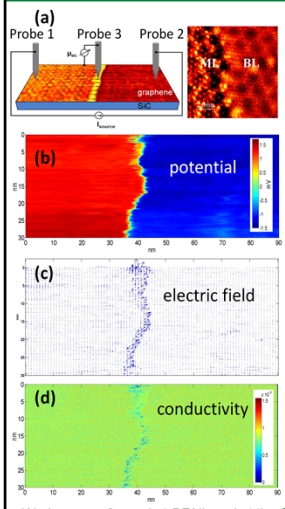
CNMS Staff Science Highlight

Spatially Resolved Mapping of Electrical Conductivity Across Domain and Grain Boundaries in Graphene



(a) Schematic diagram of simultaneous structure and electrochemical potential measurement with a multi-probe STM, and atomic resolution image of a graphene monolayer-bilayer boundary.
(b) 2D distribution of surface potential.
(c) 2D distribution of electric field.
(d) 2D distribution of electrical conductivity.

Work was performed at ORNL and at the Carnegie Mellon University

Scientific Achievement

A two-dimensional profile of electronic conductivity was quantitatively resolved on graphene with scanning tunneling potentiometry (STP). Both grain and domain boundaries exhibit a potential barrier for electron transport, showing an electronic transition region with direct correlation to charge density variations and boundary atomic structures.

Significance and Impact

This work presents a new atomic level approach to the study of the spatial profile of conductivity in a 2D material with a one-to-one correspondence to the structure. The study reveals the roles of different types of defects in both epitaxial and CVD grown graphene, providing information on the electron scattering process at an unprecedented atomic level.

Research Details

- Electrical transport properties are studied with a 4-probe STM by measuring the electrochemical potential variation across individual defects with a current flowing in the graphene.
- Transport properties are analyzed and correlated to the defect structures and electronic properties.

K. W. Clark, X.-G. Zhang, I. V. Vlassiouk, G. He, R. M. Feenstra, and A.-P. Li, *ACS Nano*, DOI: 10.1021/nn403056k

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Highlight Narrative

This paper reports the first direct measurement of the spatial profile of electrical conductivity across extended defects in graphene with a one-to-one correspondence to the defect structure. Defects studied include domain boundaries defined by substrate steps and change in graphene layer thickness in epitaxial graphene on SiC, wrinkles and grain boundaries in CVD graphene on Cu. A 4-probe STM was used in a scanning tunneling potentiometry mode to map 2D distributions of electrochemical potential. The 2D distributions of electric field and conductivity were then numerically extracted by solving conduction equations. Amazingly, an electronic transition region is revealed at both kinds of boundaries, with a transition width much wider than the structural transition coinciding at the boundaries. A quantitative modeling of grain boundary resistance reveals the changed electron wave vector within the boundary region, due to the variations of charge density states.

This work presents a new approach to the study of spatial distribution of conductivity in graphene, enabling to reveal electronic scattering processes at defects and boundaries in graphene down to atomic scale. The new method can be applied to other 2D materials systems where nano-and mesoscale transport phenomenon is related to the local variations of structural and electronic properties.

Reference:

Spatially Resolved Mapping of Electrical Conductivity across Individual Domain (Grain) Boundaries in Graphene

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