Process for Formation of Graphene Layers on Surface of Silicon Nanowires

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Applications for graphene generally have difficulty fitting to the constraints of its growth methods. Graphene layers for device applications are often produced on flat catalytic substrates, then exfoliated and transferred to the device. This procedure is time consuming and is difficult to apply to complex device configurations. One solution is to form graphitic structures with complex configurations on-site. The method outlined here is to use nickel as the catalyst at an interface with a passivation layer like SiO_2 as part of complex silicon architectures. Carbon structures are formed from carbon precursors at the nickel surfaces and the nickel is later removed by etching.[1] This will leave graphitic films that remain on the surface conforming with the shape of the silicon architecture.

Growth conditions have been found for nickel layers deposited on 30nm thick SiO_2 films on silicon nanowires which produce carbon layers on the nanostructure surface (Fig1). Both methane or amorphous carbon can be used as the carbon precursors and the nickel catalyst layer is later etched away while preserving the carbon products. Raman micro-spectroscopy supported by SEM and TEM observations have been used for the initial characterization of the resulting structures.

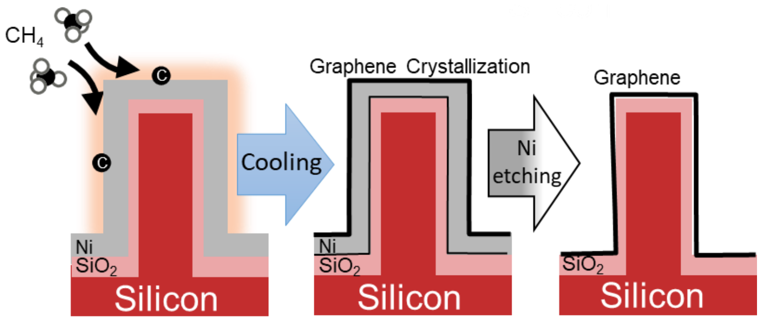

Fig. 1: Example graphitic growth process in which methane is decomposed on nickel during annealing to form graphene sheets that remain on the SiO2 surface of Si nanowires after Ni etching.

After quick annealing in methane and nickel etching, conductive carbon layers can be seen in SEM covering the entire nanowire surfaces and mimicking the nanowire shape. The layers are loose but do not wash away during etching due to the unique nanowire structure. Furthermore, these layers can cover the entire nanowire sample area which spans a few square millimeters. Raman micro-spectrography shows that the observed layers have a graphene structure as evident by strong carbon G and 2D peaks (Fig2). The peak ratio suggests a multi-layer structure. The new configuration of graphene with regular bending structures is expected to have altered properties. The nanowire architecture may be favorable for future device configurations due to the increased surface area and in combination with the optical properties of the silicon nanowires.

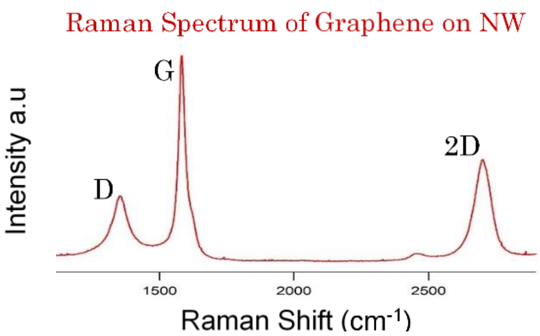

Fig. 2: Raman spectroscopy plot showing the presence and structuring of carbon directly on a 35nm SiO_2 thin film on silicon nanowires.

Reference:
[1] Daniel Q. McNerny, et al. "Direct fabrication of graphene on SiO_2 enabled by thin film stress engineering" Scientific Reports 4: 5049 (2014).