Dark and Photo-Conductivity in Ordered Array of Nanocrystals

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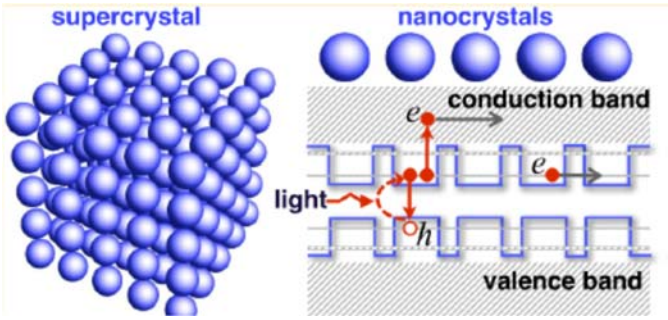

A band structure of a super-crystal consisting of nano-crystals (NCs) is calculated and a theory of the photo- and dark conductivities is developed. The electron transport properties are calculated assuming scattering by the structural defects of the super-crystal. A new mechanism of photo excitation, specific for this system, is proposed. It is triggered by a very efficient Auger ionization of charged NCs into high energy quasi-free states of the super-crystal with the simultaneous recombination of electron-hole pairs. The mobility of the photo excited carriers is found to be three orders of magnitude larger than the dark mobility when the NC are in contact. The low value of dark mobility is caused by small width of the band formed by overlapping ground states of the NCs. Both these values decrease exponentially with a distance between NCs. Therefore the photo-current, the magnitude of which is proportional to the excitation intensity and resident electron density, can be 2--3 order of magnitude larger than the dark current. The results of these calculations are in good agreement with available experimental data. The Anderson and the Mott insulator-metal transitions are considered for the dark conductivity. The threshold of the transition is calculated as a function of a lattice constant, NC radius, and disorder. The temperature dependence of the dark conductivity above the threshold is calculated. It is predicted that the increase of the dark conductivity in the transition range is accompanied by a suppression of the Auger processes and by decrease of the photo current.