Combined Focused-Electron-Beam-Induced-Deposition and Electron Beam Lithography for spin transport measurements in Graphene.

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Graphene – a single-layer hexagonal lattice of carbon atoms – has recently attracted a lot of attention in the scientific community, in particular after the observation of exotic transport phenomena such as the anomalous quantum Hall effect [1]. Moreover, a very high [2] and tunable conductivity at room temperature together with a spin polarized transport up to room temperature [3] makes graphene a promising material for applications in Spintronics. Investigation of the spin polarized transport in graphene becomes consequently of the key importance. This requires a clear distinction between charge and spin signals. In that sense, a “non-local” technique has been used by Tombros et al. [4] combined with the use of magnetic contacts.

The drawback of the commonly-used technique for fabricating electrical contacts (electron beam lithography, EBL) is that for the spin polarized transport measurement one needs an additional tunnel barrier between the contact and the sample in order to adjust their respective spin resistances. This increases the complexity of the lithography process and may possibly affect physical properties of graphene itself.

We have recently discussed [5] the influence of the FEBID on graphene. We showed that the deposition process, although up to some extent harmful for this material, is a good way of preparing complex graphene based devices. In our recent work (poster contribution by J. Fan et al.) we focus on the lithography (both Electron Beam and UV) processes.

Here, we present a complete procedure of fabrication of a fully operative graphene based device with magnetic electrodes, suitable for the investigation of spin transport. In our approach graphene flakes are obtained by mechanical exfoliation and deposited on thermally oxidized n-doped Silicon wafers (Au covered on the back-side for easy application of gate voltage). All the samples are first identified with optical microscope, and the most promising flakes are carefully checked by Raman spectroscopy. As a next step we perform EBL followed by Ti/Au evaporation and lift-off. In order to accomplish the device fabrication we put Cobalt electrodes by FEBID on top of graphene and connected to recently prepared connections. The Co electrodes have width varying from 100 nm to 1 μm assuring that the switching fields are different for each electrode thus allowing a study of spin polarized transport while sweeping applied magnetic field.

In Figure 1 we present the FEBID of Co that allows a very precise fabrication of magnetic electrodes on graphene flakes of size down to a few microns with well controlled dimensions.

Figure 2 presents a completed device optical image (left) and a close-up of the central part of the device, where the EBL and FEBID fabricated connections meet. Again one can appreciate a high accuracy of this two-step process allowing a nice combination of the two common nano- and microfabrication methods.

References

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Figures

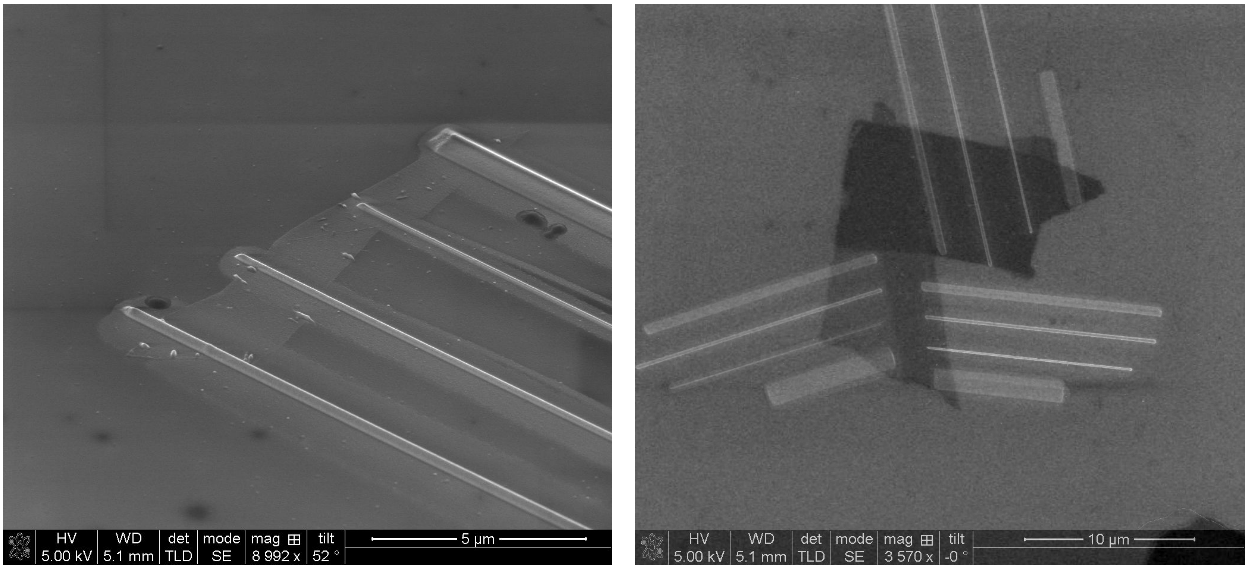

Figure 1. Left: SEM image of a graphene flake with FEBID deposited Co electrodes with different width for a non-local spin transport measurements (see text for details). Right: a proof of a high precision of the FEBID process – single layer, bilayer and multilayer graphene flake regions connected each with own set of four electrodes.

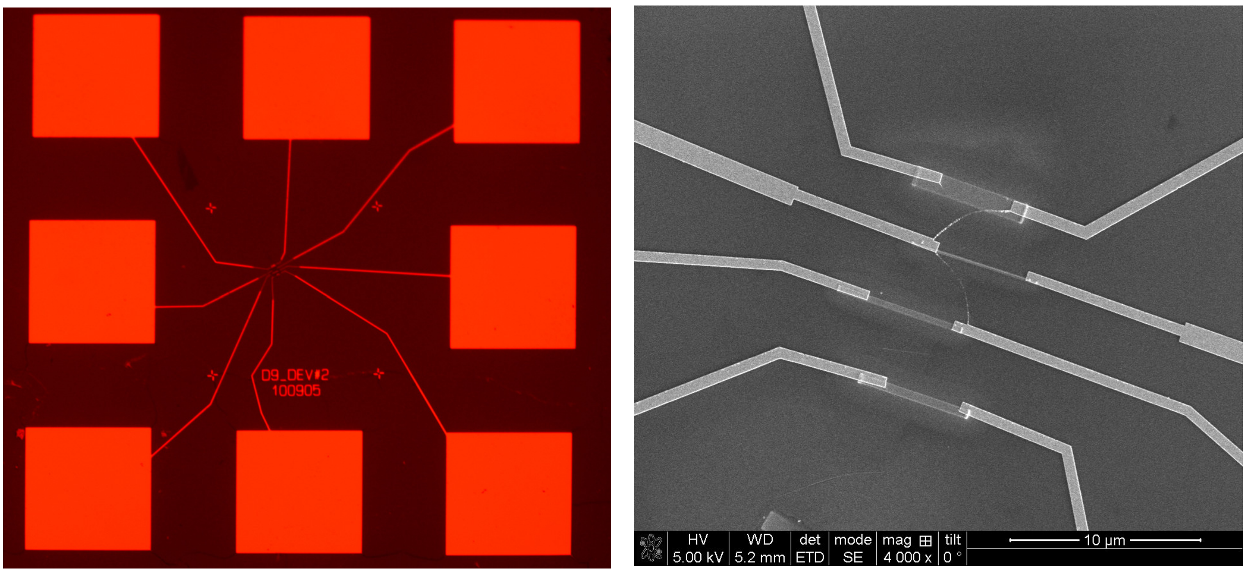

Figure 2. Left: optical microscope image of a complete graphene device for spin transport measurements. Central part of the device is presented in the SEM image on the right. Co FEBID electrodes are made on top of graphene flake (not visible in the photo). The rest of connections as well as large μWelding pads are fabricated with EBL and Ti/Au evaporation.