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Compensation of Bulk Charge Carriers in Bismuth Based Topological Insulators via Swift Heavy Ion Irradiation

Authors : Jyoti Yadav, Rini Singh, Anoop M.D, Nisha Yadav, N. Srinivasa Rao, Fouran Singh, Takayuki Ichikawa, Ankur Jain, Kamlendra Awasthi, Manoj Kumar

Abstract : Nanocrystalline films exhibit defects and strain induced by its grain boundaries. Defects and strain affect the physical as well as topological insulating properties of the Bi2Te3 thin films by changing their electronic structure. In the present studies, the effect of Ni7+ ion irradiation on the physical and electrical properties of Bi2Te3 thin films was studied. The films were irradiated at five different fluences (5x1011, 1x1012, 3x1012, 5x1012, 1x1013 ions/cm2). Thin films synthesized using the e-beam technique possess a rhombohedral crystal structure with the R-3m space group. The average crystallite size, as determined by x-ray diffraction (XRD) peak broadening, was found to be 18.5 ± 5 (nm). It was also observed that irradiation increases the induced strain. Raman Spectra of the films demonstrate the splitting of A_1u^1 modes originating from the vibrations along the c-axis. This is by the variation in the lattice parameter 'c,' as observed through XRD. The atomic force microscopy study indicates the decrease in surface roughness up to the fluence of 3x1012 ions/cm2 and further increasing the fluence increases the roughness. The decrease in roughness may be due to the growth of smaller nano-crystallites on the surface of thin films due to irradiation-induced annealing. X-ray photoelectron spectroscopy studies reveal the composition to be in close agreement to the nominal values i.e. Bi2Te3. The resistivity v/s temperature measurements revealed an increase in resistivity up to the fluence 3x1012 ions/cm2 and a decrease on further increasing the fluence. The variation in electrical resistivity is corroborated with the change in the carrier concentration as studied through low-temperature Hall measurements. A crossover from the n-type to p-type carriers was achieved in the irradiated films. Interestingly, tuning of the Fermi level by compensating the bulk carriers using ion-irradiation could be achieved.

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