# Preparation of a Nanostructured Composite of Titanium Dioxide and Polythiophene: New Routes Towards 3D Heterojunction Solar Cells

*Carolien L. Huisman, Albert Goossens, and Joop Schoonman*

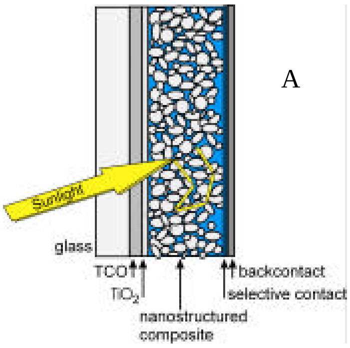
Laboratory for Inorganic Chemistry, Faculty of Applied Sciences, Delft University of Technology, Julianalaan 136, 2628 BL Delft, The Netherlands. Phone: ++31-15-2782637, fax: ++31-15-2788047, email: c.l.huisman@tnw.tudelft.nl, web page: www.dct.tudelft.nl/ac

## Design of a 3 dimensional hybrid solar cell

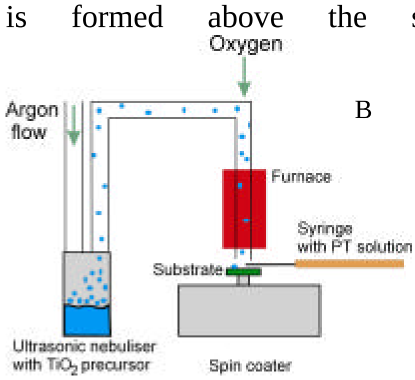
In 1991 Prof. Grätzel and his co-workers have shown that a solar cell, consisting of nanoporous titanium dioxide and covalently attached ruthenium complexes, exhibits an efficiency of around 10%. This is a large step forward in the utilisation of organic dyes in combination with wide-bandgap semiconductors in photovoltaic devices. Since that time much effort has been directed towards the development of similar nanostructured heterojunctions that can function without liquid electrolyte. One of the possible solutions is the use of dyes that are not only the light-absorbing and electron-injecting species, but also can transport holes. Electrons diffuse through the n-type semiconductor to the front electrode and the remaining holes migrate through the p-type organic layer to the back electrode. Although organic substances have in general much lower hole mobilities than inorganic compounds, semiconducting polymers, like polythiophenes and polyphenylene vinylenes, have been used successfully in combination with $C_{60}$ molecules. Designing a solid-state heterojunction is a tedious task, as intimate, nano-range contact is required as well as control over morphology, structure, and layer thickness. A one-step process, in which both the n-type metal oxide and the p-type semiconducting polymer are deposited on the substrate in the form of a nanostructured network, is an elegant method to achieve the desired 3-dimensional heterojunction.

## Technique

Nebulized Vapour Deposition (NVD) is a novel technique, which enables the formation of nano-sized particles of metal oxides (like $TiO_2$) and the simultaneous built-up of a polymer network. Titanium isopropoxide (TTIP) is ultrasonically agitated in a flask and an aerosol of small droplets is formed above the surface.




A




B

Fig. 1: a) Schematic representation of a nanostructured heterojunction. b) Set-up of Nebulized Vapour Deposition.

Using an inert carrier gas, these droplets are led through a glass tube where they are heated to form $TiO_2$ particles. The decomposition reaction to $TiO_2$ is spontaneous at temperatures above 100°C, but to ensure that stoichiometric anatase $TiO_2$ is formed, oxygen is added. The $TiO_2$ particles are deposited on a substrate, which is placed on a spin coater at the end of the tube. At the same time drops of a polythiophene (PT) solution are applied onto the substrate. The substrate is rotating at high speed, making sure that both $TiO_2$ particles and polymer drops are equally spread and form an interpenetrating network. By variation of parameters like gas flow, furnace temperature, precursor concentration, and polymer addition interval, the crystal structure, particle size, and percolation of the deposited blend can be influenced.

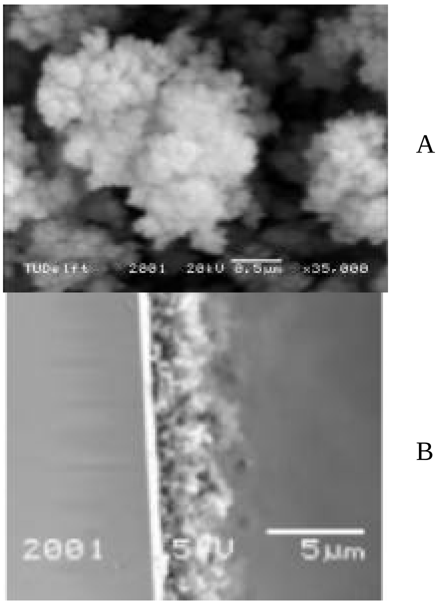



Fig. 2. a) Top view of deposited $TiO_2$ particles. Small particles with diameters of ~50 nm form agglomerates of several µm. b) Cross-section of the same sample. The film thickness is about 4 µm.

Synthesized solar cells

To investigate whether or not the $TiO_2$ particles, produced with NVD, are suitable to use in a solar cell, first a conventional dye sensitized cell has been constructed using a Ru-complex (Ru353) and an iodine/iodide electrolyte. This cell shows a clear photovoltaic effect and a photocurrent action spectrum, which indicates that the Ru-dye injects in the $TiO_2$. Also a polymer-based cell is produced by spincoating PT on top of a film of $TiO_2$ particles. The current-voltage characteristics of this cell are compared to a cell constructed from a flat-film $TiO_2$, with a spincoated PT layer with similar optical density. The nanostructured cell shows a higher photocurrent, but a fairly low fill factor. The next step in the process is to simultaneously deposit $TiO_2$ and PT on a sample. Experiments are currently directed towards this objective.

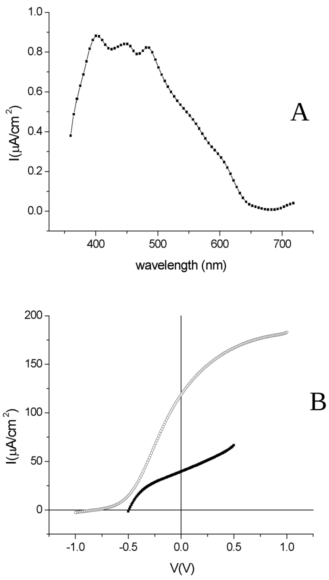



Fig.3. a) Photocurrent action spectrum of a ~4 µm thick dye sensitized $TiO_2$ layer immersed in $I_2/I^-$ electrolyte. b) Current-Voltage characteristics of: (■) a ~100 nm thick spincoated layer of PT on flat $TiO_2$ (~100 nm thick, deposited using Chemical Vapour Deposition) and (o) spincoated PT on a ~3 µm layer of nanoparticles $TiO_2$, deposited using NVD. In both cases the illumination direction is through the conducting oxide using white light and a 360 nm high-pass filter.