Exciton-surface plasmon polariton coupling in GaAs/AlAs/GaAs core-shell nanowires covered with Au and Al films

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An important focus in nanowire research is the design of plasmonic metal/semiconductor composite structures to obtain novel optical device properties for applications in biological labeling/sensing, light-emitting diodes, lasers, and solar cells. By an appropriate choice of a metal possessing a surface plasmon frequency, which is reasonably close to the excitonic transition energy of the nanocrystal, exciton coupling to surface plasmon polaritons (SPPs) can be enhanced. The coupling of excitons to SPPs in Au- and Al-coated GaAs/AlAs/GaAs core-shell nanowires, possessing diameters of ~100 nm, was probed using time-resolved cathodoluminescence (CL) [1]. The GaAs/AlAs/GaAs nanowires were grown by molecular beam epitaxy (MBE) using the self-assisted VLS method on Si(111) [2]. Uniform diameter GaAs nanowires were grown with a high aspect ratio with no significant tapering and a pure zinc-blende structure, as revealed by TEM. The Au and Al films were deposited at near normal incidence onto the nanowires at room temperature. The surface roughness was studied with high resolution SEM and AFM. Excitons were generated in the metal coated nanowires by injecting a pulsed high-energy electron beam through the thin metal films. Due to the opacity of the metal with respect to light/laser excitation from the top surface, CL is shown to be a particularly useful probe for the metal/nanowire (or more generally for metal coated nanostructure systems) in that the high-energy electron beam can easily penetrate the metal film and create excess *e-h* pairs in the semiconductor nanostructure. The variable distance from the surface, at which excitons recombine, results in a range in the expected Purcell enhancement factor (F_p) which describes the enhanced radiative recombination rate due to coupling of the excitons to the SPP modes of the metal film. The SPPs can be converted to free-space photons if the propagating SPPs in the thin metal film are scattered by the surface/interface roughness or grain boundaries of the polycrystalline metal film, owing to the momentum change associated with the scattering that enables a matching with the ω vs k light dispersion relation. The Purcell enhancement factor (F_p) was obtained by direct measurement of changes in the temperature-dependent decay and radiative lifetimes caused by the nanowire exciton-SPP coupling. In order to analyze the coupling, we have developed a model for the average F_p in the Au and Al covered nanowires by taking into account the dependence of F_P on the distance from the metal film and the thickness of the film covering the nanowires possessing various cross-sectional shapes [1]. The present study suggests a more general approach for treating metal-covered nanostructures in which exciton diffusion in the mesoscopic regime can influence the observed plasmonic effects.

[1] Y. Estrin, D. H. Rich, A. V. Kretinin, and H. Shtrikman, Nano Lett. 1**3,** 1602 (2013).
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