Abstract

The thesis “SYNTHESIS AND CHARACTERIZATION OF NANO STRUCTURED TRANSITION METAL OXIDE THIN FILMS FOR DEVICE FABRICATION” documents the synthesis, characterization and device fabrication of binary and ternary transition metal oxide thin films. Binary oxides of manganese, cobalt and iron and ternary oxides of cobalt-manganese, manganese-iron and copper-cobalt are synthesized via spray pyrolysis technique and the prepared samples are subjected to structural, morphological, electrical and optical characterizations. The work aims to probe into the properties of the metal oxide thin films and to fill up the gaps regarding certain areas of study as pointed by literature review.

From the results obtained, it was quite evident that the properties of the films were dependent on the preparation parameters like substrate temperature, precursor concentration, thickness etc. Substrate temperature and thickness played a vital role in shaping up the structural, electrical and optical properties of spray deposited binary oxide thin films. The metal oxide thin films possessed diverse crystal structures as pointed by XRD and the crystallinity was found to be thickness and temperature dependent. Among the three binary oxides, haussmanite and hematite thin films were more crystalline than cobalt oxide films. Identification of co-ordination of metal ions with oxygen through IR spectral investigations confirmed the formation of the binary oxide structures. Surface chemistry investigation by XPS revealed the cation states. Elemental composition and the stoichiometry of the samples were estimated by EDS that informed the presence of native elements in appropriate levels without any impurity elements.

Deposition temperature had significant effect on crystallinity which in turn was reflected in electrical conductivity of the films. The observed trend of
conductivity with temperature validated grain size effects. Cobalt oxide had better conductivity than the other two giving it an upper edge to be utilised as gas sensor. UV-Vis-NIR spectroscopy pointed out the high optical transmittance of Mn$_3$O$_4$ thin films than the binary oxides of cobalt and iron. Photoluminiscent properties were more pronounced for Mn$_3$O$_4$ and Co$_3$O$_4$ while Fe$_2$O$_3$ exhibited the least luminescence.

Ternary oxides too showcased vivid crystal structures as revealed from XRD. FTIR served as a confirmatory tool by identifying the characteristic bands related to the constituent metals and oxygen. The cationic distribution and the chemical states of the mixed oxides were extracted by deconvoluting the XPS peaks. The oxidation states of the constituent ions were elucidated clearly from their multiplet splitting. Electrical conductivity values of the materials proved that copper cobaltites were highly conductive while the others were almost insulators. The fascinating mechanisms responsible for the conduction processes are brought out. Optical characterization revealed the absorption edges and the transmitting capacity of the samples. Manganese ferrites possessed better transmittance than its counterparts and the films were found to have moderate photoluminiscent nature.

Among the binary oxides, cobalt oxide (Co$_3$O$_4$) showed promising gas sensing characteristics. In the case of the ternary oxides, it was copper cobalt oxide that showed remarkable gas sensing behavior. The dependence of sensitivity on temperature was analysed. It was evident that the films showed a marked increase in sensitivity and a quicker response at increased temperature.

The present work will generate new fundamental knowledge of electronic and atomic dynamics of transition metal oxides in condensed matter. The development of devices based on the unique properties will lead a giant leap forward and promote a wide range of technological advancements.