Tension in the nanoworld

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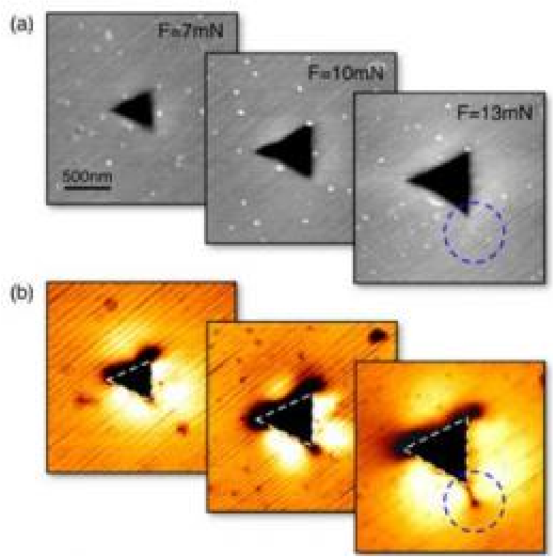

Infrared visualization of nanocrack evolution. a) Topography of triangular indents (depressions) at the surface of a SiC crystal. Indentation was performed by pressing a sharp diamond tip into the crystal surface. With increasing force F, the depression becomes larger and deeper. b) The infrared near-field images recorded at about 10 µm wavelength clearly show the regions around the indent where the crystal lattice is compressed (bright) or stretched (dark). Because of the exceptional high spatial resolution, the images reveal the onset and formation of nanoscale cracks (marked by dashed blue circles) when the indentation force is increased. Credit: Max Planck Institute for Biochemistry, Andreas Huber

(PhysOrg.com) -- A joint team of researchers at CIC nanoGUNE (San Sebastian, Spain) and the Max Planck Institutes of Biochemistry and Plasma Physics (Munich, Germany) report the non-invasive and nanoscale resolved infrared mapping of strain fields in semiconductors.

The method, which is based on near-field microscopy, opens new avenues for analyzing mechanical properties of high-performance materials or for contact-free mapping of local conductivity in strain-engineered electronic devices (*Nature Nanotechnology*, advanced online publication, 11 Jan. 2009).

Visualizing strain at length scales below 100 nm is a key requirement in modern measurement because strain determines the mechanical and electrical properties of high-performance ceramics or modern electronic devices, respectively. The non-invasive mapping of strain with nanoscale spatial resolution, however, is still a challenge.

A promising route for highly sensitive and non-invasive mapping of nanoscale material properties is scattering-type Scanning Near-field Optical Microscopy (s-SNOM). Part of the team had pioneered this technique over the last decade, enabling chemical recognition of nanostructures and mapping of local conductivity in industrial semiconductor nanodevices. The technique makes use of extreme light concentration at the sharp tip of an Atomic Force Microscope (AFM), yielding nanoscale resolved images at visible, infrared and terahertz frequencies. The s-SNOM thus breaks the diffraction barrier throughout the electromagnetic spectrum and with its 20 nm resolving power matches the needs of modern nanoscience and technology.

Now, the research team has provided first experimental evidence that the microscopy technique is capable of mapping local strain and cracks of nanoscale dimensions. This was demonstrated by pressing a sharp diamond tip into the surface of a Silicon Carbide crystal. With the near-field microscope the researchers were able to visualize the nanoscopic strain field around the depression and the generation of nanocracks.

"Compared to other methods such as electron microscopy, the technique offers the advantage of non-invasive imaging without the need of special sample preparation" says Andreas Huber who performed the experiments as part of his Ph.D. project. "Specific applications of technological interest could be the detection of nanocracks before they reach critical dimensions, e.g. in ceramics or Micro-Electro-Mechanical Systems (MEMS), and the study of crack propagation", says Alexander Ziegler.

The researchers also demonstrated that s-SNOM offers the intriguing possibility of mapping free-carrier properties such as density and mobility in strained silicon. By controlled straining of silicon, the properties of the free carriers can be designed, which is essential to further shrink and speed-up future computer chips. For both development and quality control, the quantitative and reliable mapping of the carrier mobility is strongly demanded but until now no tool has been available. "Our results promise interesting applications of s-SNOM in semiconductor science and technology such as the quantitative analysis of the local carrier properties in strain-engineered electronic nanodevices" says Rainer Hillenbrand, leader of the Nano-Photonics Group at MPI and the Nanooptics Laboratory at nanoGUNE.

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