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Analysis of single junction a-Si:H solar cells grown on different TCO's

Lucie Prušáková [a,*], Soňa Flickyngerová [c], Marinus Fischer [b], Ivan Novotný [c], Martijn Tijssen [b], Marie Netrvalová [a], Miro Zeman [b], Vladimír Tvarožek [c], Pavol Šutta [a]

[a] University of West Bohemia, New Technology Research Centre, Univerzitni 8, 306 14 Plzen, Czech Republic
[b] Delft University of Technology, DIMES, Delft, Netherlands
[c] Department of Materials & Technology, Slovak University of Technology, Bratislava, Slovakia

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A B S T R A C T

In consequence of previous investigation of individual transparent conductive oxide (TCO) and absorber layers a study was carried out on hydrogenated amorphous silicon (a-Si:H) solar cells with diluted intrinsic a-Si:H absorber layers deposited on glass substrates covered with different TCO films. The TCO film forms the front contact of the super-strata solar cell and has to exhibit good electrical (high conductivity) and optical (high transmittance) properties. In this paper we focused our attention on the influence of using different TCO's as a front contact in solar cells with structure as follows: Corning glass substrate/TCO (800, 950 nm)/*p*-type μc-Si:H (~5 nm)/*p*-type a-Si:H (10 nm)/a-SiC:H buffer layer (~5 nm)/intrinsic a-Si:H absorber layer with dilution $R = [H_2]/[SiH_4] = 20$ (300 nm)/*n*-type a-Si:H layer (20 nm)/Ag + Al back contact (100 + 200 nm). Diode sputtered ZnO:Ga, textured and non-textured ZnO:Al [3] and commercially fabricated ASAHI (SnO_2:F) U-type TCO's have been used. The morphology and structure of ZnO films were altered by reactive ion etching (RIE) and post-deposition annealing.

It can be concluded that the single junction a-Si:H solar cells with ZnO:Al films achieved comparable parameters as those prepared with commercially fabricated ASAHI U-type TCO's.

1. Introduction

Hydrogenated amorphous silicon (a-Si:H) is a promising semiconductor material for low-cost solar cells. Solar applications of a-Si:H are limited due to the metastable defect creation, the so-called Staebler–Wronski effect [1]. It has been demonstrated that solar cells with a-Si:H absorber layers prepared from silane source gas diluted with hydrogen in plasma enhanced chemical vapour deposition (PECVD) showed less degradation during light exposure than their conventional undiluted counterparts [2]. At present, the most important research area in the field of a-Si:H based solar cells is considered to be further development and implementation of efficient light trapping. Light trapping techniques help to capture light in the desired parts of a solar cell, which are the absorber layers, and prevent it from escaping. Efficient light trapping in a-Si:H silicon solar cells is based on scattering of light at rough interfaces resulting in a longer average optical path through the absorber layer. This ensures efficient light confinement that substantially enhances light absorption in the absorber layer and increases the photocurrent of the solar cell. Transparent conductive oxide films play a central role in light trapping approaches and, at present, determine the efficiency of the state-of-the-art solar cells. The development of TCO materials with required optical and electrical properties and optimal surface texture is today the most important issue in the field of thin film silicon solar cells.

2. Experimental details

ZnO:Al (AZO)/ZnO:Ga (GZO) films were prepared in a planar RF sputtering system (Perkin Elmer 2400/8L), using ceramic targets (ZnO + 2% Al_2O_3/ZnO + 2% Ga_2O_3) in Ar working gas at a constant pressure of 1.3 Pa onto Corning 7059 glass substrates. Other deposition conditions are listed below (Table 1). Two post-deposition technology steps were applied on some of the samples: RF sputter ion etching and post-deposition annealing in 80% of N_2 + 20% of H_2 forming gas (see Table 1). The thickness of the films had decreased by 80 nm after etching.

The structural parameters of the films (preferred orientation of crystallites, crystallite size, micro-strains) were studied by X-ray diffraction analysis (XRD) using an automatic X-ray powder diffractometer (X'pert Pro. Copper Kα characteristic radiation ($\lambda = 0.154$ nm) was used). Film thicknesses were measured using

* Corresponding author. Tel.: +420 377 634 733; fax: +420 377 634 702.
E-mail address: lprusak@ntc.zcu.cz (L. Prušáková).

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Table 1
Parameters of the deposition and post-deposition treatment of ZnO films.

Sample	Thickness [nm]	RF power [W]	Temperature [°C]	Sputter etching			Annealing	
				RF power [W]	Time [min]	T [°C]	T [°C]	Time [min]
AZO 1	800	800	200	–	–	–	–	–
AZO 2			200	75	30	RT	–	–
AZO 3			200	–	–	–	400	60
AZO 4			200	75	30	RT	400	60
GZO	950	600	RT	–	–	–	–	–

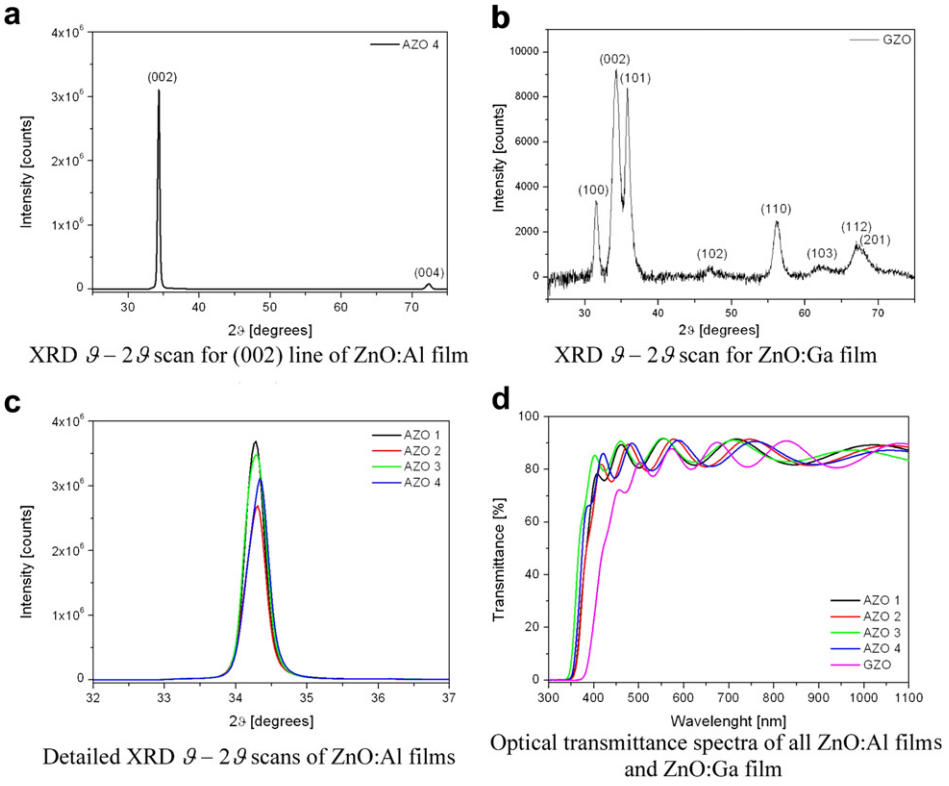

Fig. 1. Structural and optical data of AZO and GZO films. (a): XRD $\vartheta - 2\vartheta$ scan for (002) line of ZnO:Al film. (b): XRD $\vartheta - 2\vartheta$ scan for ZnO:Ga film. (c): Detailed XRD $\vartheta - 2\vartheta$ scans of ZnO:Al films. (d): Optical transmittance spectra of all ZnO:Al films and ZnO:Ga film.

a surface profile measuring system (DEKTAK 150), their electrical properties were obtained by the four-point probe and Hall measurements and optical transmittance was determined by spectrometer Specord 210. Surface morphology of the films was observed using an atomic force microscope (AFM).

Finally, we applied the ZnO films as substrates for single junction thin film solar cells based on amorphous hydrogenated silicon (a-Si:H). A series of a-Si:H *p-i-n* solar cells have been deposited using the AMOR PECVD deposition system in the Laboratory of Photovoltaic Materials and Devices, TU Delft – Dimes, Netherlands. For comparison commercial ASAHI U-type as well as TCO substrates mentioned above were used.

The solar cells have been characterised by illuminated current–voltage (*I–V*) measurements. The external parameters of the

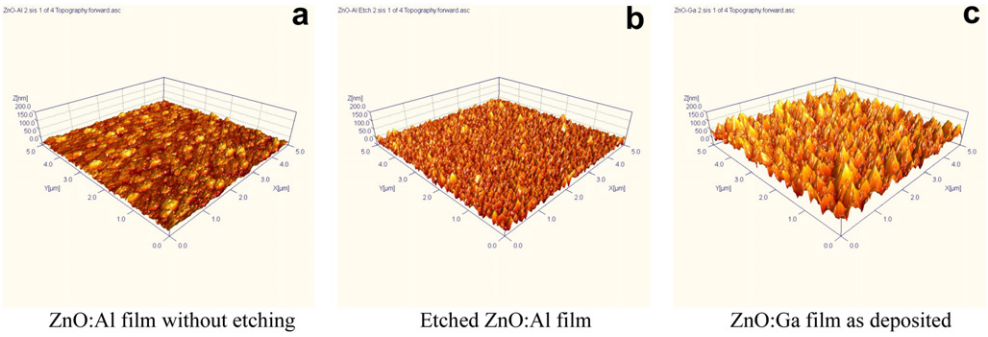

Fig. 2. AFM topography of AZO and GZO films. (a): ZnO:Al film without etching. (b): Etched ZnO:Al film. (c): ZnO:Ga film as deposited.