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The Effect of Substrate Temperature on the Electrical, Electronic, Optical Properties and the Local Structure of Transparent Nickel Oxide Thin Films

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The electrical, electronic, optical properties and the local structure of Nickel Oxide (NiO) thin film have been investigated by X-ray photoelectron spectroscopy (XPS), Reflection Electron Energy Loss Spectroscopy (REELS), UV-spectrometer,Hall Effect measurement and X-ray absorption spectroscopy (XAS). The XPS results show that the Ni 2p spectra for all films consist of $Ni2p_{3/2}$ at around 854.5 eV which indicate the presence of Ni-O bond from NiO phase and for the annealed film at temperature above 200°C shows the coexist Ni oxide and Ni metal phase. The REELS spectra showed that the band gaps of the NiO thin films were abruptly decreased with increasing temperature. The values of the band gaps are consistent with the optical band gaps estimated by UV-Spectrometer. The optical transmittance spectra shows that the transparency of NiO thin films in the visible light region was deteriorated with higher temperature due to existence of Ni^0. Hall Effect measurement suggest that the NiO thin films prepared at relatively low temperatures (RT and 100°C) are suitable for fabricating p-type semiconductor which showed that the best properties was achieved at 100°C, such as a low resistivity of 7.49 Ω.cm. It can be concluded that the annealing process plays a crucial role in converting from p type to n type semiconductor which leads to reducing electrical resistivity of NiO thin films. Furthermore, the extended X-ray absorption fine structure (EXAFS) spectrum at the Ni K-edge was used to address the local structure of NiO thin films. It was found that the thermal treatments increase the order in the vicinity of Ni atom and lead the NiO thin films to bunsenite crystal structure. Moreover, EXAFS spectra show in increasing of coordination number for the first Ni-O shell and the bond distance of Ni-O with the increase of substrate temperature.

Keywords: Nickel Oxide (NiO), Substrate temperature, Electrical and optical properties