Abstract

Eco-friendly green biosynthesis of SnO$_2$ and TiO$_2$ nanostructures has been carried out using medicinal mushroom, *Ganoderma lucidum* (G Lucidum) in the present work. The medicinal plant species, *G. lucidum* was used a reducing and chelating agent for the synthesis of metal oxides. SnO$_2$ based ethanol (C$_2$H$_5$OH) gas sensors and TiO$_2$ based chlorine (Cl$_2$) gas sensors were investigated. The effects of molar concentration of precursor on the structural properties and gas sensor performance were investigated. Furthermore the effects of noble metal sensitization on the response of gas sensors were investigated. Noble metals such as Silver (Ag), Gold (Au) and palladium (Pd) were used for sensitization of SnO$_2$ and TiO$_2$. The change in surface energy, electronic sensitization and the chemical sensitization (spillover effect) caused by sensitization of noble metals on SnO$_2$ and TiO$_2$ surface were investigated. Pure SnO$_2$/TiO$_2$ and Ag, Au and Pd sensitized SnO$_2$/TiO$_2$ nanostructures were characterized using X-ray diffraction (XRD), Field emission scanning electron microscopy (FESEM), High resolution transmission electron microscopy (HRTEM), Energy Dispersive X-Ray Spectroscopy (EDAX), Ultraviolet/Visible Absorption Spectroscopy (UV/Vis spectroscopy), X-ray photoelectron spectroscopy (XPS) and Brunauer, Emmett and Teller (BET) measurements for micro structural, morphological, elemental analysis and adsorption-desorption studies of NO$_2$ on the surface of the resultant products.

The green synthesized nanostructured SnO$_2$ film showed excellent selectivity towards C$_2$H$_5$OH gas. The sensing properties of the films of different molar concentrations of precursor solution (0.1 M through 0.5 M of SnCl$_4$) were studied, the maximum response of 69.6 % was obtained at 100 ppm C$_2$H$_5$OH concentration for 0.3 M SnCl$_4$ (S3) film. However, the response was found to decrease as the molar concentration of SnCl$_4$ solution increased. The electronic and chemical sensitization of impregnated films showed enhanced gas sensing performance of the films. Ag, Au and Pd sensitized SnO$_2$ films showed increased gas sensing performances towards C$_2$H$_5$OH gas (74.0 % for Ag-SnO$_2$, 96.5 % for Au-SnO$_2$ and 71.5 % for Pd-SnO$_2$) with enhanced response and recovery time. Au-SnO$_2$ film showed maximum gas sensing performance of 96.5 % towards 100 ppm C$_2$H$_5$OH concentration at decreased
temperature of 200 °C with fast response and recovery of 14.6 s and 24.5 s respectively. Thin films of TiO\textsubscript{2} nanostructures fabricated by a green synthesis and Doctor’s blade method were investigated for Cl\textsubscript{2} gas sensor. The effect of molar concentration of Ti precursor (TTIP), operating temperature, sensitization by noble metals such as Au, Ag and Pd on the gas sensing behavior of TiO\textsubscript{2} film have been studied. The gas sensing properties of TiO\textsubscript{2} based sensors were studied for different oxidizing and reducing gases.

The effect of structural properties such as texture coefficient (Tc), crystallite size (D), interplaner distance (d), dislocation density (δ), microstrain (ε) and specific surface area (S) on pure TiO\textsubscript{2} Cl\textsubscript{2} gas sensors were studied. The sensing properties of the films were studied from 5 ppm to 400 ppm of Cl\textsubscript{2} gas concentrations and the maximum response of 56.9 % was obtained at 100 ppm Cl\textsubscript{2} gas concentration at 250 °C. It was observed that the TiO\textsubscript{2} film at 0.1 M TTIP (T1) showed excellent sensing characteristics with rapid response and recovery of 96.5 s and 56.1 s respectively. The performance of pure TiO\textsubscript{2} films was enhanced by noble metal sensitization. Ag, Au and Pd sensitized TiO\textsubscript{2} films showed increased gas sensing performances (110.5 % for Ag-TiO\textsubscript{2}, 127.2 % for Au-TiO\textsubscript{2} and 135.7% for Pd-TiO\textsubscript{2}) towards Cl\textsubscript{2} gas at 100 ppm concentration with enhanced response and recovery time. The operating temperatures of Ag-TiO\textsubscript{2} and Pd-TiO\textsubscript{2} were found to be decreased on noble metal sensitization, 200 °C for Ag-TiO\textsubscript{2} and 150 °C Pd-TiO\textsubscript{2}. Pd-TiO\textsubscript{2} film showed maximum gas sensing performance of 135.7 % towards 100 ppm Cl\textsubscript{2} gas concentration at 150 °C with fast response and recovery of 15.7 s and 52 s. Thus the gas sensing results demonstrate high response, excellent selectivity, outstanding repeatability in response, and long term stability to hazardous Cl\textsubscript{2} gas at decreased temperature of 150 °C, hence Pd-TiO\textsubscript{2} may be a preferred candidate for chlorine gas sensor.