Ph.D. course in Physics and Nanoscience - XXXVII cycle

3rd year report – Ermes Peci

Supervisors: Dr. F.Bisio and Prof. M.Canepa

RESEARCH ACTIVITIES

The central topic of my Ph.D. research activity is the investigation of two-dimensional systems made of transition metal dichalcogenides (TMDCs), such as WS_2 and MoS_2. These atomic-thick materials exhibit intriguing optical and electronic properties, and they can be exploited as functional layers in novel devices.

During the third year of my Ph.D. project, the gold-assisted exfoliation process of 2D materials has been further optimized and the key role of the environmental conditions has been better understood. Previously limited to a specific kind of substrates (functionalized silicon dioxide), a novel technique developed with Dr. Riccardo Galafassi allowed to obtain large-area monolayer crystals of 2D TDMCs on arbitrary substrates without any surface functionalization, eventually enabling a direct exfoliation on transparent materials.

This gold-assisted exfoliation technique allowed to easily produce batches of samples of large-area TMDCs with high crystalline quality, overcoming the limitations in size, quality, and quantity of other techniques, like chemical vapor deposition or scotch-tape exfoliation. Large-area MoS_2 monolayers fabricated as above were also exploited by Dr. Lorenzo Ramò and Valentina Venturino for building plasmonic-2D semiconductor hybrid systems, with the final goal of developing a nanothermometer to study heat transfer at the nanoscale.

Within this framework, a proposal for the LaserLaB-Europe facility at Vrije Universiteit Amsterdam has been developed, aimed at exploiting Raman spectroscopy to investigate heat diffusion in two-dimensional transition metal dichalcogenides. The local temperature will be probed by Raman mapping over TMDC samples covered with a thin film of copper phthalocyanine (CuPc), which has a characteristic temperature-dependent Raman shift in the fingerprint region. The experiments in Amsterdam are scheduled to be performed between September and October, in collaboration with Prof. A. Baldi, Prof. S. Askes, and Prof. F. Ariese.

Another research topic has been the investigation of laser exposure on exfoliated MoS_2 monolayers. Indeed, laser exposure was proven capable of increasing the photoluminescence yield in proximity of the laser spot by more than one order of magnitude. This phenomenon has been investigated by means of tip-enhanced photoluminescence (TEPL) spectroscopy in the framework of a collaboration between our group and Prof. Dietrich R.T. Zahn's group at Technische Universität Chemnitz, involving a 3-months stay at TU Chemnitz to perform the experiments. To investigate the chemical alterations of the MoS_2 monolayer by laser exposure, a nanoscale chemical mapping was performed at the ESCAMicroscopy beamline at the Elettra synchrotron facility (Trieste). The chemical shifts observed there showed excellent correlation with TEPL data, allowing a thorough understanding of the phenomenon. An article with these results is currently under preparation.

CONFERENCES

EOSAM2024, 12th European Optical Society Annual Meeting, Naples (Italy), September 9-13, 2024; oral presentation: *Fast thickness mapping of large-area exfoliated two-dimensional transition metal dichalcogenides by imaging spectroscopic ellipsometry*

META2024, 14th International Conference on Metamaterials, Photonic Crystals and Plasmonics, Toyama (Japan), July 16-19, 2024; invited oral presentation: *Towards Plexcitonics: Direct Plasmonic Nanostructures Lithography on 2D Transition Metal Dichalcogenides*

WSE2023, 12th Workshop on Spectroscopic Ellipsometry, Prague (Czech Republic), September 19-21, 2023; oral presentation: *Dielectric Function of Two-Dimensional Tungsten Disulfide in Homo- and Heterobilayer Stacking*

PUBLICATIONS

Published articles:

N. Petrini, E. Peci, N. Curreli, E. Spotorno, N.K. Tofighi, M. Magnozzi, F. Scotognella, F. Bisio, I. Kriegel, *Optimizing Gold-Assisted Exfoliation of Layered Materials with (3-Aminopropyl)triethoxysilane (APTES): A Promising Approach for Large-Area Monolayers*, Adv. Optical Mater., 2303228 (2024)

Submitted to Adv. Eng. Mater.:

L.Ramò, E.Peci, M.C. Giordano, P.Canepa, F.B. de Mongeot, M.Canepa, F.Bisio, *Non-invasive deterministic plasmonic nanostructures lithography on 2D transition metal dichalcogenides*

In preparation:

E.Peci, Y.Pan, et al., *Strong Photoluminescence Enhancement of Monolayer Molybdenum Disulfide by means of Laser-induced Defect Passivation*

L. Ramò, E.Peci, et al., *2D Transition-Metal Dichalcogenides as Nanothermometers*

P.Canepa, E.Peci, et al., *Surface Patterns on CVD-Grown Monolayer WS_2 Flakes: an investigation with AFM Adhesion and Friction signals*

TEACHING ACTIVITY

Teaching assistant (30 hours) for the 2nd semester of the "General Physics" course (Prof. Guido Gagliardi), B.Sc. in Biomedical Engineering, Università di Genova. Exercises at the blackboard (thermodynamics, electromagnetism) and tutoring activity.

Teaching assistant (30 hours) for the Stages@DIFI project for high-school students. Hands-on demonstrations of optical and scanning probe microscopy techniques applied to daily life objects.