Structural, Morphological and Thermoelectric Characterization of CuO-ZnO Film Semiconductor for Thermoelectric Cell by Electrodeposition Method

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Abstract

Copper oxide (p-type CuO) and zinc oxide (n-type ZnO) thin film semiconductors were synthesized and evaluated as low-cost, environmentally friendly materials for a proof-of-concept thermoelectric device. The fabrication process involved alkaline vapor oxidation for CuO and a combination of electrodeposition and chemical bath deposition for ZnO, offering scalable and energy-efficient routes. The influence of NaOH concentration (3M, 4M, 5M) on CuO film properties was systematically studied. X-ray diffraction (XRD) and scanning electron microscopy (SEM) analyses revealed that films synthesized in 5M NaOH exhibited enhanced crystallinity and surface morphology. Alkaline vapor oxidation was conducted for 24 and 48 hours, and both CuO and ZnO films were subjected to thermoelectric characterization. Using a custom-built setup, Seebeck coefficient, electrical conductivity, and thermoelectric power factor (PF) were measured. The highest PF values were observed for ZnO (2.310 nW/K^2·m) and CuO oxidized for 48 hours (2.746 nW/K^2·m). These values align with reported ranges in recent literature and demonstrate the potential of CuO–ZnO systems in all-oxide thermoelectric generators. The results confirm that simple chemical processing routes can produce oxide thin films with viable thermoelectric performance, supporting sustainable and cost-efficient device fabrication. Furthermore, the morphological tuning through oxidation duration and concentration offers a pathway for material property engineering without requiring high-vacuum or high-temperature conditions. This study highlights the feasibility of integrating CuO and ZnO as a p–n junction pair in micro-scale or flexible energy recovery modules, particularly for wearable electronics or self-powered sensors operating in ambient or low-heat environments. The favorable material compatibility, low toxicity, and mechanical stability of the films also make them attractive candidates for next-generation energy harvesting technologies in distributed and low-power applications.

Author keywords

electrodeposition; n-type ZnO; p-type CuO; power factor (PF); Seebeck coefficients

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