COURSE STRUCTURE

B.TECH

ELECTRONICS & COMPUTER ENGINEERING (ECSE)

Under

Choice Based Credit System(CBCS)

(w.e.f. 2024-25)

Credit Structure For B.Tech. (All Branches) w.e.f. 2024-25

Category	Courses	L	T	P	C	Total Credits
Humanities & Social Sciences (HSS)	Management	3	0	0	3	19
	English- I	0	0	4	2	
	English-II	0	0	4	2	
	English for Professional Purposes-I	2	0	0	2	
	English for Professional Purposes-II	2	0	0	2	
	Soft Skills-I	0	0	2	1	
	Soft Skills-II	0	0	2	1	
	Soft Skills-III	0	0	6	3	
	Soft Skills-IV	0	0	6	3	
Basic Sciences (BS)	Mathematics Courses-I	3	1	0	4	21
	Mathematics Courses-II	3	1	0	4	
	Mathematics Courses-III	3	1	0	4	
	Chemistry	2	0	1	3	
	Environmental Studies	2	0	0	2	
	Physics	2	1	2	4	
Engineering Sciences (ES)	Computer Programming	3	0	1	4	21
	Mechanical Engineering	3	0	0	3	
	Engineering Drawing	0	0	2	1	
	Engineering Workshop & Practice Lab	0	0	2	1	
	Electrical Engineering	3	0	2	4	
	Electronics Engineering	3	0	2	4	
	Dept. Specific	¾	0	2/0	4	
Project	Mini Project-I				1	14
	Mini Project-II				1	
	Mini Project-III				2	
	Industrial Training				2	
	Academic Project				2	
					6	
Program Core (PC)	Core Subjects & Branch				52	52
Program Electives (PE)	Advanced Subjects of Branch				26	26
Open Electives (OE)	Multidisciplinary Subjects from Other Branch				12	12
Mandatory Non Graded (MNG) Courses	Four Courses of LTP= 002 (Ethics & Values, Environmental Studies, Disaster Management, Cyber Security, Waste to Management, Entrepreneurship, Constitution of India etc.)				4 U	4 U
Grand Total						**165**

Program Core (Credits=52)

S. No.	Subject (Electronics Domain)	Credit	Subject (CS Domain)	Credit
1	Signal and System	4	Object Oriented Programming System Using C++	3
2	Solid-state devices and circuits	4	Object Oriented Programming System Using C++ Lab	1
3	Microprocessors	3	Operating System	3
4	Microprocessors Lab	1	Operating System Lab	1
5	Control System	3	Database Management System	3
6	Analog and Digital Communication	3	Database Management System Lab	1
7	Data Communication Network	3	Data Structure and Algorithms usin C	3
8	VLSI Design	3	Data Structure and Algorithms usin C Lab	1
9	Digital Electronics	3	Machine Learning	3
10	Digital Electronics Lab	1	Machine Learning Lab	1
11	----------		Design and Analysis of Algorithms	3
12	----------		Design and Analysis of Algorithms Lab	1
	Total	28	Total	24

Program Electives (Credits= 26)

S.No.	Subject (Electronics Domain)	Credit	Subject (CS Domain)	Cred
1	Sensor and Instrumentation	3	Natural Language Processir	3
2	Digital Signal Processing	3	Optimization Techniques	3
3	Robotics & Automation	3	ASIC Design	3
4	Mechatronics	3		3
5	Analog Mixed Mode VLSI	3	Big Data Analytics	3
6	MEMS	3	Parallel Processing	3
7	RF Integrated Circuits	3	Cognitive Computing	3
8	Avionics	3	Multimedia Communicatior	3
9	Optical Communication	3	Complier Design	3
10	Optical Communication and Microwave Lab	3	Pervasive & Ubiquitous Computing	3
11	Wireless Communication	3	Reliability Engineering	3
12	Embedded System Design (nev syllabus)	3	Cryptography and Network Security	3
13	Embedded System Lab	1	C# and .NET	3
14	Analog Integrated Circuit	2	Real Time System	3
15	Digital Image Processing	3	Automata Theory	3
16	Analog Integrated Circuit Lab	1	Cyber security	3
17	Information Theory and Codir	3	Deep Learning	3
18	Artificial Intelligence	3	Computer vision	3
19	Introduction to IoT	3	IIoT and Cyber Physical System	3
20	Introduction to IoT Lab	1	Virtualization and Cloud computing Lab	1
21	Fundamentals of Digital Desigı Using Verilog	3	Virtualization and Cloud computing	3
22	Fundamentals of Digital Desigı Using Verilog lab	1	Web Technology	3

23	Simulation Lab II	1	Data Science	3
24	Computer-Aided Design Lab	1	Quantum Computing	3

Open Electives (Credits =12)

S.No.	Subject	Credit
1	Renewable Energy Sources	4
2	Industry 4.0: Artificial Intelligence Applications	4
3	Integrated Waste Management for smart city	4
4	Smart Grid	4
5	Innovation and Entrepreneurship	4
6	Fundamental of Electric and Hybrid Vehicles	4
7	Research Methodology and IPR	4
8	Biomedical Instrumentation	4
9	International Economics and Globalization	4
10	Drone Technology	4
11	Quantum Mechanics	4
12	Design Thinking	4
13	Biology for Engineers	4

B. Tech. ECSE: First Semester

S. No.	Cat.	Code	Subject	L	T	P	J	C
1	BS	BMAS0104	Engineering Calculus	3	1	0	0	4
2	BS	BECS 0002	Semiconductor Physics	2	1	0	0	3
3	ES	BECG0007	Electrical Circuits and Networks	3	0	0	0	3
4	BS	BECS 2001	Semiconductor Materials and Characterization	3	0	0	0	3
5	ES	BCSG0002	Computer Programming	3	0	0	0	3
6	ES	BCSG0801	Computer Programming Lab	0	0	2	0	1
7	ES	BECG0806	Idea Lab	0	0	2	0	1
8	BS	BECS 0801	Semiconductor Physics Lab	0	0	2	0	1
9	HS	BELH 0811	English Communication Skills-I	0	0	4	0	2
			Total					21

B. Tech ECSE: Second Semester

S. No.	Cat.	Code	Subject	L	T	P	J	C
1	BS	BMAS 1105	Matrices, Differential Equations, and Laplace Transform	3	1	0	0	4
2	ES	BECG 0008	Introduction to Internet of Things	3	0	0	0	3
3	ES	BECG 2001	Electronics Engineering	3	0	0	0	3
4	ES	BCSG1001	Python Programming	3	0	0	0	3
5	ES	BECG1800	Electronics Lab I	0	0	2	0	1
6	ES	BECG 0807	Internet of Things Lab	0	0	2	0	1
7	ES	BCSG1800	Python Programming Lab	0	0	2	0	1
8	ES	BMEG0804	Engineering Drawing & Modelling	0	0	2	0	1
9	HS	New Code	English Communication Skills-II	0	0	4	0	2
10	PW	APFJ0001	Field Project	0	0	0	4	1
	Total							20

Third Semester

CODE	TYPE	COMPULSORY/ OPTIONAL	SUBJECT	TEACHING SCHEME			CREDITS	CONTACT HRS /WEEK
				L	T	P		
	THEORY							
BMAS1103	BS	Compulsory	Engineering Mathematics III	3	1	0	4	4
ONLS0002	BS	Compulsory/Online	Environment and Development	2	0	0	2	2
BECC0005	PC	Compulsory	Signal and Systems	3	1	0	4	4
	PC	Compulsory	Digital Electronics	3	0	0	3	3
BECC0001	PC	Compulsory	Data Structures and Algorithm using C	3	0	0	3	3
BECC0002	PC	(Only one)	Operating System	3	0	0	3	3
BELH0003	HS	Compulsory	English for Professional Purposes-I	0	0	4	2	4
	Practicals							
	PC	Compulsory	Digital Electronics Lab	0	0	2	1	2
BECC0800	PC	Compulsory	Data Structures and Algorithm Lab using C	0	0	2	1	2
BTDH0301	HS	Compulsory	Soft Skills-I/Coding 1(Python)	0	0	2	1	2
			Operating System Lab	0	0	2	1	2
MBAM0002	MNG	Compulsory	Leadership and Organizational Behaviour	0	0	2	0	2
	PE		Simulation Lab II	0	0	2	1	2
			TOTAL				**26**	**35**

Fourth Semester

CODE	TYPE	COMPULSORY/ OPTIONAL	SUBJECT	TEACHING SCHEME				CREDITS	CONTACT HRS /WEEK
				L	T	P	J		
		THEORY							
	PC	Compulsory	SSDC	3	0	0	0	3	3
BECC0008	PC	Compulsory	Microcontroller /Microprocessor	3	1	0	0	3	3
	PC	Compulsory	Object Oriented Programming Using C++	3	0	0	0	3	3
BCSO0001	OE	(Only one)	Database Management System	3	0	0	0	3	2
BELH0004	HSS	Compulsory (Except for CSED)	English for Professional Purposes-II	0	0	4	0	2	4
BECE0001	PE	(Only one)	Elective 1 (EC)	3	0	0	0	3	3
BECE0002	PE		Elective 1 (CS)						
		Practicals							
BECC0801	PC	Compulsory	Linear Integrated Circuits Lab	0	0	2	0	1	2
BCSO0070	OE	Compulsory	Database Management System lab	0	0	2	0	1	2
			Microcontroller Lab/Microprocessor Lab	0	0	2	0	1	2
			Object Oriented Programming Using C++	0	0	2	0	1	2
BTDH0302	HSS	Compulsory	Soft Skills II	0	0	2	0	1	2
BECJ0950	PW	Compulsory	Mini Project-I	0	0	0	4	1	4*
MBAM0001	MNG	Compulsory	Basic Course in Entrepreneurship	0	0	2	0	0	2
			TOTAL					**23**	**30+4***

BECS0002: SEMICONDUCTOR PHYSICS

Course Objective:

- To understand the background of intrinsic and extrinsic materials.
- To understand the effect of temperature on the various properties of Semiconductor materials.
- To familiarize the students with characteristics and applications of solid state devices like BJT, MOSFET etc. and study their parameters.
- Analysis of BJT and MOFET amplifiers with parasitic, coupling and bypass capacitors and understand the effect of capacitances in its frequency response.

Credits: 03 **Semester I** **L–T–P: 2–1–0**

Module No.	Contents	Teaching Hours (Approx.)
1	**Semiconductors: Energy Band and Charge Carriers:** Energy bands in semiconductors, Types of semiconductors, Charge carriers, Intrinsic and extrinsic materials. Carrier concentration: Fermi Level, Electron and hole concentration equilibrium, Temperature dependence of carrier concentration, Compensation and charge neutrality. Conductivity and mobility, Effect of temperature, Doping and high electric field. **Junctions:** p-n junction and contact potential, Fermi levels, Space charge,	14
2	**Bipolar Junction Transistors (BJT):** Minority carrier distribution, Solution of diffusion equation in base region, Terminal current, Current transfer ratio, Ebers-Moll equations, Charge control analysis. **MOSFET:** Basic construction of MOSFET and working, I-V characteristics, enhancement and depletion modes, Complimentary MOS (CMOS). Photonics: LED: Radiative transition, Emission spectra, Luminous efficiency and LED materials, Solar cell and photodetectors: Ideal conversion efficiency, Fill factor, Equivalent circuit, Voc, Isc and Load resistance, Spectral response. Reverse saturation current in photodetector.	14

Red- Deletion, yellow-addition

Recommended Books

1. Streetman, B. and Banerjee, S., Solid State Electronics, Prentice Hall India, (2006).

2. Sze, S.M., Physics of Semiconductor Devices, John Wiley, (1981).

3. Tyagi, M.S., Introduction to semiconductor materials and devices, John Wiley, (2000).

4. Pierret, R.F., Semiconductor Device Fundamentals, Pearson Education Inc., (2006).

BECG0007: ELECTRICAL CIRCUITS AND NETWORKS

Course objective:

- To explain the basic concepts and laws of DC and AC electrical networks and solve them using mesh and nodal analysis techniques.
- To learn different network theorem and analyze the electric circuit using network theorem.
- To Introduce Two port network.
- To analyze circuits in time and frequency domain.
- Synthesize the network using passive elements.

Credits: 03 **L–T–P-J: 3–0–0-0**

Module No.	Content	Teaching Hours
I	**A1: Introduction to Electrical circuit analysis :** Revie of electrical device resistor capacitor inductor. Node and mesh analysis, source transformation. concept of dependent source (VDVS, VDCS.CDVS$CDCS) and its application **A2: Steady state Analysis** AC analysis: AC fundamentals, average &rms values of different AC waveforms, phasor algebra, analysis of series AC circuits,A3: Steady state Analysis **A3: : Network Theorems (Applications to ac networks):** AC network theorem (Superposition, reciprocity, Thevenin's, Norton's, Maximum power transfer, compensation and Tallegen's theorem as applied to A.C. & D.C. circuits)	21
II	**B1: Two Port Networks:** Characterization of LTI two port networks: Z. Y, ABCD and h parameters, reciprocity and symmetry. Inter-relationships between the parameters, inter-connections of two **B1: Transient Analysis:** RL, RC and RLC circuits – classical approach. **B3: Network function, driving point and transfer function concept of pole and zero** **B4 Single phase Transformers**: Constructional feature, Working Principle, EMF equation, Ideal transformer, Equivalent Circuit, Phasor diagram	21

Text Books:

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- Charles K. Alexander and Matthew N.O. Sadiku,"5thEd.Fundamentals of Electric Circuits*Publisher*: McGraw Hill Education.
- D. Roy Choudhary, "*Networks and Systems*" 2nd Ed., New Age International (P) Ltd. Publishers.
- A.Chakrabarti, "*Network Analysis & Synthesis*", Dhanpat Rai & Co.

BECG 0806: IDEA LAB

Credits: 01 **L–T–P-J: 0–0–2-0**

Course Objectives

- To Understand the working of electronics equipment.
- To become familiar with the components used in drones.
- To understand the operations of Arduino/Raspberry Pi and their applications in IOT.

Experiment Number	List of Experiments
1	To study the modern electronics hardware like mobile phone and drones.
2	Study of Electronics components and instruments.
3	Assembling and disassembling the electronics hardware like drones.
4	Introduction to IoT and IoT based Sensors.
5	Introduction to Arduino/Raspberry Pi.
6	Integration of IoT with Arduino/Raspberry Pi for Drone Technology

Outcomes:

1. Flying a Drone, surveying, and data analysis
2. Drone Workshop.
3. Hackathon based on IoT and Drone Technology

BECS 0801: SEMICONDUCTOR PHYSICS LAB

Credits: 01 **Semester I** **L–T–P: 0–0–2**

Module No.	Contents	Teaching Hours (Approx.)
1	1. Study of Hall Effect 2. Energy Gap of A Material of P-N Junction 3. Parameter extraction from I-V characteristics of a PN junction diode 4. Parameter extraction from I-V characteristics of a zener diode 5. Study of diode rectification 6. V-I Characteristics of Light Emitting Diodes 7. Study of a photodiode 8. Study The Characteristics of P-I-N and Avalanche Photodiode Detectors.	20

BECG 0008: INTRODUCTION TO IIINTERNET OF THINGS

Objective: *To Implement Data and Knowledge Management and use of Devices in IoT Technology.*

Credits: 0 3 **L–T–P: 3–0–0**

Module No.	Content	Teaching Hours
I	**Introduction to IoT:** Introduction to IoT - Sensing, Actuation, Logical desig n of IoT, Functional blocks of IoT, Communication models, IoT & M2M: Machine to Machine, Difference between IoT and M2M, **Introduction to Sensors:** About Sensor, Properties Of Sensors Basic physical principles of sensing, Categorization of Sensor, PIR Sensor , Temperature Sensor, Ultrasonic Sensor, IR Sensor, MQ2/ MQ3	20
II	**Implementing IoT** Introduction to different IoT Tools, Introduction to Arduino Programming. Integration of Sensors and Actuators with Arduino. Implementation of IoT with Arduino/Node MCU/Raspberry Pi **IoT Over Network** IOT Networking Protocols: TCP/ IP, 6LowPan, RPL Communication Protocol: CoAP, SMTP, HTTP, MQTT, MQTT-S	20

Reference Books:

- Pethuru Raj and Anupama C. Raman, "The Internet of Things: Enabling Technologies, Platforms, and Use Cases", (CRC Press)
- Arshdeep Bahga and Vijay Madisetti "Internet of Things: A Hands -on Approach", by (Universities Press)

Outcome: After completion of Lab, student will be able to:

- CO1: Understand the concepts of Internet of Things .
- CO2: Analyze basic protocols in IOT .
- CO3: Design IoT applic ations in different domain and be able to analyze their performance .
- CO4: Able to implement basic IoT applications on embedded platform .

BECG 2001: ELECTRONICS ENGINEERING

Credits: 03 **L–T–P-J: 3–0–0-0**

Course Objectives

- To facilitate understanding of Digital logic fundamentals and logic gates.
- Be familiar with the principle and theory of semiconductor materials.
- To facilitate understanding of Analog components such as PN Junction Diode, BJT, Operations Amplifiers.

Module No.	Contents	Teaching Hours
I	**Digital Electronics:** Number systems; Binary Addition & Subtraction;1's and 2's complement, Subtraction using 2's complement; Boolean algebra; Logic gates; Implementation of basic gates using universal gates; Realization of Boolean functions using basic & universal gates; Canonical forms (SOP & POS); Simplification of Boolean functions using Boolean postulates & K-map up to 4 variables with don't care condition. (8) **Transport phenomenon in semiconductors:** Semiconductor materials; Intrinsic and Extrinsic semiconductors; Mass-action law, (3) **Junction diodes:** P-N Junction diode: construction, operation & characteristics; Zener and Avalanche breakdown mechanisms; (4) **Diode applications:** Rectifiers: half wave, full wave: Centre-tapped and bridge type, (3)	18
II	**Diode applications:** Clippers; Clampers; Zener diode as voltage regulator; Regulated power supply. (4) **Bipolar Junction Transistor (BJT):** Bipolar junction transistor: construction & operation; CB, CE, CC configurations & their Characteristics; Operating point; Transistor as a switch; Need of biasing; Biasing methods: fixed bias, emitter bias, potential divider bias. (9) **Operational Amplifier (Op-Amp):** Operational amplifier: Block diagram, ideal and practical Op-Amp characteristics; Inverting, non-inverting and differential configurations (open loop and closed loop); Applications of Op-Amp as adder, subtractor, integrator and differentiator. (4)	17

Text Book:

- Morris Mano, "*Digital design*", Pearson Education.
- Robert L. Boylestad and Louis Sashelsky, "*Electronic devices and circuit theory*", Pearson Education/PHI, New Delhi.

Reference Books:

- R.A. Gayakwad, "*Op-amps & linear Integrated circuits*", PHI.
- R.J. Smith and R.C. Dorf, Circuits, "*Devices and System,*" Willey, 5th edition.

Course Outcomes: After successfully completing the course students will be able to:

CO1: Understand Number systems, theorems and postulates of Boolean algebra, K-Map.

CO2: logic gates, Implementation of logic expression using logic gates, implementation of logic expression using universal gates only.

CO3: Understand semiconductor and transport mechanism of charge carrier in semiconductor material, PN junction diodes with its V-I characteristics.

CO4: Apply the diodes in rectifiers, clippers, clampers and voltage regulator circuits.

CO5: Understand the basic concepts of Bipolar Junction Transistor with their characteristics.
CO6: Design DC biasing amplifier circuits using transistors.
CO7: Understand operations amplifier and its applications in the circuits such as adder, subtractor, integrator and differentiator.

BECG1800: ELECTRONICS LAB - I

Objective:

- Evaluate the performance of PN junction diode, npn BJT and N-channel EMOSFET.
- Analyze the operations of Rectifiers, clampers and clipper circuits.
- Verify the truth tables of basic gates (NOT, OR, AND) and universal gates (NAND, NOR)

Credits: 01 **L–T–P-J: 0–0-2-0**

Module	List of Experiments:		Lab Hours
I	01	Realization of NOT, AND, OR gate using NAND/NOR gate.	24
	02	Realization and analysis the half adder/subtractor using logic gates.	
	03	Realization and analysis the VI characteristic of PN junction diode.	
	04	Realization and analysis the Half wave and Center tapped / Bridge type Full wave rectifier.	
	05	Realization and analysis the biased parallel clipper circuits.	
	06	Realization and analysis the clamper circuit.	
	07	Realization and analysis the Zener diode as shunt voltage regulator.	
	08	Realization and analysis the input and output characteristic of common emitter BJT.	
	09	Find Threshold voltage of enhancement type n-channel MOSFET.	
	10	Realization and analysis of OPAMP as inverting summing amplifier.	
	11	Minor project based on experiment performed.	

Course outcomes: After completion of this course, student would be able to:

1. Evaluate the performance of PN junction diode, npn BJT and N-channel EMOSFET.
2. Analyze the operations of Rectifiers, clampers and clipper circuits.
3. Verify the truth tables of basic gates (NOT, OR, AND) and universal gates (NAND, NOR)
4. Implement IC-741 of Op-Amp to analyze its applications as adder and subtractor.

Mapping of Course Outcomes (COs) with Program Outcomes (POs) and Program Specific Outcomes (PSOs):

COs	**POs/ PSOs**
CO1	PO1,PO2, PO3 /PSO2, PSO3
CO2	PO1,PO2, PO3 /PSO2, PSO3

BECG 0807: INTERNET OF THINGS LAB

Objective: *Coordinate and help to increase and optimize the utilization of results and value creation in the area of IoT.*

Credits: 01 L–T–P: 0–0–2

Module No.	Content	Lab Hours
I	• WAP to interface and blink the LED using Arduino UNO. • WAP to interface for different sensors (Like DHT11, temperature, IR, Ultrasonic etc) to Arduino UNO. • WAP to interface temperature sensor to ESP8266. Turn on the LED if temperature value met threshold value. • WAP to interface in between Bluetooth module and Arduino UNO. • Write a python program for Gateway to store sensor data on loca l MySQL database. • WAP to transmit the data wirelessly for longer distance using multi -hop technique. • Configure the gateway as local MQTT broker (Mosquitto), configure one ESP8266 as sender (Publisher), and receive the data on the Smartphone (MQTT Dashboard).	12*2=24

Text Books:

- ESP8266: Programming NodeMCU Using Arduino IDE - Get Started With ESP8266 (Internet Of Things, IOT, Projects In Internet Of Things, Internet Of Things for Beginners, NodeMCU Programming, ESP8266) Kindle Edition .

Outcome: After completion of course, student will be able to:

- CO1: Students will be able to identifying the technical problems and be proficient in the analysis, design, test, and implementation of instrumentation and control systems utilizing appropriate software and hardware tools and devices.

CO2: Understand the functionality of system components

BECS 2001: SEMICONDUCTOR MATERIALS AND CHARACTERIZATION

OBJECTIVES:

1. The students become aware of latest Fabrication Technologies and their relation with material structuring and properties.
2. The common used analytical tools for characterizing modern materials at highest sensitivity
3. To understand stereographic projections and their use in characterization of crystalline materials

Credits: 03 **Semester II** **L–T–P: 3–0–0**

Module No.	Contents	Teaching Hours (Approx.)
1	**Introduction and structure of materials:** atomic structures and bonding, types of bonding, band formation. Defects and imperfections in solids: Point, Line and Planer defects; Interfacial defects and volume defects. Special classification of Semiconductor Materials- degenerate (semi-metal) and non-degenerate semiconductor; elemental and compound semiconductor; direct and indirect band gap material Electrochemical Approaches: anodic oxidation of alumina films, porous silicon, and pulsed electrochemical deposition, Chemical Vapor deposition	16
2	Epitaxial growth techniques, pulsed laser deposition, Magnetron sputtering - Micro lithography (photolithography, soft lithography, micromachining, e-beam writing, and scanning probe patterning). Ellipsometry, X-Ray diffraction, Scanning Electron Microscopy, Transmission Electron Microscopy, Photoluminescence Spectroscopy.	12

Text/ References books:

1. W. D. Callister, "Materials Science and Engineering: An Introduction", John Wiley & Sons, 2007.
2. K. Barriham, D.D. Vvedensky, Low dimensional semiconductor structures: fundamental and device applications, Cambridge University Press, 2001.
3. J. George, Preparation of Thin Films, Marcel Dekker, Inc., New York. 2005.
4. B. D. Cullity, “Elements of X-ray Diffraction”, 4th Edition, Addison Wiley, 1978.
5. M. H. Loretto, “Electron Beam Analysis of Materials”, Chapman and Hall, 1984.
6. S.O. Kasap Principles of Electronic Materials and Devices, 3rd edition, McGraw-Hill Education (India) Pvt. Ltd., 2007.

Course Outcomes:

1. Understand the basics of Microstructural aspects with the different processing of materials.
2. Understand the importance of structure-property correlation study of materials and its suitable applications.
3. Compare single crystal and polycrystalline growth
4. Select the characterization tool for specific application
5. Compare the principle and operation of different characterization tools such as optical microscope, Scanning electron microscopes and transmission electron microscope