Graphenea

Measurement Protocols and Handling Instructions

Graphene Field-Effect Transistor Chip: GFET-S11

Typical Measurement Configurations

The following explains the electrical measurements that can be performed on the different devices in GFET-S11.

Van der Pauw geometry

These devices allow for 4-probe measurements in a van der Pauw geometry. This is a very common and versatile geometry specially suited for characterisation of thin-films and 2D materials. It allows for true extraction of resistivity values of materials via sheet resistance, removing the influence of the contacts and improving the sensitivity of the measurements. Precisely, as the contact area in our GFETs is orders of magnitude smaller than the graphene area, these devices should provide very accurate readings.

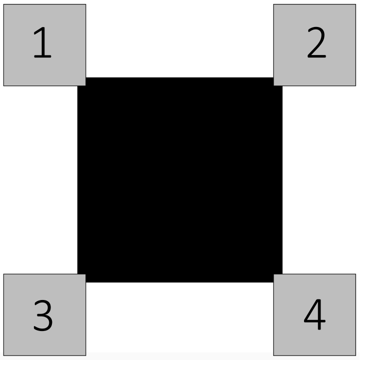

Figure 1. a) Typical van der Pauw devices with the contacts numbered clockwise.

$$R_{12,34} = \frac{I_{12}}{V_{34}},$$

Basic measurements

The sheet resistance is defined as the resistivity of a sample ρ divided by its thickness t, with units of Ω/sq. One can use Ohm's law and carry out a measurement flowing a current through electrodes 1 and 2, I_{12}, and measuring the voltage drop in the electrodes 3 and 4, V_{34}. Thus, the resistance $R_{12,34}$ would be

$$R_{12,34} = \frac{I_{12}}{V_{34}},$$

one can use this value in combination with the vdP equation to extract sheet resistance values.

$$e^{-\pi R_{12,34}/R_s} + e^{-\pi R_{23,12}/R_s} = 1$$

Reciprocal measurements

To obtain even more accurate values of R, one can use the reciprocity theorem which states that $R_{12,34}=R_{34,12}$. Thus, one can carry out two additional measurements such as

$$R_v = \frac{R_{12,34} + R_{34,12}}{2} \qquad R_h = \frac{R_{23,41} + R_{41,23}}{2},$$

and use this values in the vdP equation which becomes

$$e^{-\pi R_v/R_s} + e^{-\pi R_h/R_s} = 1$$

Reversed polarity measurements measurements

To have even more accuracy in the measurements, one can carry out reversed polarity measurements. One measure the resistance of the current flowing in both directions, cancelling out non-linear effects of second order. This is relevant when one wants to exclude thermodynamic effects that might spurious signals

$$R_v = \frac{R_{12,34} + R_{34,12} + R_{21,43} + R_{43,21}}{4}$$

$$R_h = \frac{R_{23,41} + R_{41,23} + R_{32,14} + R_{14,32}}{4}$$

one can use this value in combination with the vdP equation to extract sheet resistance values.

$$e^{-\pi R_v/R_s} + e^{-\pi R_h/R_s} = 1$$

Doping-reduction treatment

Graphene on SiO_2 is often p-doped after exposure to air due to the adsorption of water molecules and other adsorbates with the effect that the Dirac point is shifted to positive gate voltages and can cause the Dirac voltage to be located out of the recommended gate voltage range. In addition, a large hysteresis is observed between the forward and backward sweeps of a transfer curve.

Immersing the GFET chip in acetone for at least 12h reduces doping. After that, the chip should be rinsed with IPA, properly dried with an Ar or N_2 gun, and shortly introduced into the measurement equipment. In order to preserve the effectivity of this treatment, electrical characterization should be carried out in inert atmosphere or vacuum.

In addition, storage of the chips in a low humidity environment (N_2 cabinet, desiccator, or vacuum) is highly recommended.

Basic handling instructions

The graphene used in our GFETs is high-quality monolayer CVD graphene and highly prone to damage by external factors. To maintain the quality of your devices, we recommend taking the following precautions:

- Be careful when handling the GFET chip that tweezers do not make contact with the device area. Metallic tweezers should be avoided, as they can damage/scratch the chip edges/surface
- Treat the devices as sensitive electronic devices and take precautions against electrostatic discharge
- Ideally store in inert atmosphere or under vacuum in order to minimize adsorption of unknown species from the ambient air
- Do not ultrasonicate the GFET dies
- Do not apply any plasma treatment to the GFET dies
- Do not subject the GFET dies to strongly oxidizing reagents

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