SOLID PHASE CRYSTALLIZATION OF AMORPHOUS SILICON ON ZNO:AL FOR THIN FILM SOLAR CELLS

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ABSTRACT

Solid phase crystallization (SPC) of amorphous silicon is an established approach for thin film solar cells [1]. Recently, 10.4% efficiency was achieved on a 94 cm² minimodule for crystalline silicon on glass (CSG) [2]. Contacts of these solar cells are etched from the rear side in a sophisticated way. Other thin film technologies based on amorphous Si (a-Si:H) or microcrystalline Si (µc-Si:H), e.g. a-Si/µc-Si tandem cells, have a rather simple contacting scheme by using transparent conductive oxides (TCOs) as front contact [3].

In this study, a new kind of thin film silicon solar cell structure is introduced combining the advantages of the two technological pathways described above: The potential for a high material-quality by SPC and well established and simple contacting by the use of a TCO.

1. INTRODUCTION

The idea of the solar cell concept under investigation is to merge certain aspects of currently established thin film technologies which are already applied for industrial production:

The CSG concept features the potential for a high material. Light trapping is achieved as a result of texturing the glass superstrate by dip-coating with 0.5 µm silica beads. Contacts and series connection of the device are realized by several processing steps including laser scribing, inkjet printing and etching. Heavily doped n+ and p+ poly-Si layers serve for lateral conductivity.

Other thin film technologies (e.g. a-Si, a-Si/µc-Si tandem) achieve a good lateral conductivity by the use of a TCO film as front contact. The solar cell device is operated in superstrate configuration. Separation of adjacent cells is done by laser patterning. Good light trapping in the solar cells is obtained as the TCO has an intrinsic texture after deposition (SnO:F) or can be textured in a single etching step (ZnO:Al) [4].

2. SOLAR CELL STRUCTURE

The design of the solar cell structure is shown in Fig. 1. Corning 1737 glass with 1mm thickness is used as superstrate. As TCO we use ZnO:Al films that were deposited on the cleaned glass superstrates by non-reactive RF-sputtering from ceramic targets. The thickness of the ZnO:Al films was around 700 nm. Some of these layers were textured by a single etching step in diluted hydrochloric acid.

Fig. 1 Schematic drawing of the silicon thin film solar cell with a ZnO:Al layer as front contact.

The silicon layers (n+/p-/p+) had a total thickness of about 1.3µm and were deposited at intermediate temperatures. Subsequently the stack was annealed in a tube furnace at 600°C for SPC of the silicon. Afterwards, defect-passivation was applied by plasma-hydrogenation. As back contact we used electron-beam evaporated aluminum (thickness: 1.5µm).

2. RESULTS

The deposited layers generally have a good adhesion after all processing steps at various temperatures. No blistering is observed. The cross section SEM images of Fig. 2 show the layers of the solar cell structures under investigation with (a) textured and (b) smooth layers. If
the underlying ZnO:Al layer is textured (a), the structuring is also seen in the silicon layer above.

Fig. 2 Cross section SEM images of the layer system taken with an angle of 30°: (a) on textured ZnO:Al, (b) on smooth ZnO:Al.

The silicon layers were characterized by Raman measurements before and after the SPC step. After SPC a sharp crystalline peak at 520 cm\(^{-1}\) is observed. No indication for an amorphous phase can be seen. Fig. 3 shows the optical absorption spectra of a sample before (ZnO:Al/a-Si) and after (ZnO:Al/poly-Si) annealing. A blue shift of the absorption edge occurs after SPC. This behaviour is due to the much smaller absorption coefficient of crystalline silicon compared to amorphous silicon in that spectral region.

Fig. 3 Optical absorption of a glass/ZnO:Al/Si layer stack before (dashed line) and after (solid line) SPC. The silicon film in this measurement has a thickness of 300 nm.

In first solar cell structures with smooth ZnO:Al a \(V_{oc}\) of about 370 mV was measured. The external quantum efficiency (EQE) of this sample can be seen in Fig. 4. The short circuit current density deduced from this curve is \(j_{sc} = 9.4\, mA/cm^2\). The EQE measurement also points out the absolute need for light trapping in order to obtain a better collection in the long wavelength regime.

Fig. 4 External quantum efficiency of a solar cell structure using smooth ZnO:Al.

3. CONCLUSION

In conclusion, we have made first steps towards a new promising solar cell structure. It combines the SPC of silicon thin films with the use of a TCO for simple contacting. First solar cell results with \(V_{oc}\) of about 370 mV and \(j_{sc} = 9.4\, mA/cm^2\) are quite promising. The optimization of all processing steps is currently under investigation.

REFERENCES


