

Thickness dependent electrical properties of CdO thin films prepared by spray pyrolysis method

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Abstract. A large number of thin films of cadmium oxide have been prepared on glass substrates by spray pyrolysis method. The prepared films have uniform thickness varying from 200–600 nm and good adherence to the glass substrate. A systematic study has been made on the influence of thickness on resistivity, sheet resistance, carrier concentration and mobility of the films. The resistivity, sheet resistance, carrier concentration and mobility values varied from $1.56\text{--}5.72 \times 10^{-3} \Omega\text{-cm}$, $128\text{--}189 \Omega/\square$, $1.6\text{--}3.9 \times 10^{21} \text{cm}^{-3}$ and $0.3\text{--}3 \text{cm}^2/\text{Vs}$, respectively for varying film thicknesses. A systematic increase in mobility with grain size clearly indicates the reduction of overall scattering of charge carriers at the grain boundaries. The large concentration of charge carriers and low mobility values have been attributed to the presence of Cd as an impurity in CdO microcrystallites. Using the optical transmission data, the band gap was estimated and found to vary from 2.20–2.42 eV. These films have transmittance around 77% and average reflectance is below 2.6% in the spectral range 350–850 nm. The films are *n*-type and polycrystalline in nature. SEM micrographs of the CdO films were taken and the films exhibit clear grains and grain boundary formation at a substrate temperature as low as 523 K.

Keywords. Spray pyrolysis; CdO thin films; structure and morphology; II–VI semiconductor; optical properties; energy gap.

1. Introduction

CdO is a degenerate, *n*-type transparent semiconductor with wide energy gap and high electrical conductivity. Its high conductivity is due to the increased crystallite size at high substrate temperature, moderate electron mobility and high carrier concentration. The properties of CdO films can be controlled to a suitable parameter value to suit a particular application, by controlling some of the process parameters viz. the film thickness, concentration of the solution, temperature of the substrate and the solution flow rate etc. Though CdO was the first transparent conducting oxide film, studied by Badeker in 1907 (Holland 1966; Jarzebski 1973), not many investigations have been done for quite a long time. For the last few years CdO is being extensively investigated both in bulk and thin film forms. CdO has interesting properties like large band gap, low electrical resistivity, high transmission in the visible region etc. These properties make it useful for a wide range of applications such as photo-diodes (Kondo *et al* 1971), phototransistors (Su *et al* 1984), photovoltaic (Champness *et al* 1985), transparent electrodes (Benko and Koffyberg 1986) besides liquid crystal displays, IR detectors and anti-reflection coatings (Ocampo *et al* 1993). CdO has been prepared by various

deposition techniques such as activated reactive evaporation (Sravani *et al* 1991; Phatak and Lal 1992), dc magnetron reactive sputtering (Phatak and Lal 1992; Subramanyam *et al* 1997), spray pyrolysis (Chu and Chu 1990; Gurumurugan *et al* 1995) and chemical bath deposition techniques (Ocampo *et al* 1994; Varkey and Fort 1994). One of the simple, low cost techniques and a novel approach to make thin films is through spray pyrolysis. Though this technique has been widely employed for the study of transparent conducting oxide (TCO) films, the properties of the films vary from one pyrolysis setup to the other. The properties of the films are also influenced by the geometry of the experimental setup. This process has good control over the thickness uniformity. The films prepared by this method are pin hole free and have good adherence to the substrate. Improving the film quality, characteristics and reproducibility prompted us to prepare thin films of cadmium oxide by spray pyrolysis method. The objective of the current investigation is to prepare CdO films with larger grains under optimum conditions and then to study their structural, electrical and optical properties. More precisely to increase the grain size by controlling the film thickness.

2. Experimental

A simple glass nozzle was fabricated to give a fine and very small droplets when the solution is driven by either

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