Direct growth of patterned graphene on dielectric and flexible substrates catalyzed by a sacrificial ultrathin Ni film

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Abstract

Direct deposition of graphene on substrates would avoid costly, time consuming and defective transfer techniques. In this paper we used ultrathin films of Ni, with thickness ranging from 5 to 50 nm, as a catalytic surface on glass to seed and promote chemical vapor deposition (CVD) of graphene. Different regimes and dynamics were studied for various parameters including temperature and reaction time. When a critical temperature was reached ($T_{dewetting}$), Ni films retracted and holes formed that are open to the glass surface, where graphene deposited. As the temperature raised, dewetting continued leading to formation of metal nanoparticles and large graphene surface coverage. This growth mechanism of graphene on UTMF Ni was demonstrated in this work for temperatures within 700-1000ºC.
After CVD, the residual Ni can be etched away and the glass substrate with graphene regains maximum transparency (>90%). As examples, Fig. 1(a) shows the evolution of visible appearance (pictures) of Sample A (5 nm, 900ºC), Sample B (50 nm, 700ºC) and Sample C (50 nm, 1000ºC) after each process step: (first column) Ni as-sputtered, (second column) after graphene deposition and (third column) after Ni removal. This effect is also confirmed in graphs of Fig. 1(b) and Fig. 1(c), where the transmittance and absorbance values at 550 nm are plotted before and after Ni removal. All the results confirm a significant recovery of the samples' transmittance, in particular sample B with only a residual absorbance of about 3%, very close to the theoretical value of SLG (2.3%). In this way we could directly grow high quality single layer graphene even at temperatures as low as 700 ºC. The proposed technique has thus the potential to widen the range of substrate materials over which graphene can be directly grown. In the paper, this was demonstrated by depositing graphene patterns on ultrathin, 100 µm thick, sheet of glass with 670 ºC strain point, particularly suitable for flexible electronic and optoelectronic devices (Fig.2). Graphene was found to be continuous after Ni removal as indicated by SEM characterization (Fig. 2 (c,g-h)) with sheet resistance (Rs) values around 2 kOhm/square, similar to those reported in literature for transferred CVD graphene.

References

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Figures

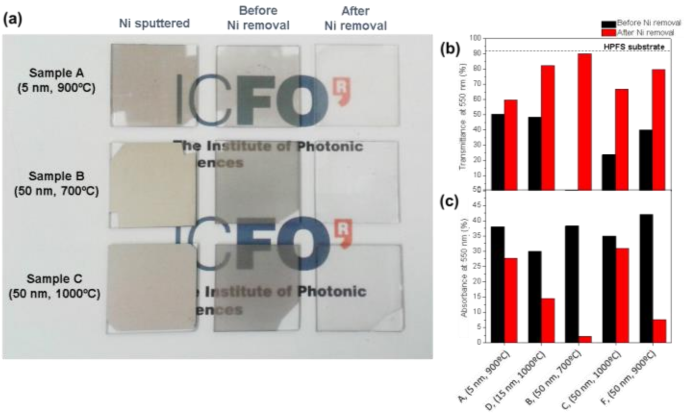

Fig. 1 (a) Picture of Sample A, Sample B and Sample C (Ni 5 nm at 900ºC, Ni 50 nm at 700ºC and 1000ºC, respectively) as deposited (first column), after graphene growth (second column) and after Ni removal (third column). (b-c) Transmittance and absorbance values at 550 nm of the best quality samples before (in black) and after (in red) Ni removal.

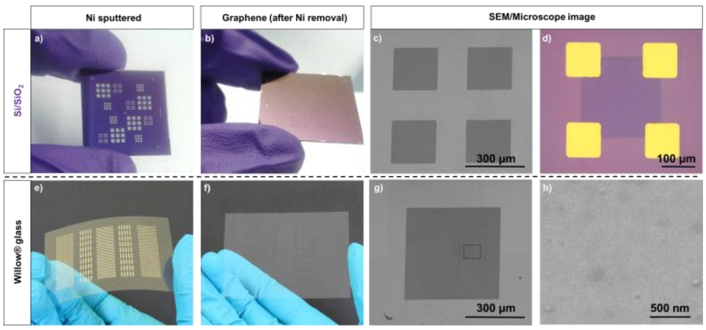

Fig. 2 Optical images of Ni 50 nm UTMF patterned on Si/SiO_2 and Corning® Willow Glass substrates in square shapes of different size (a,e) as deposited via sputtering and (b,f) after Ni removal when graphene is deposited in the same condition as Sample B (50 nm, 700ºC). SEM images in (c, g-h) show high quality graphene squares after Ni removal with absence of any metal residues and holes for both substrates. Au electrodes for Van der Paw electrical measurements are shown in (d).