

Using an electrochemical Field Effect Transistor to determine electron mobilities in quantum dot layers

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Nanocrystalline films have attracted considerable attention because of their possible use in solar cells, light emitting diodes, electrochromic windows, and batteries. The mechanism of electron transport in nanoparticulate films is essential for the performance of electrical devices.

Electron transport in porous particulate electrodes, consisting of electrically connected non-quantized particles (>10nm), has been studied extensively (1). New transport phenomena are expected if the size of the nanoparticles comes into the 1-5nm range. First, electrons occupy discrete electron levels, due to quantum confinement effects; this means that electron transport occurs by particle-to-particle tunneling. Second, the single dot charging energy (>100 meV) may result in a Coulomb-blockade of electron transport.

We investigated electron storage and transport in 3-D assemblies of insulating nanoparticles (ZnO and CdSe) using an electrochemical field effect transistor (2). Two inert electrodes, similar to the source and drain in a field effect transistor are electrically connected by a 'bridge' of the material to be studied (i.e. the porous nanoparticulate film, see figure 1) (3). This set-up, with a reference and a counter electrode, is placed in an electrolyte solution which penetrates the porous layer. The reference electrode in this system is connected as a gate electrode and is used to control the amount of electrons in the nanostructured film and hence, the control of the electrochemical potential of the bridge. The electron mobility is then obtained from measurement of the resistance of the bridge (i.e. the source-drain current i_{SD} is measured for a small source-drain potential difference).

The electron storage characteristics (the number of electrons per particle vs. the electrochemical potential) of ZnO and CdSe nanoparticulate films show quantum confinement effects (Figure 2) and a clear difference between aqueous and non-aqueous electrolyte solutions. In the case of CdSe quantum dots, the potential at which charge could be injected into the structure was strongly dependent on the particle size and the capping molecules. The electron mobility increased with the number of electrons per particle and for ZnO we possibly observed enhanced tunneling if p-type orbitals are involved in stead of s-type orbitals (Figure 3).

Furthermore the type of electrolyte solution (aqueous or non-aqueous) affected the electron mobility but the dielectric constant did not seem to have an effect.

REFERENCES

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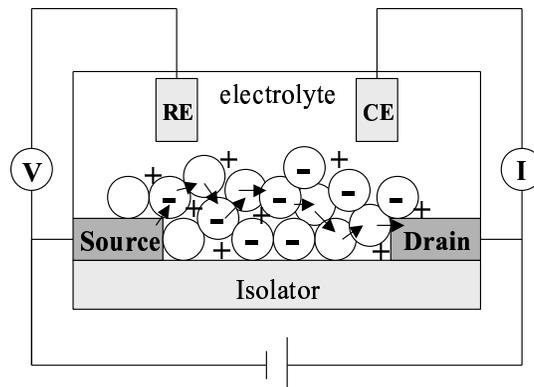


Figure 1: The electrochemical FET: The source-drain current is measured as a function of the electron concentration in the semiconductor film.

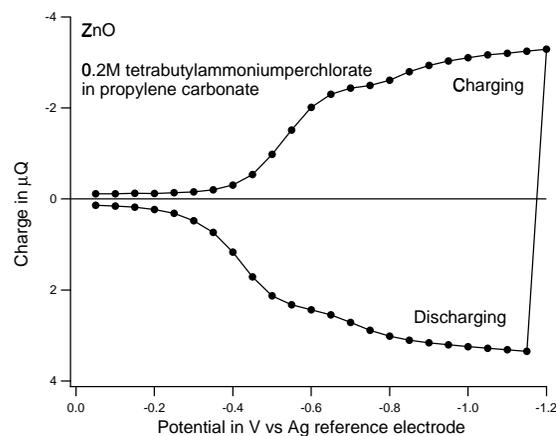


Figure 2: Charging and discharging characteristics of a nanoparticulate ZnO film as a function of the electrochemical potential.

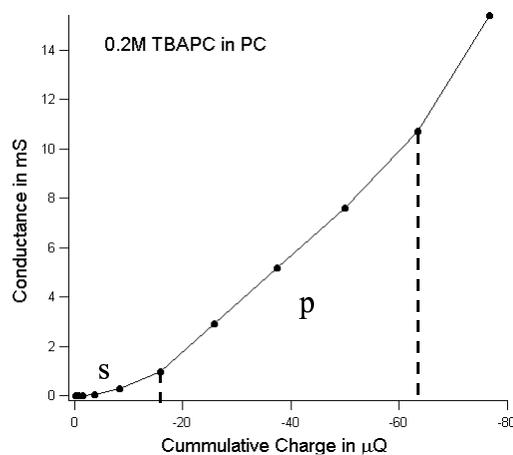


Figure 3: Conductance of the nanoparticulate ZnO film as a function of the electron concentration in the film. Two distinctive regimes of conductance are observed.