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Influence of deposition regime on physical properties of gallium doped zinc oxide films

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A B S T R A C T

Zinc oxide films doped by gallium were deposited using RF diode sputtering from a ceramic ZnO + 2% Ga_2O_3 target on Corning glass in argon atmosphere. Samples were supported in three different positions against a substrate holder – horizontal, and at 60 and 80° to the horizontal position. Two series of samples 700–1000 nm in thickness were prepared: one at room temperature (RT) and the second at 200 °C. XRD, optical and electrical experiments indicated that the films are polycrystalline having average crystallite sizes from 30 to 80 nm, integrated transmittances in the range of 400–1000 nm increased from 85 to 90 per cent and optical band-gap values increased from 3 to 3.2 eV with higher deposition temperature. The resistivity of the obliquely sputtered samples positioned at 80° to the substrate holder was one order lower than the horizontally positioned samples. No significant changes were observed in case of optical properties of the films in dependence on the tilt-angle.

1. Introduction

Zinc oxide with a wide band-gap of 3.4 eV and a large exciton binding energy of 60 meV at room temperature make it a very interesting candidate for a variety of devices such as displays, blue and ultra-violet optical devices, and in solar cells as a transparent conductive oxide and back reflector [1,2]. Non-stoichiometric zinc oxide (ZnO) is a native *n*-type semiconductor. In order to improve *n*-type conductivity, is necessary to use doping elements from the third group of the periodic table of the elements. The most common doping element for n-type ZnO is aluminium. Nevertheless, gallium is also a promising doping element for n-type ZnO conductivity [3–6]. This paper deals with the influence of deposition parameters on physical properties of the ZnO:Ga thin films suitable for photovoltaic applications.

2. Experimental details

Gallium doped zinc oxide (ZnO:Ga) thin films were prepared using a planar RF sputtering diode system Perkin Elmer 2400/8L from a ceramic target (98 wt.% ZnO + 2 wt.% Ga_2O_3) [7]. The samples in the deposition chamber were arranged in a horizontal position and at 60 and 80° to the horizontal against the sample holder (Fig. 1). Two series of samples having different substrate temperatures during the deposition were used: (i) room temperature (RT) and (ii) 200 °C.

The crystalline structure of the films was investigated by X-ray diffraction using an automatic X-ray powder diffractometer X'Pert PRO equipped with an ultra-fast linear semiconductor detector PixCel with CuKα radiation (λ = 0.154 nm) and AXS Bruker D8 equipped with a 2D position sensitive detector HiStar with CoKα radiation (λ = 0.179 nm). Optical properties were studied using a UV/Vis spectrophotometer SPECORD 210 with a maximum range of 190–1100 nm. Resistivity of the samples was measured using the four-probe method with linear configuration of the contacts under ambient conditions.

3. Results and discussion

3.1. Structural properties

XRD analysis indicated that the sample deposited in a horizontal position at room temperature has a more or less random orientation of crystallites (this means coherently diffracting domains). With increasing of tilt-angle, the preferred orientation of crystallites changes to a strongly preferred orientation of crystallographic

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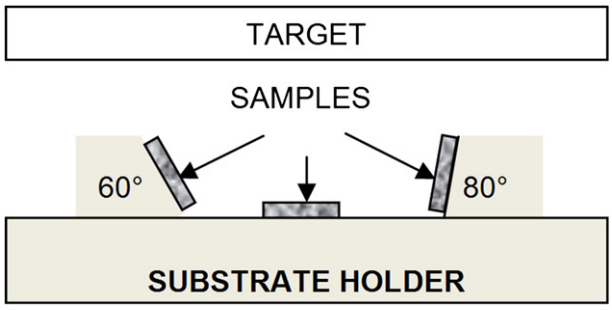

Fig. 1. Schematic layout of oblique sputtering in deposition chamber.

planes (002) to [001] perpendicular to the substrate surface. Nevertheless, the most of crystallites are tilted from the substrate surface by 14° – it follows from the azimuthal position of (002) line profile maximum (see Fig. 2). Samples deposited at 200 °C have different structural behaviour – samples deposited in a horizontal position have a very strong preferred orientation in [001] direction perpendicular to the substrate surface and samples deposited under this angle have a more random orientation of crystallites (but preferred orientation is still in [001] direction perpendicular to the substrate surface). Azimuthal line profiles of these samples show that most of the crystallites having (002) planes parallel with the substrate surface have no or very small tilted from the substrate

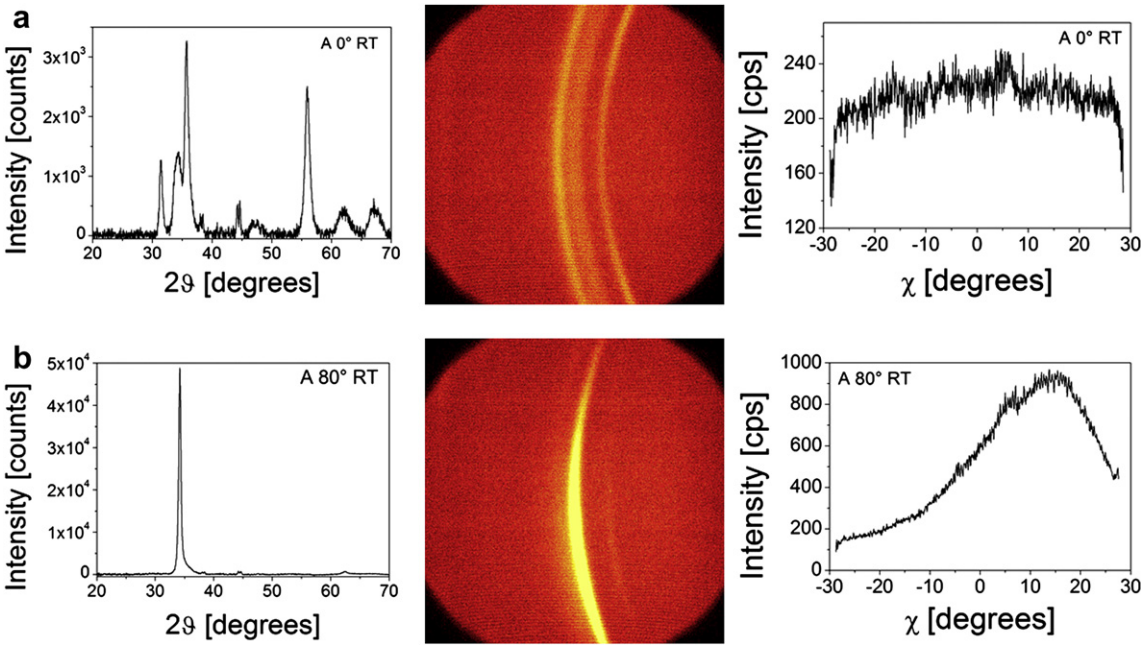

Fig. 2. XRD patterns, 2D scan and azimuthal (002) line profile of samples deposited at room temperature at a) horizontal position and b) under 80° against substrate holder during deposition.

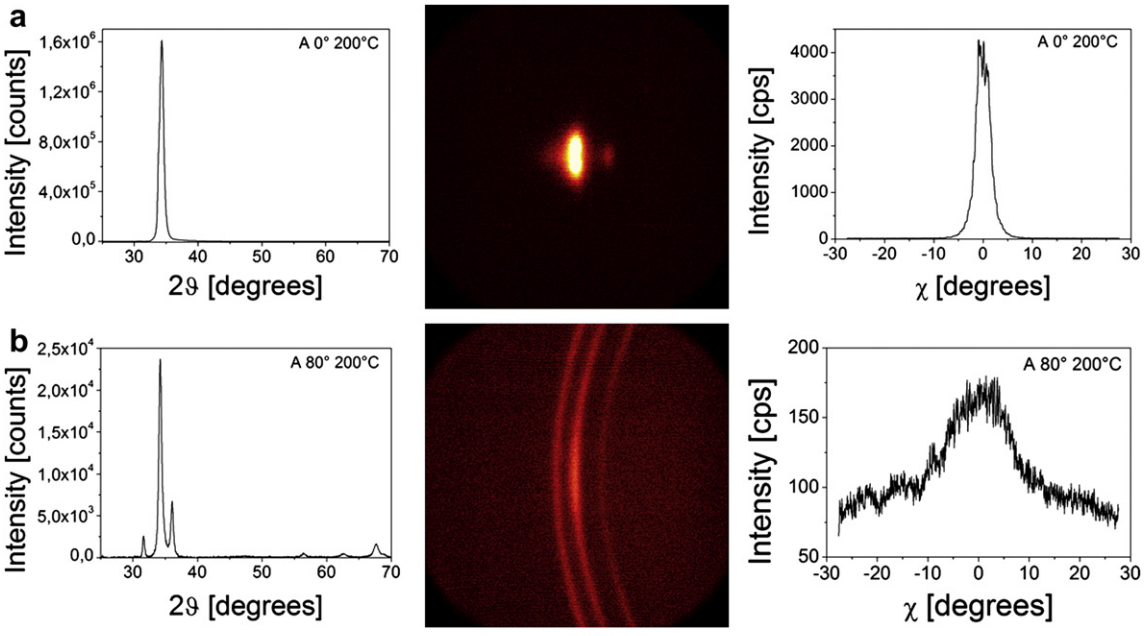

Fig. 3. XRD patterns, 2D scan and azimuthal (002) line profile of samples deposited at 200 °C at a) horizontal position and b) under 80° against substrate holder during deposition.