MATERIALI NANOSTRUTTURATI OGGI E DOMANI: CNR E ROMA TRE SI INCONTRANO

14th May 2024

14:00 – 19:00

Aula Conferenze dei Dipartimenti DICITA e DIIEM
via Vito Volterra 62, 00146 Roma

Organizzato da:
Dipartimento di Scienze, Università Roma Tre
Istituto di Struttura della Materia, CNR

ROMA TRE UNIVERSITÀ DEGLI STUDI — SCIENZE Dipartimento di Eccellenza — CNR Istituto di Struttura della Materia — Consiglio Nazionale delle Ricerche

PROGRAMME

14:00	SALUTI ISTITUZIONALI/WELCOME Coordinatore Sez. Nanoscienze-Nanotecnologie Prorettore Ricerca Direttore Scienze Direttore DIIEM Direttore DICITA Direttore CNR NANOTEC Direttore CNR ISM Promotore Convenzione ISM-Scienze Responsabile Convenzione ISM-Scienze	C. Meneghini (chairman) P. Visca G. Antonini S. A. Sciuto A. Micarelli G. Gigli A. Cricenti A. Di Carlo S. Iacobucci	
	Title	**Speaker**	**Institution**
14:40	GUEST TALK **Exosomal Biomarker Development: promises,progress, challenges** (Chairman G. Capellini)	Ya-Hong Xie	Dept. Materials Science and Engineering, University of California Los Angeles (USA)
SESSION 1 - Chairwoman A. Sodo			
15:40	Room temperature polariton nonlinear fluids	A. Fieramosca	CNR-Nanotec
16:00	High temperature superconductors for high field applications	V. Braccini	CNR-SPIN Genova
16:20	Engineering materials in multiple scales to reach novel functionalities	G. Lanzara	DICITA
16:40	Coffee break		
SESSION 2 - Chairwoman G. Iucci			
17:10	Noble metal nanostructures functionalized with organic compounds for plasmonic applications	A. Paladini	CNR-ISM
17:30	Exploring interface effects in magnetic thin film heterostructures	G. Varvaro	CNR-ISM
17:50	A nanoscale movement study of bacteria	G. Longo	CNR-ISM
18:10	Exciton-Exciton Annihilation dynamics in thin phthalocyanine films	S. Turchini	CNR-ISM
18:30	Round Table/Final Discussion (Chairman F.Offi)		

Book of Abstracts

Exosomal Biomarker Development: promises, progress, challenges

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Exosomes have risen to eminence during the past couple of decades in terms of their potential as biomarkers of a variety of diseases and even as therapeutic agents. Exosomes are vesicles of around 100 nm diameter containing lipid bilayer membrane with biological contents typical of human cells except nuclei, and secreted by human cells as part of their routine biogenesis. The lipid membrane protects the content from degradation by enzymes in common body fluids allowing for their much longer transport range. This unique characteristic combined with their demonstrated propensity of fuse with target cells through endocytosis serve as one of the channels in cell-cell communication including cancer metastasis. The understanding of exosomes including the classification of these extracellular vesicles have come a long way since they come under the spotlight of the biomedical community. Despite of the progress, many of their biological, chemical and physical properties are still being discovered. With the inherent biological heterogeneity, questions such as if the commonly employed, size-based isolation indeed groups EVs with similar biological functionality, the quantitative measure of the size heterogeneity, and the fundamental biology pertaining to their diagnostic as well as therapeutic potential, remain to be understood. In this talk, we discuss the exciting opportunities presented by the research interests in extracellular vesicles. We will begin with the biogenesis of EVs followed by the introduction of demonstrated evidence to date on the diagnostic as well as prognostic potential of EVs. I will then present my personal perspective on the technological challenges along the path towards clinical applications. Many of these challenges could potentially be addressed by engineering innovations. Examples include trying to answer if surface enhanced Raman spectroscopy (SERS) could be used as biochemical fingerprinting for distinguishing among different types of EVs, exploring if SERS could eventually be developed into a (hopefully) non-destructive proteomic techniques, the possibility of manipulate individual EVs using plasmonic tweezers, as well as the design and fabrication of novel microfluidic devices with sufficient throughput suitable for clinical applications. The motivation is to stimulate discussions among scientists of different background with the hope of leading to the formation of large scale, cross discipline collaboration.

Ya-Hong Xie is a professor of the department of materials science and engineering at the University of California Los Angeles (UCLA). Prior to joining the UCLA faculty in 1999, he spent 14 years at Bell Laboratories conducting research on semiconductor materials and devices. The interests of his group at UCLA include surface plasmon enabled biosensing and the materials and devices of wide bandgap semiconductors. He has over 200 journal publications and holds 38 US patents. He is a fellow of IEEE and a winner of 2012 Research Award of Alexander von Humboldt Foundation.

Room temperature polariton nonlinear fluids

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Excitonic polaritons are bosonic quasiparticles arising from the hybridization of a bound electron-hole pair (exciton) and an amplified electromagnetic field (usually cavity photons). Their hybrid light-matter nature has allowed the study of different fundamental phenomena as well as the proposal of plenty of technologically relevant applications. However, the realization of cost-effective and technologically relevant polaritonic devices requires, on the one hand, the exploitation of photonic structures which may offer advantageous topological phenomena, and on the other hand, a profound comprehension of the intrinsic microscopic phenomena underpinning polariton interactions, especially when novel materials with high excitonic binding energy are employed to bring the polariton physics to room temperature. Here, we present our research activity focused on the investigation of topological properties in photonic waveguides [1,2,3], high finesse microcavities coupled with transition metal dichalcogenides homo- and hetero-structures, as well as single crystals of 2D perovskite [4]. We will demonstrate how the presence of polariton interactions in these materials can be exploited to realize proof-of-concept polariton devices that operate successfully at room temperature. Furthermore, we will illustrate how perovskite single crystals, self-sustaining the formation of polaritons, can be grown using microfluidic techniques and controlled dewetting [5,6,7]. These smart and low-cost lithography techniques will enable the formation of self-assembled micro- and nanocrystals with finely controlled shapes and dimensions, which are extremely useful for the development of active polaritonic circuits directly patterned on the final substrate.

[1] J. Zhao, A. Fieramosca, *et al.,* Nat. Nanotechnol. **17**, 396 (2022).
[2] J. Zhao, A. Fieramosca, *et al.*, Nat. Commun. **14**, 1512 (2023).
[3] E. Maggiolini, L. Polimeno, *et al.*, Nat. Mater. **22**, 964 (2023).
[4] A. Fieramosca, R. Mastria, *et al.,* Nano Letters, in press.
[5] K. Łempicka-Mirek, Electrical polarization switching of perovskite polariton laser, Nanophotonics, (2024).
[6] I. Viola, Microfluidic-Assisted Growth of Perovskite Single Crystals for Photodetectors, Advanced Materials Technologies, (2023).
[7] I. Viola, Dispositivo optoelettronico che comprende cristalli singoli di perovskite organica-inorganica ibrida e metodo per produrre detti cristalli singoli di perovskite – *Italian Patent N. 102022000010502 (2022).*

High temperature superconductors for high field applications

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Superconductivity is an enabling technology whose use is mandatory in many areas of research with a significant societal impact. Indeed, its use is essential in fundamental research (e.g. for particle accelerators as Large Hadron Collider at CERN) as well as in applied research, where it supports the energy transition (e.g. magnets in fusion reactors as ITER or in other systems for energy generation, transmission and storage), and advanced techniques for medical diagnostics (e.g. MRI). The higher are the performances of the superconducting materials in terms of operating temperature, external magnetic field that can be applied without destroying superconductivity (Hc2), and current which can pass through the superconductor itself without dissipation (Jc), the greater are the advantages and possibilities brought by the superconducting devices. The most promising materials for the above-mentioned applications are the cuprate high-Tc superconductors (HTS, such as YBCO, BSCCO-2212, BSCCO-2223, Tl-1223) and the emerging Fe-based superconductors (IBS, such as Ba-122 and Fe(Se,Te)), which guarantee the persistence of large Jc in high applied magnetic field. At CNR-SPIN we develop and study superconducting materials such as Ba-122 and BSCCO-2212 multifilamentary wires through Powder-In-Tube technique, Fe(Se,Te) thin films and Coated Conductors and Tl-1223 coatings, all for high magnetic field applications. I will review the several projects and collaborations we are involved in and the results achieved in terms of fabrication processes and superconducting properties.

Engineering materials in multiple scales to reach novel functionalities

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Multifunctional materials represent a paradigm shift in material science, offering a versatile platform for addressing diverse engineering challenges across various industries. The use of these innovative materials provides unprecedented advantages such as enhanced performance, reduced weight, improved efficiency, and sustainability. This abstract delves into the fundamental concepts, design and fabrication strategies, and applications that were carried out at the Multifunctional Materials Laboratory in recent years to deliver materials that function spontaneously when exposed to external triggering sources or in response to a given stimuli. Focus will in particular be given to morphing and self-sensing materials ranging from composites to textiles. Furthermore, a concise overview of the laboratory's latest endeavors is provided, particularly highlighting the ongoing efforts in implementing those functionalities to deliver materials with characteristics mirroring human-like behavior.

Noble metal nanostructures functionalized with organic compounds for plasmonic applications

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Metal nanoparticles (NPs) exhibit many fascinating optical, thermal, and electrical properties, which are widely exploited for applications in different fields, such as optoelectronics, catalysis, sensors, and biomedicine [1-3]. These applications are based on the peculiar effect of the Localized Surface Plasmon Resonance (LSPR) of the metal NP on the absorption, emission, and scattering. In the framework of the collaboration between the EuroFel Support Laboratory (EFSL) of CNR-ISM and the Science Department of "Università di Roma Tre", several silver and gold-based nanostructures have been synthesized and investigated, using microscopy and different optical and electron spectroscopies, to understand both the chemical structure and aggregation properties as well as the morphology. Among them, gold rod-like NPs have been produced, exhibiting the typical transverse LSPR around 500 nm and the longitudinal LSPR in the range between 650 and 1200 nm. Functionalization with different dyes and loading of drugs for biomedical applications were performed. The plasmonic properties of these systems are presently under study using both steady-state and pump-probe spectroscopy, and will be exploited to photo-trigger the release of molecules loaded onto the nanostructures [4].

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Exploring interface effects in magnetic thin film heterostructures

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Interfacing different materials at the nanoscale has emerged as a powerful tool for creating advanced materials with unique properties and functionalities that are not present in the individual materials alone. This is particularly significant in the realm of magnetism, where interfaces in complex nanoscale heterostructures play a crucial role in various applications [1,2]. Among the different materials, Co/X multilayers (X = Pd, Pt, or Ni) have garnered renewed attention as key building blocks of complex heterostructures, due to their remarkable tunability of physical properties, the ability to stabilize unique spin configurations and the favorable conditions for room temperature preparation. The peculiar characteristics of these materials have recently been exploited through collaborative efforts between my research group and other laboratories to develop innovative devices and systems with applications spanning diverse fields, including information storage and processing, sensors, and biomedicine [3-8]. In this talk, I will focus on our recent studies investigating the interface effects in Co/Pt trilayers and multilayers [9], showing an asymmetric magnetic proximity effect (MPE), resulting in a different induced magnetic moment of the Pt layer depending on its position relative to the Co layer. Advanced spectroscopic and imaging techniques were combined with theoretical approaches to elucidate the origin of this asymmetry. The observed variation in magnetic moment at the Co/Pt interfaces was found to be correlated with microstructural features, which, in turn, were influenced by the growth processes during film deposition. The choice of fabrication conditions may then represent a potential way for a fine control of the MPE and the related phenomenology, thus allowing a suitable design of the heterostructure with better performance for specific technological applications.

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[3] M. Hassan, *et al*., Nat. Phys. (2024).
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A nanoscale movement study of bacteria

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Observing the movement at the nanoscale can be of great importance to study the activity of live biological systems. Monitoring this parameter can shed some light on the behavior of single cells in different environmental conditions. The ISM-CNR has developed a nanosensor to study the fine movements of living systems in native environment and has a long-standing mutual interest with prof. Visca of the Università di Roma Tre to employ this technique to the study of bacteria, to better understand their growth patterns and their response to external stimuli, including pharmacological insults. Some of the first ideas involved the study of Acinetobacter baumannii, which, when dehydrated, evidence the emergence of a subpopulation of dormant cells, becoming "viable but nonculturable" (VBNC). VBNC cells were able to resuscitate in different artificial media, HIS and urine, and to modify their lipid composition at the cost of ATP consumption and ROS production. In this sense, studying the nanoscale movements of these specimens through the nanomotion sensor we can obtain interesting new insights in the modifications of the cell's activity during this dehydration process and when the VBNC cells are re-hydrated. Other studies involved Staphylococcus aureus, which is known to develop resistances to antibiotics at a remarkable pace, presenting a significant clinical challenge and underscoring the need to increase our understanding of the fundamental processes that promote S. aureus pathogenesis, as these processes could represent targets for novel therapeutics. Iron is required for S. aureus growth and persistence and hence must be acquired during infection. In consequence, iron has become a target for more specific strategies to fight such infections. The nanomotion sensor allowed the evaluation of the activity of these bacteria when grown in absence of iron and when this fundamental component is provided. The results show the ability of S. aureus to sequestrate iron in the environment and how this allows their proliferation even in presence of an iron chelator such as bipyridyl. From a wider point of view, and to further our collaboration with University Roma Tre researchers and professors, we suggest the use of this nanomotion sensor technique as a new innovative and real-time tool to study the behavior of bacteria and more in genera of different classes of living biological systems.

Exciton-Exciton Annihilation dynamics in thin phthalocyanine films

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Excitons can transport energy via diffusion. Exciton separation to provide free carriers is the operational mechanism of many molecular based devices including solar cells. Exciton diffusion strongly depends on the morphology and the defects, and a detailed microscopic picture of exciton dynamics is desirable in optimizing the device architecture. To grasp the essential features of the dynamics, we studied exciton-exciton annihilation, a bimolecular process that is related with the exciton diffusion coefficient, providing a microscopic information on mobility. The activity deals with the study of copper phthalocyanine thin films by ultrafast transient absorption spectroscopy. The results obtained allow us to determine the constant of annihilation rates of excitons in phthalocyanine films in different types of order of aggregation of the molecules, furnishing important information for the optoelectronic properties of the system.