

Terahertz Waves Are Effective Probes for IC Heat Barriers

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(PhysOrg.com) -- By modifying a commonly used commercial infrared spectrometer to allow operation at long-wave terahertz frequencies, researchers at the National Institute of Standards and Technology

discovered an efficient new approach to measure key structural properties of nanoscale metal-oxide films used in high-speed integrated circuits. Their technique, described in a recent paper,* could become an important quality-control tool to help monitor semiconductor manufacturing processes and evaluate new insulating materials.

Chip manufacturers deposit complicated mazes of layered metallic conductor and semiconductor films interlaced with insulating [metal oxide](#) nanofilms to form transistors and conduct heat. Because high electrical leakage and excess heat can cause nanoscale devices to operate inefficiently or fail, manufacturers need to know the dielectric and mechanical properties of these nanofilms to predict how well they will perform in smaller, faster devices.

Manufacturers typically assay the structure of metal oxide films using X-ray spectroscopy and [atomic force microscopy](#), both tedious and time-consuming processes. NIST researchers discovered that they could extract comparable levels of detail about the structural characteristics of these [thin films](#) by measuring their absorption of terahertz radiation, which falls between the infrared and microwave spectral regions.

Although terahertz spectroscopy is known to be very sensitive to crystal and molecular structure, the degree to which the metal oxide films absorbed the terahertz light was a surprise to NIST researchers.

“No one thought nanometer-thick films could be detected at all using terahertz spectroscopy, and I expected that the radiation would pass right through them,” says Ted Heilweil, a NIST chemist and co-author of the paper. “Contrary to these expectations, the signals we observed were huge.”

The NIST team found that the atoms in the films they tested move in concert and absorb specific frequencies of terahertz radiation

corresponding to those motions. From these absorbed frequencies the team was able to extrapolate detailed information about the crystalline and amorphous composition of the metal oxide films, replete with structures that could affect their function.

The team's experiments showed that a 40 nanometer thick hafnium oxide film grown at 581 kelvin (307 degrees Celsius) had an amorphous structure with crystalline regions spread throughout; nanofilms grown at lower temperatures, however, were consistently amorphous. According to Heilweil, an approximately 5 nanometer film thickness is the detection limit of the terahertz method, and the efficacy of the technique depends to some degree on the type of metal oxide, though the group noted that all metal-oxide materials surveyed exhibit distinct spectral characteristics.

*More information: E. Heilweil, J. Maslar, W. Kimes, N. Bassim and P. Schenck. Characterization of metal-oxide nanofilm morphologies and composition by terahertz transmission spectroscopy. *Optics Letters*. 34 (9), 1360-1362 (2009).

Provided by NIST

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