Optimized graphene growth on Ge(100)/Si(100) substrates

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In order to widen the range of possible graphene applications, for example in high frequency electronics, it is desirable to grow graphene films directly on arbitrary insulator or semiconductor surfaces instead of on a most commonly used copper substrate. Ideally such insulating or semiconducting layers are deposited on Si wafers used commonly in integrated circuit (IC) manufacturing. Growing graphene directly on Si wafer surface is extremely challenging due to the tendency to form carbides. This tendency is much weaker when Ge is used as the substrate instead of Si [1], which has been exploited to grow high quality graphene on Ge(110)/Si(110) wafers [2]. Here, we present for the first time a CVD growth of graphene on monocrystalline Ge(100) "virtual substrates" deposited on Si(100) wafers which is the preferred wafer orientation in the mainstream Si IC fabrication. This approach benefits from the cost advantage and manufacturing compatibility of Si(100) wafers and avoids the metal contamination problems and complexity associated with graphene transfer from Cu. A clean, high quality graphene grown on Ge(100)/Si(100) wafers can be subsequently either transferred using wafer bonding approaches or used directly for fabrication of e.g. graphene THz devices [3] thus opening the way for this new material to the integration with Si microelectronics.

In the present work graphene films were synthesized in a 6-inch Black Magic system by the CVD method. As a substrate we used both 1 μm and 3 μm thick (100) oriented Ge deposited on Si(100). To ensure optimal temperature conditions, thus preventing Si diffusion through a Ge layer and Ge melting the temperature was chosen in the range between 900^0C and 930^0C with a slow ramp. During the process of graphene deposition the pressure of 700 mbar was sustained. Methane gas was used as a carbon precursor in the mixture of Ar and H_2. We optimized the ratio of $Ar/H_2/CH_4$ gases, growth time and temperature so that a continuous film was created. Furthermore, we developed the process of transferring graphene from Ge/Si wafers onto dielectric substrates aimed at showing clear and non-contaminated graphene films.

The assessment of the properties of graphene grown on Ge/Si substrates was performed using Raman spectroscopy, which confirmed the formation of graphitic structures and their quality, and SEM imaging, which showed the morphology of the graphene/Ge/Si interaction. For the purpose of electrical measurements by the Hall method and the contamination detection by performing the ToF-SIMS analysis, we developed a protocol of graphene transfer onto a dielectric substrate.

References

[1] G. Lippert, et al Carbon **75**, 104 (2014);
[2] Lee et al, Science Vol. **344** no. 6181 (2014) pp. 286-289
[3] V. Di Lecce, R. Grassi, A. Gnudi, E. Gnani, S. Reggiani, G. Baccarani, Trans. Electron Dev., **60** (2013) 4263.