ABSTRACT

Multiferroic materials that exhibiting simultaneous magnetic and electrical ordering have attracted research community in the past few years because of their fascinating science and technological applications. The coexistence of magnetic and electrical properties as well as the magnetoelectric effect of these materials allow an additional degree of freedom in the design of actuators, transducers, spin filters and high density with low power consuming information storage devices.

Novel multiferroic materials (ferromagnetic ferroelectrics) are needed mainly for applications in information storage devices. Bismuth based perovskite oxides present an excellent starting point to investigate these materials. In particular, to date, BiMnO₃ (BMO) is the only reported ferromagnetic and ferroelectric bismuth based single perovskite oxide, possessing a magnetic and electric Curie temperature (Tᵢ) around 105 and 450 K respectively in bulk form. For the synthesis of bulk BMO, high pressure and temperature are required. Hence, thin films of BMO with high stability are prepared at first using substrates which show a low mismatch with the compound that is to be formed. For this purpose, these BMO films are grown on (100) and (111) oriented n-type Si and Pt/Ti/SiO₂/Si(100) substrates by Radio Frequency magnetron sputtering. Secondly, Ca²⁺ (≤ 40 at. %) substitution with the BMO films (Bi₁₋ₓCaₓMnO₃, BCMO) gives rise to a slightly reduced unit cell volume, exerting chemical pressure, which contributes to the prevention of Bi³⁺ cations from desorption during the growth process. In the ternary Bi-Mn-O and quaternary Bi-Ca-Mn-O systems, a strong multiphase formation tendency is found. Different parasitic oxide phases like Mn₃O₄, Bi₂O₃ and MnO₂ for BMO system and CaO for BCMO
system possibly occur. As a consequence, the single phase stabilization in the BCMO films is achieved under a narrow window of deposition conditions. In particular, the deposition temperature window is critical, which is required to be 400 and 800 °C for the BCMO films crystallized on \( n \)-Si and Pt/Ti/SiO\(_2\)/Si substrates respectively. The structural, elemental, morphological, magnetic, dielectric and ferroelectric characteristics of the BCMO films are investigated using X-ray diffraction analysis, energy dispersive analysis of X-ray spectrum, X-ray photoelectron spectroscopy, atomic force microscopy, vibrating sample magnetometer, dielectric and ferroelectric measurements respectively. The BCMO films acquire single monoclinic phase and attain a very low rough surface. The required stoichiometry is achieved even though the films possess a small Mn defect and have ferromagnetism at room temperature.

Finally, in order to study the dielectric and ferroelectric properties of BCMO films, parallel plate capacitors are fabricated using \( n \)-type Si(100), \( n \)-type Si(111) and Pt/Ti/SiO\(_2\)/Si(100) substrates as bottom electrodes and gold as top electrode. The films possess higher insulating nature and exhibits room temperature ferroelectricity. It has been found that among all the as-prepared films, the Bi\(_{0.8}\)Ca\(_{0.2}\)MnO\(_3\)/Si(100) film grown at 400 °C has better electrical and magnetic properties at room temperature. An additional attempt has been made by irradiation with H\(^+\) ions and \( \gamma \)-ray for the film Bi\(_{0.8}\)Ca\(_{0.2}\)MnO\(_3\)/\( n \)-Si(100) grown at 400 °C that having better property among the developed films and the enhancement in film properties has also been discussed in detail.

In the present research, a systematic effort is made to fabricate defect free BMO films and thereby the effect of calcium modification on BMO films is also investigated to find desirable physical properties and functions of the material with regard to its microstructure and electronic configuration. The results obtained from the present investigation could be useful to study the suitability of the BCMO films for application in information storage devices.