Infrared nanospectroscopy meets FIB and TEM

R.Hillenbrand
CIC nanoGUNE Consolider, San Sebastian, Spain
Ikerbasque, Basque Science Foundation, Bilbao, Spain
r.hillenbrand@nanogune.eu

We demonstrate nanoscale-resolved infrared imaging and spectroscopy based on elastic light scattering from atomic force microscope tips (scattering-type scanning near-field optical microscopy, s-SNOM) [1]. Acting as infrared antennas, the tips convert the illuminating light into strongly concentrated near fields at the tip apex (nanofocus), which provides a means for localized excitation of molecule vibrations, plasmons or phonons in the sample surface. Recording the tip-scattered light subsequently yields nanoscale-resolved infrared images, beating the diffraction limit more than two orders of magnitude.

Using broadband IR illumination and Fourier-transform spectroscopy of the tip-scattered light [2,3], we are able to record IR spectra with 20 nm spatial resolution (nano-FTIR). Particularly, we demonstrate that nano-FTIR can acquire near-field absorption spectra of molecular vibrations throughout the mid-infrared fingerprint region, allowing for chemical mapping and identification of polymer and protein nanostructures [3].

Employing FIB machining, we succeeded in fabricating micrometer long gold tips on standard Si cantilevers (Fig. 1). These tips exhibit well-defined antenna resonances [4], as verified by EELS and nano-FTIR, which have the potential to further push the resolution and sensitivity of infrared nanoscopy.

We also introduce correlative infrared-electron nanoscopy [5], yielding TEM and infrared near-field images of one and the same nanostructure (Fig. 2). While TEM resolves the atomic structure of a sample, the IR images yield nanoscale maps of chemical composition or conductivity. We demonstrate the application potential by studying the relation between conductivity and crystal structure in cross-sections of chemically grown ZnO nanowires. The unique combination of infrared conductivity maps and atomic-scale images of the local crystal structure reveals a radial free-carrier gradient, which inversely correlates to the density of extended crystalline defects. Our results open new avenues for studying the local interplay between structure, conductivity, and chemical composition in widely different material systems, ranging from correlated and low-dimensional electron matter to biomedical tissue.

1. F. Keilmann, R. Hillenbrand, Phil. Trans. R. Soc. Lond. A **362**, 787 (2004)
2. F. Huth, et al., Nature Mater. **10**, 352 (2011)
3. F. Huth, et al., Nano Lett. **12**, 3973 (2012)
4. F. Huth, et al., Nano Lett. (2012), dx.doi.org/10.1021/nl304289g
5. J.M. Stiegler, et al., Nature Commun. **3**, 1131 (2012)

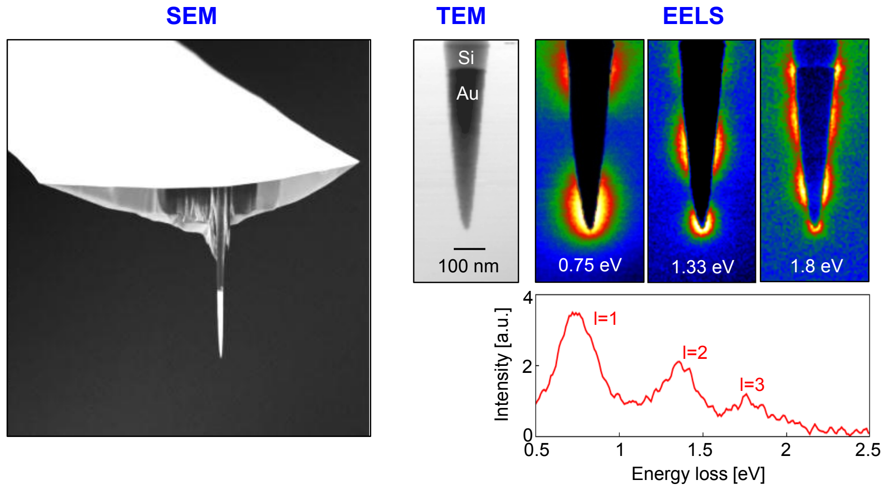

Figure 1: Left: SEM image of a FIB fabricated Au tip on a commercial AFM cantilever. Middle: TEM image of a FIB fabricated Au tip. Right: EELS maps and spectrum of plasmonic antenna modes.

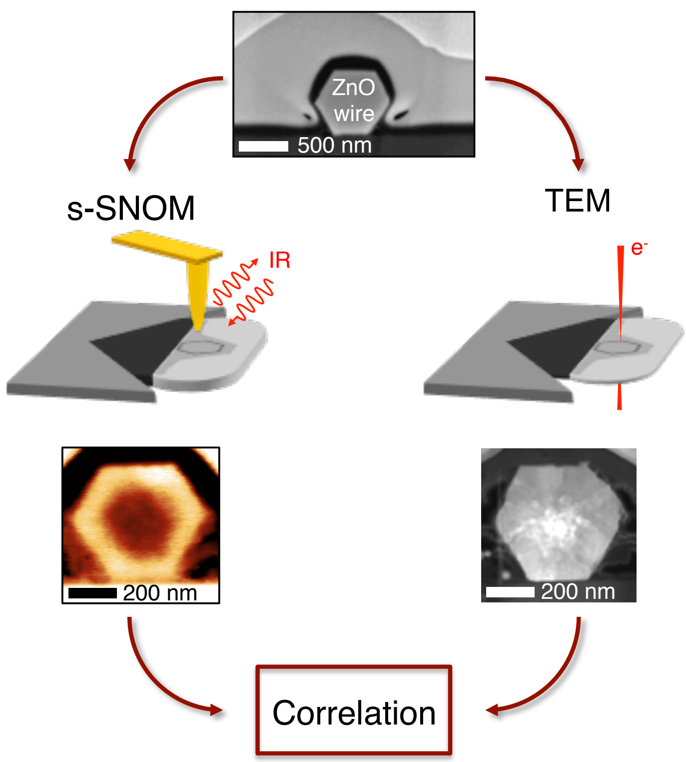

Figure 2: Schematics of correlative infrared-electron nanoscopy.