Scanning Tunneling Microscopy of the π Magnetism of a Single Carbon Vacancy in Graphene

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Pristine graphene is diamagnetic. However, graphene with single carbon atom defects could exhibit paramagnetism. Theoretically, the π magnetism induced by the monovacancy in graphene is characteristic of two spin-split density-of-states (DOS) peaks close to the Dirac point. Since its prediction, many experiments have attempted to study this π magnetism in graphene [1,2], whereas only a notable resonance peak has been observed around the atomic defects, leaving the π magnetism experimentally elusive. Here, we report direct experimental evidence of π magnetism by using a scanning tunneling microscope. We demonstrate that the localized state of the atomic defects is split into two DOS peaks with energy separations of several tens of meV (Figure 1). Strong magnetic fields further increase the energy separations of the two spin-polarized peaks and lead to a Zeeman-like splitting. Unexpectedly, the effective g factor around the atomic defect is measured to be about 40, which is about 20 times larger than the g factor for electron spins (Figure 2).

References

[1] O. V. Yazyev and L. Helm, Phys. Rev. B 75 (2007) 125408
[2] M. M. Ugeda, et. al., Phys. Rev. Lett. 104 (2010) 096804

Figures

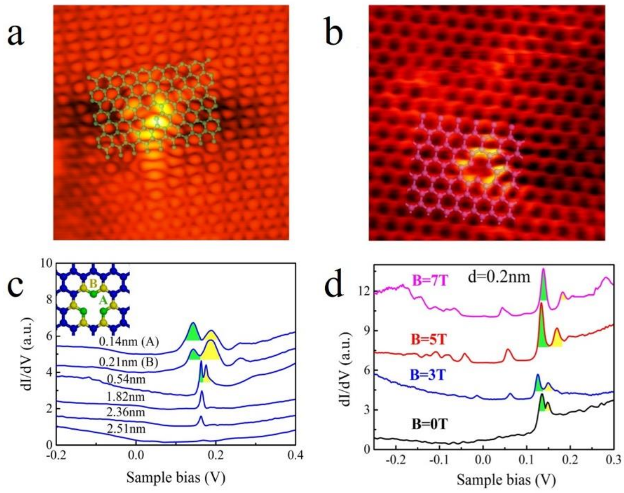

Figure 1: Graphene with atomic defects on Rh foil. **a,** Atomic resolution STM image of a single carbon vacancy in topmost graphene sheet. **b,** STM image of a single carbon vacancy in the underlying graphene. **c,** STS spectra recorded at different distances away from a single carbon vacancy. The two peaks reflect the DOS with opposite spin polarizations. **d,** STS spectra recorded at position about 0.2 nm away from the monovacancy under various magnetic fields. The energy separations of the two peaks increase with the magnetic fields

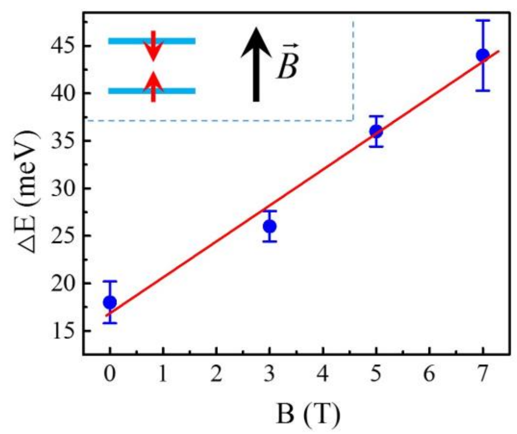

Figure 2: Energy separations of the two peaks of the monovacancy as a function of magnetic fields. A linear fit of the energy separations versus magnetic field yields an effective g-factor of 40 around the monovacancy.