SCUOLA NORMALE SUPERIORE

RELAZIONE ATTIVITA' ANNUALE DEI PERFEZIONANDI/DOTTORANDI – PRIMO ANNO
REPORT ON THE PHD ACTIVITY – FIRST YEAR

NOME E COGNOME NAME AND SURNAME	Giulia Piccinini
DISCIPLINA/PHD COURSE	Nanosciences

CORSI FREQUENTATI CON SOSTENIMENTO DI ESAME FINALE ATTENDED COURSES (WITH FINAL EXAM)	**VOTAZIONE RIPORTATA MARK**	**NUMERO DI ORE HOURS**
Nanostructured Materials	30/30	40

CORSI FREQUENTATI SENZA SOSTENIMENTO DI ESAME FINALE ATTENDED COURSES (ATTENDANCE ONLY)	**NUMERO DI ORE HOURS**
Physics on Nanostructures	44
Seminars in Condensed matter physics	44

ALTRE ATTIVITÀ FORMATIVE (SEMINARI, WORKSHOP, SCUOLE ESTIVE, ECC.) – DESCRIZIONE OTHER PHD ORIENTED ACTIVITIES (SEMINARS, WORKSHOPS, SUMMER SCHOOLS, ETC) – DESCRIPTION	**NUMERO DI ORE HOURS**
Graphene Study – 3-8 February 2019 in Obergurgl, Austria. Poster presentation. Poster title: "Effect of direct growth of WS_2 on CVD graphene"	30
Seminar – F.Carbone: *Attosecond microscopy and control of matter down to the nucleus*	1
Seminar – J-H. Ahn: *Flexible sensing platforms based on graphene and 2D materials for wearable applications*	1
NEST meeting: *Highlights in Nanoscience*	16

ATTIVITÀ DI RICERCA EVENTUALMENTE SVOLTA (MAX. 3.000 CARATTERI) RESEARCH ACTIVITY (MAX. 3000 CHARACTERS)
My research project is carried out in the 2D Materials Engineering group directed by Dr. Camilla Coletti and it focuses on the realization of van der Waals heterostructures (vdWH) for optoelectronic applications. This year I investigated the graphene/WS_2 (tungsten disulfide) vdWH, which is a system of interest since it combines the high carrier mobility of graphene with the strong light-matter interactions of single layer WS_2. In particular:

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1) I demonstrated the direct CVD growth of a single WS_2 layer on graphene single crystal arrays, deterministically grown via CVD on copper (Cu) foil and transferred on a technologically relevant substrate (i.e., SiO_2).
2) I characterized the vdWH via Raman spectroscopy, photoluminescence spectroscopy, and scanning electron microscopy (SEM). Raman spectroscopy showed that, upon WS_2 growth, graphene exhibits compressive strain and p-type doping, the latter caused by decomposition of the SiO_2 substrate during the WS_2 synthesis.
3) In order to protect the vdWH from SiO_2 decomposition, I inserted an hBN (hexagonal boron nitride) protective layer between the heterostructure and the substrate. While monolayer hBN (purchased from the Graphene Supermarket) did not improve the graphene quality in terms of doping level, a thick layer of exfoliated hBN turned out to be an excellent substrate to preserve the graphene electrical properties after WS_2 growth.
4) I fabricated multi-terminal field-effect transistor (FET) devices on the synthesized heterostructures (both with and without the hBN protective layer) in order to perform electrical measurements. The heterostructure showed a hole-transporting/electron-blocking property, which could be conveniently employed for the development of unipolar optoelectronic components.
5) In order to obtain a benchmark of the mobility of our CVD graphene, low-temperature transport measurements were required. This demanded the fabrication of edge-contacted double-gated Hall bar devices for magnetotransport measurements, which I performed. Remarkably, low-temperature mobilities up to 10^5 cm^2/Vs were found.
6) Eventually, I realized the graphene/WS_2 heterostructure by growing the two materials separately (both via CVD) and by transferring one on top of the other. Raman spectroscopy performed on such vdWH showed that this stacking process leaves the graphene much less doped than after the direct WS_2 growth on top of it.

Activities from 1) to 4) resulted in the publication "G. Piccinini et al., *Deterministic direct growth of WS_2 on CVD graphene arrays*. Accepted in 2D Materials."

EVENTUALI PUBBLICAZIONI
PUBLICATIONS (IF AVAILABLE)

G. Piccinini et al., *Deterministic direct growth of WS_2 on CVD graphene arrays*. Accepted in 2D Materials.

DATA **DATE**	05/10/2019	**FIRMA** **SIGNATURE**