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Nanometer-Scale Lateral p–n Junctions in Graphene/α-$RuCl_3$ Heterostructures

The ability to tailor the local charge environment of materials at nanometer length scales is essential for the next generation of two-dimensional (2D) electronic and plasmonic devices. In principle, charge transfer at the interface of two atomically-thin layers with different work functions should offer a means of generating ultra-sharp p-n junctions due to the suppression of fringing electric fields. Specifically, the large work function of α-$RuCl_3$ (6.1 eV) makes it an ideal 2D electron acceptor for a wide range of 2D materials, such as graphene. In our study, we use a multipronged approach employing both scanning tunneling microscopy (STM) and spectroscopy (STS) and scattering-type scanning near-field optical microscopy (*s*-SNOM) to interrogate both the electronic and plasmonic properties of graphene/α-$RuCl_3$ heterostructures. Using intrinsic nanobubbles present at graphene/α-$RuCl_3$ interfaces as a testbed for this interlayer charging process, we demonstrate that a massive shift in the Dirac point energy of graphene takes place over a lateral length scale of only 3 nm – the equivalent of a staggering 10^8 V/m internal electric field. The resulting conductivity environment in graphene gives rise to novel plasmonic behavior, including point-scattered surface plasmons and edge plasmons. Our results demonstrate that using high work function materials such as α-$RuCl_3$ in Van der Waals heterostructures presents new opportunities for controlling the local charge carrier density of graphene and other 2D materials at the ultimate limits of scalability.

Figures

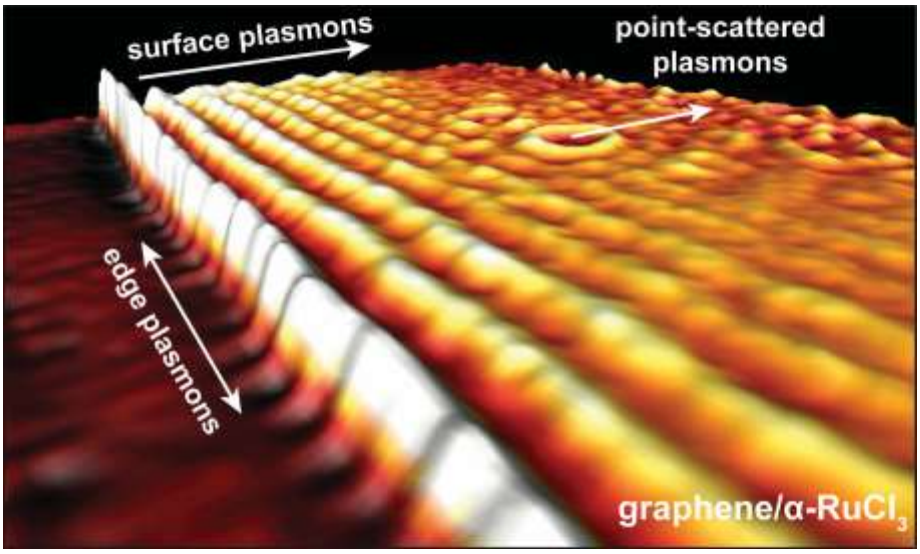

Figure 1: Nano-optical image of graphene/α-$RuCl_3$ heterostructure showing plasmonic oscillations that arise due to work function-mediated interlayer charge transfer. Nanobubble p–n junctions give rise to circular point-scattered plasmons.