In-situ Raman analysis of possible graphene damage during electron beam or ion beam patterning strategies

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Abstract

One of the needs in graphene research is to allow characterization of the material once it has been created. This characterization includes for example electrical characterization and therefore it is essential that graphene can be contacted and patterned. Patterning can be based on lithographic processes including resist spinning and removal, but if for example UV exposure or electron beam exposure is applied for the patterning, the graphene may be damaged. This may also occur by residual amounts of resist during development, or any processing for metal deposition and lift-off.

A direct way of patterning can include ion beam irradiation (FIB) or cutting graphene using an electron beam including the use of gas chemistry such as H_2O, O_2 or may be H_2. Also electron beam induced deposition is a method for direct deposition of a metal (for contacts), by exposing the graphene to a precursor gas that is decomposed by the electron beam. Whatever way of patterning is chosen, it is inevitable to check any possible local damage induced by the method itself. Especially the sensitivity of graphene damage related to the required dose for patterning is important to measure. As Raman analysis is considered as a non-destructive method for measuring damage on graphene, a combination of the two techniques is very useful.

In this paper a combination of Raman analysis and DualBeam is proposed as a tool for investigating this. A Raman laser beam coincident with an optical image can be aligned to an area that has been exposed by the electron or ion beam, without breaking the vacuum and without remounting and relocating of the area of interest. Changing from (sequential) exposure to Raman analysis is a matter of seconds and therefore this method is very convenient to understand and relate possible damage to graphene that an ion or electron beam might induce. The practical aspects of the implementation will be discussed, including geometric issues (FIB milling), visibility of graphene for different detectors and examples of high and low kV exposure of graphene and the related damage as a function of the dose.

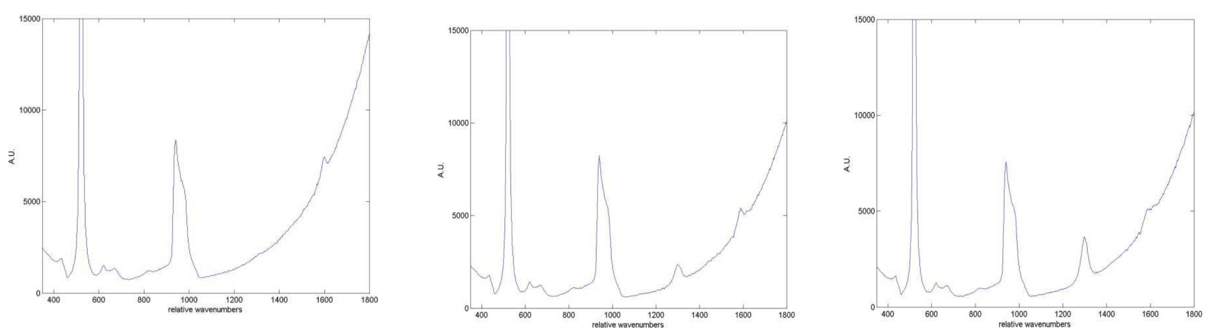

Figure 1: Raman spectra at 785 nm laser line of graphene on SiO_2. Pristine graphene (left) showing a small G and but no D band. After irradiation with an electron beam at 5 kV and a dose of $1.5.10^{+15}$ el/cm^2 showing an increase of the D band(middle) and at a cumulative dose of $6.5.10^{+15}$ el/cm^2, showing a high D band and a distorted G band. The whole series was made in a time frame of 15 minutes, while the electron beam irradiated area was 10 x 10 um.

In a similar way by stage scanning the extent to which the damage is present can be measured with respect to the irradiated area. Possible causes for an extended damage area is the availability of SE type 3, possible Back scatter electrons and in the case of ion beam irradiation re-deposition of (ionic) particles milled away from the substrate.