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Binder effects on CO_2 gas sensitivity of Mn-doped copper oxide films: A comparative study using PEG, CMC, MEG

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In today's world, with rising air pollution levels, it is essential to detect air quality, ensuring both environmental safety and public health. Gas sensors detect air quality, with sensor material as the main component. A binder is used to hold the sensor material together and ensure it sticks to the conductive glass plate, creating a uniform and stable sensing layer. However, the addition of binders can affect gas sensitivity because they modify the microstructure of the sensing layer. Therefore, it is important to identify which binder is the most suitable for sensor material for gas sensing purposes. The aim of this work was to examine the effects of three distinct binders; polyethylene glycol (PEG), carboxymethyl cellulose (CMC), and monoethylene glycol (MEG), on the surface morphological changes and carbon dioxide (CO_2) gas sensitivity of Mn-doped (4%) copper oxide as a gas sensing material. Some previous studies had investigated binders for various sensor materials to detect different gases, but the novelty of this research lies in specifically comparing the CO_2 gas sensitivity of Mn-doped (4%) copper oxide with the above mentioned binders separately. The film was prepared using the doctor blade method and coated samples were heated at 120 °C for 30 minutes. UV-visible absorption spectroscopy, XRD and SEM analysis were conducted to determine the optical and structural properties of the sample. The XRD analysis confirms the presence of both cuprous oxide (Cu_2O) and cupric oxide (CuO) in the sample, with CuO being the most dominant phase. The sample with the MEG binder had the lowest optical band gap of 2.93 eV, while the other two samples had the same optical band gap of 2.95 eV, demonstrating that there is no significant impact of the chosen binders on the optical band gap of Mn-doped (4%) copper oxide. The arithmetic average roughness (R_a) increases when CMC and MEG binders are added to the sample but decreases when PEG is added. Furthermore, the gas sensitivity, response time, and recovery time of Mn-doped copper oxide were measured for CO_2 detection at room temperature. The flow rate of CO_2 gas was varied from 10 SCCM to 20 SCCM for three different samples. Additionally, it shows less than 6% variation in results across multiple measurements. The sample with PEG quickly responded to CO_2 gas in 90 s with a recovery time of 300 s and a CO_2 gas sensitivity of 57.35%. The sample with CMC had the lowest gas sensitivity of 48% and also showed the best recovery time for CO_2 gas in 280 s. High gas sensitivity is particularly important for breath analysis used in medical diagnostic procedures. For this purpose, the MEG added sample can be chosen because it has a comparatively high CO_2 gas sensitivity of 62.23%. In conclusion, choosing the right binder with a copper oxide sample is essential for creating the optimal sensing layer to fulfill CO_2 gas sensing purposes.

Keywords: Binder, Carbon dioxide, Copper oxide, Gas sensitivity.