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Nanometer-Scale Lateral p–n Junctions in Graphene/α-RuCl3 Heterostructures

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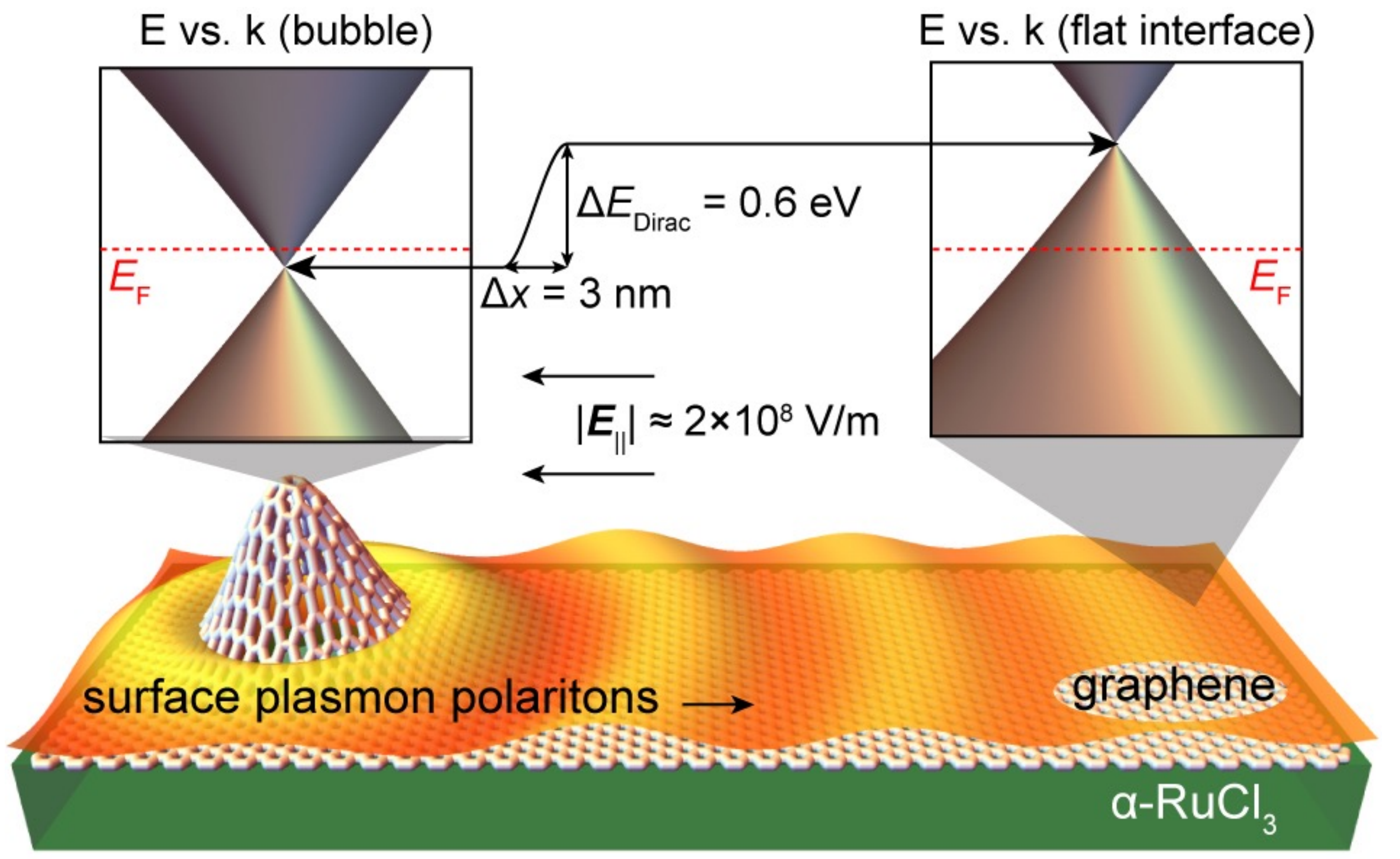
Abstract

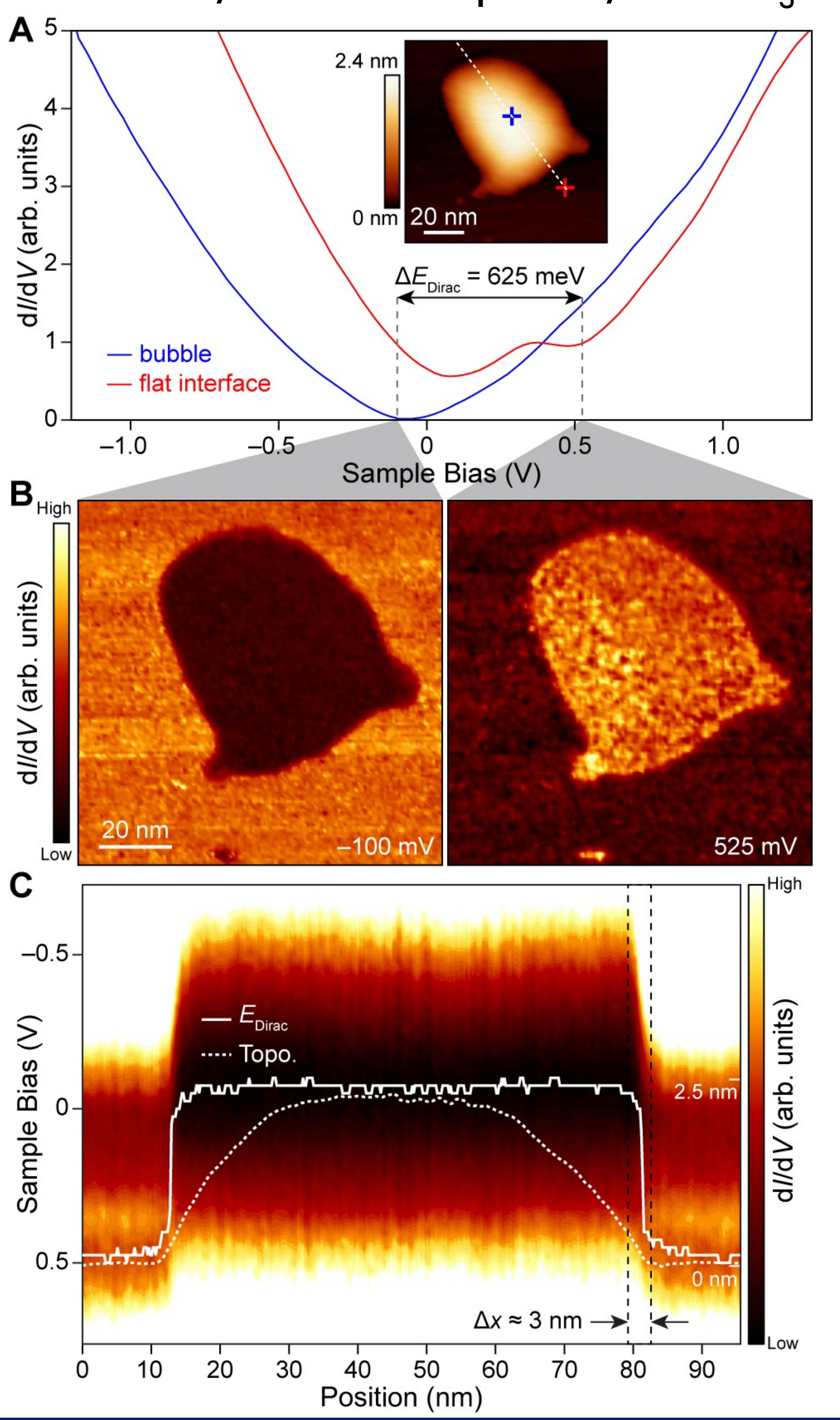
The ability to tailor the local charge environment of materials at nanometer length scales is essential for the next generation of two-dimensional (2D) electronic and plasmonic devices. The large work function of α-$RuCl_3$ (6.1 eV) makes it an ideal 2D electron acceptor for a wide range of 2D materials, 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 resulting conductivity environment in graphene gives rise to novel plasmonic behavior, including point-scattered surface plasmons and edge plasmons.

Nanobubble p–n Junctions in Graphene/α-$RuCl_3$



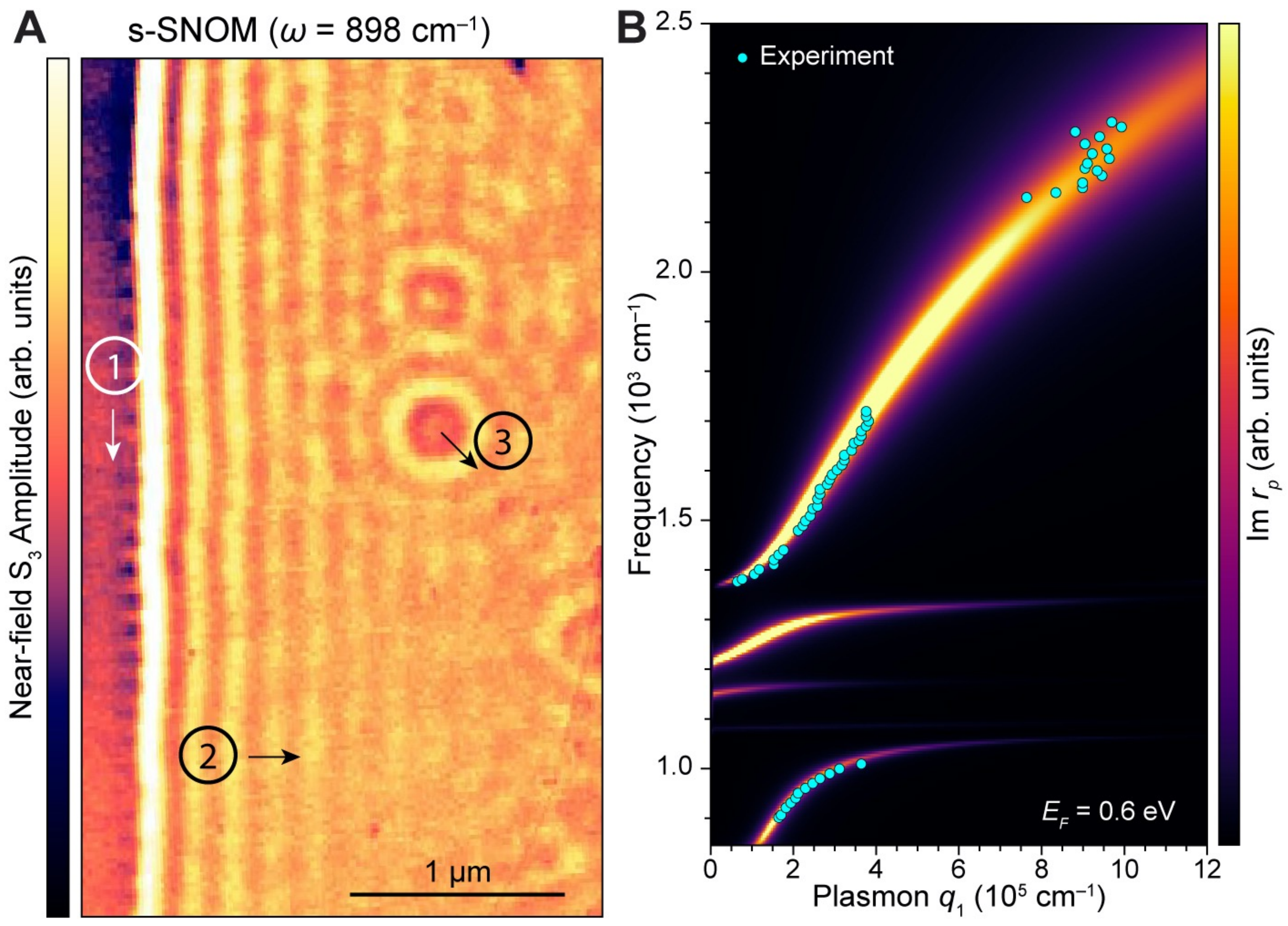
A shift in the Dirac point energy of 0.6 eV occurs over 3 nm between charge-transfer doped graphene/α-$RuCl_3$ and intrinsically n-doped graphene suspended in nanobubbles. The resulting nanoscale p–n junction acts as a hard barrier for plasmonic reflections. [1]

STM/STS on Graphene/α-$RuCl_3$ Nanobubbles



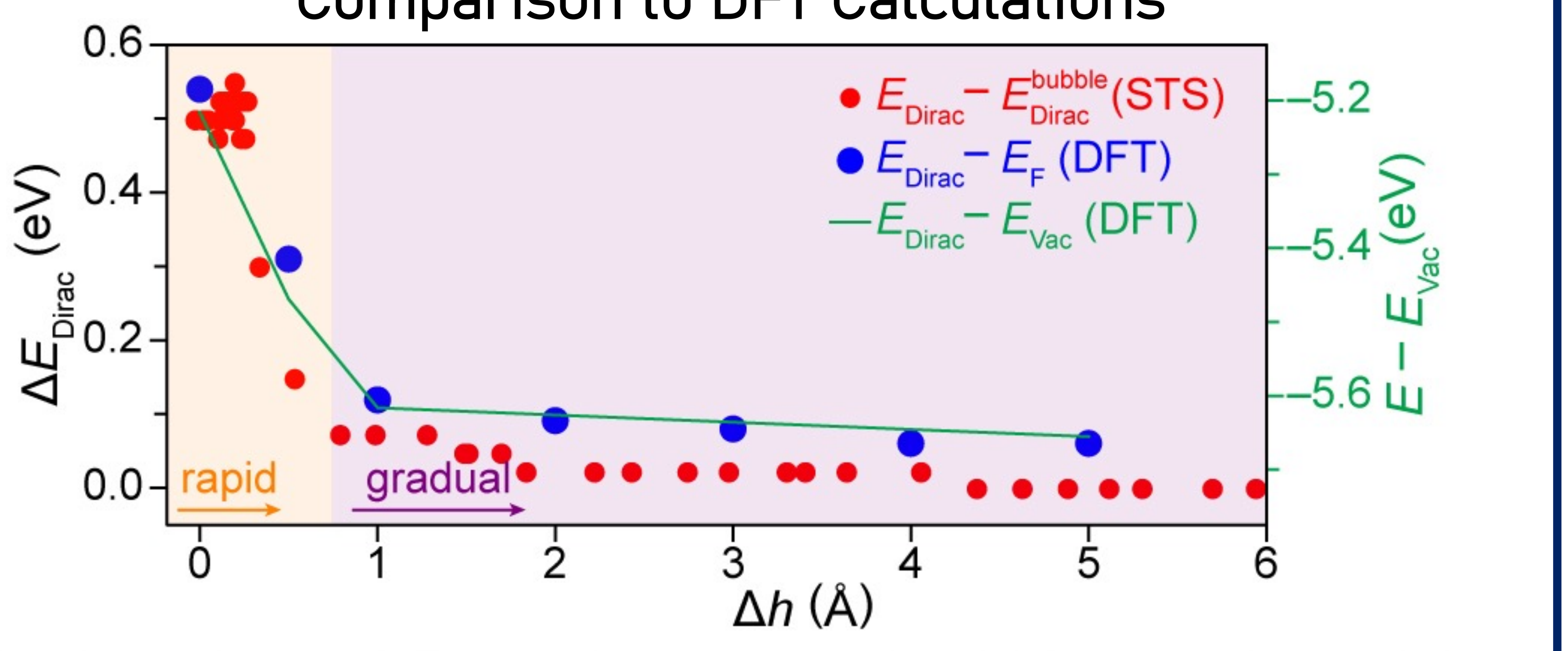
(A) Point spectra and (B) dI/dV maps of a characteristic graphene nanobubble showing a 0.6 eV shift in the Dirac point energy on the graphene nanobubble compared to the surrounding graphene/α-$RuCl_3$ interface. (C) A dI/dV linecut taken along the white trajectory shown in the inset in (A). A depletion region of 3 nm is observed, with the shift in E_{Dirac} (solid white line) occurring much more abruptly than the underlying topographic cross-section (dashed white line). [1]

Nano-Optical Imaging of Graphene/α-$RuCl_3$



(A) s-SNOM image of graphene/α-$RuCl_3$ showing three types of plasmonic oscillations. (B) The experimental plasmon dispersion matches the theoretical model of 0.6 eV doped graphene. [2]

Comparison to DFT Calculations



The dependence of E_{Dirac} on layer separation Δh for experimental data (red dots) mirrors theoretical data (blue dots and green curve). [1]

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REFERENCES

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