Electrochemical growth and characterization of ZnO Nanowires, grown on ITO substrates, for solar cells applications

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INTRODUCTION

In this paper we investigate the fabrication process of ZnO nanowires (NWs) for application in inorganic solar cells, targeted to incorporate quantum dots (QD) or an extra thin absorber (ETA) layer (Fig.1). The operation principle of this nanostructured cell is similar to the dye-sensitized solar cell (DSSC).

Compared to the TiO_2-particle network, which is conventionally used in DSSC, ZnO NWs offer:

• An improved electron transport by providing a direct electrical path between the photosensitive material and the bottom electrode, so that transport does not depend on hopping conductance

• A large surface to volume ratio that would enhance the light harvesting efficiency of the cell

The NW morphology is therefore a key issue towards the solar cell development and is highly dependent on the parameters of the fabrication process.

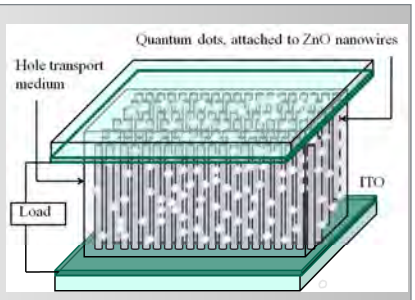

Fig. 1. Schematic presentation of the cell architecture

FABRICATION METHOD

ZnO NWs were fabricated on glass substrates, covered by tin-doped indium oxide (ITO), via electrodeposition synthesis. The process was carried out in a conventional three-electrode electrochemical cell in aqueous solution (DI water and methanol) containing a mixture of $Zn(NO_3)_2$ and hexamine. We have investigated the influence of the process parameters, namely

• concentration of solution components
• the applied potential
• deposition temperature
• deposition time

on the morphology of the ZnO NWs. The structure formation of the NWs on the initial growth stages was investigated via XRD-measurements.

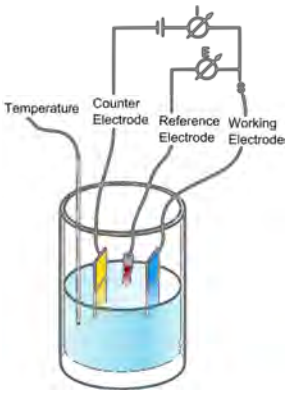

Fig. 2. Experimental setup

EXPERIMENTAL RESULTS: EFFECT OF THE PRECURSORS CONCENTRATION

It was established, that the aspect ratio of NWs can be controlled as per requirement by varying the concentrations of $Zn(NO_3)_2$ and hexamine. The reduction of $(ZnNO_3)_2$ content in the solution leads to higher aspect ratio, i.e. smaller diameter. The addition of hexamine to the solution blocks the lateral growth of NWs, decreasing therefore their thickness.

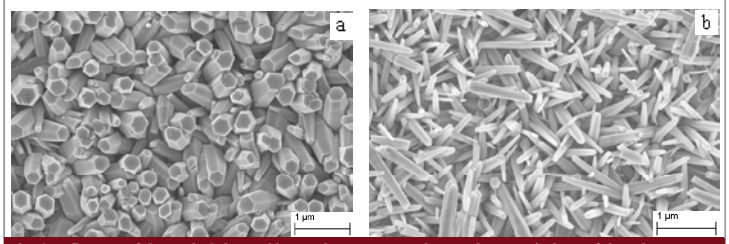

Fig. 3. Influence of the $Zn(NO_3)_2$ and hexamine concentration on the morphology of the wires (a) 5mM $Zn(NO_3)_2$, (b) 0.5mM $Zn(NO_3)_2$ +0.75mM Hexamine)

EXPERIMENTAL RESULTS: EFFECT OF THE TEMPERATURE AND THE POTENTIAL

It was established, that the process temperature influences the crystallinity of the NWs, whereas applied potential controls mostly the NWs density. Fig. 4a-b. show scanning electron microscope images of the NWs, grown at the same process conditions, but at different temperatures. It is seen, that a minimum temperature of 80° C is needed to obtain NWs with good crystalline structure. Fig. 4c-d. show the influence of the applied potential on the wires density. The increase of applied potential results in an increased density of NWs.

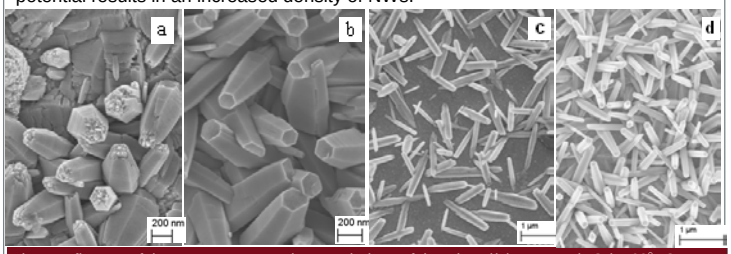

Fig. 4. Influence of the temperature on the morphology of the wires ((a) 5mM $Zn(NO_3)_2$, 60° C ,-0.8V, (b) $Zn(NO_3)_2$, 80° C,-0.8V, (c) 0.25mM $Zn(NO_3)_2$ +0.75mM Hexamine,-1V, (d) 0.25mM $Zn(NO_3)_2$ +0.75mM Hexamine,-1.1V)

XRD-MEASUREMENTS OF INITIAL NANOWIRES GROWTH

The formation of the crystalline ZnO-structure was measured using X-ray diffraction technique in theta-2theta geometry on the samples, grown for different deposition times. The measurements were undertaken at BRUKER D8 with 2D-CCD-Detector and rotating sample holder. Fig. 5. shows the development of the ZnO-NWs structure peaks on the ITO substrate for increasing deposition times. The peaks of (100), (002), (101), (102) and (110) directions could be identified. The formation of ZnO structures is observed for samples of deposition times longer than 1 min. The growth of the (002) is fastest and favourable growth direction, followed by (101) and (100). This competing development of three major peaks can explain different growth direction of the ZnO-NW (see Fig. 6). Because of the lattice mismatch between the ITO-substrate and the ZnO it is advisable to use a seeding layer of ZnO-nanoparticles to obtain an aligned growth of NWs the ITO surface.

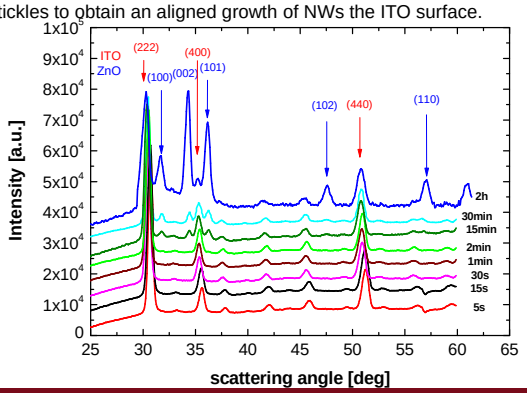

Fig. 5. XRD-Measurement of structure formation of ZnO-NWs at different deposition stages

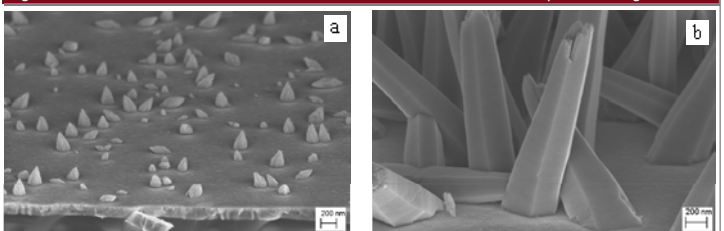

Fig. 6. SEM-Images of NWs, grown for a) 2min and b) 2hours

CONCLUSIONS

▪ A relatively simple and low-cost method electrodepostion method was introduced for fabrication of NWs for solar cells application.

▪ The influence of the process parameters, such as applied potential, concentration of the precursors and temperature on the morphology and density of NWs was thoroughly investigated.

▪ It was shown, that the aspect ratio of NWs can be controlled as per requirement by varying the concentrations of precursors in the solution, whereas the density of the wires depends mostly on the applied voltage. The temperature controls the crystallinity of the NWs.

▪ The XRD-measurements show that ZnO-NWs follow the structure of ITO during the first minutes of growth. Afterwards the crystal structure of ITO starts dominating. The competing directions of growth are (002), (101) and (100), what can explain the growth of NWs in different directions.

ACKNOWLEDGMENT

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