Università degli Studi di Padova

Corso di Dottorato in Scienza ed Ingegneria dei Materiali e delle Nanostrutture
SIMN

DiSC

Lunedi **16 Dicembre 2019, ore 14.30**
Aula D

il **Dott. Alessandro Molle**

CNR-IMM, unit of Agrate Brianza

terrà il seminario dal titolo:

Synthetic and modified two-dimensional materials: from Xenes to anisotropic transition metal dichalcogenides

La presenza della S. V. sarà molto gradita

Prof. Gaetano Granozzi

Il Coordinatore del Corso di Dottorato SIMN
Prof. Giovanni Mattei

Il Direttore del Dipartimento
Prof. Michele Maggini

Short Bio
Dr. Alessandro Molle is a Senior Researcher at the Consiglio Nazionale delle Ricerche (CNR), Istituto per la Microelettronica e Microsistemi (IMM), unit of Agrate Brianza, where he carried out his Pot-Doc fellowship after his Ph.D. and MSc. from the University of Genoa. He has been chairing a M.Sc. and Ph.D. courses at the University of Milan-Bicocca and he co-edited a book on two-dimensional (2D) materials for nanoelectronics. He is principal investigator of an ERC Consolidator Grant 2017, and in charge of other national (Fondazione Cariplo, Regione Lombardia) and international (EU-FP7, EU-H2020) grants. He usually serves as symposium organizers in international meetings such the E-MRS and MRS. His main research interests are about the synthesis of two-dimensional materials like Xenes and transition metal dichalcogenides, and their device integration.

Abstract

The debut of graphene paved the way to the exploration of an "expanding universe" of two-dimensional (2D) materials that may serve as building blocks for a multifunctional nanotechnology or as a playground for an undiscovered physics [1]. The gate modulation and the exceptionally high carrier mobility in graphene transistors prompted an enormous interest in the integration of complementary and/or alternative 2D materials into ultimately scaled nanoelectronic and optoelectronic devices. I will briefly introduce this scenario by bringing selected representative cases in point where 2D materials like transition metal dichalcogenides (TDMs), e.g. MoS_2 and similar ones, offer a promising potential for technology transfer. Then I will move to the considertion of newly emerging 2D material that can be artificially produced by design. In this framework, making artificially adjustable 2D materials is an emerging route to reach a superior control of new functional properties. With this aim in mind, here I will give consideration to two distinct cases. On one hand are the epitaxial Xenes, an emerging class of 2D monoelemental lattice beyond graphene; on the other hand is the anisotropy design in MoS_2 nanosheets. By close analogy with graphene, epitaxial Xenes are comprised of monoelemental atoms arranged in a honeycomb lattice; unlike graphene, Xenes are epitaxially grown on substrates and exhibit a varying degree of buckling and/or puckering in the lattice structure [2]. Examples in this respect are silicene, germanene, stanene, borophene, epitaxial phosphorene, and recently synthesized antimonene and tellurene. Buckling in Xenes can be taken as a leverage to tune the electronic and quantum properties making it possible for Xenes to appear as semiconductors, semimetals, metals, topological, and trivial insulators. Not only the wealth of electronic states in the Xenes makes them suitable as nanotechnology platform, but also topological transitions among these electronic states are predicted to take place as a function of an external solicitation (e.g. vertical electric field, applied stress) thus paving the way to the full exploitation of topology in devices at the 2D level. On one hand, I will show the route and challenges for Xenes to be integrated in nanoelectronic devices by briefly describing a universal approach to Xene processing and eventually the concept of a topological field effect transistor. On the other hand, I will also show promising tips for exploiting specific Xenes such as silicene, as outstanding materials for nanophotonics and plasmonics if adapted to optically friendly substrates such as sapphire.

TMDs are probably the more reliable class of 2D seminconductors to be readily implementaed in a nanotechnology platform. Developing scalable methodologies for the growth of thickness-controlled TMDs is demanding in this respect. Here I will shows chemical vapour deposition of approaches to growth of MoS2 by tuning the uniformity vs the crystalline quality. This is also an enabling step for a morphology design at the 2D level where MoS_2 nanosheets are conformally deposited on pre-patterned substrates therein displaying direction-dependent properties. The so-induced morphological anisotropy is reflected in the anisotropy of the physical characteristics, such as the phonon spectrum, intrinsic charge fluctuations, and the exciton dynamics. Implications on the band-gap and exciton engineering will be discussed, and the potential for applications envisioned [3].

References

[1] For a general view on the topic: M. Houssa, A. Dimoulas, A. Molle (Eds.), "2D Materials for nanoelectronics" CRC Press (Taylor & Francis Group), 2016

[2] A. Molle, J. Goldberger, M. Houssa, Y. Xu, S.-C. Zhang, and D. Akinwande, *Nature Mater.* 16, 163 (2017).

[3] C. Martella, C. Mennucci, E. Cinquanta, A. Lamperti, E. Cappelluti, F. Buatier de Mongeot, and A. Molle., *Adv. Mater.* 30, 1705615 (2018).