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Effect of silver incorporation on the structural and morphological characteristics of RF sputtered indium oxide films

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Abstract. Radio frequency (RF) magnetron sputtered silver incorporated indium oxide thin films were prepared and their structural and morphological properties were studied using micro- Raman spectroscopy, Atomic Force Microscopy (AFM), Field Emission Scanning Electron Microscopy (FESEM) and Energy Dispersive Spectroscopy (EDS). Raman modes corresponding to the cubic bixbyite phase of indium oxide were obtained through micro-Raman spectroscopy. AFM images exhibited dense distribution of grains. Elemental analysis using EDS spectra confirmed the presence of indium, silver and oxygen in the prepared films.

1. Introduction

Transparent conducting oxides (TCO) find diverse application in the field of optoelectronics. Indium oxide (In_2O_3) is the best chosen TCO since it has good optical transparency and wide band gap (3.4-3.75 eV) [1]. In_2O_3 is suitable for manufacturing of thin film transistors, liquid crystal displays [2] etc. The oxygen deficiency in the non-stoichiometric form of In_2O_{3-x} makes it highly conducting and hence can be used as transparent electrodes in solar cells [4, 5]. In_2O_3 can substitute mercury as a battery inhibitor [6]. Noble metal incorporation into the lattice of In_2O_3 will definitely alter properties. The surface plasmon behaviour of noble metal nanoparticles to absorb visible light can be utilised to enhance the absorption capability of the host material [7]. Amongst silver (Ag) nanoparticles have an absorption band in the visible and near infra-red regions (450-650 nm) due to surface plasmon behaviour [8]. The photon absorption efficiency of In_2O_3 based solar cells can be increased by utilising the plasmonic behaviour of Ag loaded In_2O_3 thin films. They also find applications in data storage devices, in high-speed optical devices, luminescence sensing etc. [7, 8, 9]. They can catalyse as well as deteriorate the crystal growth of host material [8, 10]. They can inhibit the bacterial growth hence can be used as a good antibacterial agent [11, 12]. They act like an ideal agent for phase formation [10].

Here, RF magnetron sputtered silver incorporated In_2O_3 films were prepared and their structural and morphological were investigated using micro-Raman spectroscopy, field emission scanning electron microscopy (FESEM), atomic force microscopy (AFM), and energy dispersive spectroscopy (EDS).

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2. Experiment Details

Silver (Ag) incorporated (0, 1, 2, 5 and 10 wt%) indium oxide thin films were fabricated on micro glass slides using radio frequency (RF) magnetron sputtering technique. The as–prepared films were designated as InAg 0, InAg 1, InAg 2, InAg 5 and InAg 10 according to the Ag content of 0, 1, 2, 5 and 10 wt% respectively. The structural analysis of the films were carried out using micro Raman spectroscopy using Labram-HR 800 [HORIBA JOBIN YVON], using laser excitation radiation of wavelength 514.5 nm from Argon ion laser with spectral resolution of 1 cm-1. The morphological studies were executed using AFM (Bruker, Dimension Edge) with Scan Assist in contact mode and film thickness was measured using vertical FESEM (Nova Nano SEM- 450). Field Emission Scanning Electron Microscope (FEI-USA) was equipped with X-flash detector 6/10 (Bruker) and Quantax 200 was attached to the FESEM device.

3. Results and discussions

3.1. Micro- Raman analysis

Raman spectra of pure and Ag incorporated In_2O_3 films are recorded in the wavenumber region 50-1000 cm^{-1} (Figure 1). Raman spectrum of pure In_2O_3 film gives a sharp intense band at 135 cm^{-1} which can be attributed to the vibration of In-O bond of InO_6 structural unit [13, 14]. With increase in Ag incorporation, intensity of this band decreases. The Raman band at 307 cm^{-1} can be due to the bending vibration of InO_6 octahedron. In InAg5 and InAg10 films this bands almost disappear. The band at 360 cm^{-1} is observed in the Raman spectrum of InAg 10 film can be due to the bending vibration of In-O-In bridge [13, 14]. The Raman modes at 492 and 626 cm^{-1} indicate the stretching vibration of InO6 [21, 24, 15, 16]. The mode around 626 cm^{-1} is sensitive to metal-oxygen distance [17]. The observed Raman modes represent the characteristic modes of cubic bixbyite In_2O_3 structure. The modes at 87, 165, 217, 280, 336, 414, 567, 786, and 814 cm^{-1} can be due to the spectral contributions from glass substrate.

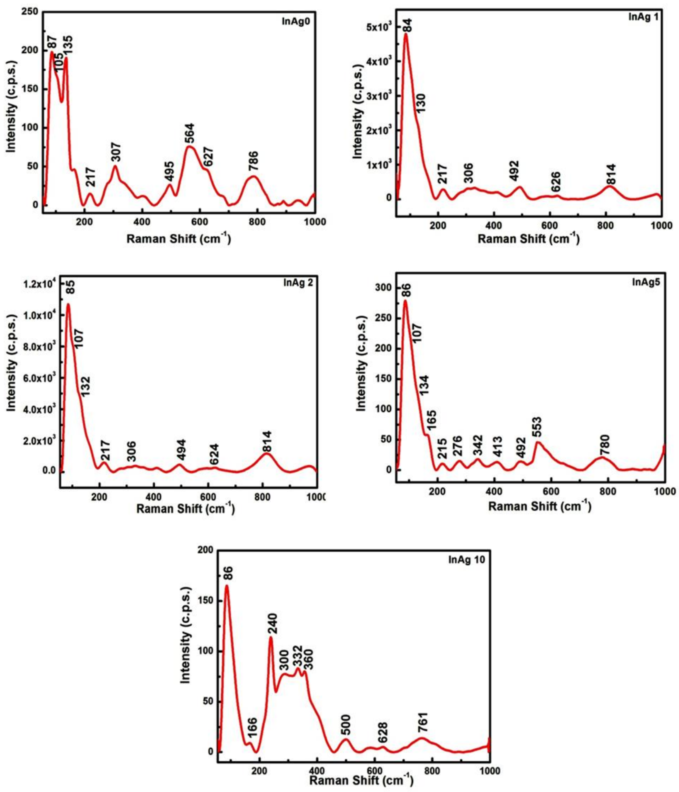


Figure 1. Micro-Raman spectra of as deposited pure and Ag incorporated In_2O_3 films

3.2. Morphological analysis

Figure 2 depicts the 2D AFM images of pure and Ag incorporated In_2O_3 films. These images show that the grains are distributed densely in the film. Agglomeration of particles is seen with silver incorporation. Thickness of the films is obtained via vertical FESEM analysis. Figure 3 shows the vertical FESEM images of pure and Ag incorporated In_2O_3 films. The pure film shows a film thickness of 345 nm. An increase in film thickness can be seen with increase in Ag incorporation up to 2 wt%. InAg2 film presents the highest value of film thickness equal to 445 nm. Thereafter the film thickness decreases. InAg5 film and InAg10 film show thickness of 269 nm and 318 nm respectively.

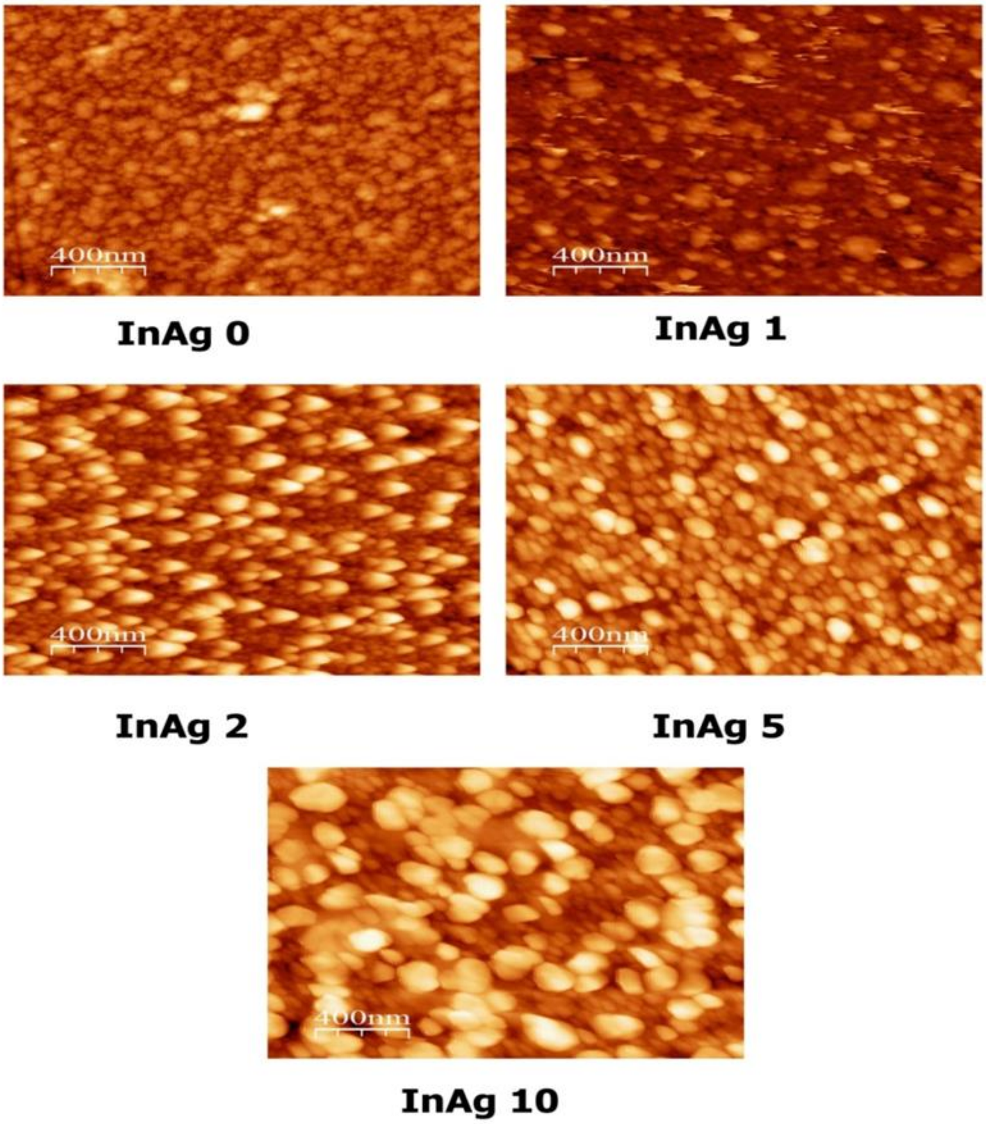


Figure 2. 2D AFM images of pure and Ag incorporated In_2O_3 thin films

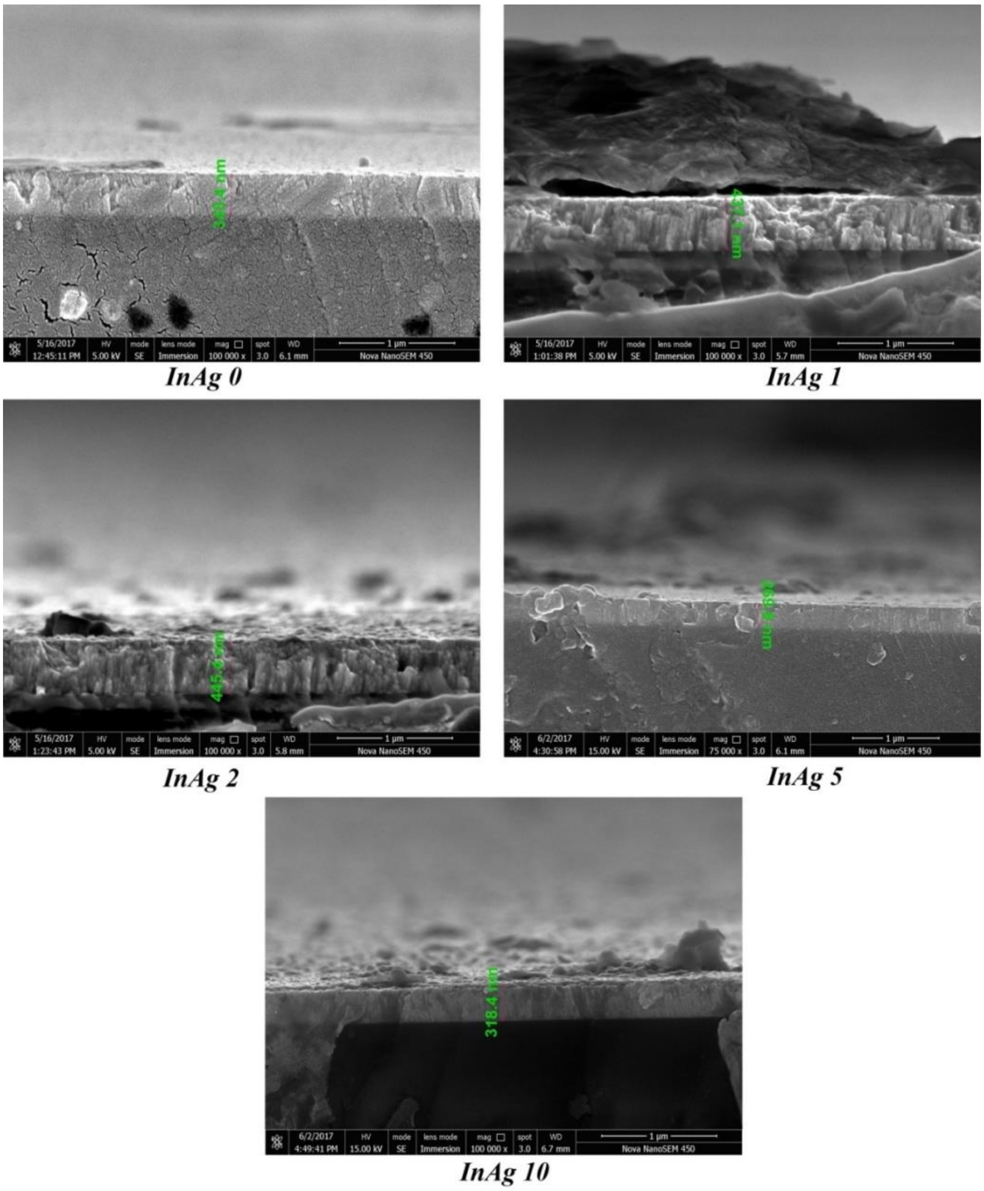
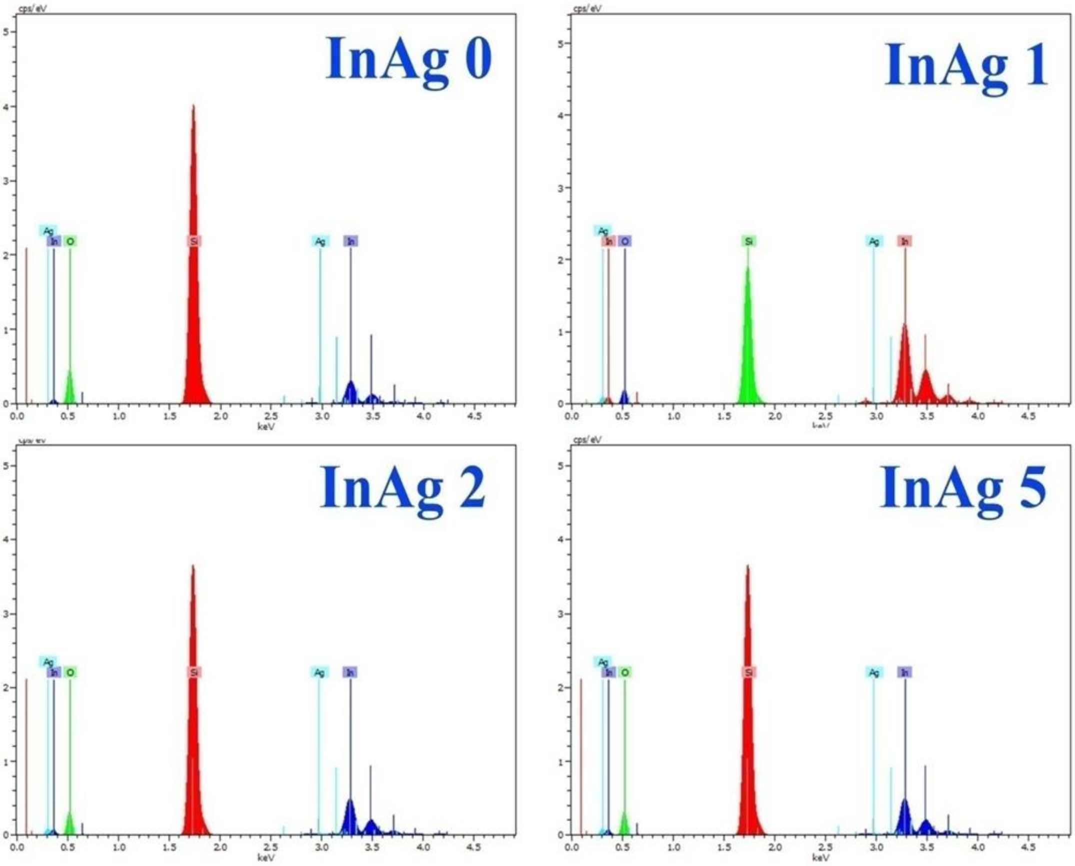
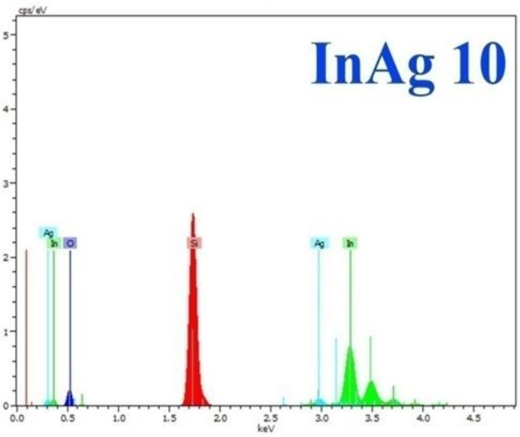


Figure 3. Vertical FESEM images of pure and Ag incorporated In_2O_3 films

3.3. EDS spectra analysis

The elemental analysis of the as prepared pure and Ag incorporated In_2O_3 films were carried out using EDS analysis and is shown in Figure 4. Formation of In_2O_3 can be confirmed with the presence of peaks corresponding to In and O. The observed peaks corresponding to Si in the EDS spectra can have their origin from glass substrate. Presence of Ag peaks confirms the presence of Ag incorporation.





SAMPLE	ATOMIC %			
	In	O	Si	Ag
InAg 0	2.68	58.01	39.31	0.00
InAg 1	13.37	51.35	35.22	0.06
InAg 2	13.82	50.96	34.88	0.34
InAg 5	4.90	51.70	43.21	0.19
InAg 10	9.18	48.63	41.14	1.05

Figure 4. EDS spectra of pure and Ag incorporated In_2O_3 films

4. Conclusion

RF magnetron sputtered Ag incorporated In_2O_3 thin films were fabricated and their structural and morphological analysis were carried out. Cubic bixbyite structure of In_2O_3 was confirmed through micro-Raman analysis. From AFM images we can observe that the grains are densely distributed. The variation of film thickness at different Ag concentration can be inferred from vertical FESEM images. Presence of indium, oxygen and silver in the films were confirmed through EDS analysis. Thus a study on the structural and morphological nature of silver loaded indium oxide films are presented in this work.

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