UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2023/2024
MASTER'S DEGREE (MSC)	ELECTRONICS ENGINEERING
SUBJECT	HETEROSTRUCTURE DEVICES
TYPE OF EDUCATIONAL ACTIVITY	C
AMBIT	20925-Attività formative affini o integrative
CODE	19700
SCIENTIFIC SECTOR(S)	ING-INF/01
HEAD PROFESSOR(S)	CUSUMANO PASQUALE Ricercatore Univ. di PALERMO
OTHER PROFESSOR(S)	
CREDITS	6
INDIVIDUAL STUDY (Hrs)	102
COURSE ACTIVITY (Hrs)	48
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	1
TERM (SEMESTER)	1° semester
ATTENDANCE	Not mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	**CUSUMANO PASQUALE** Monday 8:00 8:01 Si prega di concordare il ricevimento via mail: pasquale.cusumano@unipa.it Please arrange in advance by sending an email request to: pasquale.cusumano@unipa.it

DOCENTE: Prof. PASQUALE CUSUMANO

PREREQUISITES	Basic knowledge of semiconductor physics and semiconductor devices such as pn junction, bipolar transistors and field effect transistors. A basic knowledge of Silicon microtechnology fabrication, quantum mechanics and lasers is beneficial but not essential.
LEARNING OUTCOMES	Knowledge and understanding ability The student, after attending the course, will become accustomed to compound semiconductors and their technology, including bulk and epitaxial growth techniques and quantum confinement structures (quantum wells, wires and dots). Moreover the student will acquire a sound understanding of the structure and physical operation of heterojunction bipolar transistors, field effect transistors such as MESFET and MODFET and emissive optoelectronic devices such as LEDs and laser diodes and of the relevant fields of application. Using knowledge and understanding ability The student will acquire the ability to: 1) design heterostructures for electronic and optoelectronic devices based on compound semiconductors; 2) perform measurements for the characterization of such devices: 3) understand and evaluate the required performances of the devices in the relevant fields of application. Making judgments The student will acquire the ability to evaluate and compare the performance specified in the data sheets by manufacturers of heterojunction bipolar transistors, MESFET, MODFET, LED and laser diodes, and choose the most suitable according to the fields of application. Communication skills The student will be able to expose with competence and good technical language topics covering technology, structure and physical operation of electronic and optoelectronic heterostructure devices based on compound semiconductors, even in highly specialized contexts. Learning ability The student will be able to study and understand other types of heterostructure devices not covered in the course (photodiodes, solar cells, optical modulators, etc.) and acquire in-depth knowledge of their structure, physical operation and application fields.
ASSESSMENT METHODS	The exam is just an oral interview where the student will be asked to answear and explain questions related to the course topics and randomly picked from the course syllabus. The exam is designed to test the acquired knowledge, planning and solving ability, presentation skills and use of appropriate technical language of the student. The assessment is based on the following grades: a) excellent (30-30 cum laude): excellent knowledge of the topics, excellent use of technical language, good analytical ability, the student is able to apply knowledge to solve the proposed problems; b) very good (26-29): good knowledge of the topics, good use of technical language, the student is able to apply knowledge to solve the proposed problems; c) good (24- 25): basic knowledge of the main topics, discrete use of technical language, limited ability to independently apply the knowledge to the solution of the proposed problems; d) satisfactory (21-23): the student knows the main topics but has not a full grasp of them, satisfactory use of technical language, poor ability to independently apply the acquired knowledge; e) sufficient (18-20): minimal knowledge of the main topics and basic use of technical language, very little or no ability to independently apply the acquired knowledge; f) insufficient: the student does not have a minimum acceptable knowledge of the contents of the topics covered in the course.
EDUCATIONAL OBJECTIVES	The course provides the fundamentals of modern electronic and optoelectronic heterostructure devices based on compound semiconductors. It aims to stimulate and prepare the student to the analysis, the design and the correct use of these devices. Practical lab exercises about LEDs and LASER diodes are designed to complement the relevant topics of lectures. The heterostructure transistors operate at high frequencies and are therefore used in wireless and microwave systems while the LEDs and laser diodes are used in optical fiber telecommunication systems, displays and lighting systems. The knowledge of these devices is important for the student to join professional activities in the fields of Microwave and optical Telecommunications, both in industry and in research and development.
TEACHING METHODS	The course consists of a group of frontal lessons about compound semiconductors, heterostructures, quantum confinement and the most important heterostructure electronic devices such as HBT and FET transistors and

	optoelectronic devices such as LEDs and LASER diodes. During the course practical lab exercises using LEDs and LASER diodes in various applications are carried out by students in the Photonics Teaching Laboratory.
SUGGESTED BIBLIOGRAPHY	Slides of the full course are available to the students through the course webpage at unipa. J. Singh, “Semiconductor Devices – an introduction” McGraw-Hill (1994) ISBN 978-0071139069 P. Battacharya “Semiconductor Optoelectronic Devices”, Prentice Hall, 2nd edition (1997) ISBN 978-0134956565 J. Singh “Semiconductor Optoelectronics – Physics and technology”, McGrawHill (1995) ISBN 978-0070576377 The above paper books are available for on loan at the Engineering Central Library or at the ex DEIM library (block 9).

SYLLABUS

Hrs	Frontal teaching
6	Quantum mechanics basics - Quantum confinement and nanostructures: quantum wells, wires and dots. Analisys of real squared QW. Periodic potential and Kronig-Penney model.
5	Recap of solid state physics, Semiconductor band diagram E(k), direct and indirect bandgap semiconductors, Bulk and QW density of states and implications for population inversion
5	Semiconductor advanced concepts Degenerate doping (Fermi-Dirac integral, Joyce-Dixon approximation) Non equilibrium (high level injection) and quasi Fermi levels Non-radiative recombination through midgap traps Semiconductor surfaces Fermi level pinning Free surface indirect recombination
2	Optical waveguides based on total internal reflection Planar optical waveguides and propagation modes 2D optical waveguides and effective refractive index method
5	IV-IV, III-V and II-VI binary compound semiconductors Ternary and quaternary alloys, Vegard law, lattice constant and bandgap Lattice matched epitaxial growth Strained layers and strain effects on bandgap and effective mass Self assembled quantum dots
6	Heterojunction bipolar transistors (HBT) Metal-semiconductor field effect transistors (MESFET) Heterostructure field effect transistors (HFET) Modulation doped field effect transistors (MODFET or HEMT) High frequency small signal circuit, transition frequency
5	Optical properties of semiconductors: absorption and emission Radiative recombination centres in indirectbandgap semiconductors Light emitting diodes (LEDs) Spontaneous emission Homojuntion LED Double heterostructure LED
8	Semiconductor lasers (LASER diodes) Population inversion and optical gain by stimulated emission Gain in semiconductors: bulk and quantum well Fabry-Perot optical cavity and longitudinal modes Double heterostructure and transverse modes Current threshold for lasing Output power, slope efficiency and power efficiency Quantum well/strained quantum well laser diodes

Hrs	Workshops
2	Practical lab excercise on LEDs and LASER diodes #1
2	Practical lab excercise on LEDs and LASER diodes #2
2	Practical lab excercise on LEDs and LASER diodes #3