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PAPER

Indium doping effects on the structural, morphological and electrical properties of WO_3 powder pellets

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Abstract

Tungsten oxide powders were doped with indium at weight percentages ranging from 5 to 15 wt% and pressed into pellet form under a pressure of 200 bars. The doping process was carried out using the solid-state reaction technique. The doped samples were sintered at 750 °C for 12 h. Both undoped and indium-doped powder pellets exhibited a triclinic structure, with hexagonal $InxWO_3$ emerging as a minor phase that increased with higher indium content. Indium doping increased microstrain, the percentage of stacking faults, and defect concentration while decreasing the crystallite sizes in the WO_3 powder pellets. Morphological analysis of the samples revealed irregular grain shapes and sizes within the pellets. Notably, indium doping significantly reduced the porosity of WO_3 from 7.42% to 3.83% as the indium content increased to 15 wt%. Electrically, the n-type resistivity increased with higher doping levels, indicating deeper donor levels. Specifically, the donor states in the powder pellets increased from 0.21 eV to 0.27 eV as the indium content rose from 5 wt% to 10 wt%, and further reached 0.29 eV at 15 wt% indium. Moreover, AC signal analysis of the powder pellets demonstrated their potential as microwave resonators suitable for antenna applications. Indium doping effectively engineered the maximum cutoff frequency, with values reaching 80 GHz in WO_3 pellets doped with 15 wt% indium. These powder pellets, with thicknesses not exceeding 700 μm and electrode areas of 3.14×10^{-2} cm^2, show great promise for 5 G/6 G technology applications as concurrent quad-band antennas.

1. Introduction

Tungsten oxide has gained a wide space in literature due to its novel applications. The material is used for the fabrication of supercapacitors [1], flexible electrochromic devices [2], gas sensors [3] and terahertz dielectric lenses [4]. As supercapacitors nickel doped WO_3 fabricated by the sol–gel technique displayed maximum specific capacitance of 279 F g^{-1} proofing their potential for energy storage applications [1]. As electrochromic devices WO_3 thin films showed high coloration efficiency in the visible and near infrared regions [2]. Such features of the device nominate them as smart windows to control the light and heat fluxes as well [2]. In addition, nanostructured WO_3 gas- sensors showed high sensitivity for nickel oxide, ammonia gases and volatile organic compounds [3]. Moreover, WO_3 films coated with Fe nanosheets were found ideal as dielectric lenses. These lenses exhibited cutoff frequency in the range of 1.0–30.0 THz in addition to their enhanced light absorbability [4].

Vareous techniques are employed to enhance the performance of WO_3 nanoparticles (powders) to make them stabler and adequate for technological applications. As for examples, 7.5 at% lanthanum doping into WO_3 nanoparticles enhanced their NiO_2, NH_3, SO_2, CO, CO_2 and CH_4 gas sensitivity [5]. The doping improved the resistance of the powders to the humidity fluctuations [5]. In addition, indium doped WO_3 cubic nano-blocks synthesized via one-pot hydrothermal method exhibited high repeatability, long term stability and high