

# Curriculum Vitae

## Prof. Marco Fanciulli, Ph.D.

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### PERSONAL DATA

- Place and date of birth : Imperia, Italy 14.07.1961
- Nationality: Italian
- Gender: Male
- Marital status : Married, one daughter and one son
- Address: Piazza della Pace 4, 20863 Concorezzo (MI)

### EDUCATION

- **Ph.D. (Applied Physics)**, September 1993, Boston University.  
Thesis: "Study of wide-band-gap semiconductors using magnetic resonance spectroscopies"
- **Laurea in Ingegneria Nucleare (Master in Nuclear Engineering)**, February 1987, Politecnico di Torino, Torino, Italy.  
Thesis: "The Electron Paramagnetic Resonance in the study of amorphous semiconductors"

### PROFESSIONAL EXPERIENCE

- **Full Professor** (Condensed Matter Physics), October 2007 – present, at the Department of Materials Science, University of Milano - Bicocca, and Director of the MDM Laboratory,

IMM-CNR at STMicroelectronics/Micron, Agrate Brianza till 2015, and senior associated scientist at the MDM Laboratory after 2015.

- **Director of Research** INFN , December 2001 - September 2007. Director of the National Laboratory MDM- CNR- INFN at STMicroelectronics, Agrate Brianza.
- **First Researcher** INFN , June 1998 - December 2001 . Director of the Laboratory MDM - INFN at STMicroelectronics, Agrate Brianza.
- **Associate Professor**, October 1997 - June 1998. In October 1997, gets the position of Associate Professor (Lektor) at the Institute of Physics and Astronomy at the University of Aarhus, Aarhus , Denmark. He maintains the research activity at ISOLDE - CERN and he is responsible for the Mössbauer Laboratory at IFA in Aarhus.
- **Assistant Research Professor**, October 1993 - September 1997. Institute of Physics and Astronomy , University of Aarhus, Aarhus, Denmark, and ISOLDE Collaboration, CERN , Geneva , Switzerland.
- **Research Assistant** , September 1990 - September 1993. Development and characterization of wide-band-gap semiconductors. Boston University, Physics Department and Electrical Engineering Department.
- **Project Engineer** , Settembre 1989 - June 1990 ) Design and development of fiber optical fiber cables. Pirelli Cables, Milan, Italy.
- **Quality Engineer** , November 1988 - August 1989 Statistical methods for quality control and for the reliability and availability of systems, stochastic processes. Simulation of complex systems . Italtel , Milan, Italy .
- **Military service**, April 1987 - August 1988. Officer (second lieutenant) of the Italian Navy. Assignment: Dosimetry and nuclear physics teacher at the Inter-forces School for Nuclear, Biological and Chemical Defence, Rome, Italy.

## RESEARCH ACTIVITY

The main research and professional interests concern the development of materials with different functionalities dedicated to memory and logic devices for classical and quantum information processing . Such materials find application in nanoelectronic devices, spintronics and neuroelectronics . He also deals with the development of spectroscopic analytical techniques, mainly based on the electron spin, charge transport, and optical properties, for the characterization of nanostructures and devices for applications and also for more fundamental studies. The development of processes and the study of the growth of materials are also active lines of research. The work is experimental , but with a close connection with the theorists. This close interaction is considered by M. Fanciulli very fruitful and important. In the following the description of the research conducted over the years is summarized pointing out the main results.

- **Growth and characterization of semiconductors**
- **Growth.** ECR-MBE of GaN on Si. BN and AlN by sputtering, 2D materials.  
Highlights: first growth of epitaxially stabilized zinc-blende GaN on Si (1993); epitaxial growth of Gd<sub>2</sub>O<sub>3</sub> on Ge (2003); Silicene growth on Ag (2013)
- **Characterization.** M. Fanciulli started his research activity under the guidance of Prof. F. Demichelis and Prof. E. Giamello, with the study by electron spin resonance spectroscopy ( ESR ) of amorphous semiconductors of group IV and their alloys (Si, SiGe , SiGeC , ... ) . The study of defects in wide- gap semiconductors such as GaN , BN, AlN , and diamond, always by ESR and NMR also forms the central part of the doctoral activities conducted at Boston University under the guidance of Prof. TD Moustkas and also with the fruitful interaction with

Prog. A. Rigamonti. The characterization of epitaxial layers is also conducted by RHEED , Hall effect , SEM, XRD . The activity of semiconductor characterization continues in Denmark where he works on more conventional semiconductors such as silicon and germanium and alloys of group IV (SiGe , SiSn ), in addition to iron silicides. In collaboration with Prof. G. Weyer, he broadens his experimental skills to nuclear techniques such as conversion electrons Mössbauer spectroscopy (CEMS ), ion implantation of stable and radioactive isotopes carried out by M. Fanciulli in several European centers (Aarhus, Berlin, Bonn, Geneva - and on-line at ISOLDE – CERN), and to other techniques such as DLTS , AFM , RBS. He refines his knowledge of EPR spectroscopy collaborating with J. Byberg in Aarhus. The main problems relate to the study of point defects in intrinsic and extrinsic semiconductors using different spectroscopic techniques (CEMS , DLTS , ESR ). Currently this activity continues in the following lines of research:

- L1) The study of donors in silicon, SiGe, Ge for applications in quantum manipulation of information and the determination of the decay and coherence times;
- L2) The study of conduction electrons and defects in confined structures ( 2DEG , WQS , QDs, QWs ) in Si , SiGe , Ge, GaAs , AlGaAs by means of electrically detected magnetic resonance .

An important and fruitful line of research concerns the characterization by Raman spectroscopy of stress induced by process steps ( LOCOS , STI) or by epitaxy ( strained -Si). Highlights: effective mass and defects in c-GaN (1993); defects in diamond and BN (1993); point defects in silicon (1998-today), defects at the interface between oxides and semiconductors (2000-today)

- **Growth and characterization of metals**

- Iron silicides of iron and related ternary compounds. Characterization by CEMS and AFM and other techniques of structural and physico-chemical characterization of epitaxial iron silicides (stable phases, phases stabilized by the substrate ) grown by the group of Prof. Hans von Kaenel (ETH , Zurich ) by MBE .
- Structural Phase Transitions, magnetic properties and reactions at the metal/semiconductor interface. Characterization of the compounds Fe-Si and Fe-Co-Si, Fe-Mn-Si grown by PLD: structural , physico- chemical and magnetic properties . Study, at the microscopic level, of the reactivity of the interface Si/Fe , Si/ Co-Fe, Ge/Fe, SiGe/Fe with atomic mono layer resolution using CEMS.

- Ti, Co, Ni silicides for metallic interconnects in micro- and nano-electronics: structural characterization and study of the solid-state reactions with the substrate.

Highlights: identification of metastable phases (1993-1998), microstructure determination of FeSi and  $\beta$ -FeSi<sub>2</sub> phases.

- **Growth and characterization of insulators (oxides)**

- High-k dielectrics. Growth through advanced techniques such as atomic layer deposition (ALD ) and MBE and characterization of a broad spectrum of innovative materials with high dielectric constant is an activity of national and international importance. Such materials are candidates to replace silicon oxide as oxide active in logic devices MOSFETs or non-volatile memories ( NVM). The worldwide interest is substantial and also more recently also fueled by other applications in nanoelectronics, spintronics, and neuroelectronics. M. Fanciulli began this activity in 2000 and in 2001 organized the first symposium on high-k part of the E -MRS. Since then the group of M. Fanciulli continues to grow as evidenced by publications, number of invitations to international conferences, European and national projects. Among the materials of which his group has been working: Al<sub>2</sub>O<sub>3</sub> , ZrO<sub>2</sub> , HfO<sub>2</sub> , Lu<sub>2</sub>O<sub>3</sub> , Yb<sub>2</sub>O<sub>3</sub> , Y<sub>2</sub>O<sub>3</sub> , La<sub>2</sub>O<sub>3</sub>, LaAlO<sub>3</sub>, and several others.

- Boro-phosphosilicates (BPSG) and phospho-silicates (PSG). Such materials with low dielectric constant are used "pre-metal" passivating layers in MOSFETs and NVM and also have applications in optoelectronics as optical wave guides. The study of these materials has been addressed by M. Fanciulli and co-workers by optical spectroscopy and electron spin resonance. The experimental and theoretical work, with the theory group of Prof. Pacchioni at the University of Milan Bicocca, led to several publications providing important information for the optimization of the functional material in the device.  
Highlights: growth of  $\text{Lu}_2\text{O}_3$  and RE-Oxides by ALD; growth of oxides by ALD on Si, Ge, InGaAs, growth of  $\text{GeO}_2$  by ALD; characterization of defects in BPSG; investigation of the oxide/semiconductor interface (Si/high-k; Ge/ $\text{GeO}_x$ ).
- **Materials, processes, and analytical tools for ultra-scaled electronic devices**
  - Materials. The materials studied aiming at the reduction of scale of microelectronic devices are related to active oxides ( $\text{SiO}_2$ , oxynitrides, high-k), passive oxides ( $\text{SiO}_2$ , BPSG, PSG) and metallic interconnects (Ti, Co, or Ni silicides, Cu, TiN, TaN).
  - Processes. Development of ALD or MBE processes for the growth of oxides with high dielectric constant on Si and other substrates with high mobility (s-Si, Ge, InGaAs).
  - Analytical techniques. A continuous reduction of the scale of microelectronic devices requires the development of suitable analytical techniques. M. Fanciulli is active in the development of techniques, based on the electrical detection of electron spin resonance (EDMR and its variants), and other techniques (C-V, DLTS, Laplace DLTS, inelastic tunneling spectroscopy IETS), able to characterize the defects at the oxide/semiconductor interface in capacitors or transistors directly. He also, with his collaborator Dr. G. Seguini, developed the technique of internal photoemission (IPE) for the determination of energy barriers in MOS structures, a fundamental parameter in the evaluation of high-k materials for logic and memory devices.  
Highlights: study of defects at the oxide/semiconductor (Si, Ge) interface; development of high-k dielectrics; determination of band offsets for different oxide/semiconductor systems.
- **Materials, processes, and analytical tools for emerging nanoelectronic devices.**

Among the emerging nanoelectronic devices on which M. Fanciulli is actively involved we find different schemes for the realization of non-volatile memories with high potential for scalability:

  - The change of phase in certain materials (chalcogenides) thermally induced locally that involves "switching" between two electrical states;
  - The same switching electrically induced in certain oxides, a phenomenon still not clear from the microscopic point of view;
  - This switching can be also exploited in memristors for neuromorphic computing or for synapsis emulation
  - The realization, by implantation or deposition assisted by electron beam, of nanocrystals (ncs) in silicon oxides or in high-k. The ncs act as a nano-floating gate and one can design a single-electron memory based on the Coulomb blockade effect. Several experimental approaches for the experimental characterization of the ncs have been developed in the framework of this activity. Just to mention a couple: the original methodology based on ToF-SIMS (developed together with S. Ferrari and M. Perego), and the determination of the Debye-Waller factor as function of the size of Sn ncs by CEMS.
  - Investigation of silicon nanowires doping
  - Development of 2D materials: silicene (growth, characterization, devices), TMDCs (growth with novel methods and characterization)  
Highlights: processes for ncs growth; contribution to the industrial development of PCM and

ReRAM; investigation of switching mechanisms in ReRAM. Memristors for neuromorphic computation. Silicon Nanowires doping. 2D systems (Silicene transistor, MoS<sub>2</sub> production)

- **Materials, processes, and analytical tools for spintronic devices**

Given the experience and interests of M. Fanciulli spintronics can be considered a natural evolution of his research effort. M. Fanciulli focuses on two specific issues related to this field:

- **Ferromagnetic tunnel junctions ( FTJ )**. Realization of multilayers and functional devices by innovative processes such as hybrid ALD, ALD/CVD, which allow control of the interfaces, crucial for the functionality of the device. Study at the atomic level using CEMS of the metal (Fe)/oxides interfaces. Growth of metals by ALD processes using non-hazardous and environmentally friendly precursors, growth of oxides and metal oxides ferromagnetic tunnel for the realization of FTJ fully based on oxides .
- **Spin electronic in semiconductors for nanoelectronics an quantum information processing (QIP)** . Development of structures in Si for the preparation, manipulation and detection of the electron spin, due to donors or electrostatically confined, to be used as qubit in solid-state devices for QIP with high potential for scalability and integration. In this context, each activity is at the experimental limits, both in terms of realization and concepts. M. Fanciulli targeted schemes for manipulating (electric fields and other external perturbation ) and detecting (by means of electrical detected electron spin resonance such as the EDMR and Random Telegraph Noise in MOSFETs) the single spin in silicon nanostructures. He developed experimental techniques dedicated to these objectives and investigated the fundamental properties that must be met by the qubit, in particular the decay and coherence times, by means of spin echo, contributing to the understanding of the donors in group IV semiconductors. In collaboration with A. Debernardi compares experimental results and theoretical calculations thus enriching the quality of work done at MDM.

Highlights: ALD processes for magnetic oxides and MTJs; investigation of RTN in silicon MOSFETs; determination of decoherence times for donors in silicon, SiGe, and Ge; study of donors in silicon nanostructures; SiQDs for QIP.

- **Materials, processes, and analytical tools for neuroelectronic devices**

Realization of EOS ( electrolite / oxide / semiconductor ) devices with high dielectric constant oxides (TiO<sub>2</sub>, STO) for the capacitive excitation of neurons (neuroelectronics). This activity, conducted in collaboration with the group of Prof. P. Fromherz , at the Max Planck Monaco, refers only to the electronics and electrical and functional evaluation, by means of biocompatible techniques (electrolyte ) of the grown stack. The work now involved a more large international collaboration.

Highlights: realization of EOS capacitors with TiO<sub>2</sub> on silicon needles; characterization of the TiO<sub>2</sub>/Si interface; realization of novel EOS with biocompatible high-k oxides based on Hf.

## INVITED CONTRIBUTIONS

1. **M. Fanciulli**, "Point Defects in Silicon: From Micro- to Nano-electronics and Beyond", INFMeeting 2000, Genova, Italy (2000)
2. **M. Fanciulli**, "The Challenges of modern microelectronics: applied and fundamental physics", LXXXVII Congresso Nazionale della Societa' Italiana di Fisica, Milano (2001)
3. **M. Fanciulli**, "High-k dielectrics for nanoelectronics and spintronics", XII Workshop on Computational Material Science (CMS2002), Villasimius, Italy (2002)
4. **M. Fanciulli**, "Spintronics: experimental and theoretical challenges", VI Workshop CAPI02, Milano (2002).

5. **M. Fanciulli**, "Shallow donor electron spin as qubits in Si and SiGe", Euroworkshop on Quantum Computers, Villa Gualino, Torino, March (2003)
6. **M. Fanciulli**, "From fundamental research to applications in nanoelectronics and spintronics", Casimir Lectures on "strengthening the Academia-Industry ties", University of Milano, June (2003)
7. **M. Fanciulli**, "Semiconducting iron disilicides", IUMRS-ICAM 2003, Yokohama, Japan
8. **M. Fanciulli**, "Shallow donor electron spins as qubits in silicon: decoherence and hyperfine interaction manipulation", 2004 IEEE NTC Quantum Device Technology Workshop, Clarkson University, Potsdam, N.Y., USA, May 17-21, (2004)
9. **M. Fanciulli**, "Opportunities for fundamental and applied research", Casimir Workshop, University of Milano, Milano, Italy February 24 (2005)
10. **M. Fanciulli**, "Atomic layer deposition of high-k dielectrics on Ge and GaAs", MRS Spring Meeting, Symposium G, San Francisco (USA), March 28-April 1, (2005)
11. **M. Fanciulli**, "Random telegraph signal in Si n-MOSFETs: a way toward single spin resonance detection", 4<sup>th</sup> International Conference on Unsolved Problems of Noise and Fluctuations in Physics, Biology & High Technology, Gallipoli (Lecce), Italy, June 6-10, (2005)
12. **M. Fanciulli**, "More Moore: opportunities for fundamental and applied research", EARMA Conference, Genova, Italy, June 16-18 (2005)
13. **M. Fanciulli**, "High-k dielectrics for ultra-scaled and emerging nanoelectronic devices", MMD Meeting 2005, Genova (2005)
14. **M. Fanciulli**, "Defects at the high-k/semiconductor interfaces investigated by spin-dependent spectroscopies", NATO Advanced Research Workshop Defects in Advanced High-k Dielectrics Nano-Electronic Semiconductor Devices, St. Petersburg, Russia, July 11-14, (2005)
15. **M. Fanciulli** "Spin coherence, manipulation, and detection in Si", Electron Spin Resonance and Related Phenomena in Low Dimensional Structures Workshop, Sanremo-Imperia (Italy), March 2006
16. **M. Fanciulli**, "Nanocrystals in high-k dielectric stacks for non-volatile memory applications" CIMTEC, Acireale-Catania (Italy), June 2006
17. **M. Fanciulli**, "High-k dielectrics on high mobility substrates: interface properties" E-MRS Spring Meeting, Nice, France May 2006
18. **M. Fanciulli**, "Shallow donors in silicon based nanostructures for quantum information processing: experiments and theory", 39th Workshop: low-dimensional dynamical phenomena and simulations, Erice (Italy) - 26-31 July 2006
19. **M. Fanciulli**, "In-situ investigation of the early stages of the growth by ALD of high-k dielectrics on silicon and high mobility-substrates" E-MRS Fall Meeting, Warsaw, Poland September 17-21 (2007)
20. **M. Fanciulli**, "Microwave Effects in Silicon Nanostructures" NanoE3, Margaret River, Australia, September (2008)
21. **M. Fanciulli**, "Electrically detected magnetic resonance investigation of semiconductor-oxide interfaces and silicon nanostructures", EFEPR, Antwerp, September (2009)
22. **M. Fanciulli**, "Transition Metal Binary Oxides for ReRAM Applications", 216th ECS Meeting Vienna, Austria, October (2009)
23. **M. Fanciulli**, "Oxides for ultra-scaled CMOS and Innovative non-volatile memory devices",

- FNMA09 and IMIM09 Sulmona, Italy, September (2009)
24. **M. Fanciulli**, “Electrically detected magnetic resonance in silicon nanostructures and at the semiconductor/oxide interfaces”, NIS Colloquium Magnetic Resonance in Surface and Interface Science, Torino, Italy, March (2009)
  25. **M. Fanciulli**, “Magnetic resonance spectroscopy of defects at the dielectric-semiconductor interface: high mobility substrates and semiconducting nanowires”, INFOS 2011, Grenoble (FR) 21-24 June (2011)
  26. **M. Fanciulli**, "Magnetic resonance spectroscopy of defects at the dielectric-semiconductor interface: high mobility substrates and semiconducting nanowires", 17th Conference on "Insulating Films on Semiconductors", INFOS 2011 Grenoble, France, June (2011)
  27. **M. Fanciulli**, “Atomic Layer Deposition”, ECOST on Oxides, Modena, Italy March (2013)
  28. **M. Fanciulli**, “Semiconductor/oxide interface passivation in germanium and in silicon nanowires”, VII International Workshop on Semiconductor Surface Passivation (SSP-2013), Cracow, Poland, September (2013)
  29. **M. Fanciulli**, “Defects at the Ge/Oxide Interface: Properties and Passivation”, MRS Spring Meeting, Symposium BB: Materials for End-of-Roadmap Devices in Logic, Power and Memory San Francisco April 21-25 (2014)
  30. **M. Fanciulli**, “Physical foundations and future perspectives of the epitaxial silicene”, Epioptics-13 and Silicene-1, Erice, Italy 26 July – 01 August 2014
  31. **M. Fanciulli**, “Defects in silicon and germanium nanowires”, Gettering and Defect Engineering in Semiconductor Technology 2015 —30 Years of GADEST, September 20th to 25th, 2015, Bad Staffelstein, Germany
  32. **M. Fanciulli**, “Defects and dopants in silicon and germanium nanowires”, 228th ECS Meeting, Symposium D4, October 11 – 15 Phoenix, USA (2015)
  33. **M. Fanciulli**, “Electron spin relaxation and coherence in silicon”, EMRS Fall meeting, Symposium A, September 18-21 Warsaw, Poland (2016)
  34. **M. Fanciulli**, “Silicon Nanowires: Donors, Surfaces and Interface Defects”, 228th ECS Meeting, Symposium G01, October 2 – 6 Honolulu, USA (2016)
  35. **M. Fanciulli**, “Defects and Dopants in Silicon Nanowires and at their Interface with Oxides”, SURFINT 2017, November 20 – 23, Florence, Italy (2017)
  36. **M. Fanciulli**, “High-k dielectrics for CMOS and emerging logic devices”, TO-BE COST Action "Towards Oxide-Based Electronics" Sping Meeting 2018, Sant Feliu de Guíxols (Catalonia, Spain) 12-14 March 2018

- **Honors and Awards**

- 2015 Fellow of the American Physical Society (APS) “*For outstanding contributions in the growth and characterization of materials and nanostructures for emerging devices for information processing.*”

- **Committee memberships**

- 2007-2009, member of the ISOLDE and Neutron Time-of-Flight Experiments Committee (INTC). The INTC -established in August 1999- takes over the duties of evaluating proposals for experiments on the ISOLDE facility that was formerly in the hands of the ISC. In addition it reviews the experiments proposed for the TOF facility due to start operating in 2000
- NMP program committee expert advisor (since 2009)
- Scientific Council of the L-NESS - Laboratory for Nanostructure Epitaxy and Spintronics on Silicon (2010-2016)

- **Memberships**

- American Physical Society (APS);
- Material Research Society (MRS);
- Electrochemical Society;
- European Association of Research Managers and Administrators (EARMA);
- International EPR Society (IES);
- Italian Group on Electron Spin Resonance(GIRSE).

- **Referee**

- EPSRC (UK)
- EC
- Applied Physics
- Applied Physics Letter
- Hyperfine Interactions
- Journal of Applied Physics
- Nature Materials
- Physical Review Letter
- Physical Review B
- Physica Status Solidi
- Nature Materials

- **Collaborations**

M. Fanciulli collaborates with a broad range of national and international groups. Some selected examples from the current collaborations:

- **National:** STMicroelectronics, Micron, Dipartimento di Fisica, Scuola Normale Superiore, Pisa, Dipartimento di Fisica, Università di Modena, Università di Padova, Dipartimento di Scienze Biomediche.
- **International:** National Center for Scientific Research “DEMOKRITOS”: IMS and IMEL, Athens, Greece, Interuniversitair Micro-Electronica Centrum (IMEC), Leuven, Belgium , IBM Zurich Research Lab, Zurich, Switzerland, Max-Planck-Institute for Biochemistry, Department of Membrane and Neurophysics, Martinsried, München, Germany, TU-Clausthal, Germany, Bruker BioSpin, Rheinstetten, Germany, CNRS – LAAS, Toulouse, France, Department of Physics and Astronomy, University of Aarhus, Denmark, CNRS – PHASE, Strasbourg, France, FZR, Institute for Ion Beam Physics and Materials Research, Dresden, Germany, CERN – ISOLDE, Geneva, Switzerland, MEPI, Moscow Engineering Physics Institute, Russia, Institute of Organometallic Chemistry of the Russian Academy of Sciences, Nizhny Novgorod, Russia, Department of Physics, Boston University, USA, ETH, Swiss Federal Institute of Technology Zurich, Switzerland, University of Texas, Austin, USA, CEA, Grenoble, France.

## **PATENTS**

1. "Microwave detector", Italian Patent BG 2005 A000021



2. "A novel method for the production of transition metal dichalcogenides thin films", Italian Patent Request N. 102018000002349, 2.02.2018.

## TEACHING ACTIVITY

- **1997/1998**
  - Lektor “Defects in crystalline materials”, IFA Università di Aarhus, Denmark.
- **2000/2001**
  - External Professor of Physics of Semiconductors I and II, Department of Physics, University of Milano Statale.
- **2001/2002**
  - External Professor of Physics of Semiconductors I and II, Department of Physics, University of Milano Statale.
- **2002/2003**
  - External Professor of Physics of Semiconductors I and II, Department of Physics, University of Milano Statale.
- **2003/2004**
  - External Professor of Physics of Semiconductors, Department of Physics, University of Milano Statale.
- **2004/2005**
  - External Professor of Physics of Semiconductors, Department of Physics, University of Milano Statale.
- **2005/2006**
  - External Professor of Physics of Semiconductors, Department of Physics, University of Milano Statale.
- **2006/2007**
  - External Professor of Semiconductor Technology, Department of Materials Science, University of Milano-Bicocca.
- **2007/2008**, Full Professor, University of Milano-Bicocca:
  - Physics and Technology of Semiconductors (4 Cr.) (LM SdM)
  - Physics of Materials II Laboratory (4 Cr.) (LM SdM)
- **2008/2009**, Full Professor, University of Milano-Bicocca:
  - Semiconductors Module II (4 Cr.)
  - Nanoelectronic Devices (4 Cr.)
- **2009/2010**, Full Professor, University of Milano-Bicocca:
  - Semiconductors Module II (4 Cr.)
  - Nanoelectronic Devices (4 Cr.)
  - Materials and Processes for Nanoelectronics and Spintronics (4 Cr.)
- **2010/2011**, Full Professor, University of Milano-Bicocca:
  - Semiconductors Module II (4 Cr.)
  - Nanoelectronic Devices (4 Cr.)
  - Materials and Processes for Nanoelectronics and Spintronics (4 Cr.)
- **2011/2012**, Full Professor, University of Milano-Bicocca:
  - Physics of Semiconductors (6 Cr.)
  - Nanoelectronic Devices (4 Cr.)
  - Materials and Processes for Nanoelectronics and Spintronics (4 Cr.)
- **2012/2013**, Full Professor, University of Milano-Bicocca:
  - Physics of Semiconductors (6 Cr.)
  - Nanoelectronic Devices (4 Cr.)
  - Surfaces and Interfaces (4 Cr.)
- **2013/2014**, Full Professor, University of Milano-Bicocca:
  - Physics of Semiconductors (6 Cr.)

- Nanoelectronic Devices (4 Cr.)
  - Surfaces and Interfaces (4 Cr.)
- **2014/2015**, Full Professor, University of Milano-Bicocca:
  - Physics of Semiconductors (6 Cr.)
  - Nanoelectronic Devices (4 Cr.)
  - Surfaces and Interfaces (4 Cr.)
  - Physical Characterization of Materials with Lab. (1Cr)
- **2015/2016**, Full Professor, University of Milano-Bicocca:
  - Physics of Semiconductors (6 Cr.)
  - Nanoelectronic Devices (4 Cr.)
  - Surfaces and Interfaces (4 Cr.)
  - Physical Characterization of Materials with Lab. (1Cr)
- **2016/2017**, Full Professor, University of Milano-Bicocca:
  - Physics of Semiconductors (6 Cr.)
  - Nanoelectronic Devices with Laboratory (4 Cr.)
  - Surfaces and Interfaces (4 Cr.)
  - Physical Characterization of Materials with Lab. (1Cr)
- **2017/2018**, Full Professor, University of Milano-Bicocca:
  - Physics of Semiconductors (6 Cr.)
  - Nanoelectronic Devices with Laboratory (4 Cr.)
  - Physical Characterization of Materials with Lab. (1Cr)

- **Lectures at international schools**

- **M. Fanciulli**, "CEMS investigation of epitaxially stabilized iron-silicides", XXXII Zakopane School of Physics - Condensed Matter Studies by Nuclear Methods, Zakopane (1997).
- **M. Fanciulli**, "Isomer shifts and quadrupole splittings in iron silicides: Experiment and theory", Conference on Hyperfine Interactions in the Solid State: Expe Conference on Hyperfine Interactions in the Solid State: Experiments and First-Principles Electronic Structure Calculations, Miramare - Trieste, July (1998).
- **M. Fanciulli**, "Conversion Electron Mössbauer Spectroscopy of Iron-Silicides", International School of Solid State Physics, 16th Course: Silicides: Fundamentals and Applications, Erice (1999).
- **M. Fanciulli**, "Shallow donor electron spin as qubit in Si and SiGe", EUROWORKSHOP on Quantum Computers – Villa Gualino, Torino 10-21 February 2003
- **M. Fanciulli**, "Integration of oxides with semiconductors for *more Moore* and *more than Moore* technologies, TO-BE COST ACTION School, Sant Feliu de Guíxols (Catalonia, Spain) 15-17 March (2018).

- **Lectures at national schools**

- **M. Fanciulli**, II EPR School, Marcelli- Ancona, Italy, 20-27 September 1992, "Magnetic resonance techniques in the study of semiconductors".
- **M. Fanciulli**, III EPR School, Brallo di Pregola - Pavia, Italy, 29 September - 6 October 1996, "Magnetic resonance techniques in the study of semiconductor materials and devices".
- **M. Fanciulli**, IX National School on Materials Science – INFM, Genova 24-28 September 2001, "Magnetic Resonance Techniques".
- **M. Fanciulli**, National School of Condensed Matter Physics – Torino, Villa Gualino 8-21 September 2002, "Scanning probes: special applications".

- **M. Fanciulli**, University of L'Aquila 2004/2005, Master in “Systems, technology, and processes for the characterization and testing of DRAM and FLASH memories, Lectures on Advanced dielectrics: growth, characterization, and applications”
- **M. Fanciulli**, XI National School on Materials Science, Cortona 17-27 October 2005, “Magnetic resonance techniques for the investigation of interfaces and low dimensional systems”.
- **M. Fanciulli**, “Resonant tunneling, electron spin resonance and related phenomena in silicon nanostructures”, National School on Condensed Matter Physics DMD, Materials and Devices Department, “Physics of Spin in Materials” Chiavari, 2 - 9 November 2009
- **Lectures at Doctorate Schools**
  - **M. Fanciulli**, “High-k dielectrics for emerging nanoelectronic, spintronic, and neuroelectronic devices”, Università of Milano, Doctorate in Physics, October 26, 2006
  - **M. Fanciulli**, “Oxides for ultrascaled nanoelectronics and emerging devices”, University of Milano-Bicocca, Doctorate in Materials Science, June 6, 2007
- **Supervision of Bachelors**
  - **S. Cocco**, Università degli Studi di Cagliari, Tesi di diploma di laurea in Scienza dei Materiali "Caratterizzazione elettrica di strati sottili di SiO<sub>2</sub> e ZrO<sub>2</sub> per applicazioni microelettroniche" Relatore interno: Dr. Paolo Ruggerone, Relatore esterno: Dr. Marco Fanciulli A.A 2000-2001
  - **Marco Giglio**  
Laurea (Bachelor) in Physics  
Title: Study of the donor de-activation in silicon and germanium nanowires  
Year: 2014  
Tutor: Prof. Marco Fanciulli
  - **Alessio Corso**  
Laurea (Bachelor) in Physics  
Title: Density of states and incomplete ionization of donors in silicon  
Year: 2016  
Tutor: Prof. Marco Fanciulli
  - **Chiara Carra**  
Laurea Triennale (Bachelor) in Physics  
Title: “Electrical detected electron spin resonance of defects at the Si/SiO<sub>2</sub> interface as function of the modulation frequency of the magnetic field”  
Year: 2017  
Tutor: Prof. Marco Fanciulli  
Co-tutor: Dr. Stefano Paleari
  - **Marco Dosi**  
Laurea Triennale (Bachelor) in Physics  
Title: “Electrically detected magnetic resonance of defects at the Si/SiO<sub>2</sub> interface as a function of photogenerated carriers concentration”  
Year: 2018  
Tutor: Prof. Marco Fanciulli  
Co-tutor: Dr. Stefano Paleari
  - **Gianluca Formenti**  
Laurea Triennale (Bachelor) in Materials Science  
Title: “Realizzazione di strutture ordinate di nanofili in silicio mediante attacco chimico assistito da metallo”

Year: 2018

Tutor: Prof. Marco Fanciulli

Co-tutor: Dr. Matteo Belli (MDM-IMM-CNR)

- **Supervision of Masters**

- **C. Rosenblad** , Master Thesis, "Characterization of iron silicides by Mössbauer spectroscopy", IFA , University of Aarhus. Supervisor : Prof. G Weyer , Co -Supervisor : Dr. Marco Fanciulli
- **C. Ridder**, Master Thesis, " Precipitates of Sn in Si " , IFA , Aarhus University. Supervisor : Prof. G Weyer , Co -Supervisor : Dr. Marco Fanciulli .
- **R. Mantovan** , Laurea degree in Physics, University of Milan, Department of Physics. Academic year 2001-2002 Thesis: " Structural and vibrational characterization by conversion electrons Mössbauer spectroscopy (CEMS) of nanocrystalline tin in silicon oxide obtained by ion implantation ." Supervisors : Prof. Marco Fanciulli and Prof. Paolo Milani .
- **O. Costa** , Laurea degree in Physics, University of Milan, Department of Physics. Academic year 2004-2005 Thesis: " Characterization of defects at the silicon / oxide by means of non-contact electrically detected spin resonance". Supervisor : Dr. Marco Fanciulli , Co-supervisor: Prof. Ivano Pollini .
- **C. Monguzzi** Laura degree in Physics, University of Milan, Department of Physics. Academic Year 2004-2005 Thesis: "Thermal, optical and electrical characterization of the phase change materials  $\text{Ge}_2\text{Te}_2\text{Sb}_5$  and nitrogen - doped  $\text{Ge}_2\text{Te}_2\text{Sb}_5$ " External Supervisor : Prof. Marco Fanciulli, External Co-supervisor: Dr. Andrew Teren , Supervisor: Prof. Ivano Pollini.
- **Andrea Andreozzi**  
Laurea Degree in Physics  
Thesis Title : "Molecular Beam Deposition and characterization of  $\text{Gd}_2\text{O}_3$  su Ge, GaAs e InGaAs"  
Thesis Year : 2008  
Internal Supervisor : Prof. Marco Fanciulli  
External Supervisor : Dr. Sabina Spiga  
Co-Supervisor: Dr. Alessandro Molle
- **Eleonora Magni**  
Laurea Degree in Physics  
Thesis title: Investigation of the resistive switching mechanisms in transition metal oxides  
Thesis Year: 2009  
Internal Supervisor : Prof. Marco Fanciulli  
External Supervisor : Dr. Sabina Spiga
- **Davide Rotta**  
Laurea Degree in Physics  
Thesis title: Spin dependent transport in silicon nanowires  
Thesis Year: 2011  
Tutor: Prof. Marco Fanciulli
- **Martina Basini**  
Laurea Magistrale in Physics  
Title: Fabrication and characterization of Silicon Nanowires produced by metal-assisted chemical etching  
Year: 2012  
Tutor: Prof. Marco Fanciulli  
Co-tutor: Dr. Carmen Canevali

- **Marco Lorenzo Valerio Tagliaferri**  
 Laurea Magistrale in Physics  
 Title: Time resolved quantum transport in silicon nanostructures  
 Year: 2012  
 Tutor: Prof. Marco Fanciulli  
 Co-tutor: Dr. Enrico Prati
- **Alessandro Crippa**  
 Laurea Magistrale in Physics  
 Title: Interaction between microwaves and electronic states in silicon nanostructures  
 Year: 2012  
 Tutor: Prof. Marco Fanciulli  
 Co-tutor: Dr. Enrico Prati
- **Ascanio Digiacomò**  
 Laurea Magistrale in Materials Science  
 Title: PratiMagnetic characterization of Ta-CoFeB-MgO films grown on pre-patterned CMOS substrates for application in racetrack memories  
 Year: 2012  
 Tutor: Prof. Marco Fanciulli  
 Co-tutor: Dr. Roberto Mantovan
- **Lorenzo Baldrati**  
 Laurea Magistrale in Physics  
 Title: Characterization of electrically active defects at germanium/oxide interfaces by magnetic resonance spectroscopy and electrical measurements  
 Year: 2013  
 Tutor: prof. Marco Fanciulli  
 Co-tutor: Dr. Stefano Paleari
- **Andrea Corna**  
 Laurea Magistrale (Master) in Physics  
 Title: Electron Spin Resonance investigation of donors in Germanium  
 Year: 2013  
 Tutor: Prof. Marco Fanciulli  
 Co-tutor: Dr. Stefano Paleari
- **Federico Accetta**  
 Laurea Magistrale in Physics  
 Title: Characterization of electrically active defects at germanium/oxide interfaces by magnetic resonance spectroscopy and electrical measurements  
 Year: 2013  
 Tutor: Prof. Marco Fanciulli  
 Co-tutor: Dr. Alessandro Molle
- **Marcello Ghidina**  
 Laurea Magistrale (Master) in Physics  
 Title: Fabrication and electrical characterization of metal-insulator-metal capacitors  
 Year: 2014  
 Tutor: Prof. Marco Fanciulli  
 Co-tutor: Dr. Sabina Spiga
- **Giovanni Delcastello**  
 Laurea Magistrale (Master) in Materials Science  
 Title: Morphological, mechanical and electrical characterization in deep isolation shallow trenches for SOI based power technologies

- Year: 2014  
 Tutor: Prof. Marco Fanciulli  
 External tutor: Dr. Daniele Merlini (STMICROELECTRONICS)
- **Lorenzo Gelmi**  
 Laurea Magistrale (Master) in Physics  
 Title: Development of devices for neuroelectronics based on Electrolyte-Oxide-Semiconductor/Metal structures (EOS and EOM)  
 Year: 2014  
 Tutor: Prof. Marco Fanciulli  
 Co-tutor: Dr. Grazia Tallarida  
 Co-tutor: Dr. Sabina Spiga
  - **Simone Cortese**  
 Laurea Magistrale (Master) in Physics  
 Title: Electrical Characterization of Memristive Devices based on Transition Metal Oxides  
 Year: 2014  
 Tutor: Prof. Marco Fanciulli  
 Co-tutors: Dr. Themis Prodromakis (University of Southampton), Dr. Sabina Spiga
  - **Mauro Sironi**  
 Laurea Magistrale (Master) in Physics  
 Title: Depassivation of intrinsic and phosphorus-doped hydrogen-terminated silicon nanowires produced by metal-assisted chemical etching  
 Year: 2014  
 Tutor: Prof. Marco Fanciulli  
 Co-tutor: Dr. Stefano Paleari
  - **Andrea Corna**  
 Laurea Magistrale (Master) in Materials Science  
 Title: Development of electrolyte/oxide/metal devices for neuron interfacing  
 Year: 2015  
 Tutor: Prof. Marco Fanciulli  
 Co-tutors: Prof. Stefano Vassanelli (University of Padua), Dr. Grazia Tallarida
  - **Davide Vincenzi**  
 Laurea Magistrale (Master) in Physics  
 Title: Synthesis and characterization of epitaxial silicene on Ag(111)/mica substrates  
 Year: 2015  
 Tutor: Prof. Marco Fanciulli  
 Co-tutor: Dr. Alessandro Molle, Dr. Carlo Grazianetti
  - **Cristina Mazza**  
 Laurea Magistrale (Master) in Physics  
 Title: Charge transport in Metal Oxide Semiconductor based quantum dots: experiments and simulations  
 Year: 2015  
 Tutor: Prof. Marco Fanciulli  
 Co-tutor: Dr. Marco Demichielis
  - **Fabio Fumagalli**  
 Laurea Magistrale (Master) in Materials Science  
 Title: "Electrical Characterization of Metal-Insulator-Metal (MIM) Resistive Switching Devices"  
 Year: 2016  
 Tutor: Prof. Marco Fanciulli

- Co-tutor: Dr. Sabina Spiga  
Co-tutor: Dr. Stefano Brivio
- **Anna Tarabini**  
Laurea Magistrale (Master) in Physics  
Title: “Electrical characterization of Pt-related defects in silicon nanowire”  
Year: 2016  
Tutor: Prof. Marco Fanciulli  
Co-tutor: Dr. Stefano Paleari
  - **Antonio Pizio**  
Laurea Magistrale (Master) in Materials Science  
Title: “Magnetic Resonance Investigation of Group IV Semiconductor Nanowires”  
Year: 2016  
Tutor: Prof. Marco Fanciulli  
Co-tutor: Dr. Stefano Paleari
  - **Pierpaolo Melloni**  
Laurea Magistrale (Master) in Materials Science  
Title: “Growth and characterization of MoS<sub>2</sub> thin films”  
Year: 2016  
Tutor: Prof. Marco Fanciulli  
Co-tutor: Dr. Alessandro Molle
  - **Silvia Bandelloni**  
Laurea Magistrale (Master) in Materials Science  
Title: Electron spin relaxation and coherence of paramagnetic defects at the Si/SiO<sub>2</sub> interface in silicon nanowires  
Year: 2017  
Tutor: Prof. Marco Fanciulli  
Co-tutor: Dr. Matteo Belli
  - **Alessandro Danei**  
Laurea Magistrale (Master) in Materials Science  
Title: Sviluppo e caratterizzazione di condensatori metallo-isolante-metallo per applicazioni in dispositivi di potenza  
Year: 2017  
Tutor: Prof. Marco Fanciulli  
Co-tutor: dott. Sabina Spiga (MDM-CNR)  
Co-tutor: dott. Gabriella Ghidini (STMICROELECTRONICS)
  - **Luca Bettamin**  
Laurea Magistrale (Master) in Materials Science  
Title: Characterization of electrical activities of mammalian neurons based on nanoprobe  
Year: 2017  
Tutor: Prof. Marco Fanciulli  
Co-tutor: dott. Guilhem Larrieu (LAAS-CNRS)
  - **Valentina Arosio**  
Laurea Magistrale (Master) in Materials Science  
Title: Characterization of extended defects in silicon crystals induced by high energy silicon implants  
Year: 2017  
Tutor: Prof. Marco Fanciulli  
Co-tutor: dott. Maria Luisa Polignano (STMICROELECTRONICS)  
Co-tutor: dott. Isabella Mica (STMICROELECTRONICS)



- **Emanuele longo**  
 Laurea Magistrale (Master) in Physics  
 Title: Electrochemical characterization of high-k dielectrics and silicon nanowires for neuroelectronics  
 Year: 2017  
 Tutor: Prof. Marco Fanciulli  
 Co-tutor: dott. Stefano Paleari
  - **Tommaso Antonelli**  
 Laurea Magistrale (Master) in Materials Science  
 Title: Growth and characterization of two-dimensional tin-based lattices on Ge(111) surfaces  
 Year: 2017  
 Tutor: Prof. Marco Fanciulli  
 Co-tutor: dott. Alessandro Molle (MDM-CNR)  
 Co-tutor: dott. Carlo Grazianetti (MDM-CNR)
  - **Andrea Marzo**  
 Laurea Magistrale (Master) in Materials Science  
 Title: Crescita e Caratterizzazione di Strati Bidimensionali di MoS<sub>2</sub>  
 Year: 2018  
 Tutor: Prof. Marco Fanciulli  
 Co-tutor: dott. Massimiliano D'Arienzo
- **Supervision of Doctorates**
  - **S. Spiga**  
 Doctorate in Physics, Applied Physics, and Astrphysics, XIV cycle  
 Research subject: "Structural and electrical properties of nanocrystals produced by ion implantation in thin SiO<sub>2</sub> films"  
 Tutor: Prof. Marco Fanciulli  
 Tutor: Prof. Mario Guzzi
  - **E. Bonera**  
 Ph.D. in Physics  
 Research subject: "Micro and Near-Field Optical Characterisation of Microelectronic Materials" 2002, University of Leeds (UK),  
 Supervisors: D.A. Smith, D.N. Batchelder, and M. Fanciulli.
  - **M. Perego**, Ciclo: XVI, Università degli Studi di Milano, anno accademico 2002/2003,  
 Dottorato di ricerca in fisica, Astrofisica e fisica applicata, Tesi Relatore: Prof. Marco Fanciulli.  
 Doctorate in Physics, Applied Physics, and Astrphysics, XVI cycle  
 Research subject: "TOF-SIMS characterization of nanocrystals embedded in thin SiO<sub>2</sub> films"  
 Tutor: Prof. Marco Fanciulli
  - **R. Mantovan**  
 Doctorate in Physics, Applied Physics, and Astrphysics, XVIII cycle  
 Research subject: "Mössbauer spectroscopy investigation of materials for non-volatile memory devices"  
 External Tutor: Prof. Marco Fanciulli  
 Tutor MDM: Prof. Paolo Milani
  - **Luca Lamagna**  
 European doctorate in Nanostructures and Nanotechnologies, XXII cycle

Research subject: “Atomic Layer Deposition of rare earth high-k oxides and Spectoscopic Ellipsometry characterization”

Tutor: Prof. Marco Fanciulli

Tutor MDM: Prof. Marco Fanciulli

- **Antonio Vellei**

European doctorate in Nanostructures and Nanotechnologies, XXII cycle

Research subject: “Realization, modeling and characterization of silicon nanoelectronics devices for quantum computing”

Tutor: Prof. Marco Fanciulli

Tutor MDM: Prof. Marco Fanciulli

- **Andrea Andreozzi**

European doctorate in Nanostructures and Nanotechnologies, XXIV cycle

Research subject: “Nanodevice fabrication using block-copolymer based technology”

Tutor: Prof. Marco Fanciulli

Tutor MDM: Dr. Michele Perego

- **Roberto Fallica**

European doctorate in Nanostructures and Nanotechnologies, XXIV cycle

Research subject: “Characterization of phase-change material nanostructures”

Tutor: Prof. Marco Fanciulli

Tutor MDM: Dr. Massimo Longo

- **Guido Petretto**

European doctorate in Nanostructures and Nanotechnologies, XXIV cycle

Research subject: “Density functional simulation of doped silicon nanowires”

Tutor: Prof. Marco Fanciulli

External Tutor: Dr. Alberto Debernardi (MDM Lab., CNR-IMM).

- **Carlo Grazianetti**

Doctorate in Nanostructures and Nanotechnologies, XXVI Cycle

Research subject: “Scanning Tunneling Microscopy Investigation of III-V Compound Semiconductors and Novel 2D Nanolattices”

Tutor: Prof. Marco Fanciulli

External Tutor: Dr. Alessandro Molle (MDM Lab., CNR-IMM).

- **Stefano Paleari**

Doctorate in Material Science, XXVI cycle

Research subject: “Characterization of Defects at the Interface Between Germanium and Oxides by Electrically Detected Magnetic Resonance and Admittance Spectroscopy”

Tutor: Prof. Marco Fanciulli

- **Davide Rotta**

European doctorate in Nanostructures and Nanotechnologies, XXIV cycle

Research subject: “Emerging devices and materials for nanoelectronics: Si spin qubits and MoS<sub>2</sub> thin film transistors”

Tutor: Prof. Marco Fanciulli

- **Marco Tagliaferri**

European doctorate in Nanostructures and Nanotechnologies, XXV cycle

Research subject: “Quantum transport in silicon nanostructures”

Tutor: Prof. Marco Fanciulli

- **Alessandro Crippa**

European doctorate in Nanostructures and Nanotechnologies, XXV cycle

Research subject: “Microwave effects in silicon nanostructures”

Tutor: Prof. Marco Fanciulli

- **Simone Selmo**

European doctorate in Materials Science and Nanotechnology XXIX cycle

Research subject: "Functional analysis of In-based nanowires for low power phase change memory applications"

Tutor: Prof. Marco Fanciulli

External Tutor: Dr. Massimo Longo

## **COORDINATION AND ORGANIZATION ACTIVITIES**

### **1. Realization, management, and direction of the MDM (Materials and Devices for Microelectronics) – CNR-INFM, Agrate Brianza, Italy.**

Since the end of June 1998, when he started his new position as first researcher at INFIM, M. Fanciulli works on the realization, coordination, management and direction of the MDM Laboratory. He proposes the strategic research lines to the scientific council, and he is very active in funds raising at the national, industrial, and international level, to support the development in terms of equipment and personnel, of the Lab. When he started in 1998, the Lab. Equipment consisted of an AFM and a SNOM, two undergraduate fellows and a student. Thanks to the friendship, support, and appreciation of his Danish colleagues, Fanciulli brings at MDM from Denmark, a complete system for Mössbauer spectroscopy and a spectrometer for the electron spin resonance (ESR) operating in X-band. Then, thanks to the success in getting projects, new equipment is acquired (Raman spectrometer, spectrometer for X-ray diffraction and reflectivity). At the same time he works on the very basic infrastructure such as internet, and an on-line library. He handles personally the logistic issues, the equipment acquisition, and the hiring of the research personnel. Today at MDM operate around 45 people, including researchers, post-doctoral fellows, graduate students and undergraduates, three technicians and three secretaries. In 2010 INFIM was merged with CNR and the MDM now is a research unit of the Institute of Microelectronics and Microsystems (IMM) of CNR. The growth and processing facilities and the instrumentation for characterization are listed below in order to allow an objective assessment of the results obtained. In 2015 a new re-organization of CNR sets a time limit to the Director position and significantly changes the responsibilities of the head of the unit. M. Fanciulli maintains a key role in the scientific coordination of research lines.

#### **The MDM-IMM-CNR Laboratory.**

The laboratory now occupies an area of approximately 450 m<sup>2</sup> including a clean room of about 100 m<sup>2</sup>. Offices occupy an additional space of approximately 230 m<sup>2</sup>.

Growth and advanced process

- 100 m<sup>2</sup> clean room class 1000-100.
- 2 Atomic Layer Deposition (ALD), equipped with Ozone
- Glove box for the manipulation of precursors
- MBE dedicated to the growth of oxides and semiconductors
- 2 Thermal and e-beam evaporators
- Fume cupboards for cleaning the wafers and for the lithographic processes
- Rapid thermal annealing (RTP)
- Photolithography
- e-beam lithography
- Metallographic microscope

#### **Characterization**

- Scanning Probe Microscopy (ambient temperature and controlled atmosphere): AFM, STM, MFM / EFM, SKPM, SThM
- UHV-STM/AFM (SKP, BEEM)
- X-ray reflectivity and diffraction (XRD, XRR)
- SEM
- ToF-SIMS
- 2 XPS (in-situ and ex-situ)
- LEIS
- Electrical characterization: I-V, C-V, G-V, C-t, Hall Effect, Magnetotransport, DLTS, Laplace-DLTS (5-500 K)
- Noise at low frequency (0.3-500 K)
- Optical Spectroscopy:  $\mu$ -Raman and photoluminescence (PL) (5-500K), internal photoemission (IPE) (5-500 K), FT-IR (mid and far-IR) (5-500 K), Spectroscopic Ellipsometry
- Electron spin resonance and ENDOR at X-band (5-560 K), Q-band (ESR only), pulse-EPR (X-band)
- Cryomagnetic System for transport measurements and electrically detected magnetic resonance operating with fields up to 12 T and temperatures up to 260 mK.
- Inelastic electron tunneling spectroscopy (IETS) (0.3 - 300 K)
- Conversion electrons Mössbauer spectroscopy (CEMS) (120-300 K)

**Responsible of the Mössbauer Laboratory, IFA University of Aarhus Denmark.**

In the period 1996-1998 he is responsible for the Mössbauer spectroscopy laboratory at the Institute of Physics and Astronomy, University of Aarhus, where he maintains up 7 spectrometers operating in different experimental configurations.

**MSNS Laboratory, Department of Materials Science, University of Milano Bicocca.**

In 2007 he starts to set-up a new Laboratory at the Department of Materials Science, University of Milan Bicocca: the Materials and Spectroscopy for Nanoelectronics and Spintronics (MSNS) Laboratory. The Lab. Now has 3 EPR/ENDOR and EDMR spectrometers working in X- and Q-bands and in the temperature range 4-600 K, 2 furnaces, electrical characterization facilities: Keithley 4200 SPS, Probe station, DLTS, IETS, a small ALD system, a Ruby laser for laser processing, equipment for silicon nanowire production and harvesting, and reserved access to the FIB-SEM facility of the University.

**2. Conferences and Symposia**

- **E-MRS Spring Meeting 2001, Symposium Q: High-k Gate Dielectrics**", Chairman
- Bad-Honnef Workshop on Hardware Concepts for Quantum Computing, 2003, Chairman
- **E-MRS Spring Meeting 2003, Symposium I: Functional Metal Oxides - Semiconductor Structures**", Chairman
- **European Exploratory Workshop, Villa Nobel- Sanremo, Italy 2005: Rare Earth Oxide Thin Films: growth, characterization, and applications.** Chairman
- **Villa Nobel International Workshop** on Electron spin resonance in low dimensional structures and related phenomena, 2006, Chairman
- **E-MRS Spring Meeting 2008, Symposium H: Materials and emerging technologies for non-volatile-memory devices.** Chairman
- **MRS Fall Meeting 2008, Symposium J: Material Science for Quantum Information processing technologies.** Chairman

- **E-MRS Spring Meeting 2011**, Symposium D: Synthesis, processing & characterization of nanoscale multi-functional oxide films III, Chairman

## PROJECTS

### • European

- 1. NEON** - "Nanocrystals for electronic applications", GRD1-2000-25619 (2001-2004)  
Role: Scientific Responsible, Coordinator of the Work Package on the Structural Characterization
- 2. INVEST** - "Integration of very high-k dielectrics with silicon CMOS technology", IST-2000-28495 (2001-2004)  
Role: Scientific Responsible, Coordinator of the Work Package on the Structural Characterization
- 3. ESRQC** - "Electron spin resonance based quantum computing", IST-2001-33573 (2002-2003)  
Role: Coordinator and principal investigator
- 4. ET4US** - "Epitaxial technologies for ultimate scaling", IST-2003 (2004-2006)  
Role: Scientific Responsible, Coordinator of the Work Package on Advanced Gate Stack Materials
- 5. REALISE** - "Rare earth oxide atomic layer deposition for innovations in electronics", IST-2005 (2006-2009)  
Role: Scientific Responsible, Coordinator of the Work Package on Interface engineering for NVM and CMOS.
- 6. EMMA** – “Emerging Materials for Mass-storage Architectures”, IST-Call 5  
Ruolo: Responsabile Scientifico, Coordinatore della attività “Memory materials and electrode technology”.  
(2006-2009)  
Role: Scientific Responsible for MDM
- 7. AFSID** - "Atomic Functionalities on Silicon Devices" (2009-2011)  
Ruolo: Scientific Coordinator for MDM, Coordinator of the WP on “Novel functionalities”.
- 8. CYBER-RAT** - "A Brain-Chip Interface for High-resolution Bi-directional Communication” (2009-2011)  
Role: Scientific coordinator for MDM
- 9. RAMP** - “Real neurons-nanoelectronics Architecture with Memristive Plasticity” (2013-2015)  
Role: Scientific Responsible for MDM, Coordinator of WP2 on EOS/EOSFET development
- 10. IONS4SET** - “Ion-irradiation-induced Si Nanodot Self-Assembly for Hybrid SET-CMOS Technology”, ICT 25 (2016-2019)  
Role: Scientific Responsible for MDM, Coordinator of WP3 on Metrology of Structures and Devices
- 11. MOS-QUITO** - “MOS-based Quantum Information TechnOlogy”, ICT 25 (2016-2018)  
Role: Key person for MDM
- 12. NFFA** - “Ordered arrays of monodispersed silicon nanowires” (2016-2017)  
Role: Principal Investigator

### • International

1. Bilateral project Italy-Russia, "Innovative high dielectric constant films for CMOS structures", Ministry of Foreign Affairs, (2003 and 2004). Role: Coordinator and scientific responsible.
2. Bilateral project Italy-Poland, "Experimental and theoretical investigation of the interfaces

between high-k dielectrics and semiconductors", Ministry of Foreign Affairs (2005). Role: Coordinator and scientific responsible.

- **National**

1. **ASI**: "High Tc IR Detector" (2000-2002). Role: scientific responsible for the MDM Lab.
2. **CNR 5%** - "Optimization of dielectrics, conductive and silicide materials and of their deposition and annealing treatments; development of innovative low-k dielectrics." (1999-2001). Role: scientific responsible for the MDM Lab.
3. **MADESS** - "Ferroelectrics thin films for CMOS non-volatile memories" (1999-2001). Role: scientific responsible for the MDM Lab.
4. **MADESS** - "Definition of advanced processes for the formation of insulating and conducting thin layers to be integrated in 0.25  $\mu\text{m}$  technology non-volatile memories" (1999-2001). Role: scientific responsible for the MDM Lab.
5. **EDERA**, - "Electrically Detected Magnetic Resonance - INFM - PA2001, (2001-2002). Role: Principal Investigator
6. **MDM/STMicron** - "Materials and processes for the 0.15  $\mu\text{m}$  non-volatile memories technology node" (2000-2001). Role: Coordinator
7. **FIRB**: "Miniaturized Systems for Electronics and Photonics", Ministry of Research, (2002-2004). Role: scientific responsible for the MDM Lab.
8. **FIRB**: "Quantum phases of ultra-low electron density semiconductor heterostructures", Ministry of Research, (2002-2004). Role: scientific responsible for the MDM Lab.
9. **MDM/STMicron** - "Materials and processes for the 0.13  $\mu\text{m}$  non-volatile memories technology node" (2002-2003). Role: Coordinator and scientific responsible
10. **MDM/STMicron** - "Materials and processes for novel memory devices" (2004). Role: Coordinator and scientific responsible
11. **MDM/STMicron** - "Materials and processes for novel memory devices" (2005). Role: Coordinator and scientific responsible
12. **Fondazione CARIPO – SOLARIS**: "Growth of metallic and insulating atomic layers for microelectronics and spintronics" (2005-2006). Role: Coordinator and scientific responsible
13. **MDM/STMicron** - "Growth and characterization of materials for advanced microelectronic devices, including non-volatile memory" (2006). Role: Coordinator and scientific responsible
14. **MDM/STMicron** - "Growth and characterization of materials for advanced microelectronic devices, including non-volatile memory" (2007). Role: Coordinator and scientific responsible
15. **MDM- MEFHI** (Moscow) Bilateral Project (2007-2008). Role: coordinator
16. **MDM/Numonyx** - "Advanced materials and characterization for the 45-32 nm technology nodes non-volatile memory devices and beyond" (2008). Role: Coordinator and scientific responsible
17. **MDM/Numonyx** - "Advanced materials and characterization for the 45-32 nm technology nodes non-volatile memory devices and beyond" (2009). Role: Coordinator and scientific responsible
18. **Fondazione CARIPO – ELIOS**: "Single atom electronics and spintronics" (2009-2011). Role: Coordinator and scientific responsible
19. **MDM/Numonyx** - "Advanced materials and characterization for the 32 nm technology nodes non-volatile memory devices and beyond" (2010). Role: Coordinator and scientific responsible
20. **MDM/Micron** - "Advanced materials and characterization for the 32 nm technology nodes non-volatile memory devices and beyond" (2011). Role: Coordinator and scientific responsible

21. **QuDec** (2011-2013)- Quantum Decoder, Italian Ministry of the Defense. Role: Coordinator, principal investigator
22. **MDM/Micron** - "Advanced materials and characterization for the 32 nm technology nodes non-volatile memory devices and beyond" (2012). Role: Coordinator and scientific responsible
23. **MDM/Micron** - "Advanced materials and characterization for the 22 nm technology nodes non-volatile memory devices and beyond" (2013). Role: Coordinator and scientific responsible
24. **MDM/STMicroelectronics** - "Advanced materials and characterizations for MEMS and Smart Power devices" (2013). Role: Coordinator and scientific responsible
25. **MDM/STMicroelectronics** - "Advanced materials and characterizations for MEMS and Smart Power devices" (2014). Role: Coordinator and scientific responsible
26. **MDM/STMicroelectronics** - "Advanced materials and characterizations for MEMS and Smart Power devices" (2015). Role: Coordinator and scientific responsible

## PUBLICATIONS

[L] = letter journal	Total = 63
[R] = Review (Invited and Books)	Total = 16
[A] = Regular article with referee	Total = 155
[a] = Proceeding article with referee	Total = 104
[p] = Proceeding with internal referee	Total = 24
[B]= Book	Total = 2

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356. E. Ferraro, M. Fanciulli, M. De Michielis, “Controlled-NOT gate sequences for mixed spin qubit architectures in a noisy environment”, *Quantum Information* 16, 11 UNSP 277 (2017)
357. J. L-Battaglia, A. Saci, I. De, R. Cecchini, S. Selmo, **M. Fanciulli**, S. Cecchi, M. Longo, “Thermal resistance measurement of In<sub>3</sub>SbTe<sub>2</sub> nanowires”, *Phys. Stat. Solidi A* 214, 1600500

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358. R. Mantovan, R. Fallica, A. Gerami, A. Mokhles, T.E. Molholt, C. Wiemer, M. Longo, H.P. Gunnlaugsson, K. Johnston, H. Masenda, D. Naidoo, M. Ncube, K. Bharuth-Ram, **M. Fanciulli**, H.P. Gislason, G. Langouche, S. Olafsson, G. Weyer, "Atomic-scale study of the amorphous-to-crystalline phase transition mechanism in GeTe thin films", *Scientific Reports* 7, 8234 (2017) [A]
359. **M. Fanciulli**, "High-k dielectrics for CMOS and emerging logic devices", *Surf. Science* to be published (2018) [R]

### BOOKS and PROCEEDINGS

1. "High-k Gate Dielectrics", Proceedings of the E-MRS 2001 Spring Meeting, Symposium Q, Strasbourg (2001), **M. Fanciulli**, M. Houssa, E.W.A. Young, and S. Haukka Eds. [P]
2. "Hardware Concepts for Quantum Computing", *Physica Status Solidi B*, M. Brandt, M. Stutzmann, and **M. Fanciulli** Eds. (2003) [P]
3. "Functional Metal Oxides - Semiconductor Structures", Proceedings of the E-MRS 2003 Spring Meeting, Symposium I, Strasbourg (2003), A. Dimoulas, J. Fompeyrine, **M. Fanciulli**, M. Alexe, and G. Osten Eds. [P]
4. **M. Fanciulli** and G. Scarel Eds., "Rare Earth Oxide Thin Films: growth, characterization, and applications", *Topics in Applied Physics*, Vol. **106** Springer (2006) [B]
5. **M. Fanciulli** Ed., "Electron spin resonance in low dimensional structures and related phenomena", *Topics in Applied Physics*, Vol. **115**, Springer (2009). [B]
6. "Synthesis, processing & characterization of nanoscale multi-functional oxide films III", Proceedings of the E-MRS 2011 Spring Meeting, Symposium D, Strasbourg (2011), Edited by Valentin Craciun, Maryline Guilloux-Viry, Marin Alexe, Gustau Catalán Bernabé and **Marco Fanciulli**, *Thin Solid Films*, Volume 520, Issue 14, Pages 4507-4826 (1 May 2012) [P]

### BRIEF COMUNICATIONS

1. N.E. Christensen, A. Svane, **M. Fanciulli**, G. Weyer, M. Methfessel and C.O. Rodriguez, "Calculation of Electric Field Gradients in  $\beta$ -FeSi<sub>2</sub> and Tin Oxides", *Bull. Am. Phys. Soc.*, Vol. 41, 788 (1996).
2. C. A. Steren, H. van Willigen and **M. Fanciulli**, "Time-resolved EPR study of the photoexcited triplet state of C<sub>60</sub> adsorbed on silica gel", *Rocky Mountain Conference on Analytical Chemistry*, Denver CO, USA, July 1994.
3. **M. Fanciulli**, G. Weyer, V. Nevolin, A. Zenkevich, H. von Känel and N. Onda, "Comparative CEMS study of non-magnetic iron-silicide phases grown on silicon surfaces by MBE or formed by laser ablation layered deposition", *Fourth Seeheim Workshop on Mössbauer Spectroscopy*, Seeheim, Germany, May 24-28 1994
4. **M. Fanciulli**, T. Lei and T.D. Moustakas, "Conduction Electron Spin Resonance in Zinc-blende GaN Thin Films", *Bull. Am. Phys. Soc.*, Vol. 38, 621 (1993).
5. **M. Fanciulli**, S. Jin and T.D. Moustakas, "Study of Defects in Diamond Thin Films with EPR Measurements", *Bull. Am. Phys. Soc.*, Vol. 37, 710 (1992).
6. T. Lei, **M. Fanciulli**, R.J. Molnar, T.D. Moustakas, R.J. Graham, J. Scanlon, "Growth of cubic GaN films on Si(100)", *Bull. Am. Phys. Soc.*, Vol. 36, 543 (1991).
7. **M. Fanciulli**, "Solid state physics in devices for dosimetry measurements" Fascicolo NBC,

## HIGHLIGHTS and Related Publications

### 1. Semiconductors

1.1. Development of the buffer layer for GaN growth (the paper and its importance has been recognized in the 2014 Nobel Prize Lecture of Prof. Shuji Nakamura)

**4. T. Lei, M. Fanciulli, R.J. Molnar, T.D. Moustakas, R.J. Graham, J. Scanlon, "Epitaxial growth of zinc-blende and wurtzitic gallium nitride thin films on (001) Silicon", Appl. Phys. Lett. 59, 944 (1991).**

1.2. Determination of the effective mass in c-GaN (as of today the only experimental determination of  $m^*$  in c-GaN)

**10. M. Fanciulli, T. Lei and T.D. Moustakas, "Conduction electron spin resonance in zinc-blende GaN thin films", Phys. Rev. B 48, 15144 (1993).**

1.3. Investigation of point defects in c-GaN, BN, Diamond

1.4. Characterization of point defects in silicon (Sn and related complexes, Bi, N, Fe) using different experimental methods (EPR, DLTS, radioactive ion implantation, optical spectroscopy)

1.5. Characterization of point defects at the interface between Silicon and oxides and Germanium and oxides: identification of the dangling bond at the interface between Ge(100) and oxides and Ge(111) and oxides (Together with previous paper the first observation of defects at the Ge/GeO<sub>x</sub> interface by magnetic resonance spectroscopy)

**305. S. Paleari, S. Baldovino, A. Molle, and M. Fanciulli, "Evidence of Trigonal Dangling Bonds at the Ge(111)/Oxide Interface by Electrically Detected Magnetic Resonance", Phys. Rev. Lett. 110, 206101 (2013)**

1.6. Growth and characterization of 2D materials such as Silicene and MoS<sub>2</sub>

**321. D. Chiappe, E. Scalise, E. Cinquanta, C. Grazianetti, B. van den Broek, M. Fanciulli, M. Houssa, A. Molle,"Two-Dimensional Si Nanosheets with Local Hexagonal Structure on a MoS<sub>2</sub> Surface", Adv. Mat. 96, 2096 (2014)**

### 2. Silicides

2.1. Identification of the local electronic structure of Fe in  $\beta$ -FeSi<sub>2</sub> and  $\epsilon$ -FeSi

**21. M. Fanciulli, C. Rosenblad, G. Weyer, A. Svane, N.E. Christensen and H. von Känel, "Conversion electron Mössbauer spectroscopy study of epitaxial  $\beta$ -FeSi<sub>2</sub> grown by MBE", Phys. Rev. Lett. 75, 1642 (1995).**

2.2. Investigation of epitaxially stabilized iron silicides

### 3. Oxides (high-k dielectrics)

3.1. Growth by Atomic Layer Deposition (ALD) and characterization of Lu<sub>2</sub>O<sub>3</sub>

**108. G. Scarel, E. Bonera, C. Wiemer, G. Tallarida, S. Spiga, M. Fanciulli, I. L. Fedushkin and H. Schumann, Yu. Lebedinskii and A. Zenkevich, "Atomic-layer deposition of Lu<sub>2</sub>O<sub>3</sub>", Appl. Phys. Lett. 85, 630 (2004).**

**118. E. Bonera, G. Scarel, M. Fanciulli, P. Delugas, V. Fiorentini, "Dielectric Properties of High-k Oxides: Theory and Experiment for Lu<sub>2</sub>O<sub>3</sub>", Phys. Rev. Lett. 94, 027602 (2005).**

3.2. Growth by ALD and characterization of GeO<sub>2</sub>

**158. M. Perego, G. Scarel, M. Fanciulli, I. L. Fedushkin, A. A. Skatova,**



- “Fabrication of GeO<sub>2</sub> layers using a divalent Ge precursor”, Appl. Phys. Lett. 90, 162115 (2007)**
- 3.3. Growth by MBE and characterization of epitaxial Gd<sub>2</sub>O<sub>3</sub> on Ge
4. Nanoelectronic devices
- 4.1. Realization and functional characterization of emerging devices for non-volatile-memory applications
- 4.2. Realization of devices, CMOS compatible, for quantum information processing  
**301. G. Mazzeo, E. Prati, M. Belli, G. Leti, S. Cocco, M. Fanciulli, F. Guagliardo, G. Ferrari, "Charge dynamics of a single donor coupled to a few-electron quantum dot in silicon", Appl. Phys. Lett. 100, 213107 (2012)**
- 4.3. 2D-based nanoelectronic devices (the paper reports on the first transistor based on silicene)  
**336. Li Tao, Eugenio Cinquanta, Daniele Chiappe, Carlo Grazianetti, Marco Fanciulli, Madan Dubey, Alessandro Molle, Deji Akinwande , "Silicene field-effect transistors operating at room temperature" , Nature Nanotechnology 10, 227 (2015)**
- 4.4. Processing, characterization, and theoretical investigation of silicon and germanium nanowires and nanostructures  
**260. G. Petretto, A. Debernardi, M. Fanciulli, "Confinement Effects and Hyperfine Structure in Se Doped Silicon Nanowires" , Nano Letters 11, 4509–4514 (2011)**  
**265. M. Fanciulli, A. Molle, S. Baldovino, A. Vellei , "Magnetic resonance spectroscopy of defects at the dielectric-semiconductor interface: Ge substrates and Si nanowires", Microelectronic Engineering 88, 1482 (2011)**  
**356. A. Giorgioni, S. Paleari, S. Cecchi, E. Vitiello, E. Grilli, G. Isella, W. Jantsch, M. Fanciulli, F. Pezzoli, “Strong confinement-induced engineering of electron g factor and spin lifetimes in group IV heterostructures”, Nat. Comm. 7, 13886 (2016)**
- 4.5. Development of processes for the ALD growth of magnetic materials and realization and functional characterization of spintronic devices based on magnetic tunnel junctions
5. Neuroelectronics
- 5.1 Development of devices for neuron stimulation and recording and for synapsis emulation.  
**354. S. Brivio, E. Covi, A. Serb, T. Prodromakis, M. Fanciulli, and S. Spiga, “Experimental study of gradual/abrupt dynamics of HfO<sub>2</sub>-based memristive devices”, Appl. Phys. Lett. 109, 133504 (2016)**
6. Advanced characterization
- 6.1. Development of advanced magnetic resonance spectroscopy methods to address interfaces and low dimensional systems
7. Other achievements
- 7.1. Realization (with no starting grants) of the MDM Laboratory, now a well-established and recognized research center in which long term project as well as medium/short terms research activities are carried out also in strong collaboration with the industrial partner.

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