

Electron transport in anatase TiO₂ nanocrystal films

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Metal oxide nanocrystal films are found in photovoltaics, electrocatalysts, and sensors. The performance of these devices critically depends on the electron transport through the network and hence inter-particle contact within the film is indispensable [1]. Electron transport in semiconductor nanocrystal electrodes occurs mainly by diffusion and is trap-limited [2]. However, due to the high structural and energetic disorder of nanoparticle electrodes, the impact of particle consolidation, density and energetic distribution of trap states on the electron transport is still not fully understood.

TiO₂ particle powder was prepared by chemical vapor synthesis and consists of isolated, non-aggregated anatase nanocrystals with a narrow particle size distribution and clean surfaces [3]. Nanoparticle films were obtained by spreading an aqueous dispersion of TiO₂ particles onto conductive substrates. Sintering the immobilized films at different temperatures ($100\text{ °C} \leq T \leq 450\text{ °C}$) induces particle-particle contact formation. Importantly, structural properties of the films (i.e. specific surface area, particle size and crystallite domain size) were preserved as evidenced by X-ray diffraction, transmission electron microscopy and nitrogen sorption. Hence, these electrodes constitute a proper model system for studying how the electronic conductivity depends on the density of electrochemically active states, which is modified by sintering temperature. Trap distribution was determined by cyclic voltammetry, chronoamperometry, and impedance spectroscopy. The electronic conductivity was extracted from impedance spectra or directly measured by electrochemical gating [4]. Our results point to a strong impact of a narrow distribution of deep traps presumably located at particle-particle interfaces on the electronic conductivity.

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