Exploring ultrathin indium intercalated between graphene and SiC by scanning tunneling microscopy

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Abstract

Two-dimensional metals stabilized at the interface between epitaxial graphene and SiC offer fascinating platforms for quantum technology owing to new exotic physical properties [1,2]. A nontrivial challenge is to precisely visualize the atomic and electronic structures of metal layers below graphene and to control the metal properties with atomic precision which is experimentally limited. In this work, our goal is to explore and control the atomic and electronic structures of 2D indium intercalated at the EG/SiC interface using cryogenic scanning tunneling microscopy. We observed distinct atomic structures of mono, bilayer, and trilayer In below graphene. On a monolayer, individual In atoms are epitaxially registered with the √3×√3 cells of the SiC. While in a bilayer, only point defects are visualized. Strikingly, the trilayer In reveals a triangular moiré pattern, which is induced by the lattice mismatch between a top pseudomorphic and a stable In layers underneath. The dI/dV spectroscopy which is proportional to the LDOS revealed a single occupied state arising from the interface which is downshifted as the number of In layers increases. In corroboration with DFT calculations, we verify how the atomic and electronic structures evolve and originate.

We further demonstrated an ultimate approach using a bias voltage pulse applied to the STM tip-sample junction to explore the indium in the interface with monolayer precision. In such context, we locally de-intercalate the In by the voltage pulses and unveiled the interface thicknesses. The established tip-induced interface manipulation further allows reversibly tuning of In layers, hence their corresponding electronic structures can be precisely controlled. Our work demonstrates the exciting possibility of unveiling and controlling the properties of 2D metal with atomic precision using the scanning probe technique.

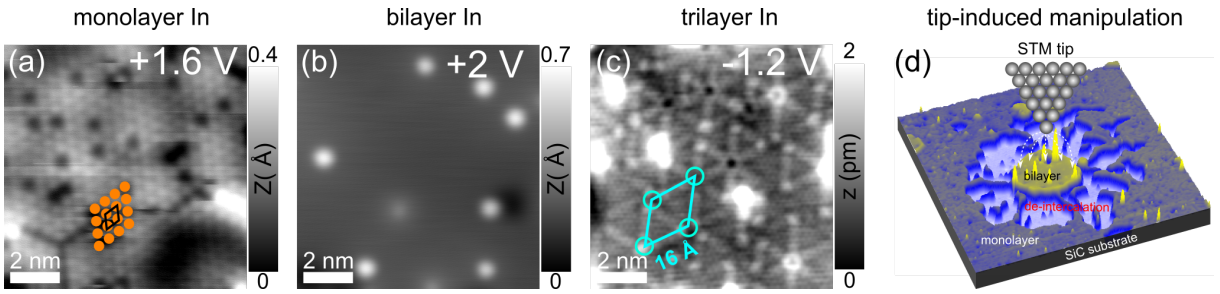

Figure 1: STM image of (a) monolayer, (b) bilayer, and (c) trilayer indium intercalated between graphene and SiC. Individual In atoms are seen in the monolayer. On the bilayer and trilayer, the atoms are not resolved, but a moiré superstructure induced by the interaction between different In layers emerges in the trilayer In. Tip-induced interface modification using a bias voltage applied to the STM tip-sample junction enables de-intercalation of In, revealing atomic details of the interface.

References

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