Application of Ge nanowire mass sensor for graphene exfoliation

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Graphene is a 2D allotrope of carbon which can be derived from graphite. It plays an important role as a novel material, which is coming to replace silicon compounds from existing devices in nanoelectronics. Although best quality graphene is obtained by mechanical exfoliation of pyrolitic graphite, thickness of individual graphene samples layers has to be determined and after that samples with appropriate layers can be used for applications [1].

Here we demonstrate both simple and effective method for graphene sample selection from the pyrolitic graphite surface and manipulation with it by using a germanium nanowire as nanoelectromechanical tool. At the same time number of graphene layers of the selected sample is determined in easy and precise way before placing graphene sample on desired position on the surface.

Experimental equipment includes nanomanipulation system, which is staged inside scanning electron microscope. It supports the control and visualization of graphene sample choosing and spotting as well as other actions we want to do.

Single clamped germanium nanowires with resonance frequencies in the range from kHz up to MHz are used as nanoelectromechanical mass sensors. Oscillation of Ge nanowire is excited by oscillating electrostatic field applied between germanium nanowire and counter electrode. Nanowire resonance is observed visually in SEM images (Figure 1a). Due to a high adhesion between germanium nanowire and graphitic structures, graphene sample can be cleaved from the graphite surface involving just tiny contact area (less than 1% of graphene sample surface).

The effective mass of the selected graphene sample, placed on the end of cantilevered nanowire (Figure 1b,c), is calculated from the difference between resonance frequencies of free and loaded nanowire [2]:

$$m_{eff} = \frac{3m_0}{\beta^4}\left[\left(\frac{f_0}{f}\right)^2 - 1\right],$$

where m_0 is mass of a uniform cantilever, β is the constant for first harmonic, f_0 and f are resonant frequencies of empty and loaded cantilever. For a particle of mass m_p, attached at a distance x from the base of the cantilever, the effective mass is given by $m_{eff} = m_p(x/l)$.

The number of graphene layers in the sample is calculated from the graphene sample mass and surface area. Surface area of graphene sample is determined from SEM images. For example, mass of sample shown in Fig. 1c is $2 \cdot 1^{-16}$ g and correspond to 2-3 graphene monolayers.

Selected grafene samples with certain number of layers can be placed in defined positions on the substrate and may be used for integration of graphene with different complex structures.

References

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Figures

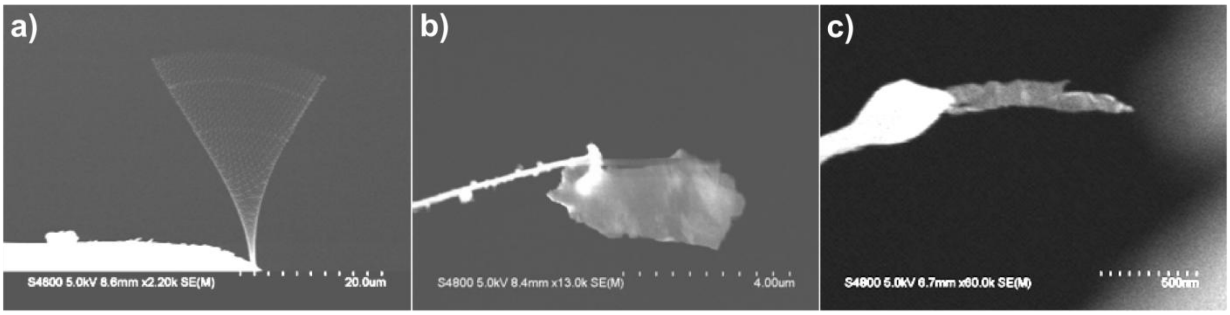

Figure 1. Images of Ge nanowire at resonance frequency (a), and graphene samples at the end of Ge nanowire afrer cleaving from the graphite surface (b,c).