Three dimensional vectorial imaging of surface phonon polaritons

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Surface phonon polaritons (SPhPs) are mixed electromagnetic and optical phonons waves that propagate at the surface of ionic materials (1). They strongly influence the optical and thermal behavior of nanomaterials. For example, they are responsible for highly coherent emission of SiC upon heating, in stark contrast with the conventional incoherent black-body radiation (2). They also induce enhanced thermal conduction in thin membranes (3) or heat transfer between two nanosurfaces (4). These applications rely on the nanostructuration of the electromagnetic field in the vicinity of surfaces of metamaterials or nanoparticles. Designing or even engineering the electro-magnetic local density of states (EMLDOS) for specific functionalities require therefore the unambiguous visualization of such field modulations at the nanometer scale. Recently, EELS in a scanning transmission electron microscope (STEM) made it possible to measure phonons spectra at the nanometer (5, 6), then atomic scales (7). Nevertheless, they were restricted to 2D imaging, and not able to reveal the complete three-dimensional vectorial picture of their electromagnetic density of states. Using a highly monochromated electron beam in a scanning transmission electron microscope, we could visualize varying SPhPs signatures from nanoscale MgO cubes as a function of the beam position, energy-loss and tilt angle, see Figure 1. Following early works on plasmons (8,9), the SPhPs response was described in terms of eigenmodes and used to tomographically reconstruct the phononic surface electromagnetic fields of the object (10). Such 3D information promises novel insights in nanoscale physical phenomena and is invaluable to the design and optimization of nanostructures for fascinating new uses.
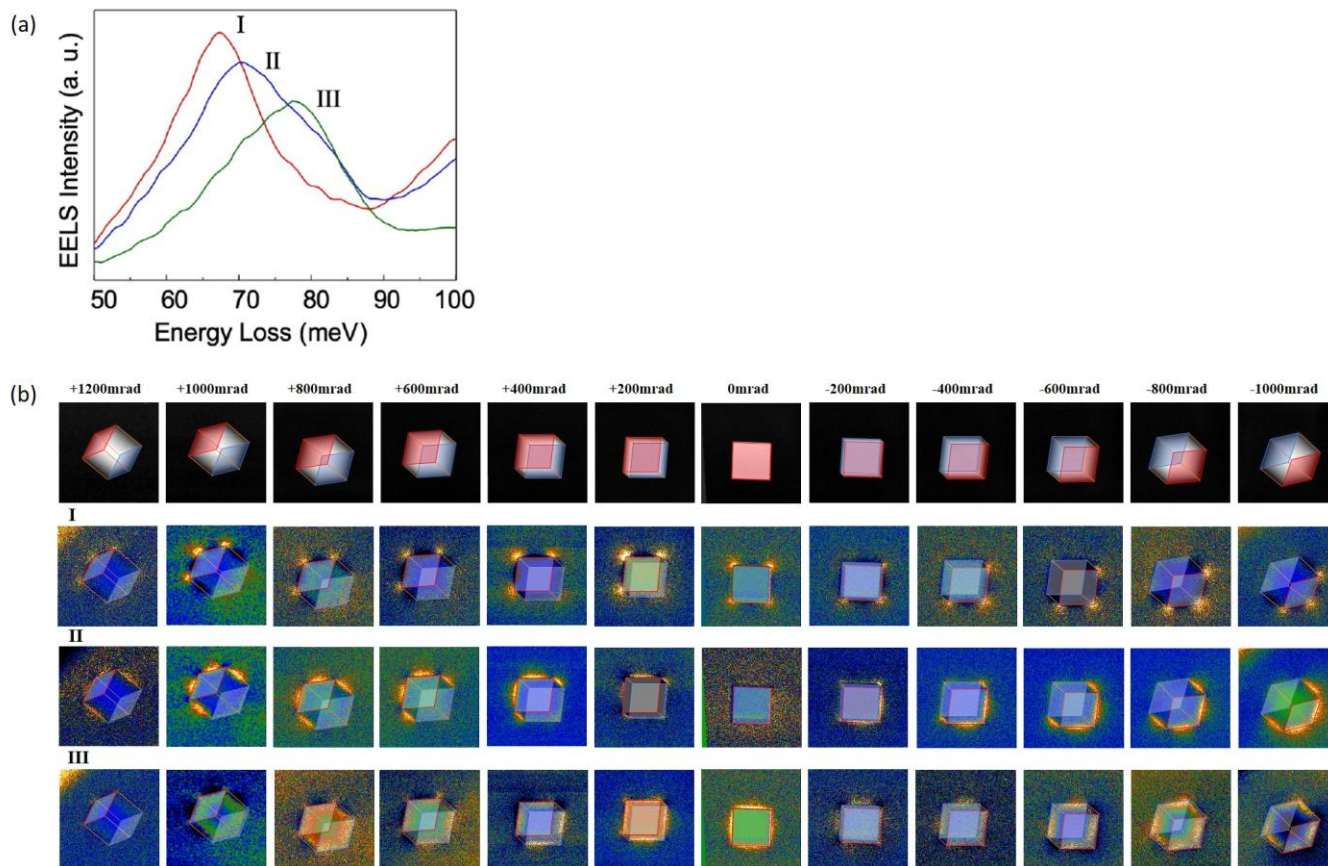
Figure 1. Figure.1 (a) Typical spectra for the three different SPhP modes on MgO cube surface. (b) 2D mapping at a series of tilt angles from +1200 mrad to -1000 mrad. From top row to bottom, HAADF images at 12 different tilt angles, the corresponding filtered maps extracted at energies of the three main surface phonon modes. The color scale of each filtered map is adjusted independently to optimize the visualization of the signals.

References

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