ABSTRACT

The multi-ferroic bismuth iron oxide (BFO) exhibits both electrical polarization and magnetization ordering and coupling between the two at room temperature. We have synthesized BFO powders using auto-combustion route and characterized the synthesized powders in terms of phase formation behavior, microstructure, electrical and magnetic characteristics. We have demonstrated Co doped BFO to be an excellent material for weak magnetic field sensing. Subsequently we have illustrated the gas sensing, electrochemical, and photo-catalytic characteristics of the auto-combustion synthesized multi-ferroic bismuth iron oxide (BFO) particles. BFO exhibits excellent volatile organic compound (VOC) sensing characteristics. For 25 ppm isopropanol, BFO sensor yields response of more than 500% with response time of few seconds. The sensor, however, is found to be cross sensitive towards methanol and ethanol. The carbon monoxide (CO) sensing characteristics of 'p' type perovskite BFO is traced to be due to the catalytic nature of BFO towards effective CO oxidation at relatively lower operating temperature (~ 200^{o}C). The 1st factor responsible of its superior catalytic behavior is related to lower metal – oxygen binding energy. The 2nd factor is governed by the 'd' electron configuration of iron cations present in BFO lattice. Finally, nature of surface adsorbed species also influence its superior CO oxidation activities at relatively lower operating temperature. These factors impart selective CO sensing behavior among nitrogen di oxide, hydrocarbon, however, its cross-sensitivity towards hydrogen (H_2) is unavoidable. The temperature dependence of resistance transients and response % characteristics of CO and H_2 gas sensing were analyzed based on Langmuir – adsorption isotherm kinetics. Modeling of resistance transients and temperature dependence of response % characteristics allowed us to estimate the activation energy (E_a) and heat of adsorption (Q) as a function of the concentration of respective test gases (H_2 and CO). An attempt has been made to differentiate the gas type based on the estimated E_a and Q values. BFO has also been established to be a conversion oxide type negative electrode for both Li and Na ion rechargeable cells. For both these rechargeable cells we have found that discharge initiates first and perovskite BFO is converted to metallic Bi, Fe, and (amorphous) oxides (Li_2O and Na_2O, for Li and Na ion cells respectively). Subsequently, bismuth is alloyed with alkali ions (Li or Na) in a two - step reaction, however, metallic Fe remains unreacted. During subsequent charging Bi_2O_3 and Fe_2O_3 are formed. During subsequent discharge and charge Bi_2O_3 and Fe_2O_3 are lithiated and delithiated to yield capacities. Similar reaction mechanism has also been proposed for Na^+ rechargeable cells. Finally, we have illustrated that electrophoretic deposition is an attractive tool to achieve improved electrochemical characteristics of perovskite BFO as a conversion type anode material for dual ion rechargeable cell. BFO powders were used as photo-catalyst for rhodamine B (RhB) and crystal violet (CV) dye degradation under solar irradiation. We have reported that the percentage of the degradation of RhB and CV dyes are ~ 99.9% and 100 % respectively for BFO after continuous illumination of visible light for 120 and 50 minutes. Reviewing the open literature, we have found that the demonstrated multi-functionality of BFO ceramics has not yet been adequately explored. Our work paves the foundation to utilize BFO in newer types of devices pertinent to the cited characteristics.

Keywords: Auto-combustion; Dielectric and impedance spectroscopy; Magnetization; Gas sensor; Li and Na-ion rechargeable cell; Photo-catalyst.