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NanoLab Talks

Department of Energy, Politecnico di Milano

2020



We strongly believe in the importance of spreading knowledge and sharing ideas for the advancement of science and for the formation of young people. This is why we organize the NanoLab Talks as periodic seminars within the activities of the NanoLab group at the Department of Energy at Politecnico di Milano, Italy. The NanoLab talks are open to everyone and are given by experts from academy, research centers and private companies on Education, Science and Technology. The topics cover different aspects of Physics, Engineering, Material Science, Nanotechnology, Chemistry and Education to a target audience composed by master thesis students, PhDs, post docs, technicians, researchers and academics.

We started in 2018 and up to now we were honoured to host more than 50 speakers presenting their research at the Nanolab Talks. This year we were forced to move to the virtual NanoLab Talks due to Covid-19 restrictions. We lost the human contact that is fundamental for networking and sharing of ideas, however the teleconference mode allowed even more people to attend the talks.

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Marco Moretti	Resonant and non-resonant inelastic x-ray scattering	POLIMI, Dept. of Physics

Politecnico di Milano, Department of Energy, Cesnef (Building 19), via Ponzio 34/3, Milan
Seminar Room 1° floor

Monday, 13th January, 2020 – 11.30

Organic ultra-thin films grown on native silicon oxides with variable vacancy states: a Scanning Force Microscopy approach

Cristiano Albonetti

*Consiglio Nazionale delle Ricerche - Istituto per lo Studio dei Materiali
Nanostrutturati (CNR-ISMN) via P. Gobetti 101, 40129 Bologna, Italy
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The master equation ruling the growth of organic films was proved by using the activation energy and the substrate temperature [1]. Ultra-thin films of sexithiophene (6T) were grown on Si/SiO_x (native) substrates with increasing resistivity ρ from 0.0015 to 1000 Ω -cm. As shown by topographic images, organic films are composed of 6T islands (i.e. sub-monolayer regime) whose morphology is influenced by ρ . Surface coverage, shape, fractal dimension and height were used to probe the film growth mode. In particular, the fractal dimension D_f [2] hints a Volmer-Weber growth mode for the highest ρ , which evolves into a Stranski-Krastanov one for the lowest ρ . The D_f evolution is non-monotonic, showing a maximum for mean resistivity (1-10 Ω -cm) where the film follows the layer-by-layer growth mode (Frank-van der Merwe). By means of ρ , the substrate surface energy (i.e. the molecular diffusion energy E_d) has been systematically varied for describing the master equation together with the activation energy E_N . These results are correlated to the decreasing of SiO_x vacancy states for increasing ρ [3], underlying also the key role of electrostatic interactions in the nuclei formation.

References

- [1] F. Dinelli *et al.* J. Phys. Chem. B 110, 258 (2006)
- [2] F. Valle *et al.* Micron 100, 60 (2017)
- [3] W.B. Ying *et al.* Appl. Surf. Sci. 181, 1 (2001)

About the speaker:



Dr. Cristiano Albonetti is a CNR research scientist joining to the Research Division on "Nanotechnology of Multifunctional Materials" at the CNR Institute for the Study of Nanostructured Materials (ISMN, Molecular Design Department). He obtained a degree in Condensed Matter Physics in 2001 at the Department of Physics, University of Bologna, and a PhD in Physics in 2005. He performs experimental research activities on scanning probe microscopy techniques (especially morphological and electrical); physics of organic films growth; physical modelling of the tip-surface interactions; fabrication and characterization of hybrid electronic devices such as organic field-effect transistors; fast and parallel techniques for nanostructures fabrication (he has one patent right on this topic).

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Politecnico di Milano, Department of Energy, CeSNEF (Building 19), via Ponzio 34/3, Milan
Seminar Room 1° floor

Monday, 10th February, 2020 – 14:30

***In situ* spectroscopies and imaging of Zn-air batteries**

Benedetto Bozzini

Dipartimento di Energia, Politecnico di Milano

Rational exploitation of the energy produced by renewable sources and electromobility, call for the development of **efficient and reliable energy storage** systems. Batteries are natural candidates for this purpose, and metal-air batteries are expected to gain momentum with respect to Li-ion technologies, because of their potentially higher energy density and sustainability. Among post-Li metal-air systems, **Zn-air batteries** are especially promising for safety, environmental and cost reasons. Disposable devices are already commercially available, but rechargeable systems are still far from the market, because two key challenges still remain open: on the one hand the optimization of **bifunctional catalysts** for the reversible air-cathode, that would increase the round-trip efficiency, and, on the other hand, the minimization of **anode degradation** in both the discharge and charge processes. Even if research is making great efforts in the field, satisfactory grasp of the mechanisms underlying these processes is still lacking. This seminar will focus on an approach to the fundamental understanding of a comprehensive range of open issues of Zn-air batteries, based on **spectroscopic and imaging methods**, with special emphasis on ***in situ* X-ray** and **non-linear optical** techniques. Some recent results will be expounded, regarding: (i) **oxygen catalyst fabrication, operation and degradation**, followed ***in situ* by soft-X ray microspectroscopies** (SXM) in the direct and Fourier spaces ([1] and ref.s therein); (ii) **unstable electrodeposition and dissolution** studied by ***in situ* SXM** [2] and by **photoelectron microspectroscopy** [3]; (iii) **surface chemistry of Zn anodes** investigated by ***in situ* sum-frequency generation spectroscopy** [4]. The talk will be completed with a brief mention to some aspects of novel energy-efficient and reversible recharge approaches, addressed by ***in situ* transient-absorption** and near-ambient pressure photoelectron methods [5].

References

- [1] B. Bozzini et al., J Phys D. 050201, 51 (2018).
- [2] B. Bozzini et al., X-ray Spectrometry 527-535, 48 (2019).
- [3] B. Bozzini et al., J Phys Chem C 15996-16007, 112 (2018).
- [4] F. Rossi et al., J Electroanal Chem (2019) <https://doi.org/10.1016/j.jelechem.2019.113641>
- [5] B. Bozzini et al., J. Power Sources 226815, 436 (2019)

About the speaker:



Benedetto Bozzini is professor of Applied Physical Chemistry at Politecnico di Milano, his research activity covers a broad area at the intersection of Electrochemical Materials Science and Spectroelectrochemistry, and concerns both developing the electrochemical synthesis of novel materials and electrochemical devices, chiefly for energetic applications (fuel cells, batteries, supercapacitors), and pushing forward our capabilities in achieving a molecular-level understanding of the electrochemical interface *in operando*, chiefly with non-linear and X-ray spectroscopies and microspectroscopies. He published over 265 articles in reviewed journals and gave over 35 invited and keynote lectures at International Congresses, Symposia and Workshops.

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Politecnico di Milano, Department of Energy, Cesnef (Building 19), via Ponzio 34/3, Milan
Seminar Room 1° floor

Thursday, 20th February, 2020 – 11.30

Interlayer charge dynamics in metallic transition metal dichalcogenides

Martino Edoardo

École polytechnique fédérale de Lausanne (EPFL)

Layered metallic transition metal dichalcogenides (TMDs) are conventionally seen as two-dimensional conductors, despite a scarcity of systematic studies of the interlayer charge transport. Motivated by the prevailing strategy of functionalizing 2D materials by creating van der Waals heterostructures, we initiated an in-depth study of out-of-plane charge dynamics and emergent properties arising from interlayer coupling. Unprecedented results have been obtained thanks to employing Focused-ion-beam-assisted 3D microfabrication of samples, which enables tailoring geometry and current paths with submicron precision [1]. In this talk, I will present the first transport data revealing c-axis-oriented quasi-one-dimensional electronic states in 1T-TaS₂, —a compound with the richest charge density wave phase diagram among TMDs. Temperature dependence of resistivity shows a robust coherent out-of-plane transport, while in-plane conduction is hindered by the presence of a unique nanoarray of charge density wave domains. Consequently, we interpret the highly debated metal-insulator transition in 1T-TaS₂ as a Peierls-like instability of the c-axis-oriented orbital chains, in opposition to the long-standing Mott localization picture [2]. Among other highlights of our current research are the anomalous transport properties observed in natural heterostructures or arising from stacking faults.

References

- [1] Moll, P. J. (2018). Focused ion beam microstructuring of quantum matter. *Annual Review of Condensed Matter Physics*, 9, 147-162.
- [2] Martino, E., Pisoni, A., Ćirić, L., Arakcheeva, A., Berger, H., Akrap, A., ... & Forró, L. (2019). Preferential out-of-plane conduction and quasi-one-dimensional electronic states in layered van der Waals material 1T-TaS₂. arXiv preprint arXiv:1910.03817.

About the speaker:



Edoardo complete his Bachelor and Master degrees in Materials Engineering and Nanotechnology at PoliMi, in 2013 and 2015. During the master, he was selected for the Alta Scuola Politecnica, receiving the diploma in management of technological innovation in 2016. During his studies he participated to the activities of the applied superconductivity lab at RSE in Milan, where he contributed to the development of superconducting devices for the power grid. Since 2016 he is pursuing a PhD in Condensed Matter Physics at EPFL. His experiments focus on transport and spectroscopy study of layered materials, performed at EPFL and user facilities in Europe and US.

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Politecnico di Milano, Department of Energy, Cesnef (Building 19), via Ponzio 34/3, Milan

Friday, 8th May, 2020 – 10.00 in teleconference
([Join Microsoft Teams Meeting](#))

Recent advances on sp-carbon nanostructures: modeling of structural, electronic and vibrational properties

Alberto Milani

Dip. Energia, Politecnico di Milano, via Ponzio 34/3 – 20133, Milano, Italy

Carbon-atom wires (CAWs) are linear, finite-length molecules, whose ideal limit is the so-called “carbyne [1]. Similar to other polyconjugated systems, CAWs display structural, electronic and optical properties which can be tuned by their length and by the nature of the end-groups, offering an appealing opportunity for developing novel functional nanostructures. In addition, 2D hybrid sp-sp² carbon nanostructures, such as graphdiynes (GDY), shows structure-dependent properties which can be properly designed to tune the semiconductor to metal transition. Focusing on CAWs terminated by different end-groups, Density Functional Theory is here employed to predict the molecular structure, the electronic gap, and the Raman response as a function of the chain structure and/or the occurrence of charge transfer, also comparing calculations with experimental data. CAWs terminated by different sp² moieties are discussed to highlight the role of end-groups on π -electron delocalization; then, the occurrence of charge transfer with metal nanoparticles is taken into account to analyze SERS spectra of selected systems [2]. Donor/acceptor CAWs are then investigated to reveal how charge transfer is modulated by both the sp-carbon chain length, and peculiar functional groups [3]. Finally, confinement in 2D γ -GDY and related nanoribbons is computationally investigated to reveal the effect of topology and edge-type on the band gap and on the vibrational response [4]. These results provide guidelines for the design of novel nanostructures based on CAWs, including also sp-sp² hybrid systems where graphene-like and polyyne-like domains are closely interconnected

References

- [1] C.S. Casari et al., *Nanoscale* 2016, 8, 4414; C.S. Casari, A. Milani, *MRS Comm.* 2018, 8, 207; A. Milani et al., *Beilstein J. Nanotechnol.* 2015, 6, 480
- [2] A. Milani et al., *J. Phys. Chem. C* 2017, 121, 10562
- [3] A. Milani et al. *Scientific Reports* 2019, 9, 1648
- [4] P. Serafini et al. *Phys. Rev. Mater.* 2020, 4, 014001

About the speaker:



Alberto Milani graduated in Materials Engineering in 2005 at Polytechnic of Milan, where, in 2009, he got also a PhD in Materials Engineering. His research activity focuses on the quantum chemical computational investigation of molecular interactions in polyconjugated materials, polymers and hydrogen-bonded complexes. In particular, his main research focus is the interpretation of vibrational (IR/Raman) spectra and the understanding of structure/properties. He published more than 75 papers or reviews on international peer-reviewed journals.

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Politecnico di Milano, Department of Energy, Cesnef (Building 19), via Ponzio 34/3, Milan

Friday, May 15th, 2020 at 10.00 a.m.

(in teleconference at this link: [Join Microsoft Teams Meeting](#))

Laser synthesis of plasmonic platforms for SERS-based therapeutic drug monitoring

Paolo M. Ossi

Dipartimento di Energia, Politecnico di Milano

Therapeutic Drug Monitoring (TDM) is a clinical practice to selectively determine the concentration of a drug in a biological fluid, usually blood plasma. TDM is critically important for Narrow Therapeutic Index (NTI) drugs, with small differences between therapeutic and toxic doses. Among others, this is true of anti-epileptic drugs (AEDs). For a fraction of AEDs the blood concentration is determined in the lab via immunoassay tests, or High-Performance Liquid Chromatography coupled to Mass Spectrometry (HPLC-MS). Both techniques are time consuming and costly. We focus on the use of light scattering with ad hoc engineered plasmonic substrates as a fast, comparatively inexpensive, complementary TDM approach for AEDs. Noble metal (Au; Ag) nanoparticles (NPs), grown by pulsed laser ablation (PLA) of a high purity target are synthesized along two paths. If ablation is carried out using ns pulses in a high-density inert, massive gas (Ar) NPs form in the expanding plasma plume. If the process is performed with ns, or ps pulses in a transparent Liquid (PLAL) a colloidal solution of metal NPs is obtained and is ultrasonically sprayed and let dry on the same kind of inert support (glass, 100-Si) as for gas synthesized NPs. In both cases, self-assembled NP arrays are obtained. The few relevant process parameters that affect the size, size distribution, shape and optical properties of the NPs and the NP arrays are ambient gas pressure and laser pulse number for PLA, as well as pulse duration and laser energy density for PLAL. The ability to adjust the wavelength of the Surface Plasmon Resonance (SPR) peak opens the way to Surface Enhanced Raman Scattering (SERS) measurements of samples of different origin with various AEDs at concentrations of clinical interest using the above sensors. The results of the investigation on the SERS response of a new AED of relevant clinical interest (Perampanel), together with the stringent control of sensor performance are critically discussed.

References

- [1] C. Zanchi et al., Appl.Phys. A 125, 311 (2019); [2] M. Tommasini et al., Nanomaterials 9, 677 (2019); [3] N.R. Agarwal et al. Appl. Surf. Sci. 466, 19-27 (2019); [4] C. Zanchi et al. Appl.Surf.Sci. 507, 145109 (2020)

About the speaker:



PMO is with Dipartimento di Energia, Politecnico di Milano.

Research: interaction between energetic photons/particles and solid surfaces, nanoparticle synthesis in laser ablation plasmas, design of plasmonic platforms, physico-chemistry of snow, surface treatments for advanced ski bases, snow tribology

Politecnico di Milano, Department of Energy, Cesnef (Building 19), via Ponzio 34/3, Milan

Friday, May 29th, 2020 at 10.00 a.m.

(in teleconference at this link: [Join Microsoft Teams Meeting](#))

Molecular doping of high mobility organic semiconductors

Alberto D. Scaccabarozzi

King Abdullah University of Science and Technology (KAUST), KAUST Solar Center (KSC), Thuwal 23955, Saudi Arabia

Doping of organic semiconductors plays a fundamental role to overcome typical limitations observed in organic electronic devices and to improve device performance. Organic light-emitting diodes (OLEDs) and organic solar cells (OSC) benefits for instance of the introduction of highly conducting injection layers, while high conductivity is one of the basic requirements for organic thermoelectric materials. Organic field-effect transistors (OFETs), on the other hand, are almost entirely based on intrinsic materials and doping has been mainly employed to pattern areas close to the contacts in order to improve charge injection.¹

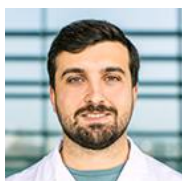
Besides the investigation of high degree of doping, ultralow doping has been recently attracting great interest, with the aim of directly doping the device's active layer. Addition of molecular dopants to the bulk heterojunction (BHJ) of organic solar cells was found to result an increased short-circuit current and higher power conversion efficiency, when compared to undoped BHJ cells.² A similar approach has been employed for OFETs, where extremely high mobilities, beyond the highest reported in literature for thin-film devices, have been reported for organic semiconductors blended with low concentrations of suitable dopants.³

Here, the synergistic effect of the different components in enhancing the charge carrier transport in various high mobility organic semiconductors, is investigated. We will show how molecular doping can induce a change in the long range transport regimes, crossing from a thermal activation to a band-like behavior. With the aid of complementary characterization techniques, we are able to elucidate the key roles of the dopant(s) on trap passivation but also on the microstructure of the host semiconductor(s), that are responsible for the ultra-high field-effect mobility values measured. Our work highlights molecular doping as a universal method for enhancing the carrier transport, and ultimately performance, in a broad range of organic semiconductors and their devices.

References

- (1) Salzmann, I.; et al. *Acc. Chem. Res.* **2016**, *49* (3), 370–378.
- (2) Lin, Y.; et al. *17.1%. Adv. Sci.* **2020**, *7*, 1903419.
- (3) Paterson, A. F.; et al. *Adv. Mater.* **2016**, *28* (35), 7791–7798.

About the speaker:



Alberto is a Postdoctoral Fellow in Thomas Anthopoulos group at the KAUST solar center (KSC), King Abdullah University of Science and Technology. His current research interests focus on the broad field of organic electronics, in particular on the study of structure-processing-property relationships in organic semiconductors for field-effect transistors. Alberto got his PhD at Imperial College London in Natalie Stingelin group. Before moving to KAUST in 2019, he was a postdoctoral fellow at CNST@Polimi Milano - Istituto Italiano di Tecnologia, in Mario Caironi group.

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Politecnico di Milano, Department of Energy, Cesnef (Building 19), via Ponzio 34/3, Milan

Friday, June 5th, 2020 at 10.00 a.m.

(in teleconference at this link: [Join Microsoft Teams Meeting](#))

Interplay between charge transfer and magnetism in surface-supported single atom magnets

Fabio Donati

*Center for Quantum Nanoscience, Institute for Basic Science (IBS), Seoul 03760, Republic of Korea
Department of Physics, Ewha Womans University, Seoul 03760, Republic of Korea*

Surface-adsorbed atoms with long magnetic lifetimes, also called single atom magnets, are the smallest unit of matter that can be used to store and manipulate information [1,2]. Hence, they represent the ultimate limit of downscaling for magnetic storage devices. In order to store and process information, it is required to tailor their magnetic states such to stabilize the electron spin orientation against thermal and quantum fluctuations [3,4]. Among the several interactions contributing to the magnetism of these atoms, the charge transfer to the surface is particularly critical as it can alter the number of unpaired electrons in the valence orbitals and potentially affect the stability of the spin states. Therefore, a proper understanding of the charge transfer mechanism is required to achieve the desired magnetic properties in the adsorbed atoms. In this work, we use X-ray absorption spectroscopy and magnetic circular dichroism to probe the magnetism of rare earth atoms adsorbed on ultra-thin films of MgO on Ag(100). Exploiting the optical selection rules of the X-ray absorption, we addressed the electron occupation and magnetic moments of Gd and Ho single atoms with orbital sensitivity. Combining our results with density functional theory, we infer a transfer of charge through the oxide layer towards the underneath silver substrate.

Finally, I will show that this mechanism can be suppressed by increasing the thickness of the MgO film. For the case of Dy atoms, this effect leads to a change in the 4f orbital occupation. I will conclude discussing the stability of electron spin states in single atom magnets in the presence or absence of charge transfer.

References

- [1] F. Donati, S. Rusponi, S. Stepanow et al., *Science* 352, 318 (2016).
- [2] F. D. Natterer, K. Yang, W. Paul et al., *Nature* 543, 226 (2017).
- [3] F. Natterer, F. Donati, F. Patthey, and H. Brune, *Phys. Rev. Lett.* 121, 027201 (2018).
- [4] F. Donati, S. Rusponi, S. Stepanow et al., *Phys. Rev. Lett.* (2020)

About the speaker:



Fabio is Assistant Professor of the Department of Physics at Ewha Womans University and Research Fellow at the Center for Quantum Nano Science, Seoul. He obtained B.Sc. (2004) & M.Sc. (2006) in Physics Engineering, and his PhD (2010) in Radiation Science and Technology from Politecnico di Milano, Italy. Part of his PhD project was carried out at the Max Plank Institute of Halle, Germany. He was post-doc at the EPFL, Switzerland until March 2017. In 2018, he received the Max Awarter award for his “achievements in physics of surfaces and interfaces”. His research focuses on the magnetism and quantum coherence properties of quantum magnets at surfaces.

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Politecnico di Milano, Department of Energy, Cesnef (Building 19), via Ponzio 34/3, Milan

Friday, 12th June, 2020 – 10.00 a.m. (Italian Time)

(in teleconference at this link: [Join Microsoft Teams Meeting](#))

Confined one-dimensional linear carbon chains

Lei Shi

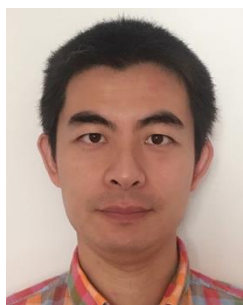
Sun Yat-sen University, School of Materials Science and Engineering, Guangzhou 510275, China

Recently, we demonstrated synthesis of confined one-dimensional linear carbon chains (LCCs) inside double-walled carbon nanotubes (DWCNTs) with the shortest chains consisting of around 30 carbon atoms (polyyne) and the longest chains with a record length of more than 6000 carbon atoms (carbyne) [1]. The carbyne formation was confirmed by near-field Raman spectroscopy and its property was much tailored by its nanotube host [2,3]. Later on, we developed a method based on density gradient centrifugation to extract the LCCs and separate the short chains [4]. However, synthesis of specific length of long LCCs is still challenging. I will show our recent efforts on tailoring the length of the confined LCCs using different carbon nanotubes as hosts [5]. Also, a new method will be introduced to grow different length of LCCs monitored by in-situ Raman spectroscopy [6].

References

- [1] L. Shi, et al. *Nature Mater.* 15, 634-639 (2016)
- [2] S. Heeg, et al. *Nano Lett.* 18, 5426-5431 (2018)
- [3] L. Shi, et al. *Phys. Rev. Materials* 1, 075601 (2017)
- [4] L. Shi, et al. *ACS Nano* 12, 8477-8484 (2018)
- [5] L. Shi, et al. In preparation (2020)
- [6] L. Shi, et al. In preparation (2020)

About the speaker:



Lei Shi received his Ph.D. degree from the University of Vienna. After postdoctoral training at the University of Vienna for more than 3 years, he joined the Sun Yat-sen University as an associate professor since October 2018 to establish a research group named “1D NanoCarbons”. His research interests focus on the 1D carbon nanomaterials, including linear carbon chains, graphene nanoribbons, and carbon nanotubes. He gave talks in more than 40 conferences/groups, including 3 in the NT series conference. He published more than 30 peer-reviewed papers in the journals of *Nature Materials*, *ACS Nano*, *Physical Review Materials*, and so on.

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Politecnico di Milano, Department of Energy, Cesnef (Building 19), via Ponzio 34/3, Milan

Friday, June 19th, 2020 at 11.00 a.m. (CEST)

(in teleconference at this link: [Join Microsoft Teams Meeting](#))

Tailoring spinterfaces by means of two-dimensional oxides

Alberto Brambilla

Physics Department, Politecnico di Milano (Italy)

A so-called *spinterface* is an interface between an organic semiconductor (OS) and a ferromagnetic (FM) substrate. This kind of system raised an ever increasing interest in the last decade, first through the realization of organic spintronics prototypical devices (e.g. organic spin valves, where an organic layer is sandwiched between two FM electrodes) then by showing new intriguing phenomena (such the occurrence of a magnetic moment at the surface of a Cu substrate) related to the formation of hybridized interface states (HIS), created by the overlapping between the electronic orbitals of the adjacent species at the interface (for a comprehensive review, see Ref. 1).

In this talk, I will focus on the spinterface formation by discussing how the presence of ultra-thin oxides at the interface may have an influence on its properties. I will consider two classes of OS, both coupled to Fe(001) substrates: i) C₆₀, which is a well-known 3D carbon-based molecule [2] and ii) Metallo-Tetra Phenyl Porphyrins (M-TPP) [3,4], which have a 2D morphology and can host different ion cores, possibly having their own magnetic moment. For both categories, I will present atomic-scale insights on the early stages of the interface formation, along with a discussion on the interplay among the structural, electronic and magnetic properties. Many results will also be supported by theoretical calculations.

References

- [1] M. Cinchetti, V. A. Dediu, L. E. Hueso, *Nature Mater.* **16** (2017) 507-515.
- [2] A. Brambilla, A. Picone, D. Giannotti, et al., *Nano Lett.* **17**, 7440–7446, (2017).
- [3] A. Picone, D. Giannotti, A. Brambilla, et al., *Appl. Surf. Sci.* **435**, (2018) 841-847
- [4] M.S. Jagadeesh, A. Calloni, A. Brambilla, et al., *Appl. Phys. Lett.* **115**, 082404 (2019).

About the speaker:



Alberto received his PhD in Physics at Politecnico di Milano in 2005, with an experimental activity focused on the investigation of thin films and interfaces of magnetic materials, oxides, and semiconductors through ultrahigh vacuum spectroscopy and microscopy techniques. He was a researcher at CNISM (Italy) and became Assistant Professor (2008) and then Associate Professor (2014) in the Physics Department of Politecnico di Milano.

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Politecnico di Milano, Department of Energy, Cesnef (Building 19), via Ponzio 34/3, Milan

Friday, June 26th, 2020 at 10.00 a.m. (CEST Time)

(in teleconference at this link: [Join Microsoft Teams Meeting](#))

Sequential Infiltration Synthesis in Block-Copolymer Thin Films for Inorganic Nanostructure Synthesis

Michele Perego

CNR-IMM, Unit of Agrate Brianza

Sequential infiltration synthesis (SIS) provides a successful route to grow inorganic materials into polymeric films through the penetration of a gaseous precursors into the polymer matrix. Fabrication of inorganic nanostructures is possible by infiltration in patterned polymer films or in self-assembled block copolymers (BCP) and subsequent removal of the polymeric template.[1-3] In this work, we focus on the synthesis of Al₂O₃ nanostructures by SIS using trimethylaluminum (TMA) and H₂O as precursors. A fundamental study is presented about the physical and chemical mechanisms of precursor diffusion and reaction in PS and PMMA thin films by means of in-situ dynamic spectroscopic ellipsometry.[4-5] Then, experimental results are presented about different Al₂O₃ nanostructures that can be obtained using cylinder forming PS-b-PMMA BCP thin films as templates. Finally, ordered arrays of Al₂O₃ pillars with diameter $d < 20$ nm are synthesized and used as hard masks for pattern transfer into the underlying silicon substrate. The possibility to fabricate isolated Si nanopillars positioned with nanometer accuracy over the Si substrate is demonstrated.

References

- [1] Q. Peng *et al.*, *Adv. Mater.* 22, 5129-5133 (2010)^[SEP]
- [2] A. Checco *et al.*, *Adv. Mater.* 26, 886–891 (2014)^[SEP]
- [3] C. Zhou *et al.*, *Adv. Funct. Mater.* 27, 1701756 (2017)
- [4] E. Cianci *et al.*, *Adv. Mater. Interfaces*, 1801016 (2018)^[SEP]
- [5] F.E. Caligiore *et al.*, *Adv. Mater. Interfaces*, 1900503 (2019)

About the speaker:



Michele Perego received the Degree in Physics from Università degli Studi dell'Insubria in 1999. In February 2004, he obtained his PhD in Physics, applied Physics and Astrophysics from Università degli Studi di Milano for his work on the ToF-SIMS characterization of silicon nanocrystals embedded in thin oxide films. In the period 2004-2007 he has been Post-Doctoral Fellow at the MDM Laboratory in Agrate Brianza where, since 2007 he has been working as research scientist. Since 2019 he is senior research scientist at IMM-CNR.

He is currently the coordinator of a research group working on the development of new bottom-up approaches for the synthesis of functional nanostructured materials.

Politecnico di Milano, Department of Energy, Cesnef (Building 19), via Ponzio 34/3, Milan

Tuesday, November 17th, 2020 at 11.00 a.m. (CEST Time)

(in teleconference at this link: [Join Microsoft Teams Meeting](#))

On-surface synthesis of molecular wires and graphene nanoribbons: structural and electronic properties

Francesco Sedona

Dipartimento di Scienze Chimiche, Università degli Studi di Padova

On-surface synthesis is a newly developing field of research that aims at making use of well-defined solid surfaces as confinement templates to initiate chemical reactions. This synthetic approach has shown that it is possible to overcome many limitations connected to the synthesis by wet chemistry, and has been successfully employed to grow a variety of low dimensional systems such as ordered metalorganic frameworks, extended porous meshes or 1D structures such as Graphene Nanoribbons (GNRs) and Molecular Wires (MWs).

Our group has been working in this field since 2015. Particular efforts have been devoted to the growth of poly(p-phenylene) (PPP) MWs on different metal surfaces and to their ability to form GNRs. Our focus has been oriented both on the control of the long-range order of these 1D structures, also through the exploration of the templating effect of different surfaces, and on the change of their electronic properties, through atomically controlled doping (Fig1).

More recently our attention has been attracted by the possibility to compare structural, vibrational and electronic properties of PPP MWs with similar structures where specific benzene rings are substituted by double or triple bonds (Fig2).

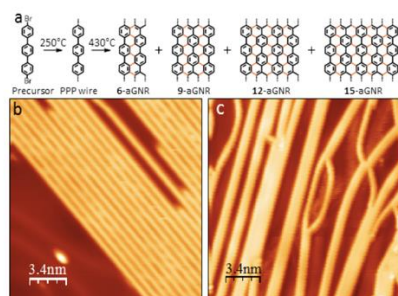


Fig1: a) Scheme of GNRs synthesis starting from DBTP b) PPP MWs c) GNRs of various width

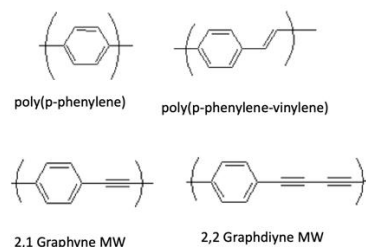


Fig2: Different types of MWs that can be obtained with on-surface synthesis approach

References

- 1) De Boni, Francesco, et al. "Templating Effect of Different Low-Miller-Index Gold Surfaces on the Bottom-Up Growth of Graphene Nanoribbons." *ACS Applied Nano Materials* (2020).
- 2) Sedona, Francesco, et al. "On-surface synthesis of extended linear graphyne molecular wires by protecting the alkynyl group." *Physical Chemistry Chemical Physics* (2020).
- 3) Basagni, Andrea, et al. "Tunable band alignment with unperturbed carrier mobility of on-surface synthesized organic semiconducting wires." *Acs Nano* 10.2 (2016): 2644-2651.
- 4) Basagni, Andrea, et al. "Molecules-oligomers-nanowires-graphene nanoribbons: a bottom-up stepwise on-surface covalent synthesis preserving long-range order." *Journal of the American Chemical Society* 137.5 (2015): 1802-1808.

About the speaker: Francesco Sedona graduated in Materials Science in 2002 at University of Padua, where he got a PhD in Materials Science in 2005 in collaboration with the University of Düsseldorf. His research activity focuses on the study of the self-assembly dynamics and reactivity of oxide nanostructured ultrathin films and of π -conjugated organic molecules on single crystal substrates. In particular, in the last years his main research focus is the structural and electronic characterization of graphene nanoribbons. He published more than 50 papers in international peer-reviewed journals.



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Politecnico di Milano, Department of Energy, Cesnef (Building 19), via Ponzio 34/3, Milan

Tuesday, November 24th, 2020 at 11.00 a.m. (CEST)

(in teleconference at this link: [Join Microsoft Teams Meeting](#))

Atomically precise graphene nanoribbons

Roman Fasel

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Graphene nanoribbons (GNRs) – narrow stripes of graphene – have attracted much interest due to their versatile electronic properties, including width-dependent bandgaps for armchair GNRs¹ and spin-polarized edge states for GNRs with zigzag edges². Manifestation of these properties requires atomically precise GNRs which can be achieved through a bottom-up on-surface synthesis approach³ that will be reviewed in the first part of this talk. In the second part, I will discuss how this approach can be applied to the synthesis of width-modulated GNRs hosting topological electronic quantum phases that emerge from localized zero-energy modes at the junctions of topologically dissimilar graphene nanoribbons⁴. The realization of 1D topological quantum phases in GNRs enables a novel route to bandgap (and effective mass) control in GNRs, which can be readily integrated in CMOS-type electronic devices⁶. This will be illustrated at the example of a novel pyrene-based GNR exhibiting an ultra-low bandgap with charge carriers behaving as massive Dirac fermions⁷. Finally, topological GNR structures might be extended to a size where magnetic ordering occurs and 1D spin chains can be realized. First attempts at fabricating such spin chains will be discussed⁸, which raise hopes for the realization of devices based on carbon nanomaterials with exotic quantum properties.

References

- [1] J. Cai et al., *Nature* **466**, 470 (2010); L. Talirz et al., *ACS Nano* **11**, 1380 (2017).
- [2] P. Ruffieux et al., *Nature* **531**, 489 (2016).
- [3] L. Talirz et al., *Adv. Mater.* **28**, 6222 (2016); Q. Sun et al., *Adv. Mater.* **30**, 1705630 (2018).
- [4] O. Gröning et al., *Nature* **560**, 209 (2018); D. Rizzo et al., *Nature* **560**, 204 (2018).
- [6] J.P. Llinas et al., *Nat. Commun.* **8**, 633 (2017); G. Borin Barin et al., *ACS Appl. Nano Mater.* **2**, 2184 (2019).
- [7] Q. Sun et al., *Adv. Mat.* **32**, 1906054 (2020).
- [8] Q. Sun et al., *Nano Lett.* **20**, 6429 (2020).

About the speaker:



Roman Fasel graduated in Solid State Physics in 1996 at the University of Fribourg and joined Empa, the Swiss Federal Laboratories for Materials Science and Technology, after post-doctoral research fellowships at La Trobe University (Melbourne) and the Fritz-Haber-Institute (Berlin). Roman Fasel and his team at Empa's nanotech@surfaces Laboratory are among the pioneers of the rapidly evolving field of on-surface synthesis, and have developed the bottom-up approach to the synthesis of atomically-precise graphene nanoribbons.

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Politecnico di Milano, Department of Energy, Cesnef (Building 19), via Ponzio 34/3, Milan

Tuesday, December 1st, 2020 at 11.00 a.m. (CEST Time)
(in teleconference at this link: [Join Microsoft Teams Meeting](#))

Resonant and non-resonant inelastic x-ray scattering

Marco Moretti (Sala)

Dipartimento di Fisica, Politecnico di Milano (IT)

Complex interactions between charge, spin, lattice and orbital degrees of freedom give rise to many fascinating properties in so-called quantum materials. Inelastic x-ray scattering (IXS) proved very effective as a spectroscopic technique to study their electronic, magnetic and vibrational properties. In this talk I will provide a generic introduction to inelastic x-ray scattering, both in the resonant (RIXS) and non-resonant (NIXS) regimes, and review some of the key experimental results. I will then narrow the discussion down to RIXS studies of elementary excitations in correlated electron systems [1], with focus on recent results on high-temperature superconducting cuprates and spin-orbit Mott-insulating iridates.

References

[1] for a review, please see L. J. P. Ament et al, Rev. Mod. Phys. 83 (2011).

About the speaker:



Marco Moretti obtained his PhD in Physics at Politecnico di Milano in 2011. He then moved to ESRF – The European Synchrotron (Grenoble, France), where he started as post-doc on ID16. He participated in the design, construction and commissioning of ID20, the inelastic hard-x-ray scattering beamline, where he became scientist and, eventually, beamline responsible. Finally, in 2018 he became professor at Politecnico di Milano (Italy). His research activity focuses on the study of the electronic structure of correlated electron systems by means of synchrotron-based spectroscopic techniques, x-ray absorption and resonant inelastic x-ray scattering, in particular.

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