. Measure the Hall voltage and learn Hall Effect, resistivity, mobility, and thermal conductivity. 5. Measure the junction temperature of two different materials and Potential difference by using Seeback & Peltier effect apparatus 6. Planck's constant measurement for understanding the photoconductivity 7. Identification of different passive, active components and ICs. 8. Measure the resistor, capacitor and inductor, transistor, diode values. 9. Assembling basic	• Introduction to semiconductors, distinguishing them from conductors and insulators. • Introduction to crystal structures and their role in semiconductor materials. • Energy band theory and the concept of valence and conduction bands. • Doping: Understanding the concept of doping and how it changes the properties of semiconductors. Studying the process of creating n-type and p-type semiconductors. • Intrinsic and Extrinsic Semiconductors • Understanding the difference between pure (intrinsic) and doped (extrinsic) semiconductors. • Concepts of electron and hole carriers in semiconductors. • Calculating carrier concentration and mobility. • Understanding the Fermi level and its importance in

		semiconductor devices and circuits. 10. Verifying device functionality and performance.	carrier behaviour. • How doping affects the Fermi level. • Conductivity in semiconductors and its temperature dependence. • Carrier Generation and Recombination: • Processes of carrier generation and recombination. • How they impact the electrical behaviour of semiconductors. • Detailed study of common semiconductor materials like silicon and gallium arsenide. • Thermal, mechanical, and electrical properties of these materials. • How semiconductor materials are used in various devices, including diodes, transistors, and photovoltaic cells. • Understanding defects and impurities in semiconductor materials. • Their impact on material properties and device performance. • Understanding the Energy band gap and measurement in semiconductor Diodes& Wafer – Germanium • Understanding the principle of Hall Effect in Semiconductor material • Study the Seeback &

			Peltier Effect Study the Photoconductivity in semiconductor materials and Planck's constant
Professional skills 35 Hrs. Professional Knowledge 10 Hrs.	Familiarize with passive and active electronic components built with semiconductor technology and Exposure to various semiconductor component, devices, sensors, small circuits.	11. Construction and test RC time constant circuits. 12. Construct and test series and parallel resonance circuits (Use of R, L and C); RC differentiator. 13. Plot the I-V characteristics of a PN junction diode under forward and reverse bias conditions. 14. Use diodes and transistors to build and test simple circuits. This could include rectifier circuits, amplifier circuits, or oscillator circuits. 15. Familiarity with curve tracer for electrical measurements of resistors, diodes, transistors, etc. 16. Measure and compare the Silicon, Germanium diode I-V (both forward and reverse) characteristics. 17. Measure and compare the I-V (both forward and reverse) characteristics of diodes with different break down voltages. 18. Learn the use of LED and photodiodes. 19. Construct and test Zener based voltage regulator circuit. 20. Measure NPN and PNP I-V	• Conductors, Insulators and Semiconductors • Current, Voltage and Power • Resistors, Resistors in series and parallel • Ohms Law and Kirchhoff's Laws • Resistor colour coding, Specification of various types of resistors and their applications • Capacitors and capacitance • Series and Parallel connection of capacitors • Inductors and inductance, Types of inductors and their construction • Semiconductor material (Silicon, Germanium, Compound Semiconductors) • PN Junction diode and their construction, Diode I-V characteristics • Understanding how changes in temperature can affect the electrical properties of semiconductors. • Brief introduction to basic semiconductor devices like diodes, transistors, and their principle of

		characteristics. 21. Measure N-type and P-type MOS transistor characteristics. 22. Construct and test a common emitter amplifier. 23. Construct and test a FET amplifier. 24. Measure the performance and characteristics of various semiconductor devices.	operation. • Light Emitting Diode, Photodiode, Zener Diode; Solar cells • Bipolar Junction Transistors, NPN and PNP BJTs and their characteristics • Metal Oxide Semiconductor (MOS) Capacitor and MOS Transistor • MOS Capacitor and MOS Transistor Characteristics • Integrated Circuits (ICs) • Identification of different ICs (Operational amplifiers, timers etc.) • Various types of sensors: temperature, flow and vacuum. • Test and measurement of Resistor, capacitor, inductor, Diode, Transistor, Sensor • Understand the internal fabrication design of Transistor • Understand the internal fabrication design of IC
Professional skills 45 Hrs. Professional Knowledge 15 Hrs.	Identify semiconductor Materials and Process management. (Simulation)	25. Identify and select various semiconductor materials, such as silicon, germanium, and gallium arsenide. Modelling cum simulation software for leaning fabrication process of semiconductor devices - 26. Using simulation software to model the behaviour of semiconductor devices.	Semiconductor Materials: Detailed study of commonly used semiconductor materials, such as silicon, germanium, and gallium arsenide. Understanding their properties, advantages, and disadvantages. Oxidation: Learning about the oxidation process, its purpose in semiconductor fabrication,

			and how it affects the properties of the semiconductor. • Photolithography: Exploring the theory behind exposing photoresist patterns onto wafers using masks and light sources. • Resolution and alignment: Factors influencing the resolution of photolithography and methods for alignment. Deposition Processes: Learning about various deposition processes used in semiconductor fabrication, such as chemical vapor deposition (CVD), physical vapor deposition (PVD), and atomic layer deposition (ALD). Etching: Understanding the purpose of etching in semiconductor fabrication and studying different etching techniques, such as wet etching and dry etching. Ion Implantation: Studying the process of ion implantation, which is used to dope the semiconductor wafer. Understanding how it works and how it affects the properties of the semiconductor. Annealing: Learning about the annealing process, which is

			used to repair damage to the semiconductor caused by processes like ion implantation. Metallization: Understanding the process of metallization, which involves depositing a thin layer of metal on the semiconductor wafer to form electrical connections. • Packaging: Studying the final steps in semiconductor fabrication, which involve packaging the semiconductor device to protect it and provide electrical connections.
Professional skills 45 Hrs. Professional Knowledge 15 Hrs.	Demonstrate assembly and packaging of semiconductor technology and Attain exposure to do assembly and packaging tools and operations.	27. Practical exposure to variety of semi-conductor packages made of plastic/ceramic; package types: DIP, PGA, BGA, CQFP, TQFP, SOIC, SOC, Lead frame, Flip chip etc. 28. Microscopic Inspection and measurement of various package types. 29. Observe various packaging techniques used to protect the semiconductor device and provide external electrical connections.	• Assembly and packaging process's introduction • Package types • Package design principles • Lead frames • Wire bonding (Different materials, Wire loop concept, Gold, silver and copper wire) • Lead Finish and Trim – Solder Ball Attach • Die attach • Transfer Moulding • Testing • Wafer Dicing • Glue and Chemicals in Various packaging • PSOC
Professional skills 45 Hrs. Professional Knowledge 15 Hrs.	Demonstrate Semiconductor Device Applications.	30. Use software tools to design and simulate digital and analog circuits using semiconductor devices. 31. Design and implement logic gates, flip-flops and	• Theroretical concepts of semiconductor devices like transistors are used in digital logic circuits, including gates, flip-flops, and memory cells.

		memory cells using CMOS technology. 32. Build analog component such as operational amplifies, voltage regulators and analog filters. 33. Design and analyze power semiconductor devices like MOSFETs, IGBTs and thyristors. 34. Construct and test BJT and MOS transistor-based switching circuits. 35. Understanding the Power Electronics applications & circuitry of Semiconductor devices like – IGBT- MOSFET, etc 36. Fabricate simple circuits on a breadboard or printed circuit board (PCB), and test their performance. 37. Measure the output of a solar cell under different light conditions, or testing the performance of an LED or laser diode. 38. Observe the activities with semiconductor sensors, such as measuring temperature with a semiconductor temperature sensor, or light intensity with a photodiode. 39. Measure the gain of an RF amplifier, or the frequency response of an RF filter. 40. Integrate semiconductor sensors into Internet of Things (IOT) devices for data collection and control.	• Use of semiconductor devices in analog circuits, such as amplifiers, oscillators, and filters. • Application of power semiconductor devices in converters, inverters, and motor drives. • Semiconductor devices are used in signal processing circuits for filtering, amplification, modulation, and demodulation. • Application of opto-electronic devices in communication systems, display technologies, and solar energy conversion. • Use of semiconductor devices in sensors for temperature, pressure, light, magnetic fields, etc., and in transducers for converting one form of energy into another. • Application of semiconductor devices in integrated circuits for various functions, including microprocessors, memory chips, and application-specific integrated circuits (ASICs). • Semiconductor devices viz. microcontroller and sensors application in automobiles enabling various systems that enhance safety.,

		41. Apply in smart homes, wearable devices and Industrial IOT. 42. Examine semiconductor application in vehicle control systems, safety features and infotainment. 43. Implement semiconductor devices in medical imaging, monitor equipment and diagnostic tools 44. Identify the application of semiconductor technology in medical electronics viz. X-ray machines, MRI scanners and wearable health devices. 45. Experiment the basic concepts of PV technology like photon to electricity conversion, Series and parallel conncetions of solar PV Modules, VI characteristics of Solar module. 46. Demonstrate FPGA applications.	performance and overall functionality. For engine control, Anti-lock Braking Systems (ABS), Electronic stability Control (ESC), Airbag systems, infotainment systems, Advance Driver Assistance systems (ADAS), Power steering, climate control, Keyless entry and start, LED lighting, Electric and Hybrid vehicles etc. • In RF circuits for wireless communication, radar systems, and microwave applications. • Emerging applications of semiconductor devices in areas like flexible electronics, quantum computing, and bioelectronics. • Importance of reliability and lifetime in various applications of semiconductor devices, and studying the factors that can affect these parameters. • Understanding the Solar PV Technology as an application of Semiconductor material for green Energy generation • Introduction to FPGA
Examination			

6. ASSESSMENT CRITERIA

LEARNING OUTCOME	ASSESSMENTCRITERIA
1. Describe the fundamental properties, characteristics and applications of semiconductor materials, including crystal structures, energy bands and carrier behaviour. (NOS: ELE/N9511)	Demonstrate the fundamental properties of semiconductor materials.
	Explain energy band theory including the concepts of valence and conduction bands, the band gap and role of energy bands in semiconductor behaviour.
	Describe the crystal structure of common semiconductor materials.
	Explain carrier behaviour in semiconductors including the concepts of electrons and holes, carrier mobility and carrier concentration.
	Identify the practical application of semiconductor materials in various fields.
2. Familiarize with passive and active electronic components built with semiconductor technology and Exposure to various semiconductor component, devices, sensors, small circuits. (NOS: ELE/N9512)	Identification of different passive, active components and ICs.
	Measure the resistor, capacitor and inductor values.
	Construction and test RC time constant circuits.
	Construct and test series and parallel resonance circuits (Use of R, L and C); RC differentiator.
	Plot the I-V characteristics of a PN junction diode under forward and reverse bias conditions.
	Use diodes and transistors to build and test simple circuits. This could include rectifier circuits, amplifier circuits, or oscillator circuits.
	Familiarity with curve tracer for electrical measurements of resistors, diodes, transistors, etc.
	Measure and compare the Silicon, Germanium diode I-V (both forward and reverse) characteristics.
	Measure and compare the I-V (both forward and reverse) characteristics of diodes with different break down voltages.
	Learn the use of LED and photodiodes.
	Construct and test Zener based voltage regulator circuit.
	Measure NPN and PNP I-V characteristics.
	Measure N-type and P-type MOS transistor characteristics.
	Construct and test a common emitter amplifier.
	Construct and test BJT and MOS transistor-based switching circuits.
	Construct and test a FET amplifier.
	Measure the performance and characteristics of various

	semiconductor devices.
3. Identify semiconductor Materials and Processes management. (Simulation) (NOS: ELE/N9513)	Identify and select various semiconductor materials, such as silicon, germanium, and gallium arsenide.
	Prepare semiconductor materials for device fabrication including processes like cleaning, etching, or surface passivation.
	Demonstrate the doping of semiconductors to create n-type and p-type materials.
	Carryout oxidation processes used in semiconductor fabrication, such as thermal oxidation.
	Carryout the photolithography, a key process in semiconductor fabrication.
	Demonstrate the deposition processes like chemical vapor deposition (CVD) or physical vapor deposition (PVD).
	Heat the wafer to activate dopants and repair crystal damage caused by ion implantation.
	Create MOS transistors involves defining gate source and drain regions.
	Build metal layers to connect various components on the chip.
	Insulate layers separate metal layers to prevent electrical interference.
	Mount the ICs in protective packages with pins for external connections.
	Check individual dies on a wafer for defects and electrical functionality.
	Ensure that packaged ICs meet their specifications before shipment.
	Reduce the environmental impact of semiconductor fabrication through cleaner processes and recycling.
4. Demonstrate assembly and packaging of semiconductor technology and Attain exposure to do assembly and packaging tools and operations. (NOS: ELE/N9514)	Semi-conductor packages made of plastic/ceramic; package types: DIP, PGA, BGA, CQFP, etc
	Wafer dicing, die attach, die wire bonding, sealing;
	Microscopic Inspection of assembly & packaging.
	Observe various packaging techniques used to protect the semiconductor device and provide external electrical connections.
5. Demonstrate Semiconductor Device Applications. (NOS:	Use software tools to design and simulate digital and analog circuits using semiconductor devices.
	Design and implement logic gates, flip-flops and memory cells

ELE/N9515)	using CMOS technology.
	Build analog component such as operational amplifies, voltage regulators and analog filters.
	Design and analyze power semiconductor devices like MOSFETs, IGBTs and thyristors, UJT, FET, Etc.
	Fabricate simple circuits on a breadboard or printed circuit board (PCB), and test their performance.
	Measure the output of a solar cell under different light conditions, or testing the performance of an LED or laser diode.
	Observe the activities with semiconductor sensors, such as measuring temperature with a semiconductor temperature sensor, or light intensity with a photodiode.
	Measure the gain of an RF amplifier, or the frequency response of an RF filter.
	Integrate semiconductor sensors into Internet of Things (IOT) devices for data collection and control.
	Apply in smart homes, wearable devices and Industrial IOT.
	Examine semiconductor application in vehicle control systems, safety features and infotainment.
	Use in engine control units (ECUs), anti lock braking systems (ABS) and advanced driver assistance systems (ADAS).
	Implement semiconductor devices in medical imaging, monitor equipment and diagnostic tools.
	Identify the application of semiconductor technology in medical electronics viz. X-ray machines, MRI scanners and wearable health devices.

ANNEXURE-I

LIST OF TOOLS & EQUIPMENT			
FUNDAMENTALS OF SEMICONDUCTOR TECHNOLOGY			
S No.	**Name of the Tools and Equipment**	**Specification**	**Quantity**
Same as Semiconductor Technician trade under CTS			
Additional Tools and Equipment Required			
1.	N/A		

ANNEXURE-II

The DGT sincerely acknowledges contributions of the Industries, State Directorates, Trade Experts, Domain Experts and all others who contributed in designing/ revising the curriculum. Special acknowledgement is extended by DGT to the following expert members who had contributed immensely in this curriculum.

List of Expert Members participated in the trade committee meeting for finalizing the course curriculum of FUNDAMENTALS OF SEMICONDUCTOR TECHNOLOGY under STC on 30.04.2024 at CSTARI, Kolkata

Sl. No.	Name and Designation (Shri/Smt./Kumari)	Organization with Address	Remarks
1.	Sunil Kumar Gupta, DDG (ER)	CSTARI, Kolkata	Chairman
2.	G. C. Saha, Joint Director/HoD	CSTARI, Kolkata	Member
3.	Brindaban Das, Deputy Director/HOO	CSTARI, Kolkata	Member
4.	Prodip Mukhopadhyay, former MD WEBEL & Sr. Advisor	MAKAUT, Kolkata	Member
5.	Tapas Kumar Chini, Ex. Senior Professor	SINP, Kolkata & RKM, Belurmath	Member
6.	Aditya Mandal, Head RF Section	VECC, Bidhannagar	Member
7.	Reema Nandi, Associate Manager	Accenture, Unitech Kolkata	Member
8.	S. Chakrabrty	GVR, Kolkata	Member
9.	Biswasjit Jana, Instructor	Don Bosco Technical Institute, Prakcircus	Member
10.	Nishchal, Scientist 'C'	STQC, ERTL(E), Sector-v	Member
11.	Sayan Mondal, Asst. Prof	BIT, Bantala, Kolkata	Member
12.	Patra Kusum Misra, Asst. Prof.	T.C.E Agartala	Member
13.	Niladri Roy, Consultant	TCS	Member
14.	Bijayeelaxmi Panda, Engineer	CTTC	Member
15.	Shekhar Pradhan, Co-Founder & Director of Business Operations	Grok Learning Pvt. Ltd.	Member
16.	Makarand Joshi, Product Manager	Grok Learning Pvt. Ltd.	Member
17.	Himanshu Samal, Global Head Sales & Strategic partnerships	Grok Learning Pvt. Ltd.	Member
18.	Satyabrata Pandab, Engineer	Central Tool Room and Training Centre, Bhubaneswar	Member
19.	Mananjaya Nayak Engineer (Training Department)	Central Tool Room and Training Centre, Bhubaneswar	Member

20.	Akshay Jadhav, Sr Design Engineer	Tata Technologies	Member
21.	Sunil Chore, Managing Director	Simusoft Technologies, Pune	Member
22.	Manohar Sadashiv Desai, Technical Head	Skill Bahn LLP, Thane, Maharashtra	Member
23.	B. Sharanappa, Assistant Director	CSTARI, Kolkata	Member
24.	Sk. Altaf Hossain, Assistant Director	CSTARI, Kolkata	Member
25.	M.J. Vijaya Raju, Assistant Director	CSTARI, Kolkata	Member
26.	Akhilesh Pandey, Assistant Director	CSTARI, Kolkata	Member
27.	P. K. Bairagi, Training Officer	CSTARI, Kolkata	Member
28.	B. Biswas, Training Officer	CSTARI, Kolkata	Member
29.	Swapan Sen, Training Officer	CSTARI, Kolkata	Member
30.	Pradip Biswas, Jr. D/Man	CSTARI, Kolkata	Member
31.	Hemant Kujur, Jr. D/Man	CSTARI, Kolkata	Member
32.	Jinendran PK, JC	CSTARI, Kolkata	Member