Deposition of Pt and Au quantum dots on TiO_2 nanoparticles: A study of ballistic electron transport with dye-sensitisation

L S G Liyanage[1] and V P S Perera[1,2] *
[1] *Department of Physics, Open University of Sri Lanka, Nawala*
[2] *Institute of Fundamental Studies, Kandy*

Metallic and metal oxide semiconductor nanoparticles have become an area of growing interest and importance in many fields. Particles in nano range (< 100 nm) have different properties than that of the bulk materials. For example, the conduction band, which is present in bulk metals, is absent in nano metallic particles, where instead they have discrete energy states. Further, the band gap energy depends on the particle size of the semiconductor. So that, when metallic and semiconductor nanoparticles are made to be in contact, they have unique optical, electronic and chemical properties.

Depletion region similar to a bulk semiconductor in contact with a metal does not exist when a metallic quantum dots are deposited on a semiconductor nano-particle because of their small dimensionality. However electrons transfer from low work function material to the higher work function material to establish an equilibrium energy state. In this study, we have deposited quantum dots of Pt and Au on TiO_2 nanoparticles by mixing TiO_2 powder (Diggusa P-25) in a measured volume of ultra diluted solutions of gold chloride hydrate and chloroplatinic acid and sintering at 500 °C in a furnace where quantum dots of Au and Pt deposited respectively on TiO_2 nano-particles.

It is important to note that the metallic composition in TiO_2//Pt or TiO_2/Au matrix is very low. However, with the increment of metallic composition in the matrix, the conductivity seems to decrease because conduction electrons in TiO_2 transfer to the metal particles increasing the resistivity since the work function of Pt and Au are lower than the work function of TiO_2. The resistivity depends on the number of metallic quantum dots on TiO_2 nano-particles as well as the size. These metallic quantum dots deposited on TiO_2 nanoparticles were examined with diffusion reflectance spectroscopy and flat band potential was determined with Mott-Schottky measurements. With the increment of Pt in the matrix, band gap seems to shrink while the flat band potential moves towards more negative values, which is consistent with the variation of resistivity.

Secondly, we have studied the transport of electrons in TiO_2/Pt matrix by employing this material in a dye-sensitised solar cell. Generally the excited level of the dye is well above the conduction band of the semiconductor so that electrons are injected as hot carriers to the semiconductor and it has been previously shown that those electrons travel ballistically through thin gold films deposited on TiO_2 films. When the composition of TiO_2/Pt matrix varied, we found an optimum cell with highest photocurrent. At this optimal level, it is supposed to form minibands between the Pt quantum dots and TiO_2 nano-particles in which electrons could travel without any phonon interaction so that the process is dissipativeless. Therefore, the photocurrent of the cells increases due to suppression of recombination. Study of quantum level effects with this type of simple techniques is encouraged to promote research in nano-technology, which is an emerging field in science.

Acknowledgement: Financial assistance by the NSF research grant RG/2004/P/03

* vpper@ou.ac.lk Tel: 011-2853777 Ext.445