Investigation of contacts between metal and few layer graphene using focused ion beam cross-sectioning

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Single-layer graphene and few-layer graphene (FLG) have attracted recently major attention of the research community due to unique physical-chemical properties, with many potential applications in microelectronics [1,2]. Systematic study of characteristics of graphene, as well as fabrication of graphene or FLG based devices, requires development of reliable technologies for successive growth or deposition, manipulation, contacting, processing and measurements of electrical properties of FLG or individual graphene layers. In particular, metal-graphene contacts play a critical role in graphene-based electronics [1]. For the experimental study of FLG-metal contacts formation, first the linear test metal (W and Ti) electrode structures were prepared by a conventional lithography and lift-off technique. Then, gaps between electrodes (~1µm wide, 5 µm deep) were cut by focused ion beam (FIB) milling to prepare a pair of metal electrodes (Fig.1). FLG flakes (10-20 nm thick) were deposited from solutions between electrodes using an ac dielectrophoresis method (Fig. 2) [3, 4]. Electrical contacts between FLG and 100 nm thick metal electrodes were further improved with thermal annealing (850 °C) under high-vacuum conditions and the electrical resistances of FLG were measured, using a 2 terminals method. For cross-sectioning, the FLG flakes deposited over electrodes were protected with a Pt layer deposited firstly by electron beam followed by ion beam (Fig.3). Thinning to improve the SEM image contrast (Fig.4) and cross sectioning of contacts between FLG and metal were made by FIB to expose the structure of contacts and investigate the metal/FLG interaction (Fig. 5). The results indicate strong diffusion of the tungsten inside the graphene flake in the area of contacts, see Fig. 6. Note that the contrast varies significantly between FLG (dark), metal (light) and the area of a metal-FLG contact (intermediate brightness). The results of 2 terminals measurements show that after annealing the resistances reduced by 3 orders of magnitude, to values as low as 0.1 kΩ for gaps ~1µm (Fig. 4). Raman imaging and EDX studies are in progress, respectively, to confirm the formation of strain in the suspended FLG flake and the metal diffusion into the FLG. Theoretical studies of the properties of contacts between graphitic layers and various metals are also in progress now.

References

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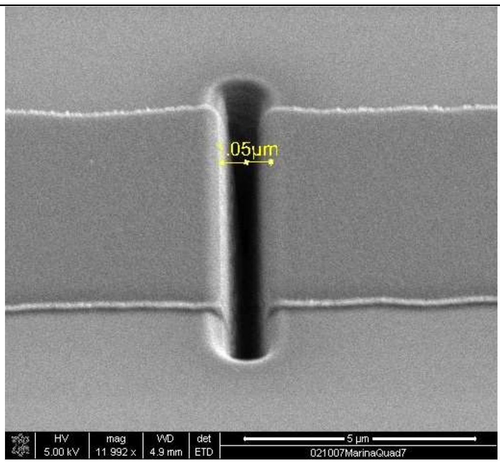

Fig. 1 – Electrodes fabricated by photolithography and cut by FIB.

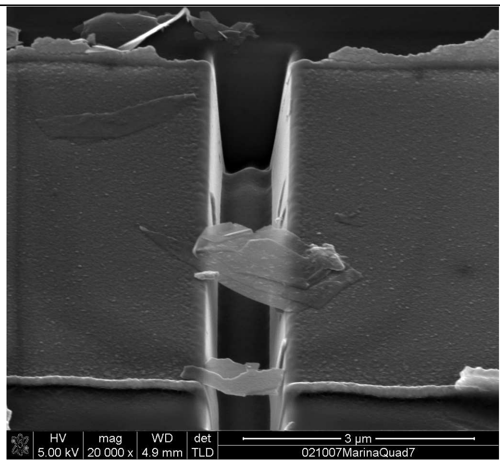

Fig. 2 – Deposition of FLG by dielectrophoresis method.

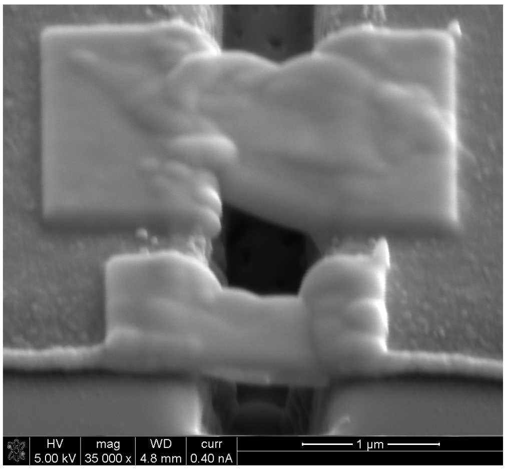

Fig. 3 – Pt layer protection over FLG.

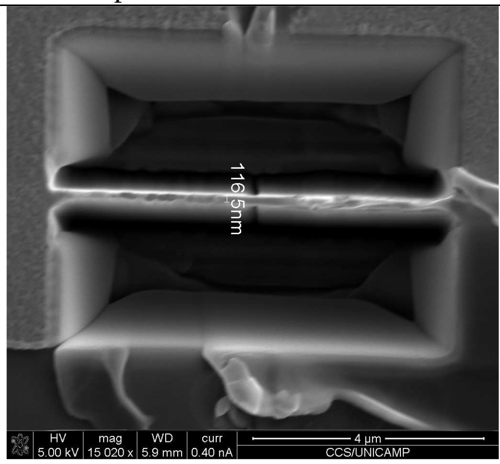

Fig. 4 –Thinning of FLG and metal-FLG contact areas.

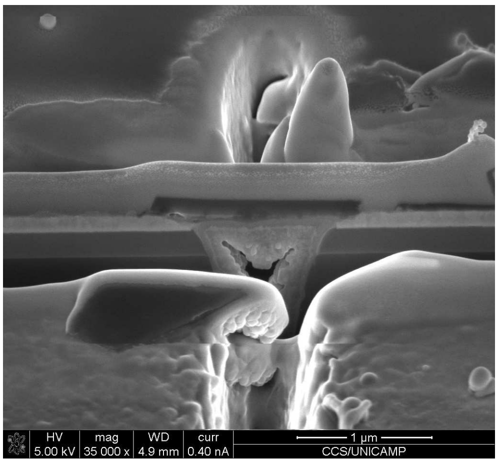

Fig. 5 – Cross section of metal-FLG contacts.

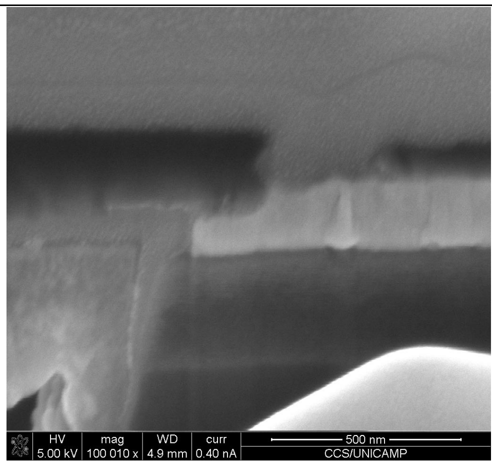

Fig. 6 – Evidence of W diffusion inside the graphene flake in the area of contacts.