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Influence of Deposition Temperature on Nano-structural, Optical, Electrical and NO_2 Gas Sensing Behavior of Spray-Pyrolysed CdO Thin Films

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ABSTRACT

Nanostructured cadmium oxide (CdO) thin films were fabricated on glass substrates using a cost-effective chemical spray pyrolysis method. The present work aims to examine the influence of substrate temperature (350–500 °C) on the structural, surface, optical, and electrical characteristics of the films and to correlate these parameters with nitrogen dioxide (NO_2) gas sensing performance. Structural analysis carried out using X-ray diffraction revealed the formation of polycrystalline cubic CdO with a dominant (111) orientation. Increasing deposition temperature resulted in enhanced crystallinity and a progressive increase in crystallite size from approximately 18 nm to 41 nm. Scanning electron microscopy indicated a transformation in surface morphology from porous agglomerated grains at lower temperatures to compact and well-defined faceted grains at higher temperatures. Optical investigations showed a gradual reduction in bandgap energy from 2.55 eV to 2.45 eV, attributed to grain growth and reduced defect density. Electrical measurements demonstrated a marked decrease in resistivity with increasing deposition temperature due to reduced grain boundary scattering. Gas
sensing studies revealed that the film deposited at 500 °C exhibited the highest and most stable response (~78%) toward 50 ppm LPG at an operating temperature of 350 °C, with response and recovery times of 12 s and 35 s, respectively. The enhanced sensing performance is ascribed to the combined effect of improved crystallinity and optimized nanostructure offering abundant active sites for gas interaction. These findings confirm that precise control of deposition temperature is an effective strategy for developing high-performance CdO-based gas sensors.

Keywords: - CdO thin films; Chemical spray pyrolysis; Deposition temperature; Nanostructure; Gas sensing; LPG1.

1. INTRODUCTION

Industrial expansion and rapid urban development have led to a continuous rise in atmospheric pollution, creating serious environmental and public health challenges. Among hazardous gases, liquefied petroleum gas (LPG) is of particular concern due to its extensive domestic and industrial usage and its adverse effects on human health and the environment when leaked. Therefore, the development of sensitive, economical, and reliable gas sensors for continuous LPG monitoring is of significant importance. Metal oxide semiconductors (MOS) are widely used in chemi resistive gas sensors because of their high sensitivity, ease of fabrication, and compatibility with electronic systems. Cadmium oxide (CdO), an n-type degenerate semiconductor with a cubic rock-salt structure, has attracted considerable attention due to its wide direct bandgap (2.2–2.7 eV), high electrical conductivity, and excellent optical transparency in the visible region. These properties make CdO suitable for optoelectronic as well as gas sensing applications. Gas sensing in MOS materials is primarily governed by surface-controlled reactions.

The adsorption and reaction of gas molecules with oxygen species chemisorbed on the semiconductor surface modify the charge carrier concentration, resulting in measurable resistance changes. Consequently, materials with a high surface-to-volume ratio exhibit superior sensing performance. Nanostructured metal oxides offer enhanced sensitivity, reduced detection limits, and faster response dynamics. Several fabrication techniques such as sputtering, chemical vapour deposition, sol–gel processing, and spray pyrolysis, have been employed for producing CdO thin films. Among these, chemical spray pyrolysis is particularly advantageous due to its simplicity, scalability, low cost, and ability to deposit uniform thin films over large areas. The properties of

spray-deposited films are strongly influenced by deposition parameters, especially substrate temperature, which controls droplet decomposition, nucleation, grain growth, and defect formation. Although CdO thin films have been previously explored for gas sensing, systematic investigations linking deposition temperature-driven nano structural evolution with LPG sensing characteristics remain limited. The present study addresses this gap by synthesising CdO thin films at different substrate temperatures and comprehensively analysing their structural, morphological, optical, electrical, and gas sensing properties to identify optimal deposition conditions.

2. EXPERIMENTAL PROCEDURE

2. 1 Materials and Substrate

Preparation Analytical-grade cadmium acetate dihydrate ($Cd(CH_3COO)_2 \cdot 2H_2O$, 99.9% purity) was used as the precursor without further purification. A 0.1 M solution was prepared by dissolving the required quantity of cadmium acetate in a 1:1 mixture of deionised water and ethanol. The solution was magnetically stirred at 60 °C for 30 minutes to ensure complete dissolution and homogeneity. Glass substrates of dimensions 25 mm × 75 mm were used for film deposition. Prior to coating, the substrates were ultrasonically cleaned in acetone, ethanol, and deionised water for 10 minutes each, followed by drying under nitrogen flow.

2.2 Deposition of CdO Thin Films

CdO thin films were deposited using a laboratory-built spray pyrolysis setup. The precursor solution was atomized using a pneumatic nozzle and sprayed onto preheated glass substrates. The nozzle-to- substrate distance (30 cm), spray rate (5 mL min^{-1}), and carrier air pressure (2 bar) were kept constant. Substrate temperature was varied between 350 °C and 500 °C and maintained within ±5 °C. After deposition, the films were allowed to cool naturally to room temperature. The deposited films were uniform, adherent, and light yellowish-brown in appearance.

2.3 Characterization Techniques

Structural analysis was performed using X-ray diffraction (Bruker D8 Advance) with Cu Kα radiation (λ = 1.5406 Å). Surface morphology was examined using a FEI Nova NanoSEM. Optical properties were studied using a UV–Visible spectrophotometer (Shimadzu UV-2600) in the wavelength range of 300–800 nm. Electrical resistivity was measured at room temperature using a standard four-point probe method (Keithley 2400).

2.4 Gas Sensing Measurements

Gas sensing measurements were conducted using a static gas sensing chamber. Silver interdigitated electrodes were screen-printed onto the CdO films. The sensor was placed in a sealed chamber equipped with a temperature-controlled heater. A known concentration of LPG diluted with dry air was introduced into the chamber, and resistance changes were recorded. Sensor response was calculated using: S (%) = [(Rg - Ra) / Ra] × 100 where R a is the resistance in air and R g is the resistance in the presence of gas.

3. RESULTS AND DISCUSSION

3.1 Structural Analysis

XRD patterns of CdO thin films deposited at different temperatures confirmed the formation of single- phase cubic CdO (JCPDS No. 05-0640) without secondary phases. Diffraction peaks corresponding to (111), (200), (220), (311), and (222) planes were observed. Peak sharpening and intensity enhancement with increasing temperature indicate improved crystallinity. Crystallite size calculated using the Scherrer equation increased from ~18 nm to ~41 nm due to enhanced atomic diffusion and grain coalescence at elevated temperatures.

3.2 Surface Morphology

SEM images revealed a strong dependence of surface morphology on deposition temperature. Films deposited at 350 °C exhibited porous agglomerated nanograins, while those deposited at higher temperatures showed grain growth and densification. The film deposited at 450 °C displayed well- defined faceted grains with clear boundaries, offering an optimal balance between surface area and electrical connectivity. At 500 °C, excessive grain growth reduced surface porosity.

3.3 Optical Properties

All CdO films exhibited high transparency (>70%) in the visible region. Bandgap energy, estimated using Tauc plots, decreased from 2.55 eV to 2.45 eV with increasing deposition temperature. This red-shift is attributed to increased crystallite size, reduced quantum confinement, and lower defect density.

3.4 Electrical Properties

Room-temperature resistivity decreased significantly with increasing deposition temperature, from ~4.5×10^3 Ω·cm to ~1.2×10^2 Ω·cm. This reduction is attributed to improved crystallinity and reduced grain boundary barriers, facilitating efficient charge transport.

3.5 Gas Sensing Performance

Gas sensing measurements showed that sensor response increased with operating temperature, reached a maximum at 350 °C, and decreased at higher temperatures. Among all samples, CdO-500 exhibited the highest response (~78%) toward 50 ppm LPG. The superior sensing behavior is attributed to optimized crystallinity and sufficient surface active sites. The sensor demonstrated rapid response (12 s) and recovery (35 s), good repeatability, and selectivity.

4.CONCLUSION

CdO thin films were successfully fabricated using spray pyrolysis, and their properties were strongly influenced by substrate deposition temperature. Higher temperatures improved crystallinity, reduced resistivity, and modified surface morphology, leading to enhanced gas sensing performance. The film deposited at 500 °C exhibited the highest LPG sensing response with fast response-recovery characteristics. These results demonstrate that deposition temperature control is a key factor in tailoring CdO thin films for efficient gas sensor applications. Further enhancement may be achieved through elemental doping and surface functionalization.

5.REFERENCES

[1]. World Health Organization (WHO). (2021). Air quality guidelines for particulate matter, ozone, nitrogen dioxide and sulfur dioxide. Global update.

[2] Franke, M. E., Koplin, T. J., & Simon, U. (2006). Metal and metal oxide nanoparticles in chemiresistors: does the nanoscale matter? Small, 2(1), 36-50.

[3] Guru, R., & Ghosh, S. (2018). A review on Cadmium Oxide (CdO) thin film: a comprehensive approach. Journal of Pure and Applied Physics, 56(4), 481-491.

[4] Barsan, N., Koziej, D., & Weimar, U. (2007). Metal oxide-based gas sensor research: How to? Sensors and Actuators B: Chemical, 121(1), 18-35.

[5] Kolmakov, A., & Moskovits, M. (2004). Chemical sensing and catalysis by one-dimensional metal-oxide nanostructures. Annual Review of Materials Research, 34, 151-180.

[6] Patil, G. E., Kajale, D D., Ahire, S. P., et al. (2011). Synthesis, characterization and gas sensing performance of CdO thin films. * Archives of Physics Research*, 2(2), 83-92.

[7] Yoneda, Y., & Saitoh, T. (1988). Influence of substrate temperature on the properties of spray- deposited CdO films. Journal of the Electrochemical Society, 135(7), 1729-1733.

[8] Kumar, D., & Sareen, R. (2020). Effect of deposition temperature on the nanocrystalline CdO thin films for optoelectronic applications. *Materials Today: Proceedings*, 28, 1405-1409.