

## Seed-free Si growth on transferred graphene by ICP Chemical Vapor Deposition

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### Abstract

Large area graphene synthesis on the target substrates as well as the depositions of reliable thin dielectric/semiconducting layers on top of the graphene are key challenges in order to realize the complete potential of graphene in novel microelectronic devices like vertical field effect transistors [1], graphene base transistors [2], or photodetectors [3], to name a few. Due to the hydrophobic nature of graphene [4] and the lack of dangling bonds, the depositions of dielectric/semiconductors are hindered, which leads to the formation of discontinuous films, where dielectrics preferably grow on defects or steps [5]. In order to better nucleate the growth of the dielectrics on graphene, several surface treatments have been investigated, including the evaporation of metal seeding layers [6] or covering graphene with polymers [7]. Unfortunately, these treatments can lead to the degradation of the electrical properties or make the technological processes more complicated. Recently, we have reported on the MBE depositions of smooth and closed Si layers on transferred graphene [8]. Zhu reported that Si<sub>3</sub>N<sub>4</sub> can be grown directly on graphene by PECVD at 400 °C at low plasma power [9], although it is known that graphene is sensible to plasma processes. In this work, we examine the possibility to grow amorphous Si directly on graphene by inductively coupled plasma enhanced chemical vapour deposition (ICPECVD). Up to now, direct depositions of Silicon by ICPECVD on graphene have not been reported yet.

Commercially available graphene was transferred (by using standard graphene transfer technique) from Cu foils on to the Si (100) wafers, covered with 100 nm SiO<sub>2</sub> layers. After the transfer, the samples were annealed at 500 °C for 1 hour in order to remove the residual polymer contamination. Depositions of Si have been performed at 100 °C using silane (SiH<sub>4</sub>) and hydrogen (H<sub>2</sub>) gases. The plasma power was kept at 50 W in all the experiments. Raman spectroscopy was done by a Renishaw inVia microscope using 514 nm laser light and 1800 lines/mm grating. Atomic force microscopy (AFM) and Scanning electron microscopy (SEM) were used to examine the surfaces of the grown Si layers.

In the first step, 10 or 50 nm amorphous Silicon has been grown on the transferred graphene. The optical image of the sample with 10 nm Si is shown in Fig.1, where a clear interface between the graphene and SiO<sub>2</sub> was visible. No evidence of any cracking or peeling of the top Si layer was observed. Figure 2 shows the SEM image of the same 10 nm Si layer, grown on graphene. It can be seen, that the layer was continuous and completely closed. A more detailed surface analysis was performed by AFM, where two regions, Si grown on graphene (Fig. 3) and Si grown on SiO<sub>2</sub> (Fig. 4) have been investigated. It is clearly visible, that the surface of Si, grown on graphene is rougher than the one grown on SiO<sub>2</sub>. The extracted root mean square (RMS) values were 1,2 nm and 0,5 nm, respectively. The growth of Si was also confirmed by Raman spectroscopy (Fig. 5), where a-Si modes were detected on graphene as well as on SiO<sub>2</sub>. Figure 6 compares Raman spectra of graphene before and after Si deposition. The typical Raman spectrum of the transferred graphene is indicated by the green line in Fig. 6. As can be seen, transfer procedure does not influence graphene quality, as a negligible D mode was measured. However, the Si deposition process partially destroys graphene, since rather high D signal was detected, as can be seen in the red line in Fig. 6. This can be explained by the fact that plasma has a negative influence on the graphene layer; therefore the plasma assisted growth of Si must be further optimized. The development of low temperature ICPECVD Si process on graphene is vital for the back end of line fabrication of novel graphene devices.

### References

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Figures

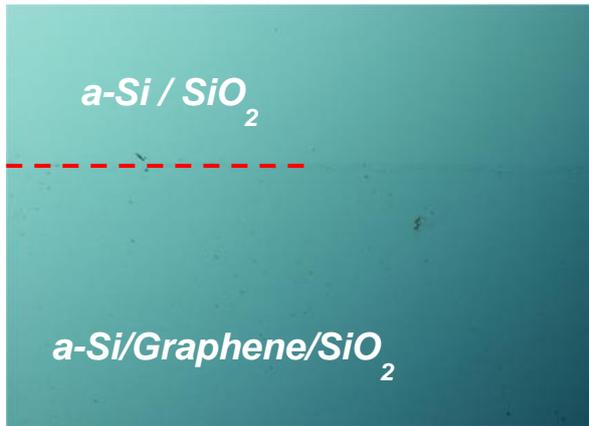


Fig. 1. Optical image of the a-Si, grown on graphene.

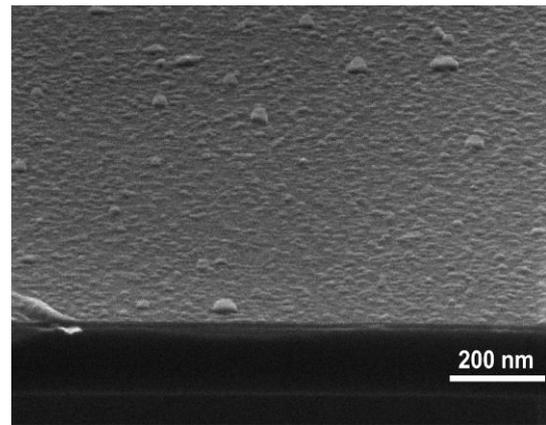


Fig. 2. Tilt-view SEM image after deposition of 10 nm Si.

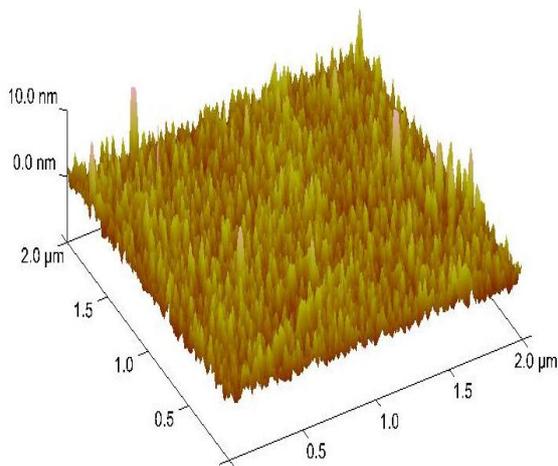


Fig. 3. AFM of 10 nm Si, grown on graphene.

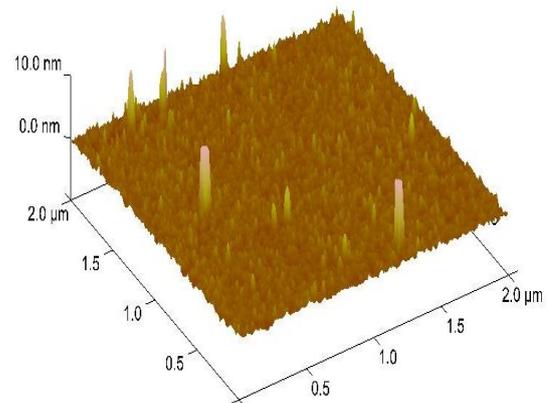


Fig. 4. AFM of 10 nm Si, grown on SiO<sub>2</sub>.

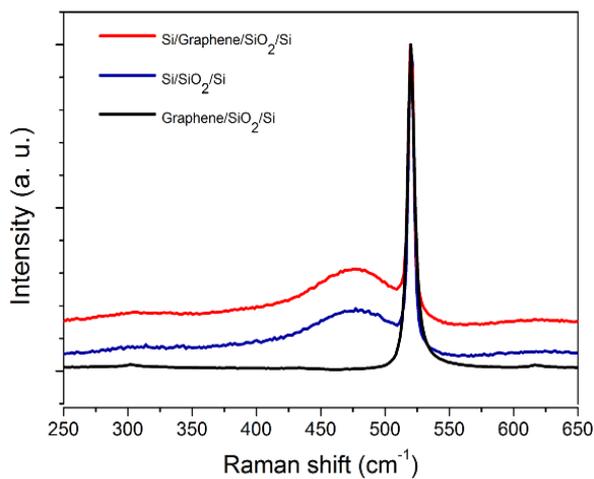


Fig. 5. Raman spectra before (black line) and after depositions of Si on graphene (red line) and SiO<sub>2</sub> (blue line).

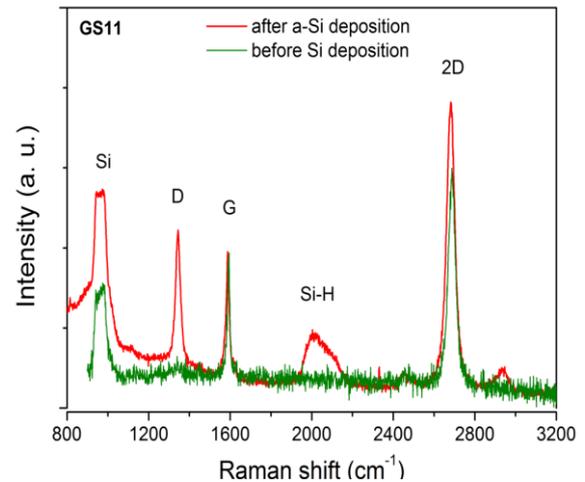


Fig. 6. Raman spectra from graphene after transfer (green line) and after Si deposition (red line).