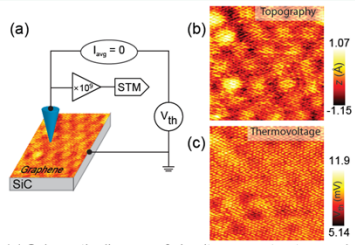
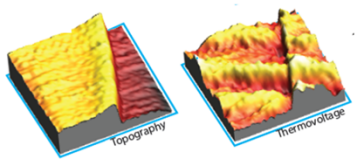
CNMS Staff Science Highlight

Atomic-Scale Mapping of Thermoelectric Power on Graphene: Role of Defects and Boundaries



(a) Schematic diagram of simultaneous structure and thermovoltage measurement with an STM. Atomic resolution images of (b) topography and (c) thermovoltage.



3D contours of topography and thermovoltage showing domains induced by step boundaries and structural wrinkles.

Work was performed at CNMS-ORNL and at the Carnegie Mellon University

Scientific Achievement

Thermoelectric power was spatially resolved on graphene with a scanning tunneling microscopy (STM) method. Periodic oscillations and microscopic domains are revealed, showing the interplays of thermoelectric power and local variation of the electronic structures due to defects, local strains, and structural boundaries.

Significance and Impact

The thermal generation of a voltage also occurs in a scanning tunneling microscope when the tip and the sample are at different temperatures. This study reveals the roles of individual defects and boundaries, providing information on the thermal to electrical energy conversion process at an unprecedented atomic level.

Research Details

- Thermoelectric properties are studied by measuring the thermovoltage between a tip and a sample caused by a temperature gradient across the tunneling barrier in a STM.
- Structures and thermopower are measured simultaneously across particular defects and boundaries.

J. Park, G. He, R. M. Feenstra, and A.-P. Li, *Nano Lett.* DOI: 10.1021/nl401473j
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Highlight Narrative

This is the first report on the spatial distribution of thermoelectric response due to electron scattering effect at defects and boundaries in graphene. It provides a rare glimpse of thermal-electrical energy conversion process at an unprecedented atomic level. Microscopic thermoelectric measurements are usually carried out with a technique developed by Philip Kim et al., where a local heater made of a metal line produces a temperature difference ΔT between the two ends of a sample, which gives rise to a thermoelectric voltage V_{th} measured by electrodes defined by standard electron beam lithography and nanofabrication process. The thermopower is obtained as the ratio of V_{th} to ΔT across a sample. This method however lacks the spatial resolution for probing the variations of thermoelectric properties across a sample surface which can be the key for revealing the inhomogeneities and defect scattering effects in thermoelectric materials.

Here an alternate method is applied to measure the thermoelectric power with an STM technique where a thermovoltage arises from a temperature gradient between the STM tip and the sample. Due to the strong dependence of thermovoltage on the electronic density of states at Fermi level, atomic resolution map of thermovoltage is obtained which allows quantitative determination of thermoelectric power across defects and boundaries. Periodic modulations in thermovoltage distribution are observed near graphene boundary, which corresponds to the Friedel oscillations of

electronic density of states associated with the intra-valley scattering in graphene. Domain structures in thermovoltage distributions are revealed arising from the modifications of local electronic structures by microscopic distortions of graphene sheet.

Reference:

Atomic-Scale Mapping of Thermoelectric Power on Graphene: Role of Defects and Boundaries

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