93391 - Semiconductor Devices and Quantum Computing
84418 - Advanced Solid-State Sensors (AY 20–21)
Massimo Rudan

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

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✓ IEEE.

TO WHOM IS THIS COURSE ADDRESSED?

- The course consists of 9 credits and belongs to the first year, first semester of the Master program entitled 934 - Electronics for Intelligent Systems, Big-data and Internet of Things (mandatory course).
- The course is made of two modules given in series; the second module (6 credits) is called Advanced Solid State Sensors and is elective in the second year of the Master program entitled 934 - Ingegneria elettronica and in the first year of the Master program entitled 9066 - Ingegneria dell'energia elettrica.
- 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 first semester starts on Wednesday, September 16, and finishes on Tuesday, December 22, 2020. The weekly hours shown in the Faculty's schedule are sufficient to complete the maximum of 90 hours. Of these, 30 hours will be allocated to the first module, 60 hours to the second one.

Note:

- The classrooms may be changed if necessary. **There are no classrooms: all lessons of this course will be delivered by remote connection using the "Teams" environment.**
- The agenda may be changed if necessary. Hours may be swapped with those of other teachers.
- Changes in the agenda may be sought in order to balance the needs of the different groups of Students.

SCHEDULE 2020-2021

- The initial schedule is: Tuesdays 09:00-12:00, Thursdays 17:00-19:00, Fridays 1530-1830.
- A few hours may be added to the schedule if a need of recovery arises. In no case the total number of hours will exceed 90.
- Due to national or local holidays of 2020, the Faculty will be closed, and no class will be given, on
  - Tuesday, December 8.
- There will be no class of this course on:

AIMS OF THE COURSE

- First part: to provide the basic physical and mathematical concepts that are necessary to understand the transport phenomena in semiconductors, and derive the mathematical model for solid-state devices.
- Second part: to apply the model to the description of the basic devices, sensors, and memories.
- Third part: to provide basic information about Quantum Mechanics, and describe its application to quantum computation.

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 dispensed with, they actually constitute the cultural basis of the course itself.

EXAMS

- The exams are oral.
- To register for the exam the Students must use the electronic lists that will be made available on the website

https://almaesami.unibo.it

- **During the pandemic emergency the exams are carried out by remote connection using the "Teams" environment.**
- **Each e-list closes 5 days before the date of the exam. These 5 days are used for providing the Students with the instructions and check the connection.**

REFERENCES (I)

- 1-1. D. A. Neamen, *Semiconductor Physics and Devices*, IRWIN, 1992.
- 1-2. S. M. Sze, *Semiconductor Devices — Physics and Technology*, Wiley, 1985.
- 1-3. E. De Castro, *Fondamenti di Elettronica — Fisica elettronica ed elementi di teoria dei dispositivi*, UTET, 1975.
- **1-4. M. Rudan, *Tavole di Microelettronica*, Pitagora Tecnoprint, 3ª Ed., 2001 (in English).**
- **1-5. M. Rudan, *Physics of Semiconductor Devices*, Springer, 2015; second edition, 2018.**
- 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).

1-9 Notes and other material available in the *https://virtuale.unibo.it* website, or in the *http://www.micro.deis.unibo.it/cgi-bin/user?rudan* website.

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 2015/2018 textbook *Physics of Semiconductor Devices* published by Springer (its *Errata corrige* is posted in the website).
- During the lessons further transparencies not included in the collection may be used. Those that are not subjected to copyright will be posted on M. Rudan's website (many are actually posted there already).

WARNING !!!!

- The page numbering of the version of *Tavole di Microelettronica* available from bookstores ot in the Faculty Library is <u>different</u> from that of the transparencies used by M. Rudan in class. In the latter, many more pages have been added since the book's publication. For this reason,

WHEN TAKING NOTES, REFER TO THE TITLE AND CONTENT OF THE PAGE, NOT TO ITS NUMBER….

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

- Questions or other issues related to the course should be addressed to:

massimo.rudan@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.
  - Numerical schemes for the solution of the models.
  - Carbon nanotubes, silicon nanowires.
  - Electronic nose (design and characterization of integrated sensors for volatile compounds).
  - Advanced memories, 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, M. Rudan, R. Guerrieri, A. Gnudi, E. Franchi, 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 IEEE Student-Branch Counselor is Prof. R. Montanari of Dept. DISI, Rebecca.montanari@unibo.it**.

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.

WARNING NO 2:

- The concepts illustrated in this class must be understood and "well digested"; a qualitative description is just the starting point: it must be followed by a thorough, quantitative analysis (i.e., using math at the appropriate level).
- In other terms, math is not the object of the class, it is the necessary tool for describing the concepts; same as being able to read music to the purpose of performing a sonata.
- Conclusion: do not consider the exam as a moment where formulas must just be written down one after the other by a strenuous effort of memory. This attitude leads invariably to a disaster… If you've problems, ask questions early enough!!

WARNING NO 3:

- The recording of the audio part of the lessons will be posted in the websites *https://virtuale.unibo.it*, *http://www.micro.deis.unibo.it/cgi-bin/user?rudan*
- This is made to help the Students, not as an encouragement not to come to class….

WARNING NO 4:

- The instructions showing how to reach some of the material associated with this course are also posted in website

https://virtuale.unibo.it