Copper nanoparticle-assisted etching of graphene layers

Jaewoo Park, Paul Bazylewski, Arash Akbari*, Sabastine Ezugwu, Reg Bauld, and Giovanni Fanchini

Physics & Astronomy, University of Western Ontario, 1151 Richmond St, London ON N6A 3K7, Canada
*Present address: Université de Sherbrooke, 2500 boul. de l'Université, Sherbrooke, QC J1K 2R1, Canada

jpark627@uwo.ca

Abstract
It has been demonstrated that metal etching by strong acids in the presence of graphene oxide and graphene layers promotes a certain degree of additional oxidation of the carbon backbone, breaking some C=C bonds, with the formation of C=O and C-OH groups.[1,2] If metallic nanoparticles on graphene are used for this oxidation process,[3] pores may locally form in the correspondence of locations at which C=C bonds are broken. At higher concentration of metallic nanoparticles, or when nanoparticles adhere more strongly to graphene, etching involves the complete removal of the graphene layer.[4] In this presentation we will review two distinct case studies of copper nanoparticle (Cu-NP) assisted etching of graphene, which offer a complementary vision of this startling material.
In the first study (**Figure 1**, [4]) Cu-NPs grown on graphene films by radio-frequency sputtering adhere well on flat graphene surfaces, but not on graphene wrinkles and ridges. By etching these Cu-NP's in nitric acid, we can remove the largest portions of flat graphene flakes, leaving behind only ridges and wrinkles as individual graphene nanoribbons (GNRs). Two classes of GNRs are formed in this way: wide GNRs from planar ridges and narrow and straight GNRs from vertical wrinkles.
In the second study (**Figure 2**, [3]) thermally evaporated Cu-NPs weakly adhere on graphene thin films and their etching in nitric acid leads to porous graphene-based membranes offering energy-efficient water filtration at relatively low differential pressures (down to 30 kPa) while still exhibiting high performance in terms of adsorption of metal ions at the part-per-million level.

References

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[3] J. Park, P. Bazylewski, G. Fanchini, *Nanoscale*, **8** (2016) 9563
[4] J. Park, A. Akbari, S. Ezugwu, R. Bauld, G. Fanchini, *Acta Materialia*, **107** (2016) 96

Figures

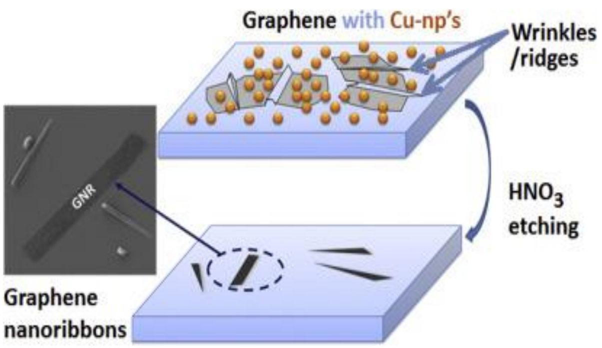

Figure 1 - Etching of Cu-NP's grown by radio-frequency sputtering on graphene , leaving behind wrinkles and ridges as graphene nanoribbons.[4]

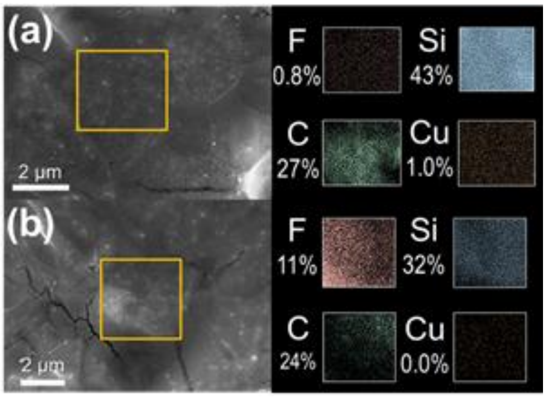

Figure 2 - Etching of Cu-NP's grown by thermal evaporation on a graphene thin film on Teflon^{TM} substrate: (a) SEM prior to and (b) after etching, which leaves behind a nano-porous graphene-based material suitable for water purification at low differential pressures. The higher detection rate of fluorine from Teflon^{TM} substrate is a consequence of higher sub-nanoporosity[3]