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Silicon-doping influence on the crystalline, surface and optical features of cadmium oxide films deposited by sol-gel spin route

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ABSTRACT

This is the first study on Si-contributed CdO films fabricated via sol-gel process. Si-doping impact on the crystalline, topographic and optical qualities of cadmium oxide has been searched with XRD, SEM, AFM and UV/vis spectrophotometer. The whole films were poly-crystalline with (111) preferential direction and the crystalline degree of CdO depended on Si-contribution effect. The crystallite size of undoped-CdO incessantly decreased with Si-content, however dislocation density increased with Si-level. The spherical CdO granules were nanoscale and their sizes varied between 20–170 nm. The RMS roughness values of films changed between 5.84 nm–40.5 nm. The optical gap value of undoped-CdO continuously declined from 2.59 eV to 2.39 eV with increasing Si-content, while the Urbach energy increased from 350 meV to 468 meV with Si-level. These results reveal that the level of Si-doping affect the features of cadmium oxide.

1. Introduction

Cadmium oxide (CdO) is one of transparent conductive oxides (TCOs) and it is very attractive material because of low electrical resistivity, very high intrinsic carrier concentration and high-rise mobility, superior visible transmitability and infrared reflectivity, a wide optical band-gap of 2.3 eV, controllable and easy fabrication, harmless for the nature, and carrier concentration [1–4]. The stoichiometric CdO has a good insulator property, but the non-stoichiometry related to cadmium interstitial and oxygen vacancy makes it n-type semiconductor material [5]. As results of the features given above, CdO has an extensive implementation in a variety of technological areas such as photovoltaic cells, gas and humidity sensors, liquid crystal displays, light emitting diodes, thermoelectric applications, smart windows [6–10]. Its effectiveness for technological applications can be improved by adding of foreign elements. The doping of cadmium oxide is achieved by replacing Cd^{2+} and O^{2-} with cation and anion dopants. An element with 3+ or more valance states can be seen to be an n-type suitable cation dopant for CdO lattice. When an element with 3+ or more valance states is replaced with Cd^{2+} ions or it locates on

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interstitial lattice positions of CdO, it gives extra free electrons to CdO structure. Thus, it is expected that a raise in the electrical conductivity, optical transmittance and infrared reflectance of CdO. Silicon has 4+ valance states [11] and it can be a suitable dopant element for CdO. Silicon can bring about an improvement in the crystalline, mechanic and morphological properties of CdO deposited on soda lime glass substrates due to lattice conformity between Si contributed film and glass substrate [11].

CdO thin film has been prepared by various growth systems such as PLD, spray pyrolysis, CBD, SILAR, magnetron sputtering, electrochemical and sol-gel preparations. Among them, the sol-gel technique using spin coater is much useful because of its controlling capability of chemical contents, making an easy doping, safe and cheap experimental setup [12–17]. According to the best knowledge, there is not any research about Si-added CdO films via a sol-gel route, therefore many papers should be focused to manage and improve characteristic properties of cadmium oxide. For this aim, pure and Si-added CdO samples were prepared on the glass substrates with a simple sol-gel spin coating route and the impact of Si adding on the crystalline, topographic, and optical features have been researched.

2. Material methods

In this investigation, pure and Si-added CdO films were prepared on the soda-lime glasses by a sol-gel spin coating procedure. Silicon-adding level varied from 0 at.% to 10 at.% in a step of 2 at.%. CdO precursor solution consisted of 0.3 M cadmium acetate dehydrate [$Cd(CH_3COO)_2{\cdot}2H_2O$] dissolved in 50 ml of 2-methoxyethanol [$CH_3OCH_2CH_2OH$], and 0.9 ml monoethanolamine (MDA) [$NH_2CH_2CH_2OH$]. Si-adding solution consisted of 0.3 M hexamethyldisilane [$(Si(CH_3)_3)_2$] solved in 10 ml of 2-methoxyethanol and 180 μl MDA. The molar ratio of MDA/metal ions was one. In order to get 2, 4, 6, 8, 10 at.% Si-added CdO samples, the necessary amounts of solutions were taken. The soda lime microscope glass substrate was cleaned with alcohol and deionized water. The precursor and doping solutions were dribbled on substrates and they were spun at the speed of 3000 rpm for 25 s by helping a Laurell Spin Coating Unit. As-grown thin layer was dried at the temperature of 200 °C for 10 min and it was repeated for ten times. At last, the samples were annealed in the air at 500 °C for 1 h. The pure, 2, 4, 6, 8, and 10 at.% Si-added CdO samples were named to be CSi-0, CSi-2, CSi-4, CSi-6, CSi-8, and CSi-10, respectively.

The crystalline property of pure and Si-added films was inquired with an x-ray diffraction (XRD-Panalytical Empyrean) analysis. The diffraction angle was changed from 20° to 90° with the step of 0.01°. The topographic structure was investigated with an atomic force (AFM-Hitachi5100N) and scanning electron (SEM-Zeiss Sigma300) microscopes. The thickness

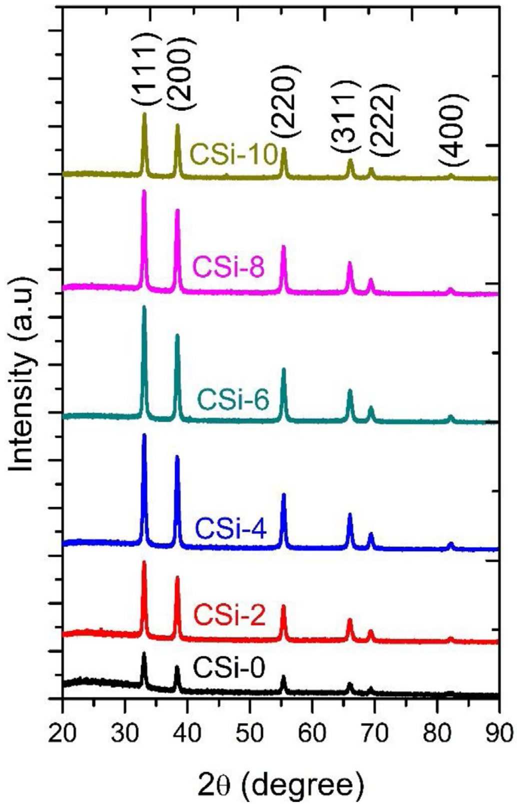

Fig. 1. XRD spectra of pure and Si-added CdO samples.