14. Curricular Unit

Advanced Physics Topics 1

Module

The Physics of Electronic Materials and Devices (PEMD)

Type

Lecture course

Contact hours

18

Professor/Researcher in charge

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Summary of Contents

Continued miniaturization of silicon devices paved the way for a host of electronic appliances that revolutionized our day-to-day life during the last half century. Nanotechnology is currently introducing a new level of complexity into very small objects that in turn will allow this dizzying pace of miniaturization not only to keep up but possibly to accelerate.
This module is designed to provide a broad view of electronic materials and devices and their fabrication techniques, going from the well-established Si-based technology, through magnetic devices for data storage, up to sensors based on new 2D materials and their applications. The module includes a session hosted by the new INL in Braga, where students will be introduced to the state-of-the-art facilities that are available at the institute.

1. Electrons in solids (4 hours)
    a. Electron in a periodic field of a crystal
    b. Energy bands in metal and semiconductor crystalline solids
    c. Band structures in 3D, 2D and 1D: silicon, graphene and CNTs
    d. Electrons in nanostructures: Landauer resistance, Coulomb blockade and resonant tunneling

2. Micro and nanoelectronic semiconductor devices (4 hours)
    a. The p-n junction and the bipolar transistor
    b. The LED and the LASER
    c. The field-effect transistor: NMOS, CMOS and graphene FETs

3. Macroelectronic devices (4 hours)
    a. Solar cells

b. MEMS and NEMS devices
c. Displays

4. Sensors and data storage (4 hours)
    a. Biosensors
    b. Magnetic devices
    c. Top down fabrication of micro and nanostructures

5. Visit to INL (2 hours)

Bibliography:

- Solid State Physics, N. W. Ashcroft, N. D. Mermin, Saunders College Publishing. Harcourt College Publishers. Fort Worth Philadelphia (1976).
- Physics of Semiconductor Devices, S.M. Sze, K.K. Ng, J. Wiley & Sons Inc., New York, 3rd Edition (2006).
- Carbon Nanotube and Graphene Device Physics, H.-S. Philip Wong and Dejih Akinwande, Cambvridge University Press, Cambridge (2011).
- Introduction to Nanoscience, S.M. Lindsay, Oxford University Press, Oxford (2010).
- Fundamentals of microfabrication: the science of miniaturization, Marc J. Madou, Taylor & Francis, Inc., 2nd Edition, New York (2002).

Evaluation

Student grading will be based on a final individual exam containing conceptual questions and problems to be solved by the student. Grading will be based on a 0-20 scale and to get approval the student must obtain at least grade 10.

Students can also adhere voluntarily to a scheme of periodic evaluation of their work, based on the weekly resolution of a problem chosen by the professor and to be returned the following class. Students can seek information of any sort in order to solve the proposed problem but they compromise to do it individually. In every class, 20 minutes of lecture time will be devoted to the discussion of the solution of that week's problem and the methods used to obtain it. Any of the students having returned the problem solved in a particular week can be asked by the professor to introduce that discussion orally, based on the solution and the way he/she obtained it. In case he or she fails to do so, the problem will not be considered for evaluation. There will be a series of 8 weekly problems, each valued 2.5 points, and totalizing 20 points. Each student can enter/leave this evaluation program freely. The student will be approved in this scheme when he/she accumulates at least

10 points. In this case he/she can decide not to present himself/herself to the final exam in which case his/her final grade will be the sum of the points accumulated in the periodic evaluation of his/her work.

Jury

Pedro Alpuim, Joaquim Agostinho, Joaquim Leitão