Hydrogen Intercalated Graphene for Aqueous Solution Gated Field Effect Transistors: An In-situ Raman / Electrical Study

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Solution gated graphene field effect transistors (SGFET) are promising candidates for sensing applications and are being widely investigated. The solution in a SGFET fulfills a twofold task. It replaces the commonly used transistor dielectric and at the same time builds the carrier medium for the quantity to detect. In this work we compared hydrogen intercalated and pristine graphene SGFETs. The hydrogen intercalation method changes the carrier concentration from n-type to p-type, accompanied by an increase in carrier mobility. The use of intercalated graphene in SGFETs therefore significantly broadens the choice of graphene for specific applications.

We report novel simultaneous measurements of the electrical parameters and Raman spectroscopy of the SGFETs. In order to achieve this, we took advantage of the transparency of the 4H-SiC(0001) substrate and measured the Raman signal through the substrate, avoiding strong background signals originating from the solution. The application of a gate voltage allowed for the tuning of the Fermi level, which was monitored using both, electrical and Raman measurements at the same time. The gate sweeps showed a significant shift of the charge neutrality point (minimum in source drain current) for the hydrogenated sample (Fig. 1). This is due to the different initial carrier concentrations for the compared samples, as mentioned above. Fig. 2 displays results of the gate sweep obtained from the Raman G band fitting for the pristine sample. We observed shifts in energy and modifications of the peak width. This can be explained by changes in the electron-phonon coupling strength caused by the shifting of the Fermi level. In addition, we observed dips in the G band energy dependence (Fig. 2, arrows), corresponding to the situation when the Fermi level is tuned to E(G)/2. This is an outstanding result, since our measurements were performed at room temperature. The position of the dips allowed for the accurate calibration of the actual Fermi level shifts directly from the measurement.

The Raman spectra of the intercalated sample showed a clear G band splitting due to broken inversion symmetry, which was induced by the applied electric field perpendicular to the bilayer graphene. This illustrates the high precision of our setup concerning the controlled manipulation and investigation of optoelectronic phenomena.

In conclusion, we show novel results on SGFETs for both intercalated and pristine samples obtained using unique in-situ optical/electrical measurements. The results provide fundamental information about the electron-phonon coupling and the inversion symmetry breaking, which are key factors for future optoelectronic graphene sensing applications.

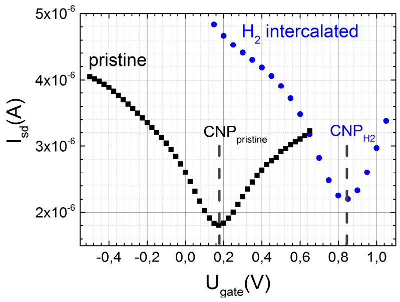

Fig. 1: source drain (I_{sd}) current as a function of gate voltage (U_{gate})

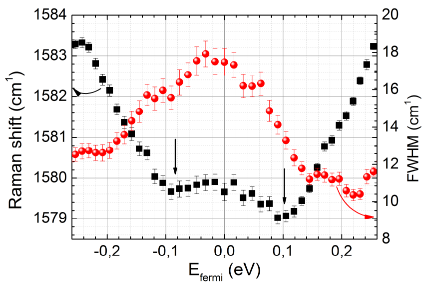

Fig. 2: *black squares:* G band energies; *red circles:* G band FWHM