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Title:Electron mobility and injection dynamics in mesoporous ZnO, SnO_2, and TiO_2 films used in dye-sensitized solar cells

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Abstract:High-performance dye-sensitized solar cells are usually fabricated using nanostructured TiO_2 as a thin-film electron-collecting material. However, alternative metal-oxides are currently being explored that may offer advantages through ease of processing, higher electron mobility, or interface band energetics. We present here a comparative study of electron mobility and injection dynamics in thin films of TiO_2, ZnO, and SnO_2 nanoparticles sensitized with Z907 ruthenium dye. Using time-resolved terahertz photoconductivity measurements, we show that, for ZnO and SnO_2 nanoporous films, electron injection from the sensitizer has substantial slow components lasting over tens to hundreds of picoseconds, while for TiO_2, the process is predominantly concluded within a few picoseconds. These results correlate well with the overall electron injection efficiencies we determine from photovoltaic cells fabricated from identical nanoporous films, suggesting that such slow components limit the overall photocurrent generated by the solar cell. We conclude that these injection dynamics are not substantially influenced by bulk energy level offsets but rather by the local environment of the dye-nanoparticle interface that is governed by dye binding modes and densities of states available for injection, both of which may vary from site to site. In addition, we have extracted the electron mobility in the three nanoporous metal-oxide films at early time after excitation from terahertz conductivity measurements and compared these with the time-averaged, long-range mobility determined for devices based on identical films. Comparison with established values for single-crystal Hall mobilities of the three materials shows that, while electron mobility values for nanoporous TiO_2 films are approaching theoretical maximum values, both early time, short distance and interparticle electron mobility in nanoporous ZnO or SnO_2 films offer considerable scope for improvement. © 2011 American Chemical Society.