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Investigation of chemical bath deposition of CdO thin films using three different complexing agents

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ABSTRACT

Chemical bath deposition of CdO thin films using three different complexing agents, namely ammonia, ethanolamine, and methylamine is investigated. $CdSO_4$ is used as Cd precursor, while H_2O_2 is used as an oxidation agent. As-grown films are mainly cubic CdO_2, with some $Cd(OH)_2$ as well as CdO phases being detected. Annealing at 400 °C in air for 1 h transforms films into cubic CdO. The calculated optical band gap of as-grown films is in the range of 3.37–4.64 eV. Annealed films have a band gap of about 2.53 eV. Rutherford backscattering spectroscopy of as-grown films reveals cadmium to oxygen ratio of 1.00:1.74 ± 0.01 while much better stoichiometry is obtained after annealing, in accordance with the X-ray diffraction results. A carrier density as high as 1.89×10^{20} cm^{-3} and a resistivity as low as 1.04×10^{-2} Ω-cm are obtained.

1. Introduction

Chemical bath deposition (CBD) is the analog in liquid phase of the well-known chemical vapor deposition technique in the vapor phase. Among all techniques used to grow group II–VI semiconductors, CBD has the advantage of being a simple, low temperature, and inexpensive large-area deposition technique. It has been widely employed in the deposition of semiconductor thin films for over forty years [1]. CBD has been extensively used in growing group II–VI semiconductors, such as CdS [1–6], CdSe [7–10], HgS [11,12], HgSe [13,14], ZnS [15–18], ZnSe [19–22], and ZnO [23–26].

CdO thin films reported in the literature have been obtained mainly by dc magnetron reactive sputtering [27], metal organic chemical vapor deposition [28,29], vacuum evaporation [30], electrochemical deposition [31], pulsed laser deposition [32], electron beam evaporation [33], spray pyrolysis [34], sol–gel [35], RF magnetron sputtering [36], and successive ionic layer adsorption and reaction [37]. However, only few attempts to grow CdO thin films using CBD have been reported [38,39]. In both cases, only ammonia has been used as the complexing agent.

In this work, we report CBD of CdO thin films using three different complexing agents, namely ammonia, ethanolamine (EA), and methylamine (MA). Transmittance, reflectance measurements and band gap calculations are carried out for as-grown films as well as annealed films. Resistivity, carrier density, and Hall mobility of annealed films are acquired using Hall effect measurements. Crystal structure as well as crystal quality are examined using X-ray diffraction (XRD), transmission electron microscopy (TEM), and Fourier transform infrared spectroscopy (FTIR). Film morphology, composition, and binding energy are studied using scanning electron microscopy (SEM), Rutherford backscattering spectroscopy (RBS), and X-ray photoelectron spectroscopy (XPS), respectively.

2. Experimental details

CdO films were prepared using aqueous solutions of $CdSO_4$ (0.038 M), $(NH_4)_2SO_4$ (0.076 M), H_2O_2 (34%), and NH_4OH (29.4%). Each bath contained 100–120 ml of de-ionized water (resistivity ∼18.2 MΩ-cm) that was kept under stirring at 85 °C. In addition to ammonia, two other complexing agents were used; EA and MA. To ensure the stability of $Cd[NH_3]_4^{+2}$ complex in the main solution, ammonia was added whenever EA or MA is being used. Similar to our previous work on CBD-ZnO [23]. It was noticed that adding ammonia is necessary to dissolve the $Cd(OH)_2$ formed upon mixing the Cd-source and EA or MA. $CdSO_4$, $(NH_4)_2SO_4$, and the desired

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