Epitaxially Grown MoS_2/Graphene Hetero-structures for Phototransistor Applications

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We have demonstrated large-area and uniform graphene growth directly on sapphire substrate by using CVD. With the graphene/sapphire sample as the new substrate, epitaxially grown MoS_2/graphene hetero-structures can be achieved by sulfurizing pre-deposited Mo films on the new substrate for phototransistor applications. With mixture gas flow ethane, Ar and H_2, four samples with different growth parameters shown in Fig. 1 (a) are prepared at 1100 °C on sapphire substrates. As shown in the SEM images (Fig. 1 (b)), scattered graphene flakes (Sample A) will gradually form a complete graphene film (sample C) with increasing growth pressures. To avoid the additional carbon clusters, Sample D with a decreasing growth time 90 min is prepared. The lowest D/G peak ratio is also observed for Sample D on the Raman spectra (Fig. 1 (c)). The higher 2D peak intensity to the G peak also suggests that a mono-layer graphene is obtained. The I_D-V_{GS} curve of the graphene transistor fabricated by using the graphene film is shown in Fig. 1 (d). The derived hole mobility 435.9 $cm^2 \cdot v^{-1} \cdot s^{-1}$ of the device is compatible with the graphene films grown on Cu foils. With the optimized direct growth graphene on sapphire substrates, MoS_2 films are fabricated by sulfurizing pre-deposited Mo films with two different thicknesses on the graphene/sapphire substrate. The Raman peak differences (21.53 and 23.38 cm^{-1}, Fig. 2 (a)) and the cross-sectional HRTEM images (Fig. 2 (b)) show bi-layer and tri-layer MoS_2 are obtained for the two samples [1]. After growth, the large-area and uniform MoS_2/graphene films (Fig. 2 (c)) are transferred to a 300 nm SiO_2/Si substrate, and fabricated into bottom-gate transistors. With the graphene as the carrier transport path, photo-excited electrons in the MoS_2 absorption layers are attracted by the positive drain voltage and form Dirac point shifts after light irradiation. The Dirac point shifts are 16 V (Fig. 2(d)) for bi-layer and 20 V (Fig. 2 (e)) for tri-layer MoS_2 photodetectors, respectively. The results indicate that with increasing MoS_2 layers, the photocurrent increases.

References

[1] C. R. Wu *et al*, Nano Lett., 16 (2016) 7093.

Figures

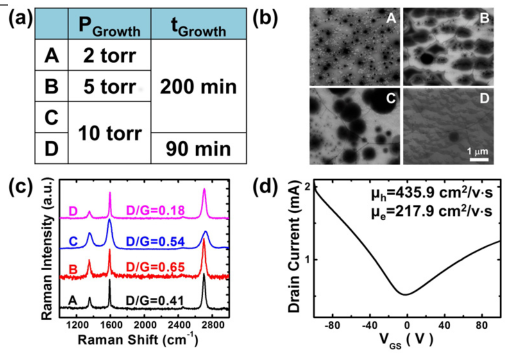

Figure 1: (a) The growth parameters, (b) SEM images and (c) Raman spectra of the four samples. (d) The I_D–V_{GS} curve of the graphene bottom-gate transistor at V_{DS} = 1 V.

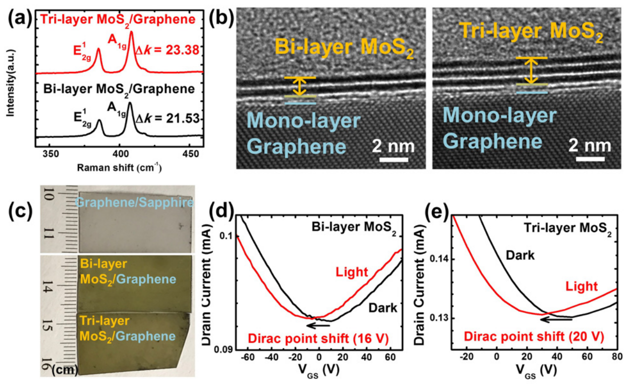

Figure 2: (a) The Raman spectra, (b) the cross-sectional HRTEM images and (c) the pictures of the bi-layer and tri-layer MoS_2/graphene samples. The I_D–V_{GS} curves of the (d) bi-layer and (e) tri-layer MoS_2/graphene phototransistor under dark and light irradiated conditions at V_{DS} = 1V.