

## Electroless and Electrochemical Deposition of Zinc Oxide on Passive Metals as Electrodes in Textile-Based Dye-Sensitized Solar Cells

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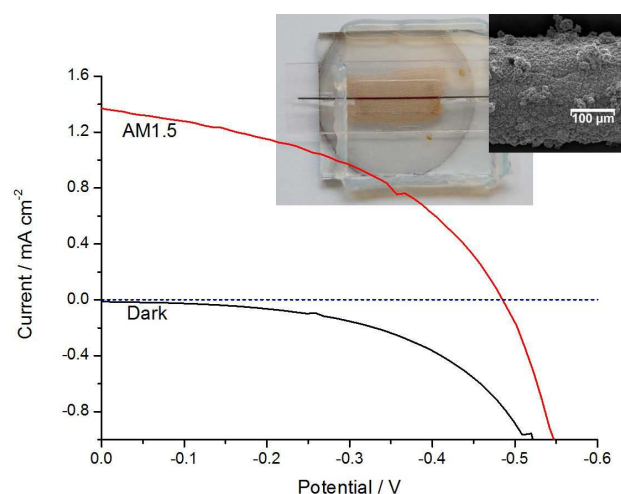
In the rapidly developing and highly integrated electronic industry, especially in the fields of portable and high-integrated micro-electronic equipment, there is an interest to incorporate power supplies like solar cells directly into the electronic products to create a grid-independent energy supply. This also holds for textile-based electronics which are developed in particular for safety, health and outdoor applications. In this context it would be favorable to use textile-based photovoltaics in order not to interfere with the mechanical ruggedness and flexibility of textiles by incorporation of a classic PV device. To use textile substrates as electrodes a cell design is needed that allows a minimum electrode distance of about 50-100  $\mu\text{m}$ , the typical limit of textile technologies like weaving. Dye-sensitized solar cells (DSCs) can fulfill this requirement. DSCs based on textile fibers could thus be integrated in such equipment due to their flexibility and customizable shape, allowing the creation of "smart textiles" and mechanically flexible and rugged solar cells.

Zinc oxide (ZnO) can be electrochemically deposited as porous semiconductor for DSCs in a three-dimensional fashion at low temperatures well compatible with textile electrodes. In past reports, Ag-coated filaments, yarns and knitted fabrics were used as substrate electrodes [1]. However, small cracks in the semiconductor allowed access of the redox electrolyte to the Ag electrode, leading to corrosion of the latter which undermined a successful operation. The investigation of alternative metals which form a stable passive oxide on the surface is of great importance to establish reliable cells.

As a model system closest to an optimum textile substrate, metal wires were used for electroless and electrochemical deposition. Electroless depositions were carried out on aluminum wires with a diameter of 250  $\mu\text{m}$  after pre-treating the substrates in hydrochloric acid and subsequently in an alkaline zinc hydroxide solution (zincate stain). Parallel experiments on aluminum sheets served to establish the deposition and characterize the products in detail. During pre-treatment, aluminum was oxidized to aluminate allowing to reduce zincate to metallic zinc which grew on the aluminum surface. The aluminum sheet or wire was placed into a classic aqueous deposition bath for the deposition of porous ZnO [2] of 5mM zinc chloride saturated with oxygen, including 0.1M KCl and 50 $\mu\text{M}$  of the xanthene dye EosinY at 70°C, however, without any electrical connections. The resulting thickness of the porous zinc oxide film was studied in dependence on the Zn-thickness from zincate treatment. By use of different thicknesses of the zinc layer and different deposition times, it was found that the electroless deposition of porous ZnO was self-limiting to about 8  $\mu\text{m}$ . This low-cost method allowed the preparation of homogeneous and adherent porous ZnO films.

In addition to such electroless deposition, electrochemical depositions were carried out on aluminum, tantalum and tungsten wires with a diameter of 250  $\mu\text{m}$  from unstirred zinc nitrate solution or from oxygen saturated aqueous zinc chloride solution, both at 70°C. A compact film of ZnO was initially deposited and following the addition of EosinY as a structure directing agent, a porous ZnO film was deposited on top.

The structure-directing EosinY molecules which filled the pores of the porous ZnO were removed by alkaline treatment [3]. The indoline dye D149 was adsorbed on the porous surface of the ZnO film as a sensitizer. Photoelectrochemical measurements were performed on the D149-sensitized ZnO films under standardized illumination conditions and in the dark on the fabricated cells in contact to an organic iodide/triiodide redox electrolyte in a two-electrode photoelectrochemical setup (Figure 1). The electrochemical deposition on the different metals and their suitability as active electrode materials in DSCs will be discussed.



**Figure 1.** IV-curves of a DSC consisting of a D149-sensitized ZnO film on a tantalum wire.

### References

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