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The Role of Surface Ligands in Electronic Charge Transport in Semiconductor Nanocrystal Arrays

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The long, insulating ligands commonly used in the synthesis of colloidal semiconductor nanocrystals (NCs) inhibit strong interparticle coupling and charge transport once NCs are assembled in the solid state into NC arrays. We introduce ammonium thiocyanate (NH_4SCN) and its derivatives, ammonium selenocyanate and selenourea to exchange the long, insulating ligands commonly used in the synthesis of colloidal semiconductor NCs. NCs may be exchanged with the new ligand in solution to form dispersions from which NC arrays are deposited or NC arrays with the long, insulating ligands may be exchanged in the solid state with the new ligands. The new compact ligands enhance interparticle coupling and charge transport in thin film, NC arrays as seen by red-shifts in the optical absorption and concomitant increases in carrier mobilities. Thiocyanate-capped CdSe thin film, NC arrays form sensitive photodetectors and n-type field-effect transistors with electron mobilities of $\sim$10 cm^2/Vs and current modulation of $>10^6$, while preserving NC quantum confinement. Temperature-dependent transport measurements reveal band-like transport in NC arrays, overcoming carrier hopping that has typified transport in NC arrays until recently. The non-caustic, chemically benign nature of the ammonium thiocyanate treatment enables the fabrication of NC thin film devices and circuits on flexible plastics.