Synergistic Effects of CVD Parameters on Low Temperature Growth of Graphene

Jun Jiao, Otto Zietz, Sam Olson, Joshua Tracy, Brendan Coyne

Department of Mechanical and Materials Engineering, Portland State University, 1930 SW 4th Ave., Portland, OR, 97201, USA

jiaoj@pdx.edu

Graphene's superior properties make it an attractive material for applications in a wide variety of research and manufacturing fields. For applications requiring growth of continuous graphene films directly on designated substrate surfaces as opposed to transferred or integrated in aqueous platelet forms, the synergetic effects of growth parameters, including the reaction temperatures, catalyst configuration, and thickness during the chemical vapor deposition (CVD) process, play a critical role. Current CVD or inductively coupled plasma CVD (ICPCVD) processes use thick (150–2,500 nm) catalysts and require temperatures exceeding 600°C to produce graphene. Several reports suggest that as CVD synthesis temperatures are reduced, Ni catalysts with small Au inclusions are capable of producing monolayer graphene [1-2]. This possibly is due to the increased catalytic activity of Ni and the ability of Au to limit the presence of multilayer portions of the graphene film [1]. However, this mechanism relies on a thick Ni-Au catalyst (550 nm–2.5 μm) where the bulk acts as a reservoir for adsorbed carbon, enabling surface growth to complete prior to bulk saturation and multilayer graphene formation. If the benefits associated with direct, continuous graphene film inclusion are to be realized, catalyst thicknesses must be reduced such that the desired properties of graphene are not diminished by a catalyst layer 2–3 orders of magnitude thicker than the resultant graphene film. The research presented here demonstrates a method of using Ni-Au and Ni-Cu catalysts with thicknesses between 1 nm and 50 nm (Figure 1) to control and minimize the carbon adsorbed in the catalyst, utilize plasma enhanced CVD to promote surface growth, and identify avenues for graphene synthesis at temperature ranges from 450°C to 500°C. This may allow the semiconductor industry to directly incorporate graphene on desired substrates as diffusion barriers during device fabrication. We discuss here the synergistic relationships between catalyst alloy content, thickness, deposition technique, synthesis temperature, and the resultant graphene film characteristics [3].

References

[1] R. Weatherup *et al.*, *ACS Nano* **6** (2012) 9996–10003.

[2] S. Olson, *et. al*, submitted to Microscopy and Microanalysis Conference, Baltimore, MD, August 5–9, (2018).

[3] This research is supported in part by the National Science Foundation, Oregon Metal Initiative, and Intel Corporation.

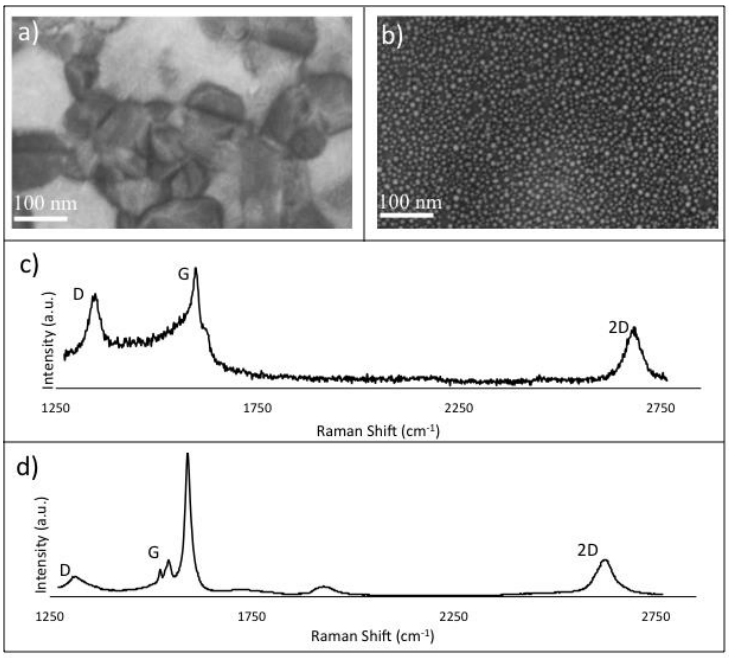

Figure 1: SEM micrographs of (a) 50 nm and (b) 1 nm catalysts post-450°C growth with the corresponding Raman spectra of the graphene grown on (c) 50 nm and (d) 1 nm catalysts.