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Effects of low energy ion sputtering on structure and microstructure of $PbTiO_3$ thin films

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Abstract – In this work, the effects of Low Energy Ion Sputtering on structure and microstructure of $PbTiO_3$ thin films were investigated. $PbTiO_3$ thin films with no preferential orientation, crack free and 500 nm in thickness were deposited on Pt(111)/Ti/SiO_2/Si(100) substrates by spin coating. The studied films presented a dense microstructure with grain size in the range 190-230 nm. An increasing in the grain size was observed when films were irradiated at 1 keV for 20 min. Decreasing the energy to 500 eV and increasing the exposure time to 120 min, no significant changes were observed in the microstructure of this film.

In the recent years, ferroelectric thin films have been subject of intense investigations owing to their striking physical properties and potential technological applications. With the advent of the nanotechnology, the main goals in the ferroelectric thin film subject are associated to the development and control of structures at the nanometer scale. Among several ferroelectrics materials of interest, the lead titanate ($PbTiO_3$) is one that have been explored as thin films with the objective of developing solid state devices destined to the microelectronic technology. In contrast with studies performed on semiconductor materials, whose literature reports several works on the formation of the spontaneous and controlled nanostructures [1], the recent literature on $PbTiO_3$ thin films reports some works on the formation of the spontaneous nanostructures such as nanotubes, nanowires and nanorods [2]. The observed nanostructures on the $PbTiO_3$ thin films were spontaneously produced by specific deposition methods or processes. Low Energy Ion Sputtering (LEIS) has been recently presented as a technique appearing to be very promising for the fabrication of semiconductor nanostructures and quantum dots [3]. The present work is devoted to the investigation of the LEIS effects on the structure and microstructure of $PbTiO_3$ thin films produced by chemical method.

$PbTiO_3$ thin films were deposited on Pt(111)/Ti/SiO_2/Si(100) substrates by spin coating at 4000 rpm for 40 seconds and crystallized in an electric furnace at 700°C for 1 h. The final films were prepared with 500 nm in thickness. The structure of the films was examined by X-ray diffraction (XRD) technique and Raman spectroscopy. Three $PbTiO_3$ films were selected and irradiated by LEIS, with low energy Ar^+ ion, under normal incidence. The used LEIS apparatus is described in details elsewhere [4]. These films were irradiated at 1 keV for 20 min, at 1 keV for 60 min and at 500 eV for 120 min. The used work vacuum was 5×10^{-5} torr, the used accelerating voltage and ion flux were 500 V and 1.0×10^{-5} $cm^{-2}s^{-1}$ respectively. The microstructure of the films was studied by using Atomic Force Microscopy (AFM) operating in contact mode.

No preferential orientations were observed on the structure of the studied $PbTiO_3$ thin films in the present work. The calculated lattice parameters agree relatively well with values given in the JCPDS data card for tetragonal phase of the $PbTiO_3$ (a = 3.899 Å and c = 4.153 Å). With respect to the films irradiated by LEIS, there are no significant differences on the microstructure of the as prepared $PbTiO_3$ film and irradiated at 1 keV for 20 min. These films presented a dense microstructure with R_{rms}=9.04 nm and grain size at around 190 nm. However, irradiating the film at 1 keV and increasing the exposure time to 60 min, a increasing in grain sizes to 230 nm was observed. Increasing the exposure time to 120 min and decreasing the energy to 500 eV, no significant changes could be observed at the film microstructure. No substantial modifications on the microstructure were observed but a perceptible shift was observed in the Raman modes A1(1TO), E(2TO), B1+E and A1(2TO) between 100-400 cm^{-1}.

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