Measuring absorption maps and spectra of plasmonic resonators with nanoscale resolution

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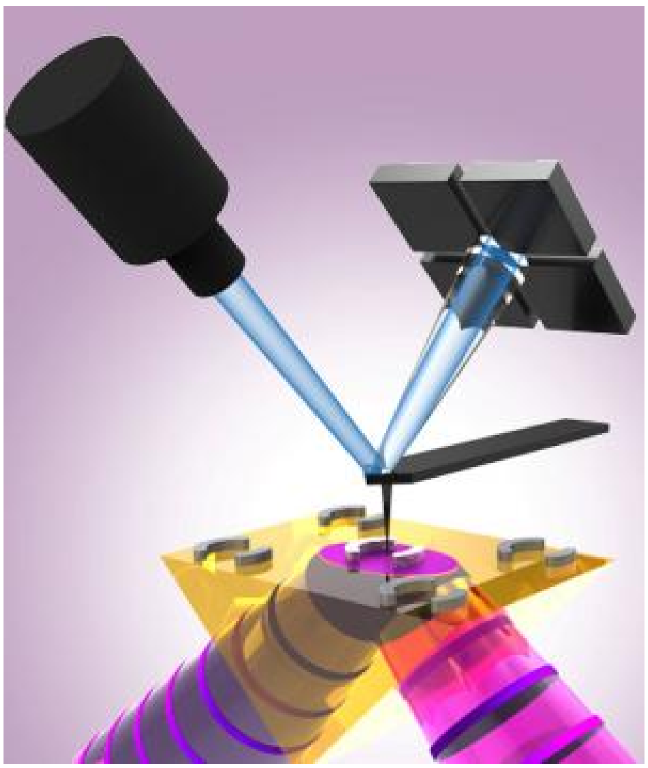

Schematic showing the photothermal induced resonance (PTIR) technique, which combines the lateral resolution of atomic force microscopy (AFM) with the chemical specificity of IR spectroscopy. A wavelength-tunable, pulsed IR laser (purple) illuminates a sample consisting of plasmonic gold resonators from the below. The resulting thermal expansion of the sample is detected locally by the AFM cantilever tip, which is monitored by reflecting a laser (blue) off the back of the cantilever.

Researchers from the NIST Center for Nanoscale Science and Technology (CNST) and the University of Maryland have for the first time used photothermal induced resonance (PTIR) to characterize individual plasmonic nanomaterials in order to obtain absorption maps and spectra with nanometer-scale resolution. Nanostructuring of plasmonic materials enables engineering of their resonant optical response and creates new opportunities for applications that benefit from enhanced light-matter interactions, including sensing, photovoltaics, photocatalysis, and therapeutics.

Progress in nanotechnology is often enabled by the availability of measurement methods for characterizing materials at appropriately small length scales. By measuring infrared absorption at the nanoscale, PTIR provides information that is not otherwise available for characterizing and engineering plasmonic materials. PTIR measures light absorption in a material using a wavelength-tunable laser and a sharp tip in contact with the sample as a local detector. Unlike many other methods that use nanoscale tips for probing materials, in PTIR the tip is passive and does not interfere with measurement. Consequently, light absorption in the sample can be measured directly without requiring either a model of the tip or prior knowledge of the sample.

The researchers collected nanoscale absorption information in two ways: first, by mapping infrared absorption while scanning a tip on a sample under constant wavelength illumination; and second, by measuring location-specific absorption spectra while sweeping a laser across a range of infrared wavelengths. Using tunable lasers that give CNST facility users the ability to vary the wavelengths from 1.55 µm to 16.00 µm, the researchers acquired the nanoscale infrared absorption spectra of gold resonators, the first such measurement of any plasmonic nanomaterial. Although absorption images allow immediate visualization and can be measured with other techniques, the PTIR spectra provide needed information to interpret the images and guide experiments.

Plasmonic materials like gold, which have large thermal conductivity and relatively small thermal expansion coefficients, were previously thought to be challenging to measure using PTIR because the technique relies on the sample's thermal expansion for measuring light absorption. According to Andrea Centrone, a Project Leader in the Energy Research Group, "we showed that PTIR characterization is not just applicable to insulators and semiconductors, as demonstrated previously, but that metals are also amenable to it. This is an important step forward for applying the PTIR technique to a wider variety of functional devices."

More information: "*Nanoscale* imaging and spectroscopy of plasmonic modes with the PTIR technique," A. M. Katzenmeyer, J. Chae, R. Kasica, G. Holland, B. Lahiri, and A. Centrone, *Advanced Optical Materials* 2, 718–722 (2014).

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