
UV LITHOGRAPHY ON GRAPHENE FLAKES PRODUCED
BY HIGHLY ORIENTED PYROLITIC GRAPHITE EXFOLIATION
THROUGH POLYDIMETHYLSILOXANE RUBBING

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Graphene is a purely two-dimensional material that has extremely favorable chemical sensor properties. It has been reported that, similar to other solid-state sensors, the absorption onto the surface of a graphene sensor of individual gas molecules, acting as donors or acceptors, leads to a detectable change in its electrical resistance [1]. In addition, graphene is an exceptional low-noise material and the signal-to-noise ratio can be optimized to a level sufficient for detecting changes in a local concentration by less than one electron charge at room temperature making the graphene a promising candidate for chemical detectors [2]. So far, the preparation techniques that allows to fabricate the best quality electronic material, are the mechanical methods. The intrinsic limitation of such techniques lies, however, in the graphene flakes dimensions of the order of microns. As a result, any kind of processing to realize a device needs to rely on lithography techniques. Typically graphene devices reported in the literature were prepared by e-beam lithography [3-5]. It is well established that technique which involves the irradiation of samples with electron beam can cause damage and disorder even at low doses of radiation [6, 7]. It is therefore desirable to pursue alternative graphene device fabrication.

Here we report on the preparation of graphene-based devices where the electrode patterning was realized by means of the UV lithography. Such a technique allows the use of the optical microscopy that, compared with electron microscopy, is undoubtedly a simpler and high throughput technique. Nevertheless, the success of UV lithography is highly dependent on cleanliness state of the substrate, which explains why in this case the use of scotch tape, releasing not easily removable glue residues, is strongly discouraged. For this reason, instead of the scotch tape we opted for the employment of a thermo-curable elastomer, polydimethylsiloxane (PDMS, Sylgard 184, Dow Corning Co.).

Graphene samples were prepared starting from highly oriented pyrolytic graphite (HOPG, ZYB grades, www.ntmdt.ru). The first process step consists in the preparation of the Sylgard film on a Si wafer using a standard recipe, with a curing temperature of 100 deg C and a curing time of 1 h. The Sylgard film was then peeled from the wafer (fig.1 a) and its polished side was pressed onto HOPG block, so that some graphene layers were transferred from graphite to the PDMS (fig.1 b).

The Sylgard film was lifted off (fig. 1 c left panel) and the exfoliated graphene layers were transferred onto $\text{SiO}_2(250 \text{ nm})/\text{Si}$ substrate by rubbing the PDMS film against substrate (fig. 1 d left panel). The observation under optical microscope (see fig.1 right panel) reveals the total absence of debris on the substrate, therefore there was no need of any treatment in acetone and isopropyl alcohol, and several flakes of graphene, easily distinguishable, ranged between 20 and 400 μm^2 , remain attached to the substrate. The flakes size is totally compatible with the UV lithography resolution limits which are generally 1-2 μm . In order to select only few layers of graphene flakes, the samples were examined by optical microscope. The graphene structure (single-, bi- and few layers) was checked through Raman spectroscopy (see fig. 2 left panel). The identified graphene few layers were treated by standard photolithography. Surprisingly the alignment of the sample with the mask is relatively simple because the graphene appears still visible through the resist layer. In fig. 3 (right panel), a scheme of the device, prepared by this technique, is reported; work is in progress to expose the device to different analytes, in order to test its sensing properties.

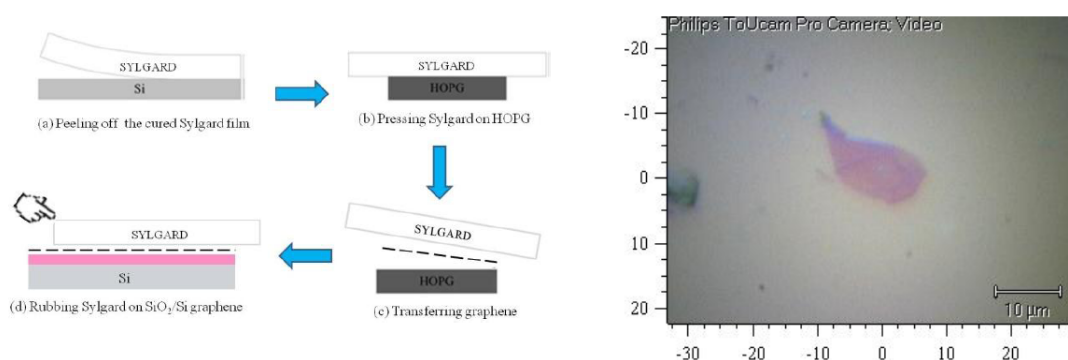


Figure 1: Left Panel:flowchart of the process for preparing graphene samples. Right Panel:optical microscope image of a flake deposited on the substrate.

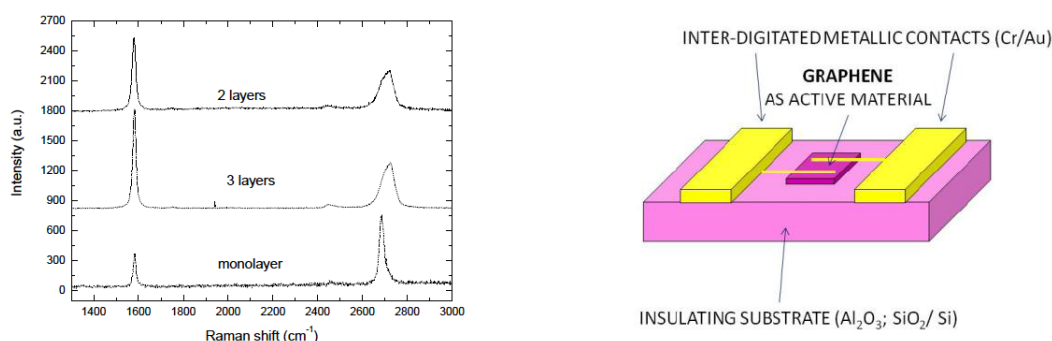


Figure 2: Left Panel: Raman spectra acquired in two different zones of the sample reported in fig. 1 (left panel). The shape of the G and 2D bands are compatible with those of a graphene multilayer with less than 5 layers [8]. A typical spectrum of a monolayer is reported as comparison. Right Panel:scheme of the device

References

- [1] Schedin et al. , Nat. Mater., 6 (2007) 652.
- [2] Ratinac et al., Environ. Sci. Technol., 44 (2010) 1167.
- [3] K. S. Novoselov et al., Science 306 (2004) 666,.
- [4] Y. Dan et al., Nano Lett., , 9 (2009) 1472.
- [5] F. Xia et al., Nano Lett., 10 (2010) 715
- [6] D. Teweldebrhan et al., Appl. Phys. Lett., 94 (2009) 013101.
- [7] I. Childres et al., Appl. Phys. Lett. 97 (2010) 173109
- [8] Z. Ni et al., Nano Res., 1 (2008) 273
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