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Conductometric CO₂ Sensing Using BaTiO₃-CuO Composite Thin Films Grown by Pulsed Laser Deposition

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Conductometric gas sensors have certain advantages including low cost, simple design, high sensitivity and fast response which make them amenable to device miniaturization [1]. Miniaturization permits gas sensors to be used in applications where larger detection systems are not feasible. This includes sensors which can be mounted in unmanned air vehicles (UAVs) for gas detection. In this study, conductometric CO₂ sensing materials were investigated with the goal of integrating these materials into sensor devices which can be incorporated onto a UAV.

Composite thick films comprised of BaTiO₃ and CuO phases have previously been shown to be sensitive to variations in CO₂ gas composition at temperatures $400^{\circ}\text{C} \leq T \leq 700^{\circ}\text{C}$ [2-4]. While the exact sensing mechanism has not been definitively ascribed, it likely involves chemisorption of CO₂ and possibly subsequent carbonate formation at the surface and grain boundaries of the CuO and/or BaTiO₃ surfaces and grain boundaries of the film. This reversible interaction changes the conductivity of the film, thus providing the basis for the sensor response.

A series of thin films of different CuO/BaTiO₃ compositions were grown by pulsed laser deposition (PLD) onto model $\sim 1\text{cm}^2$ substrates of single crystal sapphire at deposition temperatures ranging between $400^{\circ}\text{C} \leq T_{\text{dep}} \leq 650^{\circ}\text{C}$. The resulting thin films ($d < 1\text{ }\mu\text{m}$) were characterized by X-ray diffraction (XRD), chemical analysis using energy dispersive spectroscopy (EDS) and SEM. This confirmed that BaTiO₃-CuO composite films with different CuO/BaTiO₃ ratios could be grown by PLD using sintered composite targets comprised of these same two phases.

These films were then evaluated for their sensitivity to CO₂ in a synthetic air mixture of 20% O₂ and 80% N₂. Some films, notably those prepared from sintered targets of 1% CuO/ 99%BaTiO₃ exhibited high sensitivity to 100 ppm CO₂ (Figure 1).

Using the most promising BaTiO₃-CuO compositions and deposition conditions, some films were then grown directly onto sintered 3 mm² alumina sensor substrates with interdigitated Au electrodes and a Pt heater on the backside (Figure 2). These were again characterized by XRD, SEM EDS and tested for CO₂ sensitivity.

References

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Figures

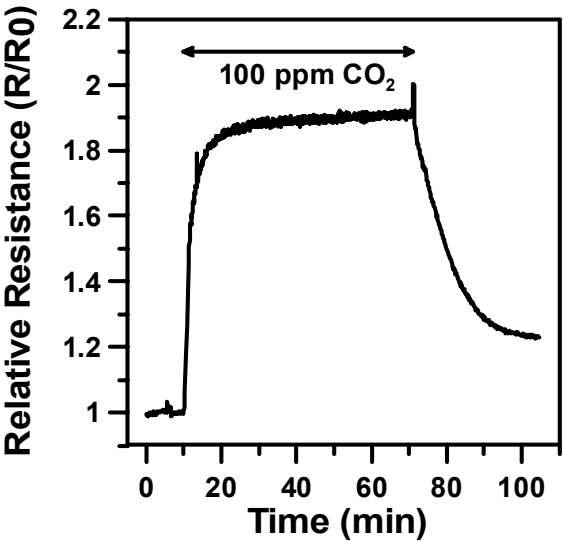


Figure 1: Dynamic sensor response to 100 ppm CO₂ in a 20% O₂/ 80% N₂ gas mixture for a BaTiO₃-CuO film prepared by PLD.

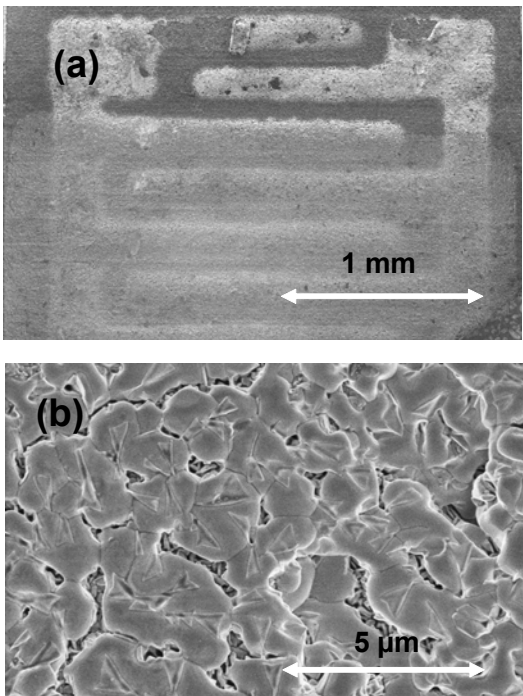


Figure 2: SEM images of the sensor device: (a) low magnification showing the Au gold interdigitated electrodes with the film covering the lower part; (b) higher magnification showing the morphology of the BaTiO₃-CuO film on the sintered alumina substrate.