

## Controlled Doping of Graphene Monolayer

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**Abstract :** We present here the experimental realization of controlled doping of graphene monolayers through charge transfer by trapping selected organic molecules between the graphene layer and underlying substrates. This charge transfer between graphene and trapped molecule leads to controlled n-type or p-type doping in monolayer graphene (MLG), depending on whether the trapped molecule acts as an electron donor or an electron acceptor. Doping controllability has been validated by a shift in corresponding Raman peak positions and a shift in Dirac points. In the transfer characteristics of field effect transistors, a significant shift of Dirac point towards positive or negative gate voltage region provides the signature of p-type or n-type doping of graphene, respectively, as a result of the charge transfer between graphene and the organic molecules trapped within it. In order to facilitate the charge transfer interaction, it is crucial for the trapped molecules to be situated in close proximity to the graphene surface, as demonstrated by findings in Raman and infrared spectroscopies. However, the mechanism responsible for this charge transfer interaction has remained unclear at the microscopic level. Generally, it is accepted that the dipole moment of adsorbed molecules plays a crucial role in determining the charge-transfer interaction between molecules and graphene. However, our findings clearly illustrate that the doping effect primarily depends on the reactivity of the constituent atoms in the adsorbed molecules rather than just their dipole moment. This has been illustrated by trapping various molecules at the graphene–substrate interface. Dopant molecules such as acetone (containing highly reactive oxygen atoms) promote adsorption across the entire graphene surface. In contrast, molecules with less reactive atoms, such as acetonitrile, tend to adsorb at the edges due to the presence of reactive dangling bonds. In the case of low-dipole moment molecules like toluene, there is a lack of substantial adsorption anywhere on the graphene surface. Observation of (i) the emergence of the Raman D peak exclusively at the edges for trapped molecules without reactive atoms and throughout the entire basal plane for those with reactive atoms, and (ii) variations in the density of attached molecules (with and without reactive atoms) to graphene with their respective dipole moments provides compelling evidence to support our claim. Additionally, these observations were supported by first principle density functional calculations.

**Keywords :** graphene, doping, charge transfer, liquid phase exfoliation

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