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Graphene as an active material for sensors and other devices

Summary

The present work deals with the study of graphene for the fabrication and optimization of graphene Field Effect Transistor (G-FETs) for sensing purposes, with a focus on the transfer process of graphene and on its functionalization.

Two parallel research activities were carried out, the first regarding the process for the fabrication of the device, with its optimization and preliminary tests, and the second regarding the functionalization of graphene for the specific detection of the analytes required.

The work started with the design of the transistor and the study of the best configuration for the sensing. The path chosen was the electrolyte gated transistor, which allows the solution under test being an active part of the device and strongly influencing the measurements.

The transistor was then fabricated, following standard lithographic processes and the techniques commonly used in literature for the growth and the transfer of graphene on the device. Standard measurements were performed to test the device behavior and compare it to other G-FETs reported in the literature.

The next step was to improve the G-FET fabrication: while the lithographic steps are extremely standardized for the device fabrication, the graphene transfer process remains one of the main limits for its implementation in mass fabrication.

Graphene was then transferred using a technique usually employed in the microfluidic field, the Hot Embossing. With a simple change of substrate, from Si/SiO_2 to Cyclo Olefin Copolymer (COC), it is possible to imprint graphene into it due to its polymeric nature. Being the substrate a polymer, if thin enough it results to be also flexible, an interesting improvement that can increase the fields where graphene can be employed.

The G-FETs successfully fabricated this way were tested and compared with the previous ones. Their sensing capabilities were also investigated with simple pH and stress measurements, in order to understand their eligibility for the biomarkers and antibiotics sensing.

The new transfer process was then tested for the fabrication of other devices. Due to the transparency of the substrate, the best application was in the optics field. A graphene Schottky diode was then fabricated and tested for its behaviour compared with previous literature.

In parallel, the functionalization protocol for the sensor was studied. Graphene is a good candidate for the functionalization with the probe that will selectively capture the analytes that need to be detected. Different molecules were taken in consideration for the bonding, and after some preliminary tests Caffeic acid was chosen for the study.

A functionalization protocol was defined for the molecule, and Raman characterization was performed to establish the successful bond of a monolayer on the graphene structure. Few other molecules were tested to increase the range of functionalization possibilities, but the results are still preliminary and further investigation is required.