Photoelectrical conversion using pn junctions based on transparent semiconductor oxides

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Faculté : Faculté des Sciences appliquées
Diplôme : Master en ingénieur civil physicien, à finalité approfondie
Année académique : 2017-2018
URI/URL : http://hdl.handle.net/2268.2/4682

Photoelectrical conversion using PN junctions based on transparent semiconductor oxides

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Master Thesis presented in partial fulfilment of the requirements for the master degree in physics engineering

Academic Year: 2017-2018

This master thesis focuses on thin film solar cells based on Transparent Conductor Oxide (TCO) that are able to generate an electric current while maintaining their transparency to visible light for photovoltaic and UV detectors applications. The studied heterostructure is based on Nickel Oxide (NiO), which is a new interesting material that exhibit an p-type behaviour, and Zinc Oxide (ZnO), a well-known n-type material subjected to many scientific researches in many fields. Moreover, dip-coating deposition technique is used in this master thesis to synthesised the heterojunction. This fabrication process is a soft chemical deposition technique where sol-gel solutions are used as precursors for the deposition. All the depositions are performed on a transparent glass substrate coated by a Fluorine Tin Oxide (FTO) thin film that plays the role of an ohmic back contact. Gold pads are deposited by sputtering on the top of the NiO (p-type side) to form the top contacts. The resulting heterostructure is characterised by different methods and the obtained I-V curves are compared to a simple analytical model.

1 Heterostructure design and fabrication

A sol-gel solution for each metal oxide (NiO and ZnO) has been synthesised for dip-coating. Each solution is taken from the literature and some minor modifications have been brought to the recipe in order to stabilise the colloidal solution. Furthermore, the dip-coating process has been optimised several times to reach good quality thin films. A cross sectional SEM image of the final heterostructure ZnO/NiO is given in Figure 1 and reveals a good structural layering of the different TCOs.

During the fabrication process, the thickness of each layer and their morphology have been studied for different viscosity of the solutions, different dip-coating withdrawal speeds and different substrates (Glass and FTO). XRD measurements were performed on different samples to identify the crystallinity. The transparency and the resulting energy band gap were deduced from transmittance measurements. AFM measurements and SEM images were performed for each TCO in order to characterise their texture and morphology.

2 Characterisation and analytical modelling

Finally, an analytical model of a PN heterojunction is developed. Under some assumptions, the model can be simplified into Equation 1 of an homojunction, where the complex behaviour of the real junction is taken into account by different factors: R_s and R_{sh} [Ω] respectively the series and shunt resistance and n [-] the ideality factor.

$$J = J_{th}\left(\exp\left[\frac{q(V_a - IR_s)}{nk_bT}\right] - 1\right) + \frac{V_a - IR_s}{R_{sh}}, \quad (1)$$

where J [A/m^2] is the current density, J_{th} [A/m^2] the thermionic current density, q the electronic charge [C], V_a [V] the applied bias voltage, I [A] the measured current, k_b [m^2 kg s^{-2} K^{-1}] the Boltzmann constant and T [K] the temperature.

From the experimental data, R_s R_{sh} and n are extracted in order to understand whether or not the simple model can be used to describe the complex heterostructure. Moreover the temperature dependency of the junction, shown in Fig.2, is analysed through this model, and the influence of UV light on the junction is finally briefly studied where a weak photo-current is observed.

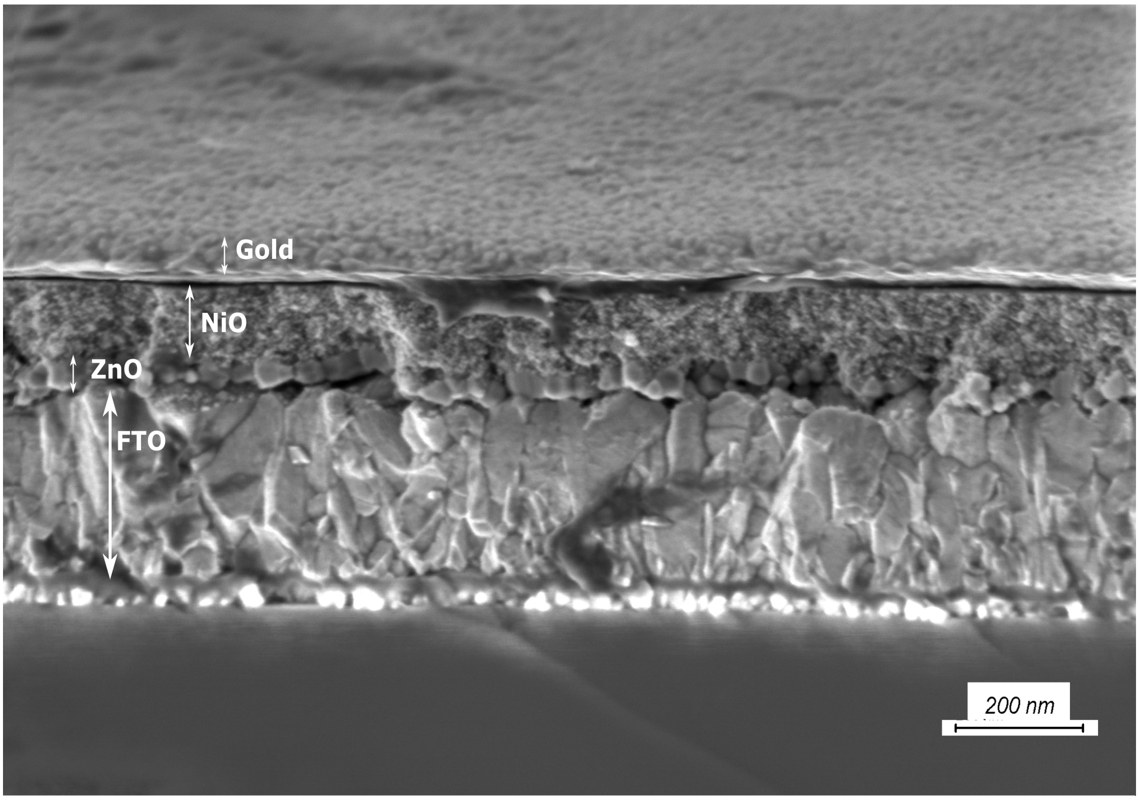

Figure 1: *SEM image (cross-section) of the heterostructure.*

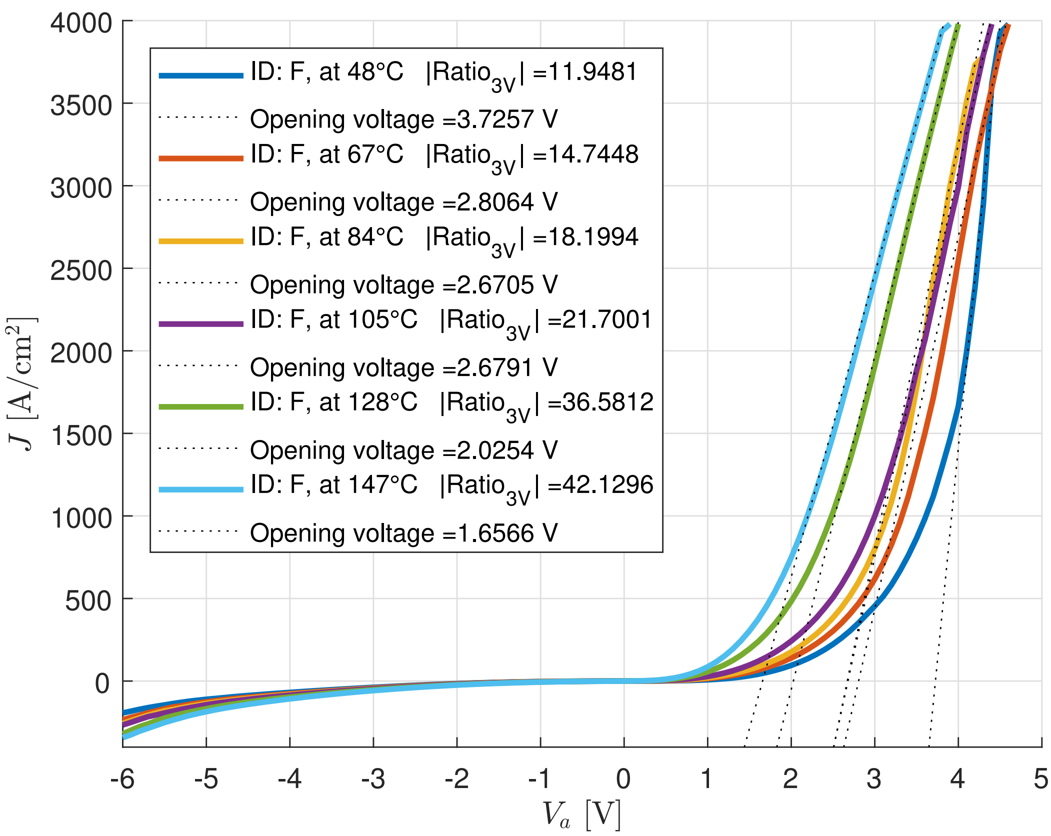

Figure 2: *Temperature dependency of the designed PN hetero-junction and its rectifying behaviour.*