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ORIGINAL ARTICLE

Conductivity and thermoelectric properties of nanostructure tin oxide thin films

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Abstract Tin oxide thin films doped with iron or copper were deposited on glass and porous alumina substrates, using the co-deposition dip coating sol–gel technique. Alumina substrate was prepared by the anodizing technique. Samples were sintered for 2 h at temperature 600 °C. The XRD spectrum of deposited samples shows a polycrystalline structure with a clear characteristic peak of SnO_2 cassiterite phase. From (I–V) characteristics measured at different temperatures for samples prepared on glass substrates, the density of states at the Fermi level was calculated. Thermoelectric effect was measured with a change of temperature for prepared samples under low pressure 1 mbar. Seebeck coefficient, the carrier concentration, the charge carrier mobility and the figure merit were determined for prepared samples under low pressure 1 mbar. Seebeck coefficient was improved when films were deposited on porous Alumina substrates.

1. Introduction

Thermoelectric phenomenon was first discovered by Thomas J. Seebeck in 1822, when he developed a voltage by joining two pieces of different materials together and placing a temperature difference to the couple. He also found that the voltage difference observed was proportional to the temperature gradient ($S = V/\Delta T$). This effect was named after him and the coefficient S (also known as α) is known as Seebeck coefficient. This coefficient is very low for metals (only a few mV/K) and much larger for semiconductors (typically a few 100 mV/K). The aptitude of a material for thermoelectric applications is determined by using a dimensionless figure of merit (Pichanusakorn et al., 2010):

$$ZT = \frac{S^2\sigma}{\kappa}T$$

in which S, σ, T and κ are, respectively, Seebeck coefficient, electrical conductivity, operating temperature and total thermal conductivity. Thermoelectric energy conversion, which directly transforms the heat into electricity, has drawn much attention in recent years and found applications in a variety of areas such as renewable and clean energy, thermoelectric power generation, small scale cooling systems for electronic devices, microrefrigerator devices, and micro-thermo-chemistry on a chip for microelectronic components (Fahrettin, 2009).The thermoelectric materials are usually bulk, thin film and low-dimensional structures such as Skutterudite

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type ($CoAs_3$-type) alloys. Since thin films are expected to have lower thermal conductivity than the bulk materials, due to strong phonon scattering at their interfaces, thermoelectric films likely open up the possibility for improvement of thermoelectric efficiency (Frank, 2007). Although some thermoelectric materials, such as Bi_2S_3 and Bi_2Te_3 films, have found particular applications, their efficiencies at the best ($ZT \sim 1$) are not enough for wider utilization in commercial applications (Banerjee et al., 2004). Thus, development of materials with high thermoelectric efficiencies is one of the main current research interests. Tin oxide (SnO_2) thin film is well known as a wide band gap n-type semiconductor (E_g = 3.6–3.8 eV) with high simultaneous electrical conductivity and optical transparency in visible region of the spectrum (Bulusua et al., 2008). So far, there are only a few reports on thermoelectric properties of SnO_2 thin films. In this paper, we report the preparation of p-type SnO_2 doped with Fe or Cu thin films with a large thermoelectric efficiency to improve the thermoelectric effect of SnO_2 doped with Fe or Cu thin films (Bagherim et al., 2009). The thermoelectrical, electrical and structural properties of these films are studied using Seebeck effect measurements.

2. Experimental

The SnO_2:Fe or SnO_2:Cu thin films have been prepared on glass and porous alumina substrates prepared by the anodizing technique, using the co-deposition dip coating sol–gel technique, the films were doped with iron or copper at concentration %5. $SnCl_4.5H_2O$ and $FeCl_3{:}6H_2O$ or $CuCl_2.2H_2O$ were purchased from MERCK company and are used as starting materials. Typically, $SnCl_4.5H_2O$ and $FeCl_3{:}6H_2O$ or $CuCl_2.2H_2O$ are mixed together in Ethanol. The obtained solution is continuously stirred at 80 °C for 4 h and aged 2 days.

Glass and porous alumina substrates were dipped in the sol–gel and then drawn from it at the speed of 7 cm/min. Then dried at 80 °C, and sintered at 600 °C for 2 h.

3. Structural characterization of films

XRD patterns of SnO_2 doped with Fe or Cu films deposited on glass substrates were recorded by Philips system using Cu Kα (λ = 0.154056 nm) radiation with 2θ in the range of 20–70° as shown in Fig. 1.

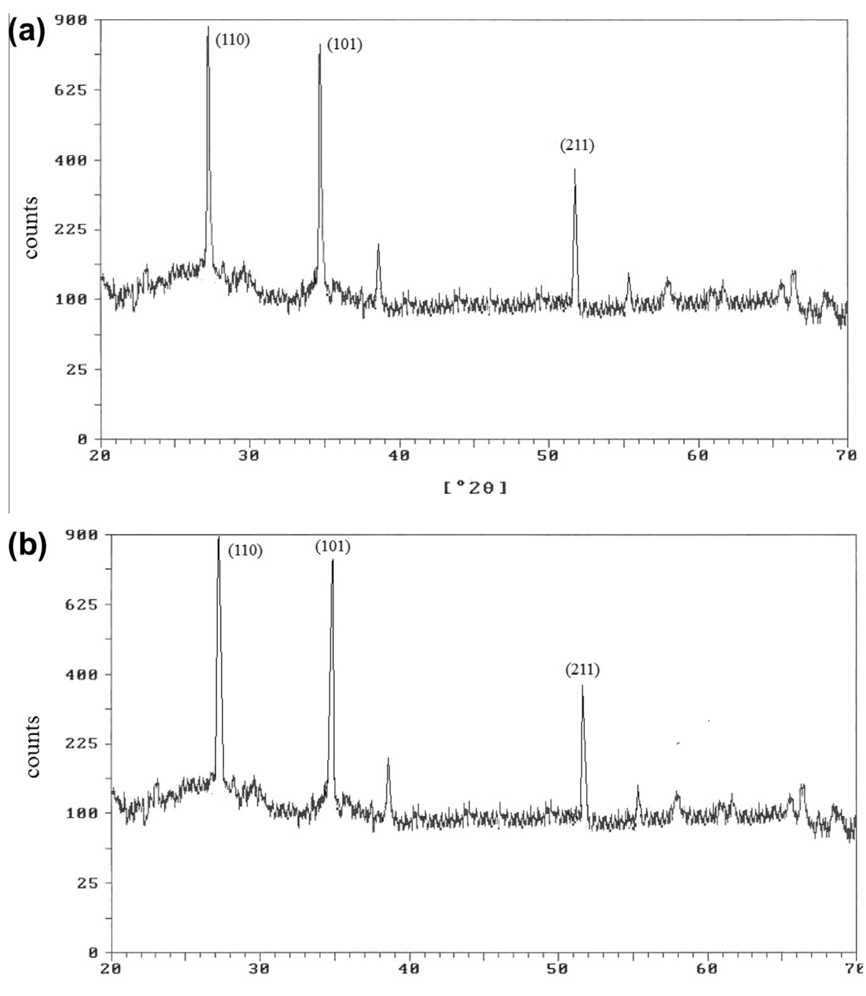

Figure 1 XRD pattern of prepared films deposited on glass substrates (a) SnO_2 doped with Fe (b) SnO_2 doped with Cu.