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Au^{3+} ion implantation on FTO coated glasses: Effect on structural, electrical, optical and phonon properties

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ABSTRACT

Effects of 11.00 MeV Au^{3+} ions implanted in FTO coated (thickness ≈300 nm) silicate glasses on structural, electrical optical and phonon behavior have been explored. It has been observed that metal clustering near the surface and sub-surface region below glass-FTO interface changes electrical and optical properties significantly. Ion implantation does not affect the crystalline structure of the coated films; however, the unit cell volume decreases with increase in fluence and the tetragonal distortion (c/a ratio) also decreases systematically in the implanted samples. The sheet resistivity of the films increases from 11×10^{-5} ohm-cm (in pristine) to 7.5×10^{-4} ohm-cm for highest ion beam fluence $\approx 10^{15}$ ions/cm^2. The optical absorption decreases with increasing fluence whereas, the optical transmittance as well as reflectance increases with increasing fluence. The Raman spectra are observed at ~530 cm^{-1} and ~1103 cm^{-1} in pristine sample. The broad band at 530 cm^{-1} shifts towards higher wave number in the irradiated samples. This may be correlated with increased disorder and strain relaxation in the samples as a result of ion beam irradiation.

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1. Introduction

Transparent conducting oxides (TCO's) are n-doped metal oxide thin films, used as substrates for a number of devices. These TCO films are very useful materials for potential applications as heat-mirror window-coatings, controlling the transmission of infrared energy into and out-of buildings, as the transparent electrode materials in photovoltaic cells, touch-screen technology, flat panel displays: including, liquid crystal displays (LCD), organic light emitting displays (OLED), plasma screen displays, optoelectronic devices, surface acoustic wave devices, gas sensors, ferroelectric photo- conductor storage devices, antistatic coatings, light-emitting, light detecting, thin film transistors and light-triggered semiconductor devices, electrodes for electro chromic devices solar cells etc. [1–11]. The characteristic features of good TCO materials involve transparent conductors, wide band gap materials with high electron mobility. This has been attempted by creating electron degeneracy in a wide band gap (>3 eV) oxides through non-stoichiometric composition and/or incorporating appropriate dopants [6] causing oxygen vacancies during film deposition [12].

Mostly used TCO materials include tin-doped indium oxide In_2O_3:Sn (ITO), fluorine doped tin oxide SnO_2:F (FTO) and aluminum doped zinc oxide ZnO:Al (AZO). These materials, instead of relying on intrinsic vacancies within the metal oxide structure, use the defect energy levels created by the extrinsic dopant species to generate n-type conduction. ITO was the first of the modern TCO materials, however this system suffers from major drawbacks due to the rarity and high cost of indium and degradation of the films at the high temperatures required for certain device processing. These drawbacks of ITO led to the development of fluorine-doped tin oxide, antimony-doped tin oxide, and more recently doped zinc oxide systems, as low cost, high performance, and durable alternatives.

Fluorine tin oxide (FTO) is a very useful TCO material that has received wide attention due to its transparency to visible light [13], high electrical conductivity, very low resistivity and high IR reflectivity properties [14]. Transport and optical properties of FTO films are highly sensitive to processing parameters, particularly, substrate temperature, film thickness, dopants, deposition pressure and other deposition conditions [6,15–17]. FTO coated glasses are used as substrate for many electronic devices. The small sheet resistivity (≈10^{-4} Ω-cm) and high optical transparency (>80%) in visible region makes them very useful substrate materials for optoelectronic applications [18–23]. However, devices fabricated on FTO substrates may be used in radiation environment. There are hardly any studies on the effect on device performance due to substrate modification after ion irradiation/ implantation.

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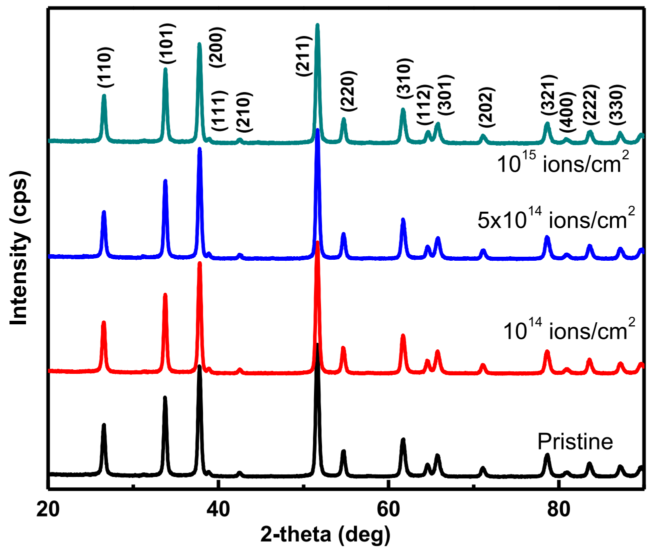

Fig. 1. X-ray diffraction pattern pristine and irradiated samples of FTO.

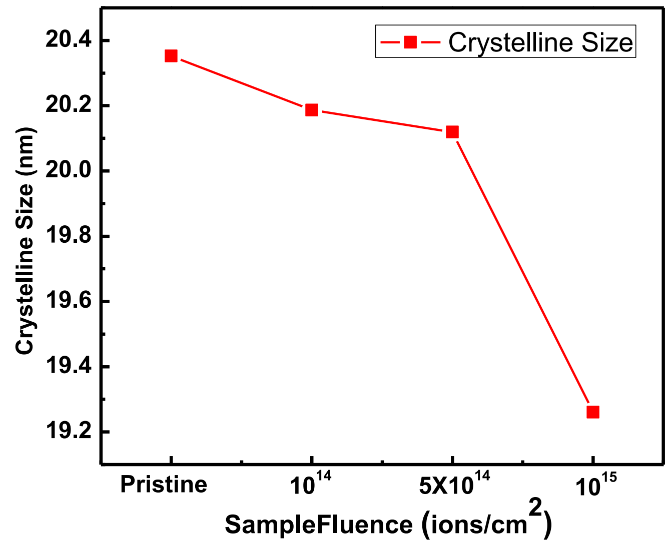

Fig. 3. Variation of crystalline size with the ion fluence.

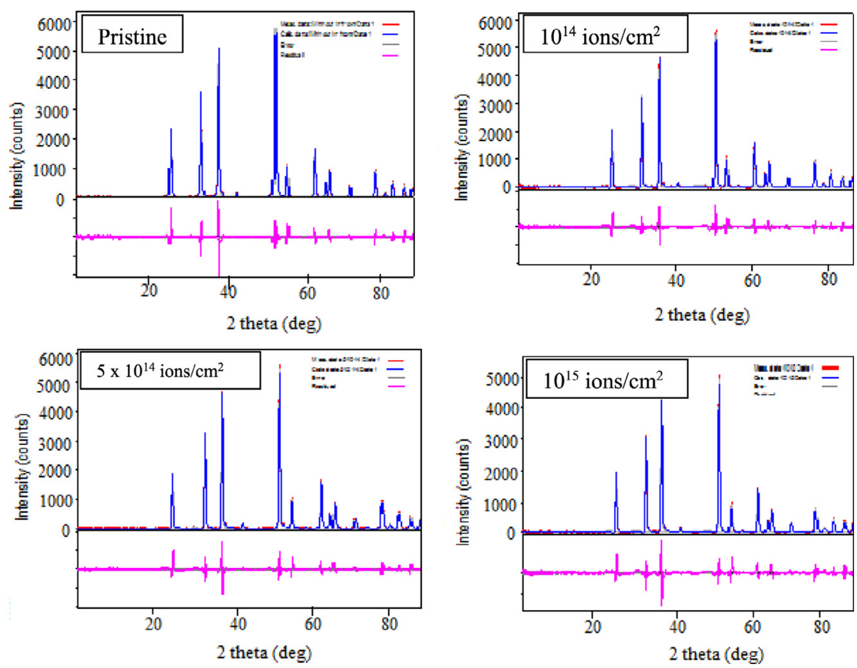

Fig. 2. Rietveld analysis pristine and irradiated samples of FTO.

Table 1
Structural parameters for pristine and 11 MeV Au^{3+} ion implanted FTO at varying fluences.

S.N.	Sample fluence (ions/cm^2)	Space group	Lattice parameter		Phase name	Refinement parameters				ICDD card no.
						Rwp	Rp	S	Chi^2	
1	Pristine	$P4_2/mnm$	a (Å)	4.7539(3)	Tetragonal	14.15	10.35	2.3251	1.4061	04-005-5703
			b(Å)	4.7539(3)						
			c(Å)	3.198(18)						
			c/a ratio	0.68						
2	10^{14}	$P4_2/mnm$	a (Å)	4.7391(2)	Tetragonal	18.17	13.17	2.5575	1.5408	04-007-8273
			b(Å)	4.7391(2)						
			c(Å)	3.1876(2)						
			c/a ratio	0.675						
3	5×10^{14}	$P4_2/mnm$	a (Å)	4.7440(2)	Tetragonal	17.45	12.85	2.4829	1.165	04-007-8273
			b(Å)	4.7440(2)						
			c(Å)	3.19(2)						
			c/a ratio	0.671						
4	10^{15}	$P4_2/mnm$	a (Å)	4.7505(3)	Tetragonal	16.3	12.13	2.4972	1.2359	04-007-8273
			b(Å)	4.7505(3)						
			c(Å)	3.19(2)						
			c/a ratio	0.668						

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