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Sprayed NiO-Doped *p*-Type Transparent ZnO Thin Films Suitable for Gas-Sensing Devices

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The spray pneumatic method has been successfully employed for the preparation of polycrystalline NiO-doped ZnO thin films. The effect of NiO content (0, 1, 2, 3, and 6 at.%) is studied on structural, optical, and electrical properties of NiO-doped ZnO thin films. The thin films were successfully deposited on a glass substrate at 450°C using the organic solar heater. XRD patterns of NiO-doped ZnO thin films indicate that the obtained ZnO thin films are polycrystalline with (100), (002), and (101) highest peaks of ZnO phase. However, α-$Ni(OH)_2$ and β-$Ni(OH)_2$ were observed at 6 and 3 at.% NiO, respectively. The crystal structure was improved for doped thin films, the crystallite size decreased by increasing the NiO content up to 6 at.% NiO. All thin films have a high optical transmission in the visible region of about 85%. The optical band gap energy decreased from 3.26 eV for 0% to 3.34 eV for 1 at.%, and further decreased to 3.27 eV for 6 at.% NiO. The thin film deposited with 3 at.% NiO has the lowest value of Urbach energy (0.091 eV). The electrical conductivity of the NiO-doped ZnO films increased greatly from 0.016 $(\Omega \cdot \mathrm{cm})^{-1}$ for 0% NiO to 0.042 $(\Omega \cdot \mathrm{cm})^{-1}$ for 3 at.% NiO. It can be noted that the deposited film after 3 at.% NiO is a *p*-type semiconductor.

Keywords: ZnO, thin films, NiO-doping, transparent conductive oxides (TCO), spray pneumatic method.