# Measurement Protocols and Handling Instructions

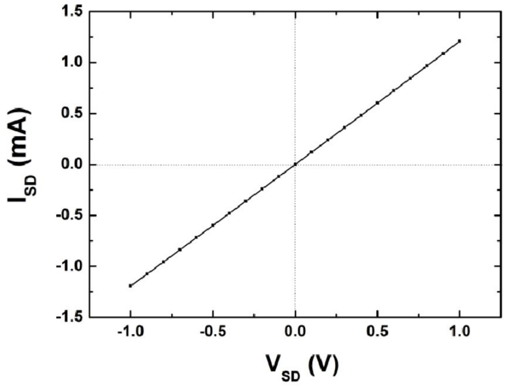
# mGFET 4x4

## Typical Measurement Configurations

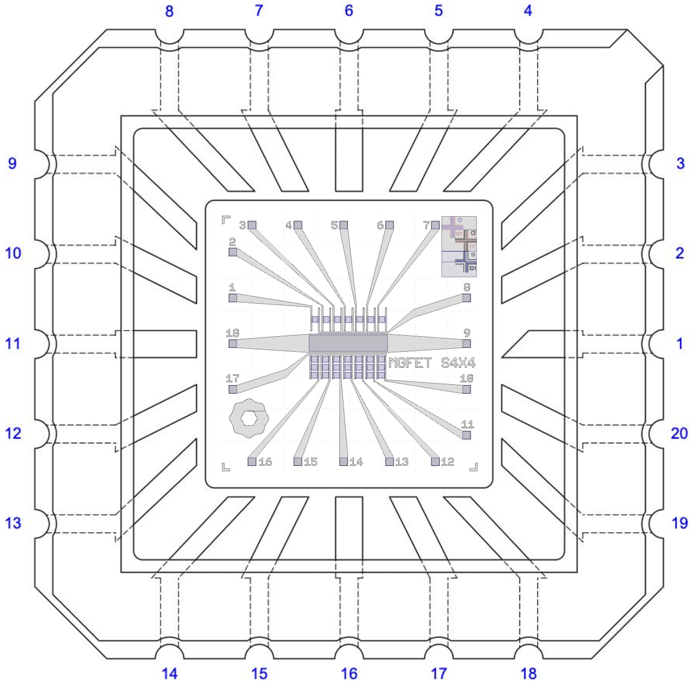
The following explains different electrical measurements that can be performed in mGFET 4x4 chips.

These devices allow 2-probe measurements:

- Source-drain voltage ($V_{SD}$): applied between the two probes (source and drain), while one of them is grounded (see Figure 1a). $V_{SD}$ enables the transport of charge carriers through the graphene channel, with an associated source-drain current ($I_{SD}$). $V_{SD}$ can be varied in order to get the desired $I_{SD}$ outcome (see Figure 1b).




*Typical output curve measured at room temperature.*




| Label | Die pad | LCC pad |
|---|---|---|
| Source 1 | 1 | 10 |
| Source 2 | 2 | 9 |
| Source 3 | 3 | 8 |
| Source 4 | 4 | 7 |
| Source 5 | 5 | 6 |
| Source 6 | 6 | 5 |
| Source 7 | 7 | 4 |
| Drain 1-7 | 8 | 2 |
| On-chip gate | 9 | 1 |
| Source 8 | 10 | 20 |
| Source 9 | 11 | 19 |
| Source 10 | 12 | 18 |
| Source 11 | 13 | 17 |
| Source 12 | 14 | 16 |
| Source 13 | 15 | 15 |
| Source 14 | 16 | 14 |
| Drain 8-14 | 17 | 12 |
| On-chip gate | 18 | 11 |

## Liquid gating

Alternatively, one can implement a 3-probe measurement. While keeping $V_{SD}$ constant, the charge carrier density of the graphene can be modified by applying a voltage to an ionic liquid in contact with the device channel. This voltage can applied in two ways:

- By an external electrode immersed in the liquid. Ag/AgCl electrodes are widely used for this purpose.
- By the non-encapsulated Au electrode located at the central area of the chip (see TDS file).

**NOTE**: Beware that solutions containing chlorine ions can react with water to form HCl which reacts/interferes with the Au on-chip electrode, creating drift. If this is the case, we recommend using an Ag/AgCl electrode.

Figure 3 shows a typical transfer curve obtained for liquid gating using the on-chip electrode.

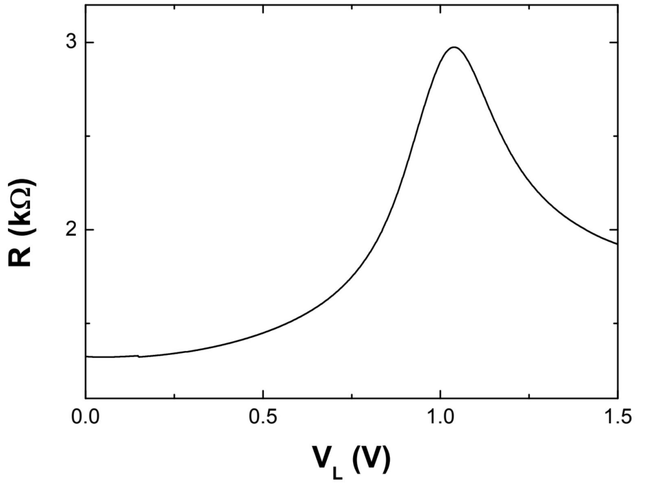



*Figure 3. Gating through Phosphate Buffered Saline (PBS, 0.001X) on a mGFET chip, using the on-chip Au electrode.*

## 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, specially during back gate measurements.

Immersing the mGFET chip in acetone for at least 12h reduces doping. After that, the chip should be rinsed with IPA, and properly dried with an Ar or $N_2$ gun. In order to preserve the effectivity of this treatment, electrical characterization via back gating should be carried out in inert atmosphere or vacuum. This treatment is also recommended for liquid gating measurements.

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 mGFETs 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 mGFET chip that tweezers do not make contact with the device area.
- 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 mGFET chip
- Do not apply any plasma treatment to the mGFET chip
- Do not subject the mGFET chip to strongly oxidizing reagents

## Device lifetime

The devices will remain conductive for a long time (at least 3 months from the moment of purchase). However, mobility variation may happen if the device is stored for a long time, especially if not stored appropriately; see handling instructions section above for recommendations.

If the device is stored in inert atmosphere and is sealed to avoid ambient contamination, mobility variation after 1 month of storage may be up to +/- 15% with respect the pristine mobility. Thus, we recommend a best use date up to 1 month after the devices are purchased.