

## LARGE AREA LOW PRESSURE-CHEMICAL VAPOUR DEPOSITED ZnO:B FOR THIN FILM SILICON BASED SOLAR CELLS

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**ABSTRACT:** This paper has been mainly dedicated to large area deposition of Zinc Oxide (ZnO) thin films by Low Pressure – Metal Organic Chemical Vapour Deposition. A customized apparatus to grow ZnO on 30 x 30 cm<sup>2</sup> substrates has been developed in our laboratory, taking care of the design and the realisation of an original reactor geometry with a novel reactant distribution system. ZnO:B material, with a low sheet resistance (< 8 Ω/sq) and with a high transmittance (> 82 %) in the whole wavelength range of photovoltaic interest, has been obtained. A homogeneous light scattering effect on large-area substrate, as a consequence of the uniform surface roughness of the ZnO film, has been achieved. The spatial distributions of both film thickness and sheet resistance have been measured. Since the spatial distribution of these material properties is strongly correlated to the spatial temperature uniformity, growth rate, resistivity and surface texturization have been studied at different deposition temperatures. From our experimental results we deduced that it was possible to select a range of deposition temperatures between 145 ± 153 °C where the material properties are quite similar and excellent in terms of transparency, conductivity and texturization.

**Keywords:** TCO, ZnO:B, LP-MOCVD

### 1 INTRODUCTION

The photovoltaic performances of thin film silicon based solar cells are crucially influenced by the optical, electrical and morphological properties of the transparent conductive oxide (TCO) material.

Recently, ZnO thin films have attracted a lot of attention as a potential substitute of SnO<sub>2</sub> substrates prepared by chemical vapour deposition, owing to some specific features including its low deposition temperature and high stability against hydrogen plasma (essential when the transparent front electrode is used for microcrystalline silicon based solar cells with p-i-n configuration [1]). In order to improve the conversion efficiency of a-Si and μc-Si solar cells, ZnO films play a very important role both as front electrode and as optical back reflector matching layer.

Different deposition techniques, such as RF or DC sputtering, e-beam evaporation, spray pyrolysis and Metal Organic Chemical Vapour Deposition (MOCVD), are utilised for ZnO thin film preparation [2-5]. Among these methods, MOCVD has several advantages for potential industrial application: i) high deposition rate (over 3 nm/sec), ii) low deposition temperature (generally, lower than 200 °C), iii) suitability for large area fabrication.

Compared to sputtering technique, MOCVD is able to give further two advantages: a) direct formation of a native surface texture, perfectly appropriate for light trapping effect, b) soft process, particularly appropriate when ZnO is deposited upon underlying layers. For high efficiency solar cells, high quality TCO is required, in terms of low optical absorption, low resistivity and well textured surface. As the variation of some process parameters can give favourable effects on a specific material property and unfavourable effects on other material properties, it was necessary to well examine the whole picture of the effects of the process parameters and to determine the best compromise in terms of high growth rate, low electrical resistivity, high optical transparency and appropriate surface texture.

Furthermore, in order to meet the need of the industrial production for silicon thin film solar cells, it is

indispensable to grow high-quality and large-area ZnO thin films as transparent-conductive oxide.

ZnO coatings showing optimised properties are not yet commercially available on large-area glass substrates. To this aim, our laboratory developed a customized Low Pressure-MOCVD apparatus, able to deposit ZnO layers on 30 x 30 cm<sup>2</sup> substrates [6], taking care of the design and the realisation of an original process chamber geometry with a novel reactant distribution system. The spatial distributions of both film thickness and sheet resistance have been measured. Since the LP-CVD process is thermally activated, the spatial distribution of these properties is strongly correlated to the uniformity of the substrate temperature. Particular attention was devoted to the changes of the material properties with the temperature variation.

### 2 EXPERIMENTAL

The schematic diagram of the LP-MOCVD customised ENEA apparatus used for ZnO film deposition is shown in Fig. 1. Boron doped ZnO thin films were grown by using diethylzinc (DEZ) and water vapour as reagents and diborane (diluted at 1% in Hydrogen) as doping gas. With regard to reagents, generally bubbled by a gas carrier, in our apparatus DEZ and H<sub>2</sub>O were contained in bubblers at room temperature and, through liquid mass flow-meters (LMFM), measured quantities of each liquid were separately evaporated and subsequently diluted with an inert gas (Argon) to avoid condensation phenomena in the line, before the letting in inside the reactor chamber by means of a homogenising vapour shower. At optimised reagent flow rates [6] the pyrolysis of diethylzinc in the presence of water was allowed by mixing them in a vacuum chamber. The reaction chamber is capable to hold substrates up to 30 x 30 cm<sup>2</sup>. By combining a very effective homogenising vapour shower with a back and forth substrate movement, a good distribution of both reagents and doping gas was obtained on the whole substrate surface. The heater is positioned in the upper part of the reactor, very near to the substrate. The substrate is heated through

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