# Supplementary materials

## Water adsorption on free-standing monolayer graphene with and without charge injection

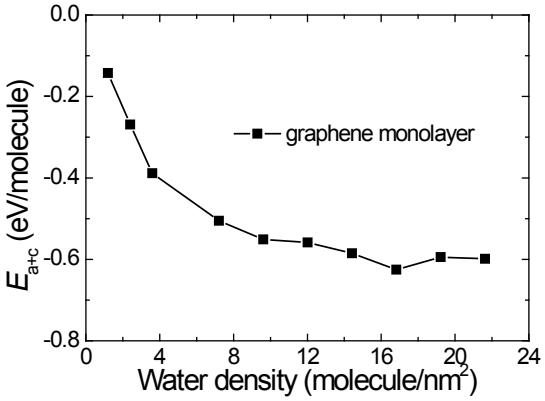


**Figure 1s.** The variation of the sum of adhesive and cohesive energy $E_{a+c}$ for water adsorbing on an uncharged free-standing monolayer graphene with water density.

The sum of adsorption and cohesive energy is calculated by $E_{a+c} = E_{wat/gra} - E_{gra} - nE^1_{wat}$, here $E_{wat/gra}$ is the total energy of relaxed water/graphene system, $E_{gra}$ is the corresponding energy for graphene, and $E^1_{wat}$ is the energy of a single water molecule and $n$ is the number of water molecules.

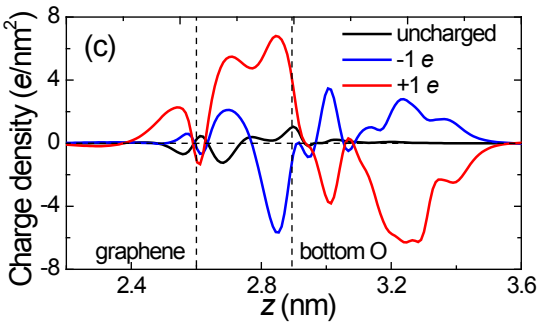


**Figure 2s.** The average charge density difference $\Delta\rho_{xy}$ along the $z$ direction for

water adsorbing on the uncharged and charged free-standing monolayer graphene.

For suspended graphene, the profiles of charge density difference shown in Figure 2s are similar to that of graphene-coated mica. The magnitude of the interfacial electron accumulation under +1*e* for the free-standing graphene is larger than that of other two graphene coating cases, leading to lower adsorption energy.

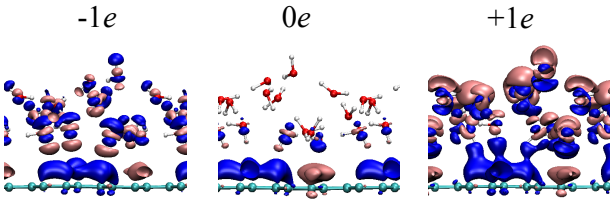


**Figure 3s.** Contour plots of the charge density difference $\Delta\rho$ [in unit of 0.005 $e/(\text{Å})^3$] of water adsorbing on the charged and uncharged free-standing graphene surface.

The range of charge density difference distributing on water at +1*e* is larger than that at -1*e*. The cohesive energies of water on the free-standing graphene are -7.99 eV at -1*e* and -7.93 eV at +1*e*, which is consistent with the distribution of charge density difference shown in Figure 3s.