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How many electrons make a semiconductor nanocrystal film metallic[1] KONSTANTIN REICH, TING CHEN, NICOLAAS KRAMER, HAN FU, UWE KORTSHAGEN, BORIS SHKLOVSKII, Univ of Minnesota - Twin Cities
— For films of semiconductor nanocrystals to achieve their potential as novel, low-cost electronic materials, a better understanding of their doping to tune their conductivity is required. So far, it not known how many dopants will turn a nanocrystal film from semiconducting to metallic. In bulk semiconductors, the critical concentration n_M of electrons at the metal-insulator transition is described by the famous Mott criterion: $n_M a_B^3 \simeq 0.02$, where a_B is the effective Bohr radius. We show theoretically that in a dense NC film, where NCs touch each other by small facets, the concentration of electrons $n_c \gg n_M$ at the metal-insulator transition satisfies the condition: $n_c \rho^3 \simeq 0.3$, where ρ is a radius of contact facets. In the accompanying experiments, we investigate the conduction mechanism in films of phosphorus-doped, ligand-free silicon nanocrystals. At the largest electron concentration achieved in our samples, which is half the predicted n_c, we find that the localization length of hopping electrons is close to three times the nanocrystals diameter, indicating that the film approaches the metal-insulator transition.

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