Supporting Information

Sub-micron size Schottky junctions on as-grown monolayer epitaxial graphene on Ge(100): a low-invasive scanned-probe based study

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S1: Study of the C-AFM tip/graphene electrical contact

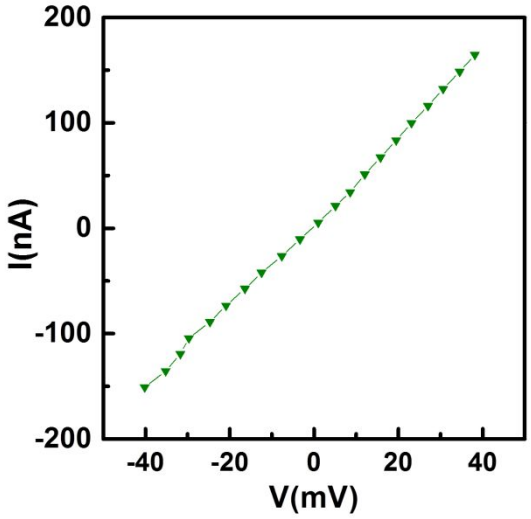

Figure S1. *I-V curve obtained using the conductive AFM tip as one of the contact electrodes to the graphene layer. The second contact layer is a few millimeters far from the C-AFM tip and is made of a large-area silver-paint drop showing very low contact resistance.*

As visible from the linear behavior, the C-AFM tip forms an ohmic contact with the graphene layer. The calculated resistance for this curve is of 250kΩ, while typical resistance values found are in the range 10^5-10^6 Ω.

S2: I-V curve for the Pt tip / Ge junction.

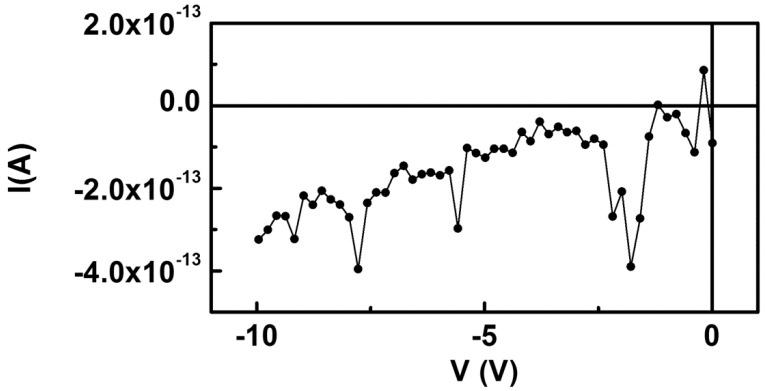

Figure S2. *I-V curve collected for the junction between the C-AFM Pt tip and the Ge substrate of the epitaxial graphene sample after graphene removal in oxygen plasma. Similar behaviour is obtained for Ge substrates thermally treated as for the graphene growth but without methane in the gas mixture.*

S3: I-V analysis of a "large-area" graphene/Ge diode device ~300μm wide

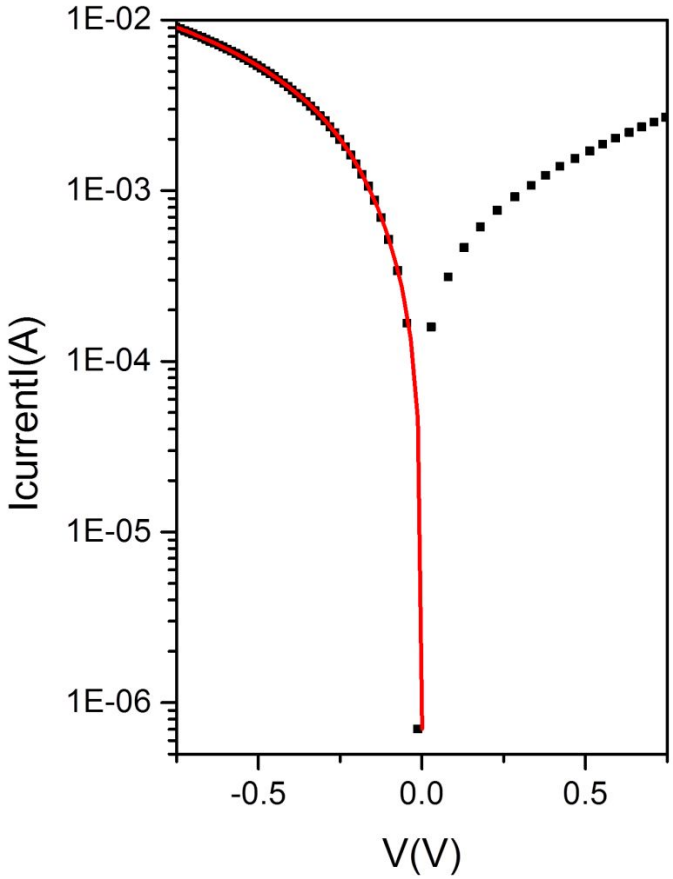

Figure S3. *I-V curve collected on a diode device having both ohmic contact and junction area with circular shape and diameter of 300μm. The device was obtained by depositing Ti/Au (50nm/200nm) ohmic contact to graphene on the as grown epitaxial graphene/Ge sample followed by plasma etching to fabricate a mesa structure. As visible, a rectifying behavior similar to that obtained for the A-B-C diodes is found. The solid red curve is the fitting curve for the forward bias region.*

The equation used in the best fitting procedure for evaluating the diode parameters is the same used for the A-B-C diodes with an additional term which includes a shunt resistance $R_{//}$. This term takes into account deviations due to parallel conductive paths which are reasonably more relevant for such large contact area on the epitaxial graphene film:

$$-I_0\left(e^{\frac{-e(V-R_sI)}{\eta kT}}-1\right)+\frac{V}{R_{//}}-I=0 \qquad \text{(eq SI.1)}$$

The resulting device and Schottky barrier parameters are reported in the following table and are quite in agreement with those obtained for the A-B-C diode devices discussed in the main text.

Implicit function fitting parameters				
η	I_0 **(A)**	φ_B **(eV)**	R_s **(Ω)**	$R_{//}$**(Ω)**
1.59	*6.44* 10^{-5}	*0.442*	*62*	*467*

Table S1. *Device parameters evaluated on a 300μm wide circular diode fabricated on graphene/Ge sample.*

S4: Hall measurements on thermally treated Ge samples

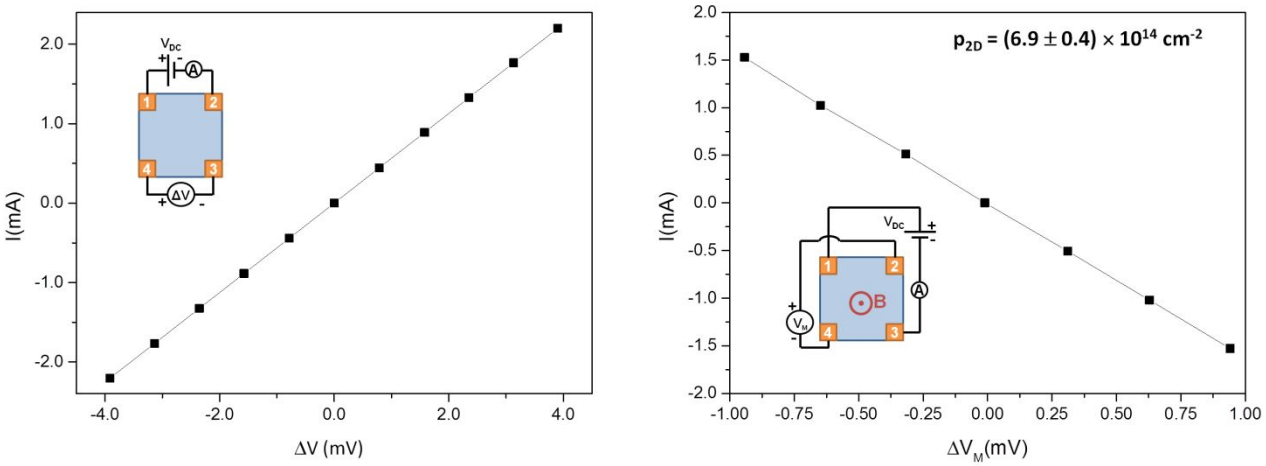

Figure S4. *The I-V curves show the resistivity and Hall measurement (in the Van der Pauw configuration) collected on an epitaxial graphene/Ge sample after graphene removal in oxygen plasma.*

A survey on several samples, including i) Ge substrates processed as for the graphene growth but without methane in the gas mixture and ii) epitaxial graphene/Ge samples after graphene removal in oxygen plasma, showed a p-type Hall behavior with sheet carrier density p(2D) within the range 8.0 10^{13} - 6.9 10^{14} cm^{-2}. The corresponding bulk carrier density is 1.3 10^{15} - 1.1 10^{16} cm^{-3}, having considered an homogenous distribution of p-type states within the whole sample thickness (see Figure S4).

S5: Probing the uniformity of p-type conversion in thermally treated Ge samples

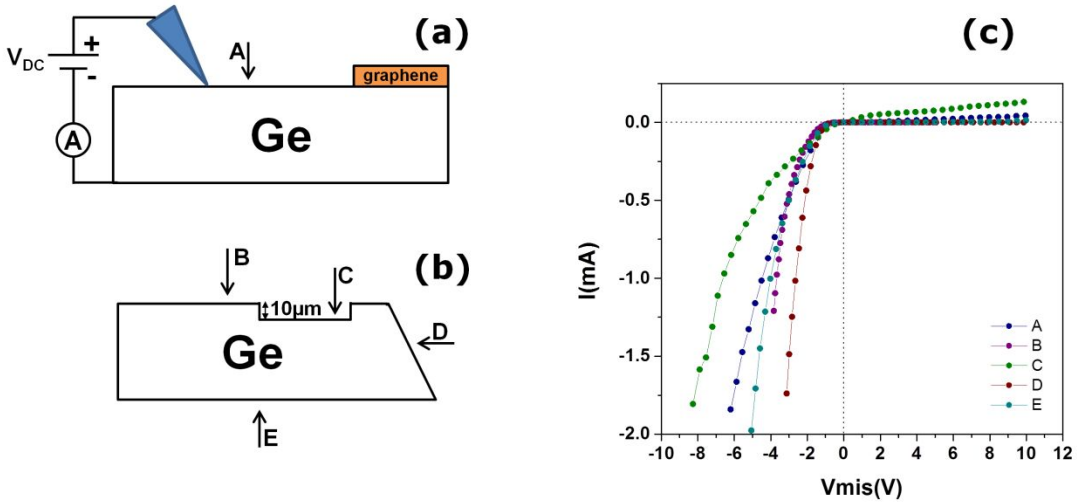

Figure S5. *Schematic of the analyzed samples and I-V measurements. (a) epitaxial graphene/Ge sample after removal of the graphene layer from a large part of the sample by using oxygen plasma etching; (b) Ge sample treated as for graphene growth but without methane in the gas mixture; (c) representative I-V curves corresponding to the measurements sites shown in the schematics of panels (a) and (b).*

In order to probe qualitatively the extent of the p-type Ge conversion we performed I-V measurements using the W micro-needle probe of a probe station as metal contact to the sample surfaces in several sites and at different depths. Two kinds of samples were considered:

- epitaxial graphene/Ge sample after graphene removal in oxygen plasma;
- same substrate as for the graphene/Ge growth, processed in the same growth conditions but without methane in the gas mixture.

The measurements circuital configuration is shown in the schematic reported in panel (a) and was used for all the kinds of samples investigated.

The sites investigated are: bottom and top surfaces (see for example arrows with letters A, B and E); the surface of 10 μm deep pits produced by reactive ion etching (see for example arrow with letter C); several points on the cleaved sidewalls (see for example arrow with letter D).

All the set of I-V curves reported in panel (c), representative of the probing sites described above and identified with the capital letters, have the characteristics of a p-type Schottky contact.

S6: Analysis of a set of I-V curves collected within a single graphene/Ge Schottky diode

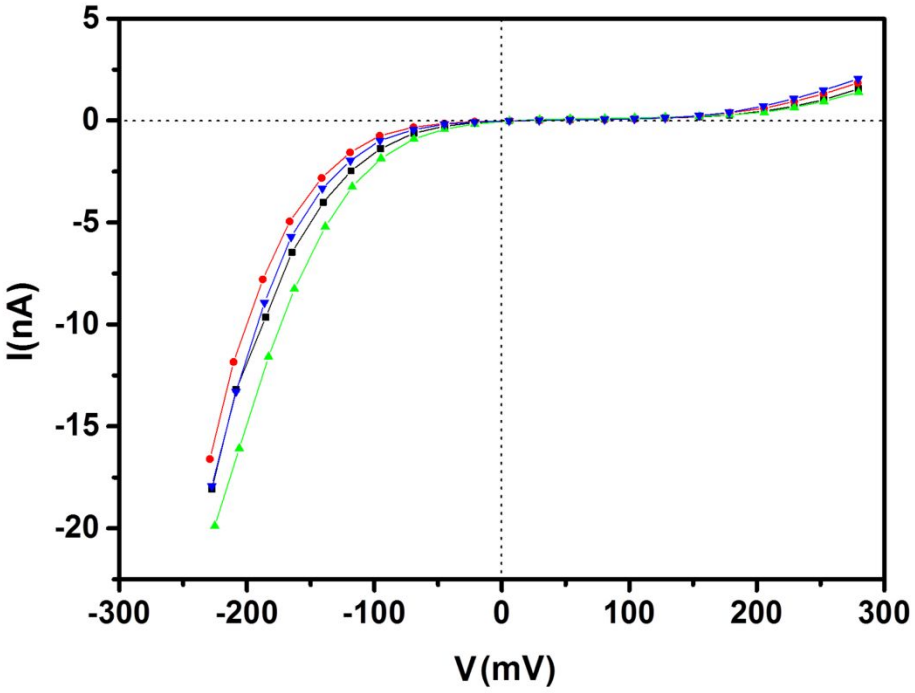

Figure S6. *Set of I-V curves collected in different sites of the graphene patch area of diode B.*

In the following Table SI.II the fitting parameters and junction physical quantities resulting from implicit function best fitting procedure are shown referring to the I-V curves measured on diode B reported above in the Figure S6.

Implicit fitting parameters			
η	I_0 *(A)*	φ_B *(eV)*	R_s *(Ω)*
1.44	*8.39 10^{-11}*	*0.461*	*1.76 10^{6}*
1.34	*1.39 10^{-10}*	*0.448*	*2.85 10^{6}*
1.71	*1.90 10^{-10}*	*0.440*	*1.70 10^{6}*
1.53	*8.19 10^{-11}*	*0.461*	*1.37 10^{6}*

Table S2. *Fitting parameters evaluated for the four I-V curves reported in Figure S6.*