Optimization of the visibility of graphene on poly-Si film by thin-film optics engineering

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Since single layer graphene (SLG) has been made visible on 300nm SiO_2/Si substrate[1] for the first time, it is believed to be a potential future electronics material due to its robustness and high electron mobility. Diversified devices based on graphene have been prototyped, including chemical sensors, resonators, and MOSFETs. Most of these prototype devices have been fabricated from graphene on SiO_2/Si. Although more recently, visibility studies of SLG has been performed on GaAs substrates using a periodical structure[2], limited types of substrates studied have hindered further research and development of graphene.

In this work, a method of optimizing the visibility of SLG on poly-Si surface is proposed, which can be extended to other materials. When a multilayer substrate such as 300nm SiO_2/Si[3] is designed to satisfy the destructive optical interference condition, the reflection will be minimized. At this critical point, even a tiny optical path added in by SLG can weaken or enhance such an interference condition and greatly change the reflection, which leads to an identifiable contrast. To achieve such an interference condition for poly-Si film, it is necessary to insert a thin film with different refractive index. In consideration of process convenience, a SiO_2 layer has been inserted between poly-Si and Si (Fig. 1(a)). Simulation of contrast of SLG on the poly-Si/SiO_2/Si has been performed, using matrix theory of optical films commonly applied to the design of multilayer anti-reflection film system.

Fig. 1(b) shows the contour plot of integral contrast of single layer graphene on various thicknesses of poly-Si and SiO_2. A maximum can be found where the thicknesses of poly-Si and SiO_2 are about 76nm and 102nm respectively. The reflection spectra (Fig. 2(a)) and contrast (Fig. 2(b)) with and without graphene have been calculated at this point. The maximum contrast is about 0.18, located in a band around 600nm. Graphene flakes peeled off from SPI-1 grade HOPG (from SPI Supplies / Structure Probe, Inc.) have been placed on the as-prepared 76nm poly-Si/102nm SiO_2/Si substrate and examined under optical microscope (Fig. 3). Raman spectroscopy has verified bi-layer graphene (Fig. 4). Further inspection of mono-layer will be performed under optical microscope with filtered illumination. In addition, atomic force microscopy will be employed to study the thickness and morphology.

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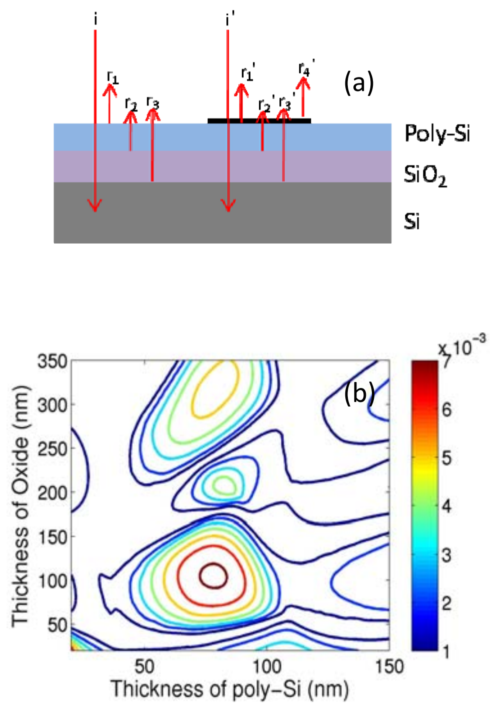

Figure 1: (a) Optical model of single layer graphene on poly-Si/SiO_2/Si substrate. (b) Contour plot of integral contrast in optical range against thickness of both poly-Si and SiO_2

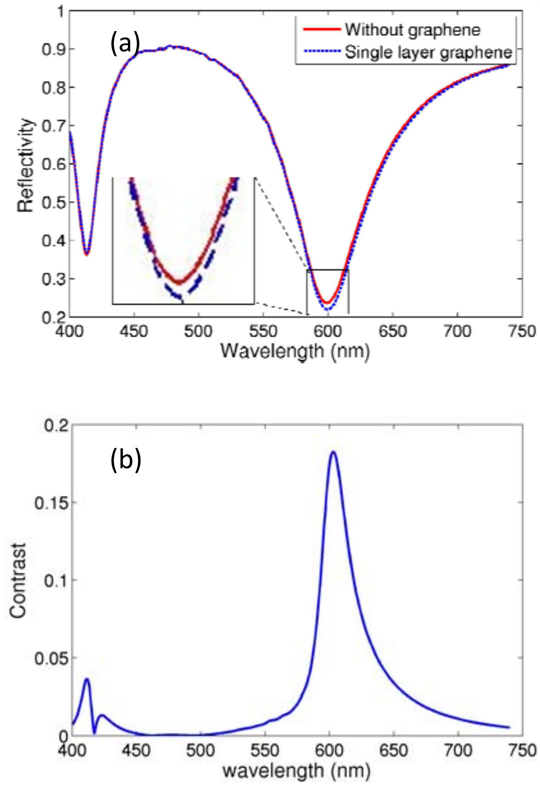

Figure 2: (a) Reflective specta of 76nm poly-Si/102nm SiO_2/Si with (blue dashed) and without (red solid) single layer graphene. (b) Contrast of graphene on the 76nm poly-Si/102nm SiO_2/Si substrate

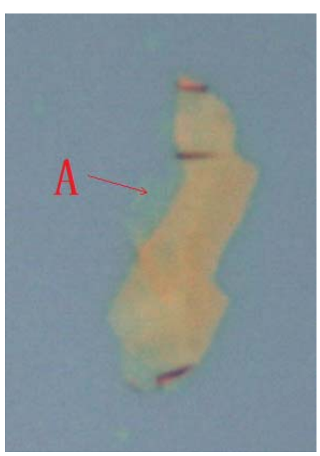

Figure 3: Optical image of a graphene flake

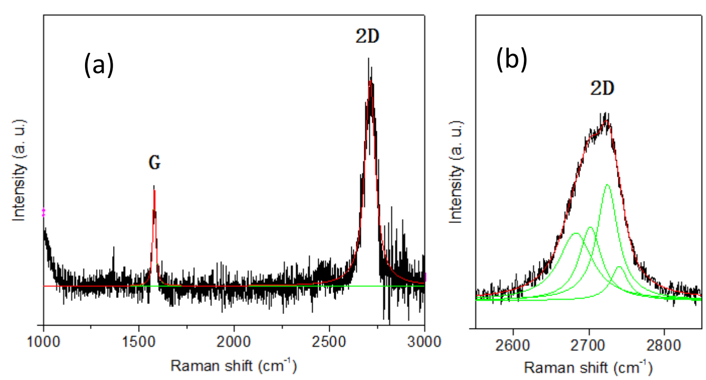

Figure 4: (a) Raman spectra of spots A in Fig. 3, G-band and 2D-band located at around 1580cm^{-1} and 2700cm^{-1} respectively, (b) The enlarged 2D band fitted with four Lorentzian peaks