

Control of Water Adsorption via Electrically Doped Graphene

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Primary CNF Tools Used: Oxford ALD FlexAL, CVC SC4500 odd/even evaporator, YES asher

Abstract:

The interaction of graphene with water molecules under an applied electric field is not thoroughly understood, yet this interaction is important to many thermal, fluidic, and electrical applications of graphene. In this work, the effect of electrical doping of graphene on water adsorption was studied through adsorption isotherms and current-voltage (IV) characterizations as a function of the Fermi level. The water adsorption onto graphene increased $\sim 15\%$ and the doping levels increased by a factor of three with a gate-to-graphene voltage of +20 or -20V compared to 0V for sub-monolayer adsorption. This change in uptake is attributed to the increase in density of state of graphene upon electrical-doping, which changes the Coulombic and van der Waals interactions. The water adsorption onto graphene is either *n*- or *p*-doping depending on the applied gate-to-graphene voltage. The ambi-doping nature of water onto graphene is due to the polar nature of water molecules, so the doping depends on the orientation of the water molecules.

Summary of Research:

Being extremely thin and thermally stable, graphene is an appealing method of surface modification [1-3]. It has been noted that water adsorption onto a supported graphene changes graphene's electronic structure. However, how water adsorption changes with altering the graphene Fermi level has never been studied experimentally [4].

We set out to test the hypothesis that the water adsorption behavior onto graphene can be tuned by electrically shifting the Fermi level, and hence the energetics of adsorption. In order to test this hypothesis, water adsorption onto back-gated graphene field effect transistors (GFETs) was studied as a function of electrical-doping via a quartz crystal microbalance (QCM) and current-voltage (IV) curve measurements.

Back-gate GFETs were fabricated onto 5 MHz AT-cut QCMs. An adhesion layer, 100 nm of Ti, was deposited onto the top electrode of the QCM via e-beam evaporation (AJA International). A 100 nm Al_2O_3 was deposited via atomic layer deposition (ALD) with trimethylaluminum (TMA) and oxygen plasma at 200°C (Oxford Flex AL) to form the dielectric onto the QCM.

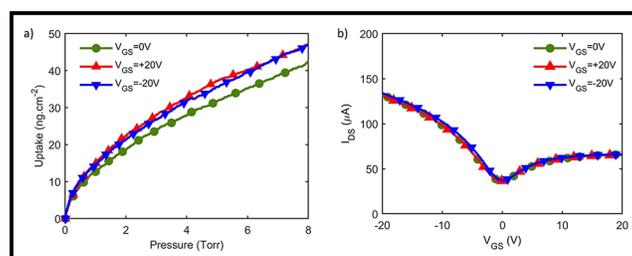


Figure 1: Adsorption isotherms were measured in an environmental vacuum chamber using the shift in the resonance frequency of the QCM upon water vapor exposure. (a) Shows the adsorption isotherms of water onto graphene for three different gate voltages: 0V, +20V, and -20V. (b) The three applied gate voltages during water adsorption induced no doping, n-doping, and p-doping, respectively.

Then, PMMA-backed CVD graphene was transferred onto the QCM. After the PMMA removal, the source and drain (5 nm Cr / 100 nm Au) were deposited on top of graphene via e-beam evaporation (AJA International), creating a 7.1 mm × 7.1 mm channel.

