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Exciton-Plasmon Coupling in ZnO/MgO Core-Shell Nanowires

CLAIRE MARVINNEY, DANIEL MAYO, Vanderbilt University, EPHRAIM BILILIGN, North Carolina State University, RICHARD MU, Fisk University, RICHARD HAGLUND, Vanderbilt University — Zinc oxide (ZnO) has emerged as one of the most promising materials for optoelectronic applications. A wide direct bandgap of 3.37 eV with a large exciton binding energy of 60 meV results in a band-edge exciton that is more thermally stable than the commonly used semiconductor GaN. Room temperature photoluminescence (PL) spectra for ZnO exhibit a sharply defined peak centered at 3.3 eV, and a broad visible peak centered around 2.3 eV. One of the most effective methods for PL enhancement for optoelectronic devices is through the Purcell mechanism via coupling localized surface plasmons to the ZnO luminescent centers. We have demonstrated dramatic band-edge emission enhancement and quenching in core-shell ZnO/MgO NWs coated variously with Ag, Al, and Au nanoparticles. The MgO coating acts as an insulating layer allowing isolation of plasmon-mediated emission due to hot-electron transfer from that due to local field mechanisms. Extremely large band-edge PL enhancement occurs at specific MgO shell thicknesses. This band-edge enhancement is hypothesized to be due to Fabry-Perot cavity resonances in the core-shell NW. Functionalization of the core-shell NWs with the various metal nanoparticles species results in PL enhancements that correspond to the strength of the plasmonic coupling, with Al nanoparticles exhibiting the highest PL enhancement. These results establish the plasmonic core-shell NW structure as a strong platform for optoelectronic applications.

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