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ZnO:Ga,Al transparent and conductive thin films for photovoltaic electrodes

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The effects of different sputtering deposition processes and post-treatment parameters on the electrical, optical, structural and morphological properties of Ga- and Al-doped ZnO thin films are reported, bearing in mind tentative applications for electrodes in photovoltaic and thermoelectric applications. Highly transparent and electrically-conductive films were deposited on glass and silicon surfaces by d.c. pulsed magnetron sputtering in an argon atmosphere. From X-ray diffraction experiments it was found that all films have a hexagonal wurtzite structure with the [001] preferred crystallographic direction, being the morphology of the films (obtained from scanning electron microscope analysis) sensitive to the process parameters. All ZnO:Ga films presented an average transmittance above 80 % in the visible region, and the lowest electrical resistivity of ~10^{-4} Ω·cm was achieved for the sample submitted to the lowest bias voltage (-40 V), which corresponds to a carrier concentration and a carrier mobility of ~7×10^{20} cm^{-3} and ~30 $cm^2V^{-1}s^{-1}$, respectively. Hydrogen-plasma-assisted thermal post-treatments were carried out in the ZnO:Al thin films to further improve the electric properties. The influence of different annealing temperatures (between 473 and 723 K), performed at different H pressures, on the final electrical, optical and structural properties of the films ZnO:Al was investigated, where an electrical resistivity of ~10^{-3} Ω·cm and an average transmittance >80 % (in the visible region and for thicknesses around 300 nm) was achieved. X-ray photoelectron spectroscopy, Raman spectroscopy and photoluminescence experiments evidenced the role of the Ga and Al dopants in the ZnO structure towards the enhancement in the electrical and thermoelectric properties.

Keywords
Oxide
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