The On-Site Nanowire-Shape Graphene Formation for Silicon Nanowire-Based Schottky Junction Solar Cells

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The Schottky junction formed by contacting an n-type semiconductor with a sufficiently high work function conductor has been explored over the years for use as a simple photovoltaic cell. The interface has rectifying diode properties and it can easily be made through various semiconductor-conductor combinations. Graphene (Gr) has been used as an alternative for the conductor material because of its relatively good electrical properties for thin and highly transparent material. Many efforts reported the doping Gr to improve its conductivity and work function, and the engineering at the interface with a passivation layer to improve the power conversion efficiency (PCE) but they have not reached levels necessary for practical use so far. In this study, the on-site growth method for forming the on-site NW-shaped Gr on a SiNW array [1-2] as illustrated in Fig. 1 was hypothesized to serve as an advantageous method of producing Schottky junction solar cells which can improve light trapping close to the junction compared to a planar device without sacrificing carrier collection. The Gr growth process was modified for fabricating functional solar cell devices, and samples were tested for their photovoltaic properties compared to equivalent planar controls.

Experiments were carried out using n-Si (100) substrates. A Bosch process plasma etching-based nano-imprint lithography technique was used to form the SiNWs within 1.21 cm^2 areas. Gr formation was performed at a comparatively cool temperature over a short time on a 200nm Ni catalyst layer. The samples were quickly moved from the cool zone of room temperature to a warm region with a temperature of around 750 ºC for 3 minutes in an atmosphere of 100 sccm He: 30 sccm CH_4 at 400 torr and were quickly removed back to rapidly cool down. After Gr formation, the Ni catalysts were etched away by dipping the samples in Marble's reagent (1g $CuSO_4$: 5 ml HCl: 5 ml H_2O) for 2 minutes, washed twice in H_2O, and blow-dried with N_2 gas. Then, 300nm Au front contacts were deposited on the SiNW sample surface with a finger pattern over a 0.5 cm^2 sample area for Schottky junction solar cell fabrication.

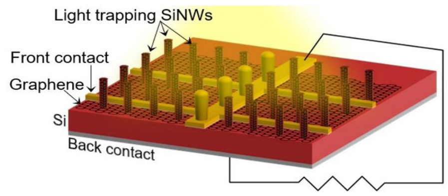

Fig. 1 Illustrations of Gr/SiNW Schottky junction solar cell with light trapping SiNWs surrounded by multilayer Gr sheet for increased carrier collection.

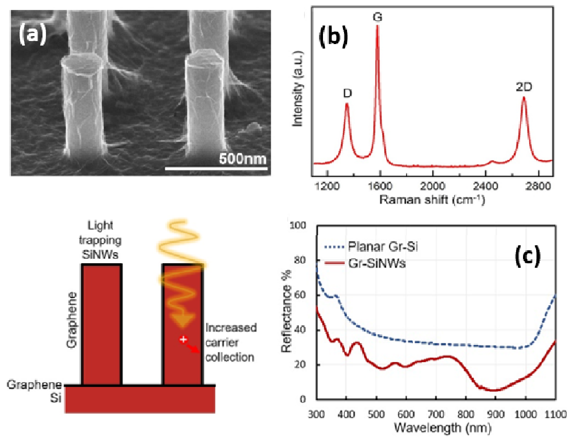

Fig. 2 (a) SEM image of SiNWs covered in Gr, (b) Raman spectrum of pristine Gr sheet on Gr-SiNW solar cell device, and (c) reflectance spectra of Gr on planar and SiNW surfaces.

Gr on the SiNWs after Ni and SiO_2 removal is clearly visible by its wrinkles in the SEM images as shown in Fig. 2(a). The Raman spectrum obtained from the surface of the Gr-SiNW samples displays the typical Gr D, G, and 2D peaks. The strong D and G peaks and moderate 2D peak implies a large proportion of defects or edges and multilayer Gr. The reflectance spectra of Gr on planar Si and SiNWs are shown in Fig. 2(c). The planar surface is not greatly affected by the high transmittance Gr. The Gr-SiNWs sample has lower reflectivity across the entire spectrum attributed to the light trapping properties of the SiNWs. The photovoltaic characteristics of the best pristine Gr-SiNW sample and planar sample will be discussed on site.

[1] S. Wallace, *et al.*, Nanoscale Adv., **2** [12] (2020) 5607-5614. [2] S. Wallace, *et al.*, Nanoscale Adv., **2** [4] (2020) 1718-1725.