Scribing graphene circuits

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Ten years after the first graphene flakes were obtained by micromechanical cleavage method [1], this promising material still has not found any large-scale industrial application. In contrast, a countless variety of fabrication methods have been demonstrated for the production of graphene sheets of different quality, size and cost. This imbalance between the raw material availability and its practical use is threatening the bright future of graphene and turning it into the *graphene bubble*.

We have explored the direct fabrication of graphene patterns by laser-assisted reduction of graphene oxide (GO), see Fig. 1(a) [2]. This method has many advantages over its counterparts, i.e. cheap, repeatable, and easy to implement in mass production … but its distinctive characteristic is the possibility to produce, without any mask, large graphene structures with micrometer resolution, as shown in Fig 1(b). While the quality is still limited by the purity of the starting GO solution (see Fig. 1(c)), the conductivity of the laser-scribed graphene is comparable, or even superior, to that of graphene sheets obtained with CVD methods, as shown in Fig. 1(d). A broad set of electrical results will be presented, including also the correlation between current noise spectral density and the graphene quality. We will disclose the path for future material optimization, focusing the discussion on flexible conductive structures.

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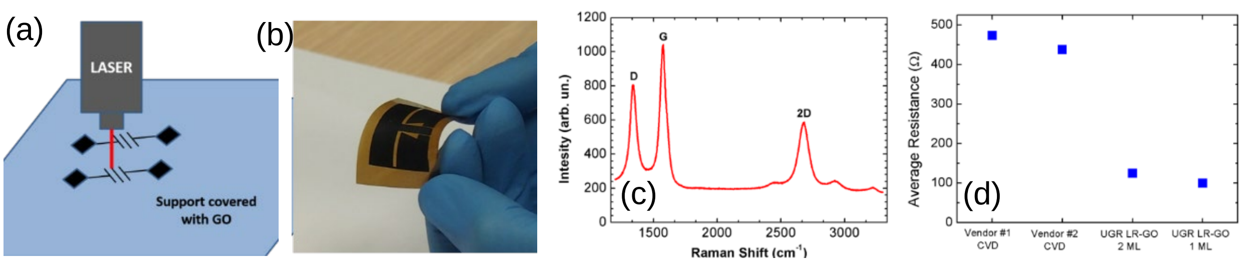

Fig. 1. (a) Graphene oxide-covered substrate patterned locally with a 780 nm laser at 40 mW to reduce GO to graphene locally; (b) prototype of a patch antenna made of reduced GO on a flexible PET substrate; (c) Raman spectrum of the multilayer graphene, with D-band indicating defects; (d) averaged four-point resistance of 1x1 cm graphene samples comparing CVD and laser-scribed reduced GO graphene produced at Univ. of Granada (from two different GO densities).

1. K. S. Novoselov, A. K. Geim, S. V. Morozov, *et al.*, "Electric field effect in atomically thin carbon films", *Science* **306**, 666 (2004).
2. Y. Zhou, Q. L. Bao, B. Varghese, *et al.*, "Microstructuring of graphene oxide nanosheets using direct laser writing", *Adv. Mater.* **22**, 67 (2009).