Abstract

This work is dedicated to investigate the unique and excellent electrical and optical properties of graphene, through the fabrication and experimental study of several graphene based devices. Particular attention is paid to the details of all stages of the fabrication process which might have an effect on the properties of the final product. It also describes the characterization of graphene transistor structures, as well as experimental studies of charge transport.

I focused part of my research on optoelectronics and plasmonics of nanomaterials, in particular, I carried on a research that matched graphene and Plasmonics, the goal was to assess how the plasmonic response of metallic nanoparticles is modified by the presence of a graphene substrate, with results that could be very attractive as a starting point for the future optoelectronics applications.

This is how the thesis is planned: in the Chapter 2 I present a brief theoretical overview on the structural, electronic and optical properties of graphene.

In Chapter 3, I present the methods used for sample preparation, investigation of graphene flakes and the measurement setup. In particular, the identification of graphene is a very delicate step and involves the use of multiple techniques that complement each other. It is extremely difficult to find small graphene crystallites in the "haystack" of millions of thicker graphitic flakes. Thus, the identification is made by combining two or more of the following techniques: optical microscopy, Raman spectroscopy, SEM and the calculation of the contrast to give raise the best visibility.

The next, Chapter 4, is dedicated to the study of graphene based devices and their related features.

First, I fabricated 2D graphene FETs (GFETs) and explored several device designs to analyze transfer characteristic, mobility, and the influence of the contacts on the overall conductance.

The contacts between graphene and metal electrodes can significantly affect the electronic transport and limit or impede the full exploitation of the graphene intrinsic properties. In this context I investigated the contact resistance on mono- and bi-layer

graphene sheets by fabricating structures suitable for transfer length method measurements with Ni and Ti metals. We also observed anomalies in GFET transfer characteristics, namely double dips, and here I present a work in which the origin of double dips in the transfer characteristics of GFET devices is explained.

In Chapter 5, I performed the characterization of Field Emission properties of several mono and bi layer graphene samples. I report the observation and characterization of field emission current from individual single- and few-layer graphene flakes laid on a flat SiO_2/Si substrate. Measurements were performed in a scanning electron microscope chamber equipped with nanoprobes which allowed local measurement of the field emission current finding that the emission process is stable over a period of several hours and that it is well described by a Fowler–Nordheim model for currents over five orders of magnitude.

In the last Chapter 6, I present an exploration of the potential that electromagnetic surface waves known as surface plasmons may have in building both photonic elements and a new photonics technology based on nanostructured metals. I report results from an investigation into the plasmonic properties of metallic nanoparticles supported by substrates made of graphene, in order to extract information of its optical properties.

In summary: the main accomplishments of this work are to:

a) The Set-up of a routine procedure to identify graphene samples and make their morphological characterization.
b) The fabrication of graphene based electronic devices, like graphene field effect transistors and non-volatile memories.
c) The Study of the influence of different metal contact on the overall conductance, and the investigation of anomalies in GFET.
d) The investigation of quantum tunneling phenomenon in graphene.
e) The investigation of graphene as a substrate for plasmonics particles.

These results will be presented in due course.