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CdO Doped CuO for Gas Sensing Environmental Applications

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Abstract: This paper describes the hydrothermal synthesis of cadmium/copper oxide nanocomposite (CdO-CuO). XRD, FESEM, and EDS were used to determine the structure, morphology and compositional. Furthermore, the LPG sensing capabilities of pure and CdO doped CuO were investigated. The sensors had sensitivity of about 24 and 36 at 275oC operating temperature and 250 ppm gas concentration. LPG is extremely flammable even at very low ppm concentrations; detecting LPG low ppm concentrations is needed for security reasons.

Keywords: *Sensor; CdO-CuO; Concentration; Sensitivity.*

1.Introduction

Air is necessary for all living things to breathe. However, air contains a wide range of gases, including hazardous, environmentally friendly, and volatile substances, some of which are hazardous to the well-being of human. These gases are emitted by humans both freely and artificially, such as through the extensive use of automobiles, businesses, power plants, and air industries, resulting in environmental damage. Pollution in the environment is becoming increasingly hazardous for humans and other things. The noticeable variation in air quality during lockdown period, suggesting major contaminants caused by mistakes made by humans. Sensors are useful in this world because they reduce people's workload. The researcher discovers various types of sensors, which are distinguished by their measuring parameters .LPG is used as a cooking, heating, and lighting fuel all over the world [1-4].

The use of LPG in daily life is increasing, as is the number of accidents caused by LPG leakage. More people are dying as a result of toxic gas leaks all over the world. LPG is a volatile gas made up of of the following substances: butane, propane, and a few other hydrocarbons [5]. LPG is a byproduct of the artificial extraction of natural gas from petroleum-based products. Accidents involving LPG have increased at an unpredictable rate in comparison to other gases due to its widespread domestic use. On 2-3 December 1984 in Bhopal, India, a methyl isocyanate gas leak from the plant of Union Carbide India Limited caused one of the most memorable accidents [6]. Another will be recorded on May 7, 2020, as a result of a styrene gas leak at LG Polymers, which is located in Visakhapatnam, Andhra Pradesh, India. According to the government, the gas leak killed 8 people and sickened over 1000 others [7]. Human injuries caused by gas leakage include coughing, fever, diarrhoea, headache, heartbeat irregularity, loss of mental state, diarrhoea, anxiety and, in some cases, death [8].

The majority of LPG sensors are made of the semiconducting material SnO_2. Researchers are currently working to enhance recognising properties by studying various semiconductors made of metal oxide (MOSs), which have been general research with TiO_2, CuO, NiO, ZnO etc and doping elements [9-14]. The most successful gas sensor research explorations have been associated with. It was acknowledged that the characteristics of a sensor can be altered through modifying the makeup of the crystal, production technology, over-and-above dopants, the effect of operating temperature. CuO is p-type semiconductor with tunable band gap used in various field applications like optical, electronics, and sensors [15-16]. Several review articles, including one on gas sensing with metal oxide nanostructures [17,18]. Cadmium oxide (CdO) on the other hand is an intriguing substance with potential applications in electronics and pollution removal.

We synthesised CdO/CuO nanocomposite, characterised it, and investigated its gas sensing applications utilising CdO and CuO nanocomposite's effective role in

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remediation of environmental damage. The nanocomposite has been used successfully as a gas sensor for pollutant and household gases such as LPG. To excellence of our ability, this constitutes the primary report on the combined study of CdO/CuO nanocomposites for environmental remediation; gas sensing of LPG, ethanol, methnol, and methane gases.

2. Experimental section

2.1 Materials

Materials: Copper acetylacetonate, Sodium hydroxide, distil water, ethanol, cadmium oxide (CdO).

2.2 Synthesis of CuO nanostructure:

Synthesis route from precursors of copper acetyl acetonate [$Cu(C_5H_7)_2$ In the first approach 5 gram copper acetylacetonate used with 0.4 gram Sodium hydroxide (NaOH) and distilled water as solvent. These solutions will keep in stainless steel autoclaves at temperatures 150 °C for 14 hours then allow simply refreshing to ambient temperature. A dark precipitate will collect after being filtered. To remove the remains of biologically inert/organic impurities, wash with filtered water and ethanol. The finished product dried at 70℃ for 48 h in hot air oven**.**

2.2 Synthesis of CdO-CuO nanostructure:

A metal autoclave with a Teflon liner and a capacity of 100 mL was filled with 4g Cu(acac)2, 40mL distilled water, 0.8g cadmium oxide (CdO), and 0.4g NaOH. The autoclave was then sealed after being filled with distilled water up to 80% of its total volume. Do the same thing as before, but this time at a temperature of 150 degrees Celsius.

2.3 Material characterizations

X-ray powder diffraction (XRD) analysis was performed at room temperature with Cu K radiation (= 0.15406nm), over the 2 collection range of 0-80 to identify the crystal phases CuO and CdO doped CuO powders. FE-SEM (Field Emission Scanning Electron Microscope) pictures and EDX (Energy-dispersive X-Ray) spectrum were collected, and gas sensing properties were investigated with the Kethely system.

3. Result and Discussion

Fig 1 depicts the XRD images of pure CuO and CdO-CuO.(a-b).The major peaks are obtained at 2 values around 35 and 38, for planes (002),(111respectively, which clearly reflect monoclinic phase of CuO and are in good agreement with the JCPD NO 05-0661[19]. Because of the sharpness of the peaks, pure CuO was highly crystalline. The peak intensity decreased after CdO doping, indicating that the CdO ions were effectively incorporated to the site of the CuO lattice without disrupting the CuO crystal structure. Cu^{2+} ions can be well substituted by Cd^{2+} ions in the lattice structure due to the similarity in the Cd^{2+} and Cu^{2+} [19].

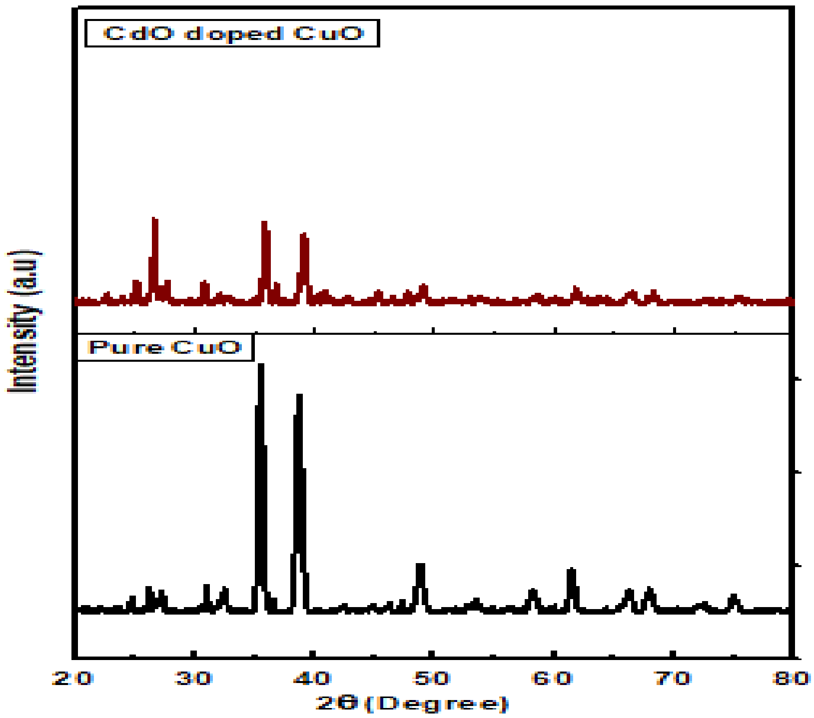

Fig 1.XRD pattern of CuO and CdO doped CuO.

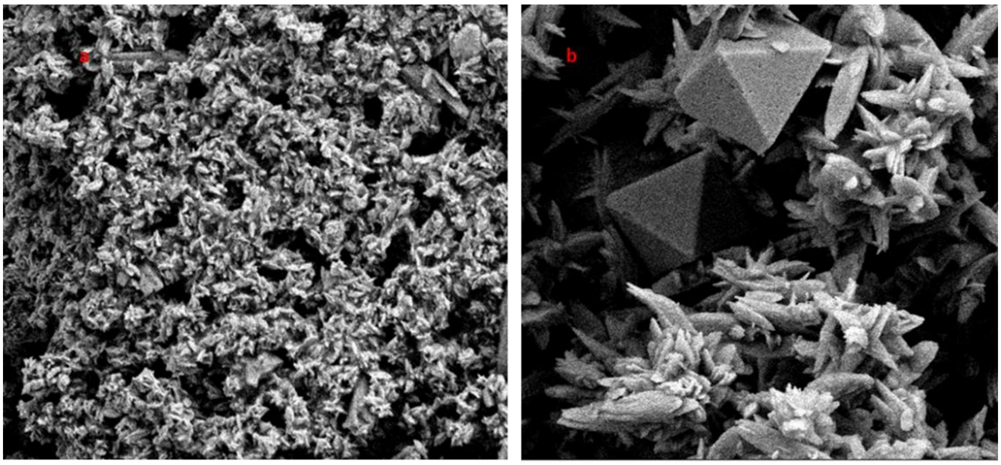

Fig 2. Morphology of CuO and CdO doped CuO nanostructure.

The surface morphologies, and EDX measurements of the pure and CdO doped CuO nanostructure shown in Fig. 2, .3. Hence, Fig. 2 (a,b) represents nanoflakes agglomerated. The growth of nanoflakes shapes in various paths. Fig 2(b) shows nanoflakes with increasing size and the various shapes of CdO doped CuO. In some places, Some aggregated nanoflakes grew to the size of a flower, while others grew to the size of a triangle. The presence of Cd, Cu, and O in the CdO-CuO nanostructure with weight percentages of 4.35, 70.03, and 25.62. Cu and O weight percentages of 57.44 and 44.56, respectively, for CuO nanostructure.

Fig 3. Chemical composition of CuO and CdO doped CuO nanostructure.

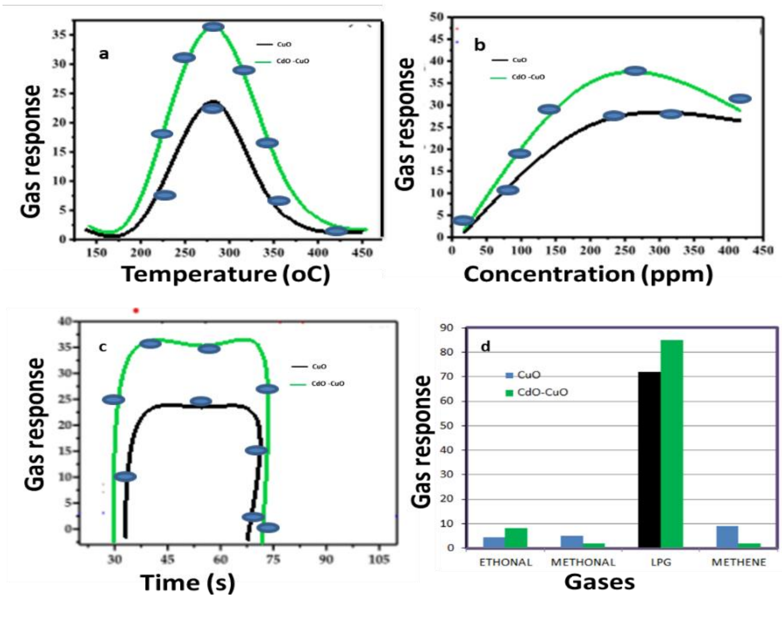

Fig 4. CuO and CdO doped CuO nanostructures gas sensing properties. a) operating temperature verses gas response, b)concentration verses gas response, c)response and recovery time verses gas response, d) gases verses gas response.

Sensor properties of pure and CdO doped CuO.

Figure 4(a) depicts the sensitivity of gas sensors to 250 ppm LPG as a function of operating temperature. The highest sensing response values correspond to 275ºC in both curves. This is a significant achievement of the current investigation because it reduced the cost of operation and the risk of detection. At a specific temperature, the sensor response starts decreasing, that could be caused due to oxygen from the environment the process of desorption from the sensing surface. [20] .

The variation of gas response with gas concentration at operating temperature as demonstrated in Fig 4 (b). Figure shows that the response of LPG increases with concentration, reaches a maximum at 250ppm, and then decreases. It is also shows CdO doped CuO nanostructure higher sensitivity (36) at 270°C when compared to pure CuO nanostructures (24). To determine the sensitivity of material-oxide semiconductor sensors, interactions among the gas being monitored and the sensors' surface are well known.

At room temperature, the initial reaction to 250 ppm LPG for pure and CdO doped CuO sensors was investigated, as shown in Fig.4(c).Gas was inserted into the chamber for this measurement, and sensor resistance. The measurements were taken in both air and gas presence. For LPG sensing, both sensors have nearly response (32s) and recovery (25 s) times. The response time is entirely determined by chemical reactions happening at the sensor surface with the target gas. Surface reactors on the nanostructure surface were credited with the quick reaction and return to normal time.

At a temperature of 275°C, the selectivity of pure and CdO doped CuO nanostructured Sensors is measured. The bar diagram in Fig 4(d) depicts the sensor's LPG selective ability. The figure clearly shows that the responses of all sensors to ethanol, methnol, and methane gases are lower than their responses to LPG.

Sensing mechanism

In the absence of a target gas, oxygen adsorbed on the sensor surface extracts electrons from the sensor material's conduction band [21,22]. The sensor's operating temperature, particle size, and specific surface area all influence the amount of oxygen adsorbed on the surface. The state of oxygen on the surface of the CuO varies with temperature.

$$O_2(gas) \text{ ----> } O_2(ads)$$

$$O_2(gas) + e^- \text{ ----->} O_2^-(ads)$$

$$O^- + e^- \text{ ---->} O^{2-}(ads)$$

The quantity of holes or the electrons in the CuO semiconductor changes as oxygen species absorb electrons from the material. When exposed to LPG, the reducible gas responds with oxygen that is taken in on the outside of the CuO nanostructure. The electrical conductivity of the CuO nanostructure changes when the electrons flow again into the semiconductor. The prepared sensor structure's high response is attributed to the distribution of optimal CdO layers within the CuO layers, leading to maximum shifting of the space charge region expanded throughout the sensing layer with target gas interaction. The incorporation of a CdO increases the initial resistance (Ra) of the CuO nanostructure sensor. Because CdO is an n-type semiconductor and CuO is a p-type, p-n junctions are formed at the CdO-CuO interfaces [23]. The formation of space charge regions at the CdO-CuO interfaces reduces the concentration of electrons in the conductivity band of the CuO nanostructure, resulting in a higher sensor resistance (R_a) value for structures. The presence of a CdO catalyst also accelerates the adsorption of oxygen from the atmosphere on the surface of CuO nanostructure[24]. As a result, the adsorbed oxygen captures more electrons from the CuO conduction band. The combined effect of these two factors results in a higher sensor sensitivity for the CdO-CuO multilayered structure than for the pure CuO nanostructure sensor.

4. Conclusions

CuO and CdO doped CuO nanostructures were prepared using an environmentally friendly low-cost hydrothermal technique and tested for LPG detection. The preliminary test results showed that the obtained sensors detected LPG with a quick response and full recovery. We can conclude from the preliminary results that the obtained sensors are promising candidates for a new metal oxide composite-based LPG detection resistive sensor. At 275ºC operating temperature and 250 ppm gas concentration, the pure and doped sensors had sensitivity of about 24 and 36, respectively.

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