

# Emiliano Bonera

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**Personal summary.** Emiliano Bonera graduated at the University of Pavia in 1998 after being also an exchange student at the University of Strathclyde in Glasgow. He obtained his Ph.D. in 2002 from the University of Leeds with a thesis about micro- and near-field optical characterisation of microelectronic materials. From 2002 he was a post-doc at the Materials and Devices for Microelectronics laboratory of CNR, where since 2004 he became a research fellow. Since 2007 he joined the Università di Milano Bicocca as an assistant professor. In 2017 he became associate professor. His interests span mainly on Raman spectroscopy, infrared spectroscopy, internal photoemission spectroscopy, photoluminescence spectroscopy, and near-field optical microscopy. He applied these techniques to the study of semiconductors, insulators, and their nanostructures for applications in micro- and optoelectronics. He holds an h index of 17 from more than 60 publications in international peer-reviewed journals. He teaches in courses of advanced laboratory physics, semiconductors, optics.

## Personal contacts and details

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First name:..... Emiliano	E-mail:..... emiliano.bonera * unimib.it
Family name: ..... Bonera	Born:..... Brescia, Italy, 14 <sup>th</sup> -Sep-1974.
Office address: .... Dipartimento di Scienza dei Materiali, Università degli Studi di Milano- Bicocca, via R. Cozzi 55, 20125, Milano, Italy	Nationality: ..... Italian
Office phone:..... +39.02.6448.5033.	Family status..... Married, two children
Mobile phone:..... +39.328.9652880.	Languages: ..... Italian (mother tongue), English (Flu- ent)

## Education

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1999-2002      **Ph.D. in Physics** (Doctor of Philosophy) at the University of Leeds, United Kingdom. Thesis title: "Micro and Near-Field Optical Characterisation of Microelectronic Materials", with supervisors prof. D. A. Smith and prof. D. N. Batchelder, University of Leeds, and thesis referees prof. D. J. Gardiner, University of Northumbria and prof A. Clarke, University of Leeds.

1994-1998      **Graduation in Physics** (Laurea) at the University of Pavia, Italy. Mark 110/110 with honours (cum laude). Dissertation title: "Near-Field Optical Microscopy - Applications to Electromigration" (in Italian), with supervisors prof. A. Borghesi, University of Milano Bicocca, and prof. G. Guizzetti, University of Pavia. Exchange student at the University of Strathclyde, Glasgow, UK.

## Professional Progress

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2017-now      Associate professor, Università di Milano Bicocca (Italy) (from 15-03-2017).

2007-2017      Assistant professor, Università di Milano Bicocca (Italy) (from 01-02-2007 to 14-03-2017).

2004-2007      Researcher at MDM/CNR Lab, Agrate Brianza (Italy).

2002-2003      Post-Doctoral Fellow at MDM/CNR Lab, Agrate Brianza (Italy).

1999-2002      Ph.D. Student at the University of Leeds (U.K.).

## Research Experience

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Le dichiarazioni rese nel presente curriculum sono da ritenersi rilasciate ai sensi degli artt. 46 e 47 del D.P.R. 445/2000

**In brief.** Techniques: Raman Spectroscopy, Infrared Spectroscopy, Internal Photoemission Spectroscopy, Photoluminescence Spectroscopy, Scanning Near-Field Optical Microscopy and Spectroscopy. Materials: Semiconductors and insulators bulk, heterostructures, and nanostructures for micro- and optoelectronics.

The principal thread of his experimental research activity has been the application of spectroscopy for topics and issues related to materials and devices for microelectronics and optoelectronics.

Most of the recent research activity has been carried out within the labs of Spectroscopy of Semiconductors of the Università di Milano Bicocca, which are also part of the LNESS inter-university center dedicated to the epitaxy of semiconductors. In the past, most of his activity was carried out at the Materials and Devices for Microelectronics (MDM) Laboratory of Agrate Brianza (Italy), where the main task was the development of basic and applied research in topics related to this industry. EB worked also in the Molecular and Nanoscale Physics (MNP) group of the University of Leeds (UK), where the goal was the development of Raman spectroscopy from both the points of view of the technique itself and all its industrial applications, ranging from polymer science, medical and forensic.

In the recent years, the activity of EB has been focussed on germanium, and in particular the possibility of **turning Ge into a direct gap semiconductor** by applying strong tensile strain. Noticeably, he coordinated a project where the researchers developed a method for the creation of extremely high local strain, by exploiting the distribution of strain within patterned SiGe nanostructures. He also set up an experimental apparatus designed for the measurement of microphotoluminescence in the range of 0.6 -0.9 eV for this weakly emitting materials.

SiGe alloys can be used for a set of different applications, and they are nowadays employed as the base materials for the realization of several optoelectronics active and passive devices. EB applied Raman spectroscopy in several ways to characterize **SiGe heterostructures and nanostructures**, for the applications. In particular he developed the technique of Raman spectroscopy for the characterisation of these alloys by measuring the phonon deformation potentials as well as by studying the effects of electronic resonances in the scattering processes. He also studied by Raman the possibility of characterising and controlling the network of dislocations which arises when alloys with different lattice constant are grown epitaxially. By exploiting the high-sensitivity and resolution of his setup, he studied novel heteroepitaxy techniques, such as dislocation-free mesoscopic pillars of Ge grown on Si.

He developed the field of Raman spectroscopy for the characterisation of **strain in memories and logic devices**. This issue is subject of an intense applicative interest

firstly because stress-related issues are a primary source of failure, and secondly because opportunely strained devices can perform better. Within this research line he measured the tensorial nature of strain, exploiting quantitative polarisation analysis combined with the use of high numerical aperture objectives. Then, he extracted quantitative information from the Raman maps by integrating finite-element models in the experimental analysis. Finally, he investigated the extension of this diffraction-limited technique to the study of sub-wavelength features.

Another important research topic was the spectroscopy of insulators. The principal achievements were obtained in the investigation of high dielectric constant insulators, also known as **high- $\kappa$  materials**, as the replacement of silicon dioxide with this class of materials was the main issue the microelectronic community. In this field, both Raman spectroscopy and mostly infrared spectroscopy were applied to the characterisation of their structural and dielectric properties, see Ref. [P 42]. Another physical property was instead investigated by **internal photoemission spectroscopy**. This technique was developed mainly for the determination of band offsets in metal-insulator-semiconductor stacks. With this hybrid optical and electrical technique one selectively photoexcites carriers in one or more layers of the device and from the analysis of the electrical response it is possible to extract information about the relative positioning of the energy levels. Again, this is particularly important for the investigation of high- $\kappa$  materials. EB also correlated the experimental results with theoretical predictions.

All the activity was carried out with a peculiar attention to the **development of instrumentation**. During the doctoral period, he contributed to the realisation of a near-field scanning optical microscope. In the meantime, he participated in the development of a Raman spectrometer with an excitation in the deep-ultra-violet at 5.1 eV, within a collaboration between the University of Leeds and Renishaw plc, a multinational in the field of motion-control and metrology. Afterwards, he connected this system to the near-field optical microscope. Following the success of Raman spectroscopy in the characterisation of strain in silicon, he developed with the contribution of Renishaw another Raman spectrometer with a near-ultra-violet excitation, resonant with the direct band gap of silicon, which allows the confinement of the investigation to the depth of the electron channel in the devices, increasing the sensitivity of more than one order of magnitude. This prototype is now commercialised. He also developed the photoconductivity bench for the aforementioned technique of internal photoemission spectroscopy. Another instrumental customisation was the modification of the commercial Fourier-transform infrared spectrometer by developing a reflection-absorption bench dedicated to the measurements of the very low absorbance of ultrathin microelectronic insulators. Finally, as an expert of optics he also collaborated

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with several colleagues by designing and realising projects for the support of other experimental activities in the laboratories where he worked.

The whole experience has been carried out with a close **collaboration with industry**, a characteristic inherited from the orientation to practical aspects of research of the laboratories he worked within. The collaboration with Renishaw has been already mentioned. Nevertheless, the most important link has always been with STMicroelectronics, especially with the Research and Development centre of the site in Agrate Brianza, but also with other sites in Crolles and Rousset (France).

### Academic appointments

2012-now **Responsible of the Teaching Laboratory Council** with the aim of coordinating the activity and expenses of the more than ten laboratories involved in the Materials Science Department.

2009-now **Member of PhD Councils**, "Dottorato in Scienza dei Materiali" (PhD in Material Science) and "Dottorato in Nanotecnologie e Nanostrutture" (PhD in Nanotechnologies and Nanostructures) of the Università di Milano-Bicocca.

### Courses held

2011-now **Fisica dei Materiali con laboratorio** (Physics of Materials with Laboratory). Università degli Studi di Milano-Bicocca. Degree of Materials Science. Module: Laboratory of Physics of Materials and Introduction to Semiconductors. 24 hours lessons + 36x2 hours lab.

Student satisfaction/Year	2013	2014	2015
EB marks	2.75/3	2.42/3	2.46/3
All courses average	2.12/3	2.15/3	2.23/3

2011-now **Sistemi ottici ed oftalmici con laboratorio** (Optics and Ophthalmics Systems with Laboratory). Degree of Optics and Optometry. Università degli Studi di Milano-Bicocca. From 2011 to 2016. 24 hours lessons + 36x3 hours lab.

Student satisfaction/Year	2013	2014	2015
EB marks	2.09/3	2.44/3	2.53/3
All courses average	2.15/3	2.25/3	2.23/3

### Supervising activity

#### Post-docs.

E. Gatti, "Spettroscopia ottica di semiconduttori del gruppo IV sottoposti a deformazione meccanica." (Optical spectroscopy of mechanically strained group IV semiconductors). From 01/02/2014 to 28/02/2015.

A. Giorgioni, "Spettroscopia ottica risolta in polarizzazione di eterostrutture basate su semiconduttori del gruppo IV" (Polarization-resolved optical spectroscopy of group-IV semiconductor heterostructures). From 01/06/2014 to 30/05/2015.

Many research work are co-authored by people from the industrial world, and a special effort was dedicated to the dissemination of the immediate practical aspects of the research. Beyond the main research activities reported in the previous paragraphs, several other investigations were with a more applied character were carried out. Among these, the investigation of metal silicides for the realisation of interconnections, chalcogenide materials for the fabrication of novel phase-change ultrascala-ble devices, borophosphosilicate glasses as intermetal passivation, electromigration in metals.

2016-now **Member of Joint Students/Professors Commission** (Commissione Paritetica) with the aim of monitoring the quality of the teaching activity and the observance of the rules established by the Department Council.

2015-now **Member of University Library Commission** with the aim of collecting and coordinating the requests and proposals for the university library with respect to the topics related to solid state physics.

2008-2011 **Laboratorio di Fisica dei Materiali** (Physics of Materials Laboratory). Degree of Materials Science. Università degli Studi di Milano-Bicocca. 16 hours lessons + 36x2 hours lab.

2007-2008 Assistant to **Laboratorio di Fisica dei Materiali** (Physics of Materials Laboratory). Degree of Materials Science. Università degli Studi di Milano-Bicocca. From 2007 to 2008. 48x2 hours lab.

2007-2008 Assistant to **Laboratorio di Fisica dello Stato Solido** (Solid State Physics Laboratory). Degree of Physics. Università degli Studi di Milano-Bicocca. From 2007 to 2008. 60 hours lab x 1 shift.

Note: The student satisfaction survey was introduced in 2013.

**PhD students.** Supervisor of two doctoral studies in Materials Science and one in Nanostructures and Nanotechnologies.

F. Basso Basset, "Spectroscopy of droplet epitaxy GaAs quantum dots for quantum information technology". From 1-1-2015 to 31-12-2017

M. Barget, "Optimization steps of germanium as light emitter: strain and n-type doping". From 1-1-2014 to 31-12-2016

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A. Picco, "Resonance effects in the Raman analysis of SiGe nanostructures". From 1-1-2010 to 31-12-2012

**Master.** Supervisor of eight master theses in Physics and four master theses in Materials Science.

### Public-funded projects

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[PJ 1] **Microspire** "micro-crystals Single Photon InfraREd detectors", EU H2020 FET (11/2017 - 12/2020). Role: Participant.

[PJ 2] **Teinvein** "Tecnologie innovative per i veicoli intelligenti", Progetto Regione Lombardia (05/2017 - 11/2019). Role: Participant.

[PJ 3] **SearchIV** "Spin optoelectronics architectures based on group IV compounds", Fondazione Cariplo (06/2014 - 06/2017). Role: Participant.

[PJ 4] **DefConIV** "Deformation control of group IV nanostructures", Fondazione Cariplo (04/2012-03/2015). Role: **Coordinator of the whole project.**

[PJ 5] **Mandis** "Nanomanipolazione delle dislocazioni da misfit per strategie innovative di integrazione eteroepitassiale su silicio", Fondazione Cariplo (2006-2009). Role: Participant.

[PJ 6] **Ddotfet** "Disposable Dot Field Effect Transistor for High Speed Si Integrated Circuits", EU FP6 2006-2009. Role: Participant.

[PJ 7] **Chemaph** "Chemical Vapor Deposition of Chalcogenide Materials for Phase-change Memories", EU-FP6 IST (01/2006 - 12/2007). Role: Participant.

[PJ 8] **Realise** "Rare earth oxide atomic layer deposition for innovations in electronics", EU-FP6 (03/2006 - 09/2009). Role: Participant.

### Private-funded research

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2016-now Responsible for research activities between Università di Milano Bicocca/CNR/STMicroelectronics (semiconductors multinational). Raman spectroscopy of strain in silicon.

2008-2011 Responsible for research activities between INFN/CNR and Numonyx (solid state memories multinational). Raman spectroscopy of memory materials.

2002-2003 Collaboration with Renishaw Plc (multinational producing spectroscopy equipment) for applications of Raman spectroscopy for microelectronics. See E.

### Conference organization

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2017 Conference 6<sup>th</sup> SemiconNano2017 "Epitaxial Growth and Fundamental Properties of Semiconductor Nanostructures", 25/28-09-2017 Como (Italy). Role: Organizing committee..

**Bachelor.** Supervisor of eight bachelor theses in Physics, twenty-nine in Materials Science, eight in Optics and Optometry.

[PJ 9] **Versatile:** "Vertically stacked memory cells based on heterojunctions made of organic/inorganic materials", EU FP6 (02/2006 - 01/2009). Role: Participant.

[PJ 10] **Guide Ottiche in SiGe,** "SiGe optical waveguides", PRIN-2005 MIUR (2006-2008). Role: Participant.

[PJ 11] **Solaris:** "Deposizione di strati atomici metallici ed isolanti per applicazioni in microelettronica e spintronica", Fondazione Cariplo (02/2005-01/2008). Role: Participant.

[PJ 12] **Et4us** "Epitaxial Technology For Ultimate Device Scaling", EU-FP6 IST (01/2004 - 12/2006). Role: Participant.

[PJ 13] **Reohk** "Rare earth oxides as high k dielectrics for CMOS," INFN Project (01/2003 - 12/2004). Role: Participant.

[PJ 14] **Esrqc** - "Electron Spin Resonance Quantum Computing. European project", EU-FP5 IST-FET (03/2002 - 02/2003). Role: Participant.

[PJ 15] **Invest** "Integration of very high-k dielectrics with silicon CMOS technology", EU-FP5 IST (06/2001 - 05/2004). Role: Participant.

[PJ 16] **Neon** "Nanoparticles for Electronics", EU-FP5 GROWTH (02/2001 - 01/2004). Role: Participant.

Bonera, "Imaging of silicon stress in microelectronics using Raman spectroscopy", Renishaw plc Application Note.

2000-2007 Responsible for research activities between INFN/CNR and STMicroelectronics (semiconductors multinational) among which the most important were the strain characterisation, the application of infrared spectroscopy to characterisation of insulators, and Raman spectroscopy for silicides.

2010 Conference 8<sup>th</sup> "Epitaxial semiconductors on patterned substrates and novel index surfaces", 14/18-06-2010, Como (Italy). Role: Organizing committee.

2010 Conference "Raman spectroscopy: introduction and recent applications", 02-12-2010, Milan (Italy). Role: Main organizer.

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## Refereeing Activity

Referee for several international journals including Applied Physics Letters, Physical Review, Journal of Raman

Spectroscopy, Solid State Communications, Journal of Physics, Applied Spectroscopy, etc.

## Publications

[P 1] A. Marzegalli, A. Cortinovis, F. Basso Basset, E. Bonera, F. Pezzoli, A. Scaccabarozzi, F. o Isa, G. Isella, P. Zaumseil, G. Capellini, T. Schroeder, L. Miglio, "Exceptional thermal strain reduction by a tilting pillar architecture: suspended Ge layers on Si (001)", *Materials & Design*. DOI:dx.doi.org/10.1016/j.matdes.2016.11.106

[P 2] M. R. Barget, M. Lodari, M. Borriello, V. Mondiali, D. Chrastina, M. Bollani, E. Bonera, "Tensile strain in Ge membranes induced by SiGe nanostressors", *Appl. Phys. Lett.* 109 (13), 133109 (2016). DOI: 10.1063/1.4963657

[P 3] M. Bollani, D. Chrastina, R. Ruggeri, G. Nicotra, L. Gagliano, E. Bonera, V. Mondiali, A. Marzegalli, F. Montalenti, C. Spinella, L. Miglio, "Anisotropic extended misfit dislocations in overcritical SiGe films by local substrate patterning", *Nanotechnology* 27 (42), 425301 (2016). DOI: 10.1088/0957-4484/27/42/425301

[P 4] F. Pezzoli, A. Giorgioni, K. Gallacher, F. Isa, P. Biagioni, R. W. Millar, E. Gatti, E. Grilli, E. Bonera, G. Isella, D. J. Paul and L. Miglio, "Disentangling nonradiative recombination processes in Ge micro-crystals on Si substrates", *Applied Physics Letters* 108 (26) 262103 (2016).

[P 5] F. Isa, A. Jung, M. Salvalaglio, Y. A. R. Dasilva, M. Meduña, M. Barget, T. Kreiliger, G. Isella, R. Erni, F. Pezzoli, E. Bonera, P. Niedermann, K. Zweiacker, A. Neels, A. Dommann, P. Gröning, F. Montalenti, and H. von Känel, "Elastic and plastic stress relaxation in highly mismatched SiGe/Si crystals", *MRS Advances* (2016). DOI: 10.1557/adv.2016.355

[P 6] F. Isa, M. Salvalaglio, Y. A. R. Dasilva, M. Medina, M. Barget, A. Jung, T. Kreiliger, G. Isella, R. Erni, F. Pezzoli, E. Bonera, P. Niedermann, P. Groning, F. Montalenti and H. von Kanel, "Highly mismatched, dislocation-free SiGe/Si heterostructures", *Advanced Materials* 28 (5), 884-888 (2016). DOI: 10.1002/adma.201504029

[P 7] V. Mondiali, M. Lodari, D. Chrastina, M. Barget, E. Bonera and M. Bollani, *Microelectronic Engineering* 141, "Micro and nanofabrication of SiGe/Ge bridges and membranes by wet-anisotropic etching", 256-260 (2015). DOI: 10.1016/j.mee.2015.03.067

[P 8] D. Scarpellini, C. Somaschini, A. Fedorov, S. Bietti, C. Frigeri, V. Grillo, L. Esposito, M. Salvalaglio, A. Marzegalli, F. Montalenti, E. Bonera, P. G. Medaglia and S. Sanguinetti, "InAs/GaAs Sharply Defined Axial Heterostructures in Self-Assisted Nanowires", *Nano Letters* 15 (6), 3677-3683 (2015). DOI: 10.1021/nl504690r

[P 9] E. Vitiello, M. Virgilio, A. Giorgioni, J. Frigerio, E. Gatti, S. De Cesari, E. Bonera, E. Grilli, G. Isella and F. Pezzoli, "Spin-dependent direct gap emission in tensile-strained Ge films on Si substrates", *Physical Review B* 92 (20), 201203(R) (2015). DOI: 10.1103/PhysRevB.92.201203

[P 10] G. M. Vanacore, G. Nicotra, M. Zani, M. Bollani, E. Bonera, F. Montalenti, G. Capellini, G. Isella, J. Osmond, A. Picco, F. Boioli and A. Tagliaferri, "Delayed plastic relaxation limit in SiGe islands grown by Ge diffusion from a local source", *Journal of Applied Physics* 117 (10) (2015). DOI: 10.1063/1.4914409

[P 11] M. Bollani, D. Chrastina, L. Gagliano, L. Rossetto, D. Scopece, M. Barget, V. Mondiali, J. Frigerio, M. Lodari, F. Pezzoli, F. Montalenti and E. Bonera, "Local uniaxial tensile strain in germanium of up to 4% induced by SiGe epitaxial nanostructures", *Applied Physics Letters* 107 (8) (2015). DOI: 10.1063/1.4928981

[P 12] V. Mondiali, M. Bollani, D. Chrastina, R. Rubert, G. Chahine, M. I. Richard, S. Cecchi, L. Gagliano, E. Bonera, T. Schulli and L. Miglio, "Strain release management in SiGe/Si films by substrate patterning" *Applied Physics Letters* 105 (24), 242103 (2014). DOI: 10.1063/1.4904455

[P 13] D. Scopece, F. Montalenti, M. Bollani, D. Chrastina and E. Bonera, "Straining Ge bulk and nanomembranes for optoelectronic applications: a systematic numerical analysis", *Semiconductor Science and Technology* 29 (9), 095012 (2014). DOI: 10.1088/0268-1242/29/9/095012

[P 14] G. M. Vanacore, M. Zani, M. Bollani, E. Bonera, G. Nicotra, J. Osmond, G. Capellini, G. Isella and A. Tagliaferri, "Monitoring the kinetic evolution of self-assembled SiGe islands grown by Ge surface thermal diffusion from a local source", *Nanotechnology* 25 (13), 135606 (2014). DOI: 10.1088/0957-4484/25/13/135606

[P 15] C. Frigeri, S. Bietti, A. Scaccabarozzi, R. Bergamaschini, C. V. Falub, V. Grillo, M. Bollani, E. Bonera, P. Niedermann, H. von Kanel, S. Sanguinetti and L. Miglio, "A Structural Characterization of GaAs MBE Grown on Si Pillars", *Acta Physica Polonica A* 125 (4), 986-990 (2014).

[P 16] S. Bietti, A. Scaccabarozzi, C. Frigeri, M. Bollani, E. Bonera, C. V. Falub, H. von Kanel, L. Miglio and S. Sanguinetti, "Monolithic integration of optical grade GaAs on Si (001) substrates deeply patterned at a micron scale", *Applied Physics Letters* 103 (26), 262106 (2013).

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- [P 17] E. Bonera, M. Bollani, D. Chrastina, F. Pezzoli, A. Picco, O. G. Schmidt and D. Terziotti, "Substrate strain manipulation by nanostructure perimeter forces", *Journal of Applied Physics* 113 (16), 164308 (2013). DOI: 10.1063/1.4802686
- [P 18] E. Bonera, R. Gatti, G. Isella, G. Norga, A. Picco, E. Grilli, M. Guzzi, M. Texier, B. Pichaud, H. von Kanel and L. Miglio, "Dislocation distribution across ultrathin silicon-on-insulator with epitaxial SiGe stressor", *Applied Physics Letters* 103 (5), 053104 (2013). DOI: 10.1063/1.4817071
- [P 19] M. Bollani, D. Chrastina, M. Fiocco, V. Mondiali, J. Frigerio, L. Gagliano and E. Bonera, "Lithographically defined low dimensional SiGe nanostripes as silicon stressors", *Journal of Applied Physics* 112 (9), 094318 (2012). DOI: 10.1063/1.4765009
- [P 20] M. Bollani, D. Chrastina, V. Montuori, D. Terziotti, E. Bonera, G. M. Vanacore, A. Tagliaferri, R. Sordan, C. Spinella and G. Nicotra, "Homogeneity of Ge-rich nanostructures as characterized by chemical etching and transmission electron microscopy", *Nanotechnology* 23 (4), 045302 (2012). DOI: 10.1088/0957-4484/23/4/045302
- [P 21] A. Picco, E. Bonera, F. Pezzoli, E. Grilli, O. G. Schmidt, F. Isa, S. Cecchi and M. Guzzi, "Composition profiling of inhomogeneous SiGe nanostructures by Raman spectroscopy", *Nanoscale Research Letters* 7, 633 (2012). DOI: 10.1186/1556-276X-7-633
- [P 22] M. Polignano, I. Mica, G. Carnevale, A. Mauri, E. Bonera, S. Speranza, "Defect Generation in Device Processing and Impact on the Electrical Performances", *ECS Transactions* 50, 303-317 (2012). doi: 10.1149/05005.0303ecst
- [P 23] C. V. Falub, T. Kreiliger, A. G. Taboada, F. Isa, D. Chrastina, G. Isella, E. Muller, M. Meduna, R. Bergamaschini, A. Marzegalli, E. Bonera, F. Pezzoli, L. Miglio, P. Niedermann, A. Neels, A. Pezous, R. Kaufmann, A. Dommann, H. von Kanel, "Three dimensional heteroepitaxy: A new path for monolithically integrating mismatched materials with silicon" *IEEE 2012 International Semiconductor Conference*, Vol. 2, pp. 45-50 (2012).
- [P 24] M. Sambì, D. Merlini, P. Galbiati, E. Bonera, F. Belletti, "A novel 0.16  $\mu\text{m}$  300 V SOIBCD for ultrasound medical applications", *IEEE 23rd International Symposium on Power Semiconductor Devices and Ics* (2011), pp. 36-39 (2011). doi: 10.1109/ISPSD.2011.5890784
- [P 25] L. K. Nanver, V. Jovanovic, C. Biasotto, J. Moers, D. Grutzmacher, J. J. Zhang, N. Hrauda, M. Stoffel, F. Pezzoli, O. G. Schmidt, L. Miglio, H. Kosina, A. Marzegalli, G. Vastola, G. Mussler, J. Stangl, G. Bauer, J. van der Cingel and E. Bonera, "Integration of MOSFETs with SiGe dots as stressor material", *Solid-State Electronics* 60 (1), 75-83 (2011). DOI: 10.1016/j.sse.2011.01.038
- [P 26] A. Picco, E. Bonera, E. Grilli, M. Giarola, G. Mariotto, D. Chrastina and M. Guzzi, "Determination of Raman Efficiency in SiGe Alloys", in *XXII International Conference on Raman Spectroscopy*, edited by P. M. Champion and L. D. Ziegler (2010), Vol. 1267, pp. 251-252. doi: 10.1063/1.3482496
- [P 27] M. Bollani, E. Bonera, D. Chrastina, A. Fedorov, V. Montuori, A. Picco, A. Tagliaferri, G. Vanacore and R. Sordan, "Ordered Arrays of SiGe Islands from Low-Energy PECVD", *Nanoscale Research Letters* 5 (12), 1917-1920 (2010). doi: 10.1007/s11671-010-9773-0
- [P 28] M. Bollani, D. Chrastina, A. Fedorov, R. Sordan, A. Picco and E. Bonera, "Ge-rich islands grown on patterned Si substrates by low-energy plasma-enhanced chemical vapour deposition", *Nanotechnology* 21 (47), 475302 (2010). DOI: 10.1088/0957-4484/21/47/475302
- [P 29] A. Picco, E. Bonera, E. Grilli, M. Guzzi, M. Giarola, G. Mariotto, D. Chrastina and G. Isella, "Raman Efficiency in SiGe alloys", *Physical Review B* 82 (11), 115317 (2010). DOI: 10.1103/PhysRevB.82.115317
- [P 30] E. Bonera, F. Pezzoli, A. Picco, G. Vastola, M. Stoffel, E. Grilli, M. Guzzi, A. Rastelli, O. G. Schmidt and L. Miglio, "Strain in a single ultrathin silicon layer on top of SiGe islands: Raman spectroscopy and simulations", *Physical Review B* 79 (7) (2009). doi: 10.1103/PhysRevB.79.075321
- [P 31] A. Trita, F. Bragheri, I. Cristiani, V. Degiorgio, D. Chrastina, D. Colombo, G. Isella, H. von Kanel, F. Gramm, E. Muller, M. Dobeli, E. Bonera, R. Gatti, F. Pezzoli, E. Grilli, M. Guzzi and L. Miglio, "Impact of misfit dislocation on wavefront distortion in Si/SiGe/Si optical waveguides", *Optics Communications* 282 (24), 4716-4722 (2009). doi: 10.1016/j.optcom.2009.09.026
- [P 32] F. Pezzoli, E. Bonera, M. Bollani, S. Sanguinetti, E. Grilli, M. Guzzi, G. Isella, D. Chrastina and H. von Kanel, "Raman spectroscopy for the analysis of temperature-dependent plastic relaxation of SiGe layers", *Acta Physica Polonica A* 116 (1), 78-80 (2009).
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[P 37] G. Scarel, C. Wiemer, G. Tallarida, S. Spiga, G. Seguini, E. Bonera, M. Fanciulli, Y. Lebedinskii, A. Zenkevich, G. Pavia, I. L. Fedushkin, G. K. Fukin and G. A. Domrachev, "Atomic layer deposition of Lu silicate films using  $[(\text{Me}_3\text{Si})(2)\text{N}](3)\text{Lu}$ ", *Journal of the Electrochemical Society* 153 (11), F271-F276 (2006). doi:10.1149/1.2347109

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$\text{Lu}_2\text{O}_3$ ", *App. Phys. Lett.* 85, 630 (2004). DOI:10.1063/1.1773360

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[P 48] E. Bonera, M. Fanciulli, and D. N. Batchelder, "Combining High Spatial Resolution and Tensorial Analysis in Raman Stress Measurements of Silicon", *J. App. Phys.* 94, 2729 (2003). DOI:10.1063/1.1592872

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[P 57] M. Fanciulli, E. Bonera, E. Carollo, L. Zanotti "EPR and UV-Raman Study of BPSG Thin Films: Structure and Defects" *Microelectr. Eng.* 55, 65 (2001). doi: 10.1016/S0167-9317(00)00430-5

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Proceedings of the 17th International Conference on Raman Spectroscopy (2000), Beijing, pp.172-173.

[P 59] E. Bonera, A. Borghesi and C. Caprile, "Near-Field Optical Imaging of Electromigration Damages in Passivated Metal Structures" *Mat. Res. Soc. Proc.* 571, 101 (2000).

## Conferences and Seminars

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### Seminars.

[C 1] "Raman spectroscopy for the determination of mechanical stress in semiconductors.", *STMICROELECTRONICS*, Italy, May 2011.

[C 2] "Raman micro-spectroscopy on Si, Ge and their alloys", Politecnico di Milano, Italy, April 2009.

[C 3] "Raman Spectroscopy for Strain Characterisation of Microelectronic Devices", ETH Zurich, Switzerland, March 2005.

[C 4] "Optical Characterisation of Nano-Aggregates", University of Milano-Bicocca, May 2004.

[C 5] National School of Condensed Matter Physics, "Scanning Probe Microscopy and Spectroscopy for Nanostructures", Torino, Italy, September 2002.

[C 6] "Latest developments of near-field ultra-violet Raman spectroscopy", ETH Zurich, Switzerland, November 2000.

### Conferences.

The list presented in this section is limited to the conferences attended as a presenting author.

[C 7] Oral Presentation. "Local uniaxial tensile deformation of germanium up to the 4% threshold by epitaxial nanostructures.", EMRS Fall, Warsaw, September 2014.

[C 8] Oral Presentation. "Group IV membranes", EpiOptics, Erice (Italy) July 2014. Invited.

[C 9] Poster. "Substrate strain manipulation by SiGe nanostructure perimeter forces", EMRS Spring, Strasbourg (France), May 2013.

[C 10] Oral Presentation. "Determination of Raman efficiency in SiGe alloys and applications to nanostructures" EMRS Fall, Warsaw, September 2010.

[C 11] Poster. "Ultrathin body silicon-on-insulator with an epitaxial Si<sub>1-x</sub>Ge<sub>x</sub> stressor." *Epitaxial Semiconductors on Patterned Substrates and Novel Index Surfaces*, Como (Italy), June 2010.

[C 12] Oral Presentation. "Recent applications of Raman spectroscopy", Raman Spectroscopy Conference, Milan (Italy), December 2010.

[C 13] Poster. "Raman spectroscopy of SiGe islands", European conference on Surface Science, Parma (Italy), September 2009.

[C 14] Oral Presentation. "Strain imaging in SiGe waveguides" EMRS Fall, Warsaw (Poland), September 2008.

[C 15] Oral Presentation. "Raman spectroscopy determination of composition and strain in Si<sub>1-x</sub>Ge<sub>x</sub>/Si heterostructures", EMRS Spring, Strasbourg (France), May 2008.

[C 16] Oral Presentation. European Mat. Res. Soc. Meeting, "Dielectric properties of La-based oxides deposited using atomic layer deposition", EMRS Spring, Nice, France, June 2006.

[C 17] Oral Presentation. European Mat. Res. Soc. Meeting, "Spectroscopy of strain in subwavelength microelectronics devices", EMRS Spring, Nice, France, June 2006.

[C 18] Oral Presentation. Expo 2006 Capitale Umano e Innovazione, "Ultra-scaled Non-Volatile Memories: The Problem of Mechanical Stress in the Technological Nodes Beyond 60 nm", Milan, Italy, March 2006.

[C 19] Oral Presentation. MMD Meeting, "Raman Mapping of Stress in Subwavelength Microelectronic Devices", Genoa, Italy, June 2005.

[C 20] Poster. European Science Foundation Workshop on Rare Earths Oxides, San Remo, Italy, May 2005.

[C 21] Oral Presentation. "Resonant Raman Microscopy of Stress in Silicon Based Microelectronics", *Microscopy of Semiconducting Materials XIV*, Oxford, U.K., April 2005.

[C 22] Oral Presentation. American Physical Society, "Dielectric Properties of High-k Oxides Theory and Experiment for Lu<sub>2</sub>O<sub>3</sub>", Los Angeles, U.S.A., March 2005.

[C 23] Poster. INFMeeting, "Infrared Characterisation of High-k Materials", Genoa, Italy, June 2004.

[C 24] Poster. INFMeeting, "Raman Spectroscopy of Stress in Silicon: Combining High Spatial Resolution and tensorial analysis", Genoa, June 2003.

[C 25] Oral Presentation, "Combining High Resolution and Tensorial Analysis in Raman Stress Measurements of Silicon", *Silicon Workshop*, Genoa, Italy, February 2003.

[C 26] Oral Presentation, "Deep-UV Raman and Infrared Characterisation of Atomic-Layer Deposited ZrO<sub>2</sub>

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and HfO<sub>2</sub>", Silicon Workshop, Genoa, Italy, February 2003.

[C 27] Oral Presentation. IV Symposium SiO<sub>2</sub> and Advanced Dielectrics, "Structure Evolution of Atomic Layer Deposition grown ZrO<sub>2</sub> films by deep-UV Raman and Far-Infrared Spectroscopies.", Trento, Italy, September 2002.

[C 28] Oral Presentation. INFM School on Nanotechnology, "Near-Field Microscopy" Torino, Italy (2002).

[C 29] Poster. INFM Meeting, "Raman Mapping of Stress in Silicon: Characterisation of Silicon Dioxide Patterned Structures", Rome, Italy, June 2001.

[C 30] Semiconductor and Optoelectronics, Leeds, UK, May 2000.

[C 31] Oral Presentation. "Near-Field Optical Imaging of Electromigration Damages in Passivated Metal Structures", Material Research Society Meeting, San Francisco, USA, April 2000.

[C 32] Oral Presentation. "Near-Field Microscopy of Microelectronic Materials", Scanning Probe Microscopy, Florence, Italy, December 2000.

[C 33] Poster. International School of Solid State Physics, Silicides, Erice, Italy, May 1999.

### Science popularization

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Enciclopedia Treccani. Author of entries about optics and spectroscopy for a popular Italian encyclopedia.

MeetMeTonight Science Fair, responsible of "LegoLuce", a set of optics experiments (microscope, eye, monochromator, ...) set up for children playing with optical elements embedded in Lego bricks. Held in 09/2015 and 08/2016 in Milan (Italy).

"Nanoelectronics, the story of a bet", a set of seminars dedicated to high school students for the promotion of science courses. Held in 2007 and 2008.

"Nanotechnology", a brief guide of the emerging technologies dedicated to people without specific knowledge in the field commissioned by Fondazione Cariplo.

### Abilitation

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2013-present "Abilitazione Scientifica Nazionale Professore Seconda Fascia 02/B1", national qualification for associate professorship in the field of experimental solid state physics.

### Collaborations

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Aix-Marseille Université (F), IHP Leibniz Institute Frankfurt Oder (D), IFW Leibniz Institute Dresden (D), Johannes Kepler University Linz (A), ETH Zuerich (CH), University of Glasgow (UK). Italian: STMICROELECTRONICS, IMM-CNR Catania, IFN-CNR Milano, Politecnico di Milano, CNR-IMEM Parma, MDM-CNR Agrate Brianza.

IMEC Leuven (B), IFW Leibniz Institute Dresden (D), Johannes Kepler University Linz (A), ETH Zuerich (CH). Italian: STMICROELECTRONICS, IMM-CNR Catania, IFN-CNR Milano, Politecnico di Milano, MDM-CNR Agrate Brianza, Università di Pavia, Università di Verona.

Moscow Engineering Physics Institute (RU), University of Leeds (UK), ETH Zuerich (CH) Universität Berlin (D), Clausthal University (D), National Center for Scientific Research Athens (GR). Italian: STMICROELECTRONICS, IMM-CNR Catania, Università di Cagliari.

Le dichiarazioni rese nel presente curriculum sono da ritenersi rilasciate ai sensi degli artt. 46 e 47 del D.P.R. 445/2000

Milano 05 Dicembre 2016,

Emiliano Bonera

Le dichiarazioni rese nel presente curriculum sono da ritenersi rilasciate ai sensi degli artt. 46 e 47 del D.P.R. 445/2000