Researchers introduce new route to thermal measurements with nanometer resolution

November 30 2015, by Syd Steinhardt

Understanding nanoscale heat flow is critical in the design of integrated electronic devices and in the development of materials for thermal insulation and thermoelectric energy recovery. While several techniques are currently available to observe heat transport over macroscopic distances, there is a need for new methods capable of revealing the dynamics of heat flow with nanometer resolution.

A CCNY team led by Physics Professors Carlos Meriles and Elisa Riedo recently reported on a versatile platform for nanoscale thermal measurements based on a combination of magnetic resonance, and optical and atomic force microscopy, in *Nature Communications*. Their paper, "Imaging thermal conductivity with nanoscale resolution using a scanning spin probe," is based on a simple notion: that a hot probe in contact with a thermally conductive material, such as a metal, cools down because heat flows from the probe into the material. The latter is prevented, however, if the sample material is thermally insulating, implying that one can infer the sample thermal conductivity by continuously monitoring the probe temperature.

To implement this idea at the nanoscale, the researchers used a thermal atomic force microscope, where the cantilever temperature can be adjusted via the application of an external current. The AFM cantilever hosts a sharp tip that makes contact with the substrate on a small, nanometer-size area. To measure the tip temperature, the CCNY team attached to the tip apex a diamond nanocrystal, whose thermally-dependent fluorescence effectively made it a tiny thermometer.

Nanometer-resolved thermal conductivity maps were then obtained as the tip was scanned over various substrates of heterogeneous composition.

The team anticipates multiple applications ranging from fundamental problems of heat flow in nanostructures and radiative heat transport in nano-gaps, to the characterization of materials undergoing heterogeneous phase transitions, to the investigation of catalytic exothermal reactions. Although in the present implementation heat flows from the AFM tip into the sample, the technique can be immediately adapted to probe the local temperature in a hot, non-uniform substrate without the need of a thermal cantilever.

"This form of nanoscale scanning thermometry can play an important role in the characterization of the 'hot spots' formed at the junctions of semiconductor heterostructures, known to be critical in the generation of heat within integrated electronic devices," said Meriles.

More information: Abdelghani Laraoui et al. Imaging thermal conductivity with nanoscale resolution using a scanning spin probe, *Nature Communications* (2015). DOI: 10.1038/ncomms9954

Provided by City College of New York