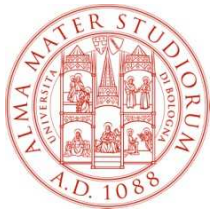
SOLID-STATE ELECTRONICS (AY 14–15)
Massimo Rudan



These slides are available in pdf format at the link entitled *Teaching Activity* of the website

http://www.micro.deis.unibo.it/cgi-bin/user?rudan

- To whom is this course addressed?
- More details about the above.
- Schedule.
- Aims of the course.
- Prerequisites.
- Exams.
- References.
- Contents.
- Contacting the teacher.
- Thesis.

✓ IEEE.

TO WHOM IS THIS COURSE ADDRESSED?

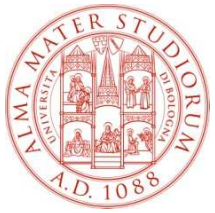
- In the Academic year 2014–2015 the Students attending the course belong to the first year of the Electronics and Communication Science and Technology program (934), to the second year of the Ingegneria elettronica program (934), and to the second year of the Sustainable Chemical and Biochemical Technology for Environment and Materials program (929).
- The course may be attended by Students different from the above who choose it on a case-by-case basis.

MORE DETAILS ABOUT THE ABOVE

- The lessons in the agenda will be given in the period February 23 through June 5, 2015. The weekly hours shown in the Faculty's schedule are a little more than those necessary to complete the maximum of 60 hours.

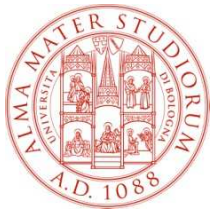
Note:

- The classrooms may be changed if necessary.
- The agenda may also be changed if necessary. Hours may be swapped with those of other teachers.
- **Changes in the agenda will be sought in order to balance the needs of the two groups of Students.**
- **The hours devoted to connected course on TCAD are specified separately.**



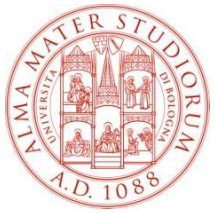
SCHEDULE

- The initial schedule is: Wednesdays 11–14 in classroom 5-1, Fridays 10–13 in classroom 5-1.
- It may happen that a few hours are added to the schedule if a need of recovery arises. In any case the total number of hours will not exceed 60.
- Due to national holidays the Faculty will be closed on
  - Easter vacations, April 2 through April 8.
  - Saturday, April 25.
  - Friday, May 1.
  - Tuesday, June 2.



AIMS OF THE COURSE

- First part: to provide the basic physical and mathematical concepts that are necessary to understand the transport phenomena in solid-state materials.
- Second part: to describe the fundamental physical properties of semiconductors, and give the derivation of the mathematical model for solid-state devices.
- To illustrate some examples of innovative research activities in the field.
- The course may be taken either on a stand-alone basis. However, it is conceptually connected to other courses given in the Faculty. Among them *Solid-state sensors*, which is also given in English.



PREREQUISITES

- Basic concepts of mathematics and physics acquired from earlier courses.
- Basic concepts about the electron devices.
- In this course further mathematical and physical concepts, not necessarily elementary, will be used. They will be explained as necessary during the lessons. The use of such concepts can not be disposed of, they actually constitute the cultural basis of the course itself.

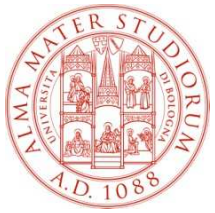
EXAMS

- The exams are oral.
- To register for the exam it is necessary to use the electronic lists that will be made available on the website

https://almaesami.unibo.it

<u>The Students that have access to the e-lists are kindly asked to use this method only</u>

- The electronic lists will carry the indication of the meeting point for the examinations' scheduling.
- DEI: second floor of the "Aule Nuove" building.



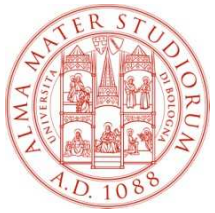
REFERENCES (I)

- Solid-State Electronics

  - 1-1. D. A. Neamen, *Semiconductor Physics and Devices*, IRWIN, 1992.
  - 1-2. M. Rudan, *Tavole di Microelettronica*, Pitagora Tecnoprint, 3ª Ed., 2001 (in English).
  - 1-3. M. Rudan, *Physics of Semiconductor Devices*, Springer, 2015.
  - 1-4. S. M. Sze, *Semiconductor Devices — Physics and Technology*, Wiley, 1985.
  - 1-5. E. De Castro, *Fondamenti di Elettronica — Fisica elettronica ed elementi di teoria dei dispositivi*, UTET, 1975.
  - 1-6. E. De Castro, *Teoria dei dispositivi a semiconduttore*, Pàtron, 1983.
  - 1-7. N. Ashcroft, N. Mermin, *Solid State Physics*, Saunders, 1976.
  - 1-8. Standard textbooks on Quantum Mechanics (A. Messiah, L. Landau, D. Bohm).

REFERENCES (II)

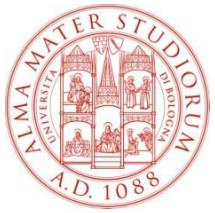
- The textbooks listed above are given as references.
- The book *Tavole di Microelettronica* is written in English and is the collection of most of the transparencies used by M. Rudan in his courses. It is meant as a teaching aid providing drawings, schemes, and calculations, not as a "replacement" of the lessons. Richer explanations are in the 2015 textbook *Physics of Semiconductor Devices* published by Springer.
- During the lessons further transparencies not included in the collection may be used. Those that are not subject to copyright will be posted on M. Rudan's website (many are actually posted there already).



CONTENTS (I)

- Introduction to Quantum Mechanics.
  - Experimental results inconsistent with the laws of Analytical Mechanics.
  - The wave function.
  - The Schrödinger equation.
- General methods of Quantum Mechanics.
  - Operators.
  - Expectation values.
  - Examples: interaction of particles with steps or barriers, tunnel effect, harmonic oscillator.

Arces



CONTENTS (II)

- Systems of interacting particles.
  - Fermi-Dirac and Bose-Einstein statistics.
  - Band calculation in solids.
  - Liouville theorem and Boltzmann transport equation (BTE).
  - Collisions terms.

- Transport theory for solid-state materials.
  - Moments method applied to the BTE.
  - Carrier temperature.
  - Mathematical model for semiconductors.

CONTACTING THE TEACHER/TUTOR

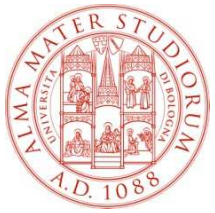
- The official agenda for contacting the teacher is:
  - Thursdays 11:30–13:30
  - Fridays 11:30–13:30

- However, it is advisable to ask for an appointment (not limited to the above agenda) during a class, or by calling 051-209-3016 (93016 when using the internal telephones of the Faculty), or by sending a message to

mrudan@arces.unibo.it

- The tutor is Dr. Ilaria Imperiale, 051-209-3049, whose e-mail address is

Ilaria.imperiale@unibo.it



THESIS (I)

- Possible subjects for a thesis in the area of semiconductor devices or materials are:
  - Advanced physical models for carrier transport in solids: through the BTE or the Schrödinger equation (coupled with the Poisson eq.), using different solution methods, among which the NEGF (Non-Equilibrium Green Function).
  - Quantum computation.
  - Carbon nanotubes, silicon nanowires.
  - Electronic nose (design and characterization of integrated sensors for volatile compounds using polymers).
  - MEMS for applications to radio-frequency circuits.
  - Advanced memory architectures, e.g., Phase-change memories (chalcogenide materials).
- Depending on the time left, some of the above research activities may be illustrated in seminars held within the course's schedule.

THESIS (II)

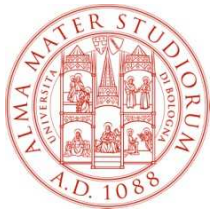
- All the thesis subjects shown above are carried out by M. Rudan, or by Colleagues of his, working at the (*)

Advanced Research Center on Electronic Systems (ARCES)

- The Professors of Electronics of the Faculty of Engineering belonging to ARCES are: G. Baccarani, G. Masetti, M. Rudan, R. Guerrieri, A. Gnudi, E. Franchi, R. Rovatti, C. Metra, S. Reggiani, N. Speciale.

ARCES is a Research Center of the University of Bologna, not a private Company.

(*) In Italian: ***Centro di Ricerca sui Sistemi Elettronici per l'Ingegneria dell'Informazione e delle Telecomunicazioni "Ercole De Castro" (ARCES).***



IEEE

- IEEE means *Institute of Electrical and Electronic Engineers* (pron. "I triple E").
- IEEE is an international Institute made of a large number of Technical Societies: *Electron Devices, Circuits and Systems, Quantum Electronics, Antennas, Telecommunications, Computers, Power Electronics,* and so on.
- Becoming an IEEE member gives access to one or more Societies and to the related Journals.
- In the University sites where IEEE is present, a Student Branch is present as well. Registration fees for Students are lower than the regular ones.

The information provided here about IEEE has no relation with the official teaching activity. It is only meant to inform the Students about the existence of the Student membership.