UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Quantum Electronics

2223-2-F5302Q035

Aims

The course aims to provide the fundamental notions on the design and fabrication of nanostructures by photons, electron beams and self-assembly. The electronic states of materials and devices will be studied through the discussion of their architectures and measurements of the optical, electronic and magnetic properties in order to understand the potential applications of quantum materials in quantum technologies.

Contents

• Introduction: Electronics for modern quantum technologies
• Quantum transport in low dimensional structures
• Spintronics
• Nanofabrication methods by photons, electrons, and by self-assembly
• Emergent functionalities: magnetoelectronics, topological electronics

Detailed program

INTRODUCTION
• Electronic devices for the modern quantum technologies. Overview of course pre-requisite, lecture contents, textbooks/literature, and assessment methods.

DESIGN AND FABRICATION OF NANOSTRUCTURES
• Introduction to lithography; Optical Lithographic techniques.
• Deep ultraviolet lithography; Resolution enhancement technologies; Extreme ultraviolet lithography.
• Electron beam lithography: basic concepts and practical aspects.

• Alternative lithographic technologies; Pattern transfer; Focused Ion Beam.
• Nanofabrication of specific nanoelectronics devices and circuits.

QUANTUM TRANSPORT
• Quantum transport in zero and one dimensional systems,
• Coulomb and spin blockade. Single electron devices. Quantum Hall effects.
• Spin transport in magnetic semiconductor quantum dots and metallic multilayers.
• Magnetoresistance and tunneling magnetoresistance.

SPINTRONICS DEVICES AND APPLICATIONS
• Functionalities of Spintronic Device Operations: spin–charge conversion, spin injection, spin transport, spin manipulation and spin read-out.
• Optical and magnetic resonance methods for electron spin injection, manipulation and detection.
• Molecular spintronics.
• Spin diodes, spin-based transistors and amplifiers, spin filters, molecular spin qubits and spin-qubits in semiconductor nanostructures.

EMERGENT FUNCTIONALITIES
• Topological spintronics and magnetoelectronics, quantum spin liquids and skyrmions.

Prerequisites

Basic concept of quantum mechanics, physics of semiconductor, and solid state physics courses (or equivalent).

Teaching form

Frontal lectures and exercise sessions using slides and/or blackboard.

Textbook and teaching resource

1. Yuri M. Galperin (2014). Introduction to Modern Solid State Physics. CreateSpace Independent Publishing Platform.
2. Davies, J. (1997). “The Physics of Low-dimensional Semiconductors: An Introduction”, Cambridge University Press.
3. Zheng Cui (2008), Nanofabrication - Principles, Capabilities and Limits, Springer New York, NY.
4. T. Shinjo (2009), Nanomagnetism and Spintronics, Elsevier
5. D. Gatteschi, R. Sessoli and J. Villain (2006) “Molecular nanomagnets”, Oxford University Press.
6. L. Bogani and W. Wernsdorfer “Molecular spintronics using single-molecule magnets”. Nat. Mater. 2008, 7 (3), 179-186.
7. Hirohata, A.; Yamada, K.; Nakatani, Y.; Prejbeanu, I.-L.; Diény, B.; Pirro, P.; Hillebrands, B. Review on spintronics: Principles and device applications. J. Magn. Magn. Mater. 509, 166711 (2020).
8. Barla, P.; Joshi, V. K.; Bhat, S. Spintronic devices: a promising alternative to CMOS devices. Journal of Computational Electronics 2021, 20 (2), 805-837.

Slides will be made available to the students through the present e-learning platform.

Semester

First semester (from October to January)

Assessment method

Students' knowledge will be evaluated through an oral exam focusing on the topics discussed during the course with presentation of quantitative analyses, equations, graphs, and schemes.

Office hours

From Monday to Friday at any working hour (an appointment should be arranged with the teacher by email).

Sustainable Development Goals

INDUSTRY, INNOVATION AND INFRASTRUCTURE