

# Physics Ph.D. Annual Report – Third year

Student: Lorenzo Ramò (XXXVI cycle)

Supervisors: Dr. Francesco Bisio and Prof. Maurizio Canepa

## Research activity

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During the third year I worked to finalize the fabrication and test of the hybrid plasmonic/semiconducting systems for measuring the heat transmission at the nanoscale. I focussed my efforts on steady-state measurements of nanoscale heat transfer performed in our laboratory.

I completed the realization of a home-assembled setup to perform steady-state detection of heat transfer at the nanoscale with plasmonic – 2D semiconductor hybrid systems by means of photoluminescence spectroscopy. In this setup two lasers are used: an infra-red laser is used to generate heat at the nanoscale via the excitation of arrays of plasmonic nanostructures; a visible laser is then employed to probe the photoluminescence of a monolayer of 2D-TMDC material. The photoluminescence spectrum of the 2D-TMDC should redshift with increasing temperature after the thermal increase caused by the plasmonic photothermal effect. Later, we upgraded the setup introducing a low-vacuum chamber to hold the sample in order to limit heat dissipations through convection. So far, however, it was not possible to detect any thermal shift with the systems analyzed.

In addition to this work, I successfully optimized a reliable recipe for the non-invasive fabrication of plasmonic nanostructures on large-area 2D semiconductors by means of thermal scanning-probe lithography. The 2D materials were fabricated by means of gold-assisted exfoliation in the field of a collaboration with Ermes Peci (another PhD student of the same group). This recipe paves the way for the fabrication of new families of hybrid plasmonic-2D material devices completely in our facility. The realization of these new samples is scheduled to be performed soon.

I spent few days at Graphene Labs at Istituto Italiano di Tecnologia at NEST in Pisa for the fabrication of new plasmonic-2D material hybrid systems taking advantage of an in-situ encapsulation of the 2D material in hexagonal-boron nitride in order to improve the stability and avoiding, at the same time, charge transfer and convection dissipation effects. Some of this samples are completed and will be analyzed soon while others will be decorated with plasmonic nanostructures by means of thermal scanning-probe lithography exploiting the new non-invasive fabrication recipe.

In collaboration with Ermes Peci and Michele Ceccardi (PhD students at DiFi) we are working on the optimization of a procedure for the transfer of 2D semiconductors from silicon substrates (on which they are exfoliated) to optically transparent and insulating substrates (necessary for optical measures). The transfer recipe is not optimized yet, but first results based on polydimethylsiloxane stripping have already been obtained.

I laid the ground for two future collaborations:

- with Prof. Andrea Baldi from Vrije Universiteit of Amsterdam in order to exploit their micro-Raman thermal mapping capability on our 2D material-plasmonic hybrid systems to obtain information on heat-dissipation in 2D semiconductors.
- with Dr. Camilla Tossi from Istituto Italiano di Tecnologia at Nest in Pisa for the realization of plasmonic arrays by means of thermal scanning-probe lithography to be exploited as seeds for the seed-mediated growth of 2D semiconductors.



## Publications

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- M. Ferrera, A. Sharma, I. Milekhin, Y. Pan, D. Convertino, S. Pace, G. Orlandini, E. Peci, L. Ramò, M. Magnozzi, C. Coletti, G. Salvan, D. R. T. Zahn, M. Canepa and F. Bisio, *Local dielectric function of hBN-encapsulated WS<sub>2</sub> flakes grown by chemical vapor deposition*, *Journal of Physics: Condensed Matter*, **35(27)**, 274001 (2023).
- L. Ramò, M. C. Giordano, G. Ferrando, P. Canepa, F. Telesio, L. Repetto, F. B. de Mongeot, M. Canepa and F. Bisio, *Thermal Scanning-Probe Lithography for Broadband On-Demand Plasmonic Nanostructures on Transparent Substrates*, (under revision for publication on *ACS Applied Nano Materials*).

## Conferences and Schools

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- Plasmonica 2023 – 9 th edition of the Workshop on Plasmonics and its Applications (5-7 July 2023, Milan)  
Oral presentation: Thermal Scanning-Probe Lithography for Broadband On-Demand Plasmonics on Transparent Substrates
- 2D Quantum matter – Summer School UniPi (10-13 July 2023, Lucca)
- CMD30 FisMat 2023 joint conference (4-8 September 2023, Milan) Oral presentation: Thermal scanning-probe lithography for broadband on-demand plasmonics on transparent substrates
- EOSAM Annual Meeting 2023 (11-15 September 2023, Dijon, France ) Oral presentation: Non-invasive fabrication of plasmonic nanostructures on dielectric substrates coated with transparent-conductive oxide

## Seminars

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Didactical oral presentation “Introduction to thermoplasmonics” (1 hour). Course: Spettroscopie e materiali per la fotonica, Master’s degree level – Laurea Magistrale in Fisica e Laurea Magistrale in Scienza e Ingegneria dei Materiali, Dipartimento di Fisica, Università degli Studi di Genova

## Courses and exams

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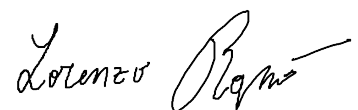
All the courses and relative exams were attended and passed during the first and second year.

## Other activities

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First semester didactical tutor for the course “Fisica e laboratorio di misure fisiche” (1th year Biological Sciences) – Prof.ssa Alessandra Pesce (50 hours) project A\_SMFN\_01

Genova, September 2023



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(Lorenzo Ramò)