Annealing temperature dependency of structural, optical and electrical characteristics of manganese-doped nickel oxide nanosheet array films for humidity sensing applications

ABSTRACT

Manganese-doped nickel oxide nanosheet array films are successfully prepared on a nickel oxide seed-coated glass substrate by an immersion method. Various annealing temperatures between 300C and 500C are applied to the manganese-doped nickel oxide nanosheet array films to study their effect on the properties of nickel oxide, including humidity sensing performance. Field emission scanning electron microscopy (FESEM), energy dispersive X-ray spectroscopy (EDS), X-ray diffraction (XRD), ultraviolet–visible (UV–vis) spectrophotometry, a two-probe current–voltage (I-V) measurement system and a humidity measurement system are used to characterise the heat-treated manganese-doped nickel oxide samples. The effect of annealing temperature can be clearly observed for the different surface morphologies and diffraction patterns. The samples exhibit average crystallite size increases of 0.63–10.13 nm with increasing annealing temperature. The dislocation density, interplanar spacing, lattice parameter, unit cell volume and stress/strain are also determined from the XRD data. The average transmittances in the visible region for all samples show low percentages with the highest transparency of 50.7% recorded for manganese-doped nickel oxide annealed at 500C. The optical band gap shows a decreasing trend with increasing annealing temperature. The I-V measurement results reveal that manganese-doped nickel oxide displays improved conductivity values with increasing annealing temperature. The sensitivity of the humidity sensors shows an ascending curve with increasing temperature. The optimal device performance is obtained with annealing at 500C, with the highest sensitivity of 270 and the fastest response and recovery times. In contrast, the sample for annealing at 300C shows poor sensing performance.