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Single-step growth of graphene and electrical contacts on SiC

Recent years have seen the emergence of two-dimensional materials that can be used as building bricks for novel nanoelectronics [1]. But an important issue for such technological developments is the contacting of atom-thick layers. The electrical contact suffers from the poor coupling between the 2D surface and the 3D metal and can be further degraded by the contamination during the lithography processes used to define the metallic electrodes.

We present here an original way to realize in a single step the growth of epitaxial graphene on silicon carbide (SiC) and of the electrical contact with niobium carbide (NbC) or tantalum carbide (TaC) electrodes [2]. The samples were realized by depositing niobium or tantalum (Nb or Ta) electrodes on the bare SiC substrate using UV optical lithography processes to define their geometry. After this, a standard graphene growth is performed in a graphite crucible in an induction furnace. During the thermal annealing, the metal reacts with the SiC to from a carbide (NbC/TaC). At the same time, few graphene layers (FGL) are grown on the whole sample establishing a bridge between the carbide electrodes as shown on Figure 1a.

The resulting contact resistance was investigated by Transfer Length Measurements (Figure 1b). This allows to estimate the contact resistance to Rc=180 Ω.µm which competes with the best reported contact resistance to multilayer graphene [3].

Since the carbide electrodes are superconducting with relatively high critical temperatures (12 K for the NbC and 10.3 K for the TaC) due to their high stoichiometry [4], we have realized Josephson junctions using the process described above. Figure 2 shows the current voltage characteristics of such junctions (for NbC electrodes in panel a and TaC electrodes in panel b). Both show Josephson supercurrents which persist up to 1.9K for NbC and 3.3K for TaC.

Implementing the presented simultaneous growth of the graphene and the electrical contacts could significantly simplify the realization of large-scale graphene circuits. It also provides access to a whole new family of metallic carbides with interesting properties which could be useful for graphene technology when new functionalities and low electrical contact resistances are needed.

References

[1] Li et al., Materials Today, 19 (2016) 322
[2] Le Quang et al., Carbon, 121 (2017) 48
[3] Ito et al., Applied Physics Express, 8 (2015) 025101
[4] Giorgi et al., Physical Review, 125 (1962) 837

Figures

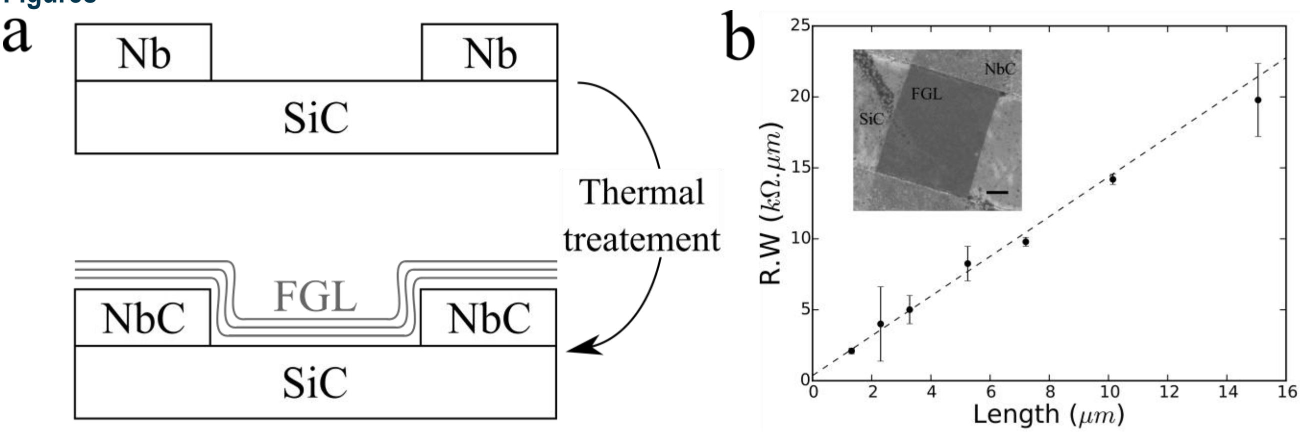

Figure 1: a) Process used for the sample realization. First, Nb electrodes are defined using standard lithography processes. Then, a thermal treatment allows to grow few graphene layers (FGL) and to transform the Nb in NbC with electrical contact between the two b) Resistance times width of the devices as function of the length. For each length, 4 to 5 devices of different widths were used to determine the plotted mean value with standard deviation as an error bar. The resistance was measured at room temperature. The linear fit of the experimental data (dashed line) gives a contact resistance of 180 Ω.µm. Inset - Scanning electron microscope image of a ribbon of dimensions (5.2 x 4.4) µm². The scale bar is 1 µm.

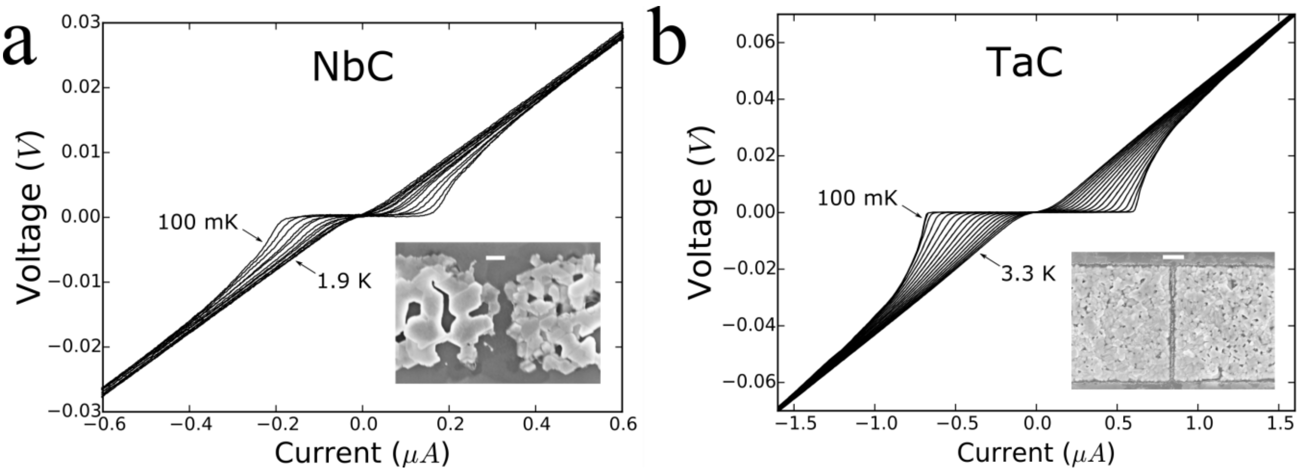

Figure 2: a) Temperature dependence of the current-voltage characteristic of the NbC junction (from T=100 mK to 1.9 K in steps of 150 mK) shown in inset (SEM picture with a scale bar of 200 nm). b) Temperature dependence of the current-voltage characteristic of the TaC junction (from T=100 mK to 3.3 K in steps of 200 mK) shown in inset (SEM picture with a scale bar of 400 nm).