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Spatially Resolved Characterization of Interface Plasmons in Si/SiO_2 Core/Shell Nanostructures

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Si based nanostructures, known to possess numerous extraordinary electrical and optical properties, have recently demonstrated their promising applications in surface plasmon waveguides and surface plasmon sensors [1]. The excitations of surface/interface plasmons (SPs/IPs) are highly sensitive to the surface morphology. For example, SPs/IPs excited in small particles are confined locally around the individual nanostructure, while they can propagate along the surface/interface in thin films or one dimensional nanostructures [2]. The research on the interface plasmon in different Si/SiO_2 nanostructures (as the surface of Si is usually covered with a thin layer of silicon oxide) would not only be of great scientific interest, but also lead to possible tuning of IP energies for different applications. Although large amount of research efforts have been devoted to the surface plasmon study of noble metal nanostructures with different shapes, few attention is paid to semiconductor nanostructures [3]. One of the difficulties may lie on the limited energy range provided in some conventional optical measurements. With the help of electron energy loss spectroscopy (EELS) performed in transmission electron microscope (TEM) or scanning transmission electron microscope (STEM), SPs/IPs are conveniently investigated even in individual nanostructure. In addition, information on the spatial distribution of specific excitations can also be addressed.

In the present study, the interface plasmons excited in different Si/SiO_2 core/shell nanostructures, including both the core/shell nanoparticles and nanocables, have been investigated using spatially resolved electron energy loss spectroscopy (SREELS). Different from spherical core/shell nanoparticles where single IP band presents at ~8 eV in the EEL spectrum, two IP bands at ~4.5 eV and ~8 eV are found in nanocables, and the intensity ratio of the two bands changes with the diameter of Si core. EELS simulations provide in-depth understanding on the interface plasmons in different nanostructures, i.e., in cylindrical objects the longitudinal charge oscillation with monopolar character is predominant in the lower energy region, while the ~8 eV resonances in both nanoparticles and nanocables are of multipolar nature for materials with spherical geometrical constraints. The spatial distribution of the two IP bands further discloses the difference of the two kinds of oscillation modes.

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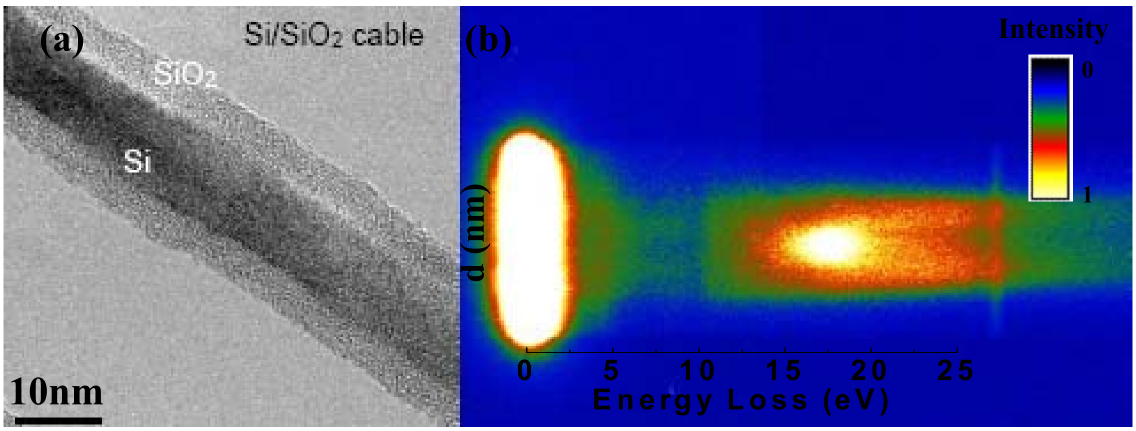

Figure 1. (a) TEM bright field images of single Si/SiO_2 cylindrical cable with ~10nm Si core diameter. (b) SREELS image taken along the radial direction of the nanocable.

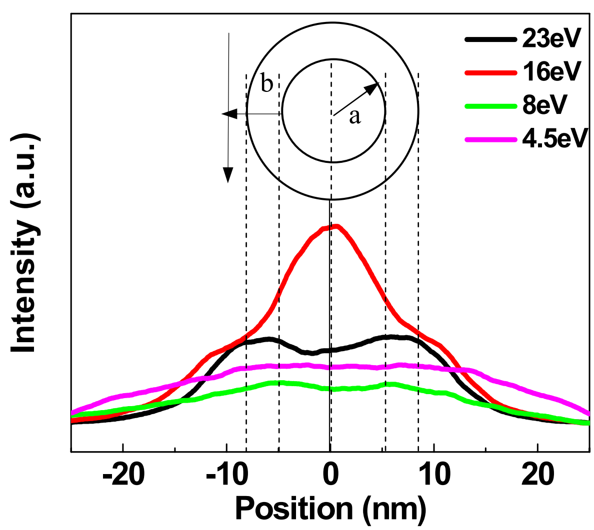

Figure 2. Experimental intensity profiles of different spectrum features as a function of spatial position in the direction perpendicular to the interface. (The center of the Si core is defined as 0);

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