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The Structural Properties of MoO_3 Thin Films Grown by Magnetron Sputtering Technique

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Abstract

The molybdenum trioxide MoO_3 thin films were growth on c-Si substrates by magnetron sputtering technique. The structural and morphological properties of MoO_3 thin films were investigated by XRD, RAMAN and SEM analysis. Prior to annealing process, X-ray diffractogram indicated that MoO_3 thin films vere amorphous nature. All of the MoO_3 thin films were applied three different annealing temperature and obtained optimum annealing temperature with 300 ^{0}C. XRD patterns of annealed thin films showed that these MoO_3 thin films have polycrystalline nature with 2θ peak at 12˚,23˚, 25˚, 38˚, 55˚and 58˚ corresponding to the (020), (110), (040), (060), (112) and (081) planes. RAMAN spectrum of the MoO_3 thin films were determined 14 Raman active peaks belong to α-phase MoO_3. The surface morphology of the MoO_3 thin films as deposited has appeared to be uniform with smaller grains and exhibits a coarse structure. Annealing of the MoO_3 thin films favors growth and agglomeration of small grains.

Key Words: MoO_3 thin films, Metal oxide semiconductors, Surface Properties, Structural Properties.

1. Introduction

Recently, remarkable attention in research has been accorded to transition metal oxide semiconductors. Metals oxides semiconductor such as ZnO, In_2O_3, SnO_2 and others have been widely studied because their existence in several advantageous structures and nanostructures, and for their high chemical and thermal stability [1, 2].

Molybdenum trioxide (MoO_3), belonging to this family has attracted as a promising material for a large number of fundamental and applied fields due to its various interesting characteristics including direct wide band gap semiconductor, relatively chemical stability, high refractive index and electronic properties. These advantages of MoO_3 have very important as an ideal candidate for several potential applications such as transparent conducting coatings [3-5].

This oxide has shown potential applications in a variety of fields such as solid catalyst, electrochromism, battery electrode, gas sensors, photocatalysis, charge injection or extraction layer in organic photovoltaic (OPVs) and organic light emitting diodes (OLEDs) [3-7].

MoO_3 thin films are mainly fabricated by using several physical and chemical deposition methods. The physical methods include sputtering, molecular beam epitaxy, and laser ablation, while the chemical method such as chemical vapor deposition (CVD), sol-gel, thermal evaporation, pulse laser deposition, and electro-deposition [6-10].

In the present study, MoO_3 thin films have been deposited onto c-Si substrates using magnetron sputtering technique. A systematic investigation is conducted to reveal the effects of annealing process on the structural and morphological properties of MoO_3 thin films by using various characterization techniques.

Experimental

Metal oxide semiconductor MoO_3 thin films have been prepared onto c-Si substrates using magnetron sputtering technique. Molybdenum target (99.99% purity) was used to form MoO_3 thin films. Substrates were sputter etched by neutral molecular source under an argon gas pressure of 0.7 Pa for cleaning process. After the cleaning process, the deposition process was started with the following deposition parameters: 50% Ar and 50% O gas flowing, gas pressure 0.73 Pa, sputtering power 200 W DC, distance between the target and substrates 0.1 meter, a deposition time of 15 minutes. All of the thin films were applied at 300 ^{o}C annealing process under one hour annealing time, after the deposition process.

Surface morphology of metal oxide semiconductor MoO_3 thin films were investigated with JEOL 5410 scanning electron microscope (SEM). Philips PW3710 Model X-Ray diffraction (XRD) system was used to determine the MoO_3 thin films structure via Cu-Kα radiation. Horiba Jobin Yvon HR-UV HR800UV spectrometer system was used for determining the Raman vibrational modes of MoO_3 thin films with 632.817 nm He-Ne laser.

Results and Discussion

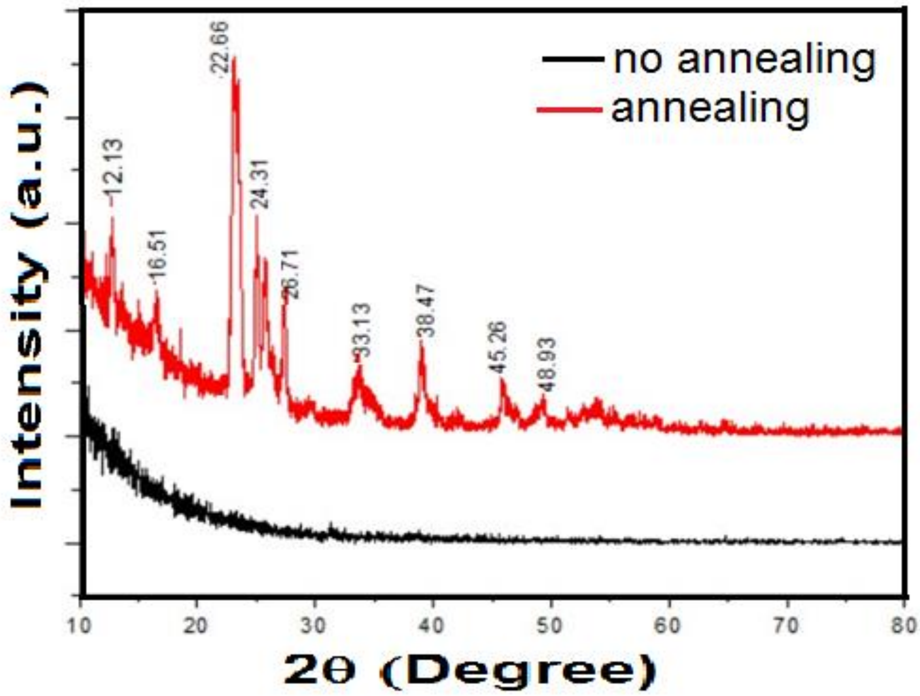

Figure 2. XRD pattern of MoO3 thin films prepared on c-Si substrates via magnetron sputtering technique.

The XRD patterns of annealing and no annealing MoO_3 thin films prepared using magnetron sputtering technique are shown in Fig. 2. Prior to annealing process, X-ray diffractogram indicated that MoO_3 thin films were amorphous nature. XRD patterns of annealed thin films showed that these MoO_3 thin films have polycrystalline nature with 2θ peak at 12˚,23˚, 25˚, 38˚, 55˚and 58˚ corresponding to the (020), (110), (040), (060), (112) and (081) planes. MoO_3 metal oxide semiconductor thin films have the orthorhombic α-phase structure with preferential orientation along (110) direction at 23˚.

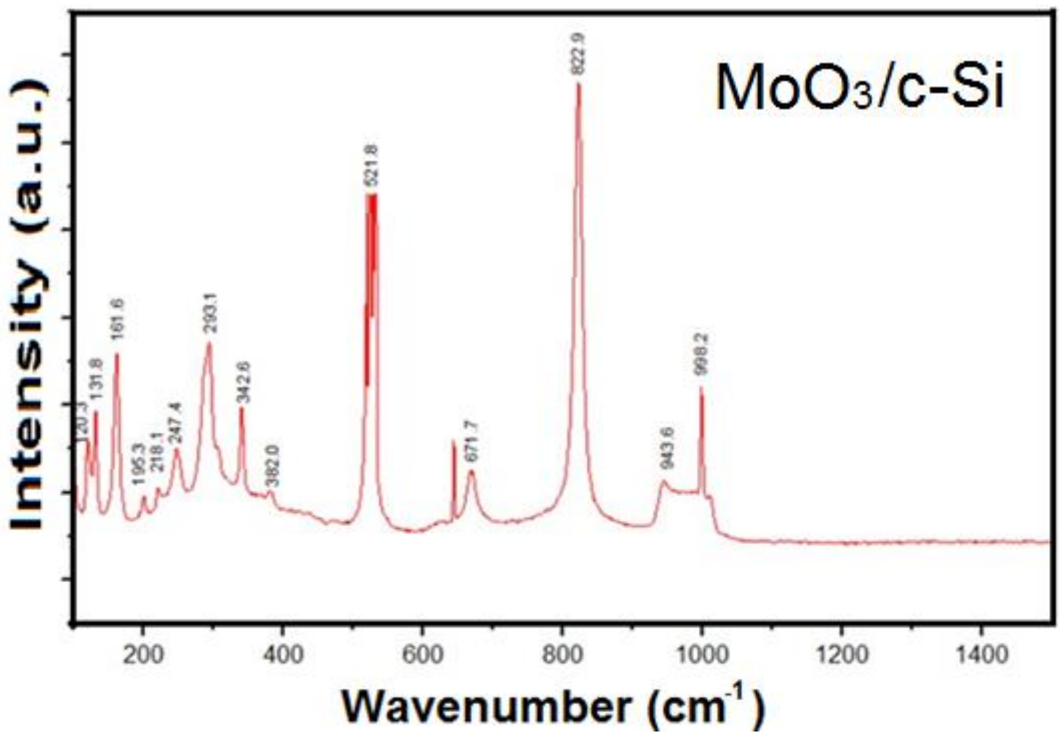

Figure 2. Raman Spectrum of metal oxide semiconductor MoO_3 thin films

The Raman spectrums of MoO_3 thin films are shown in **Error! Reference source not found.** in the range from 200 cm^{-1} to 1600 cm^{-1}. According to group theory, the orthorhombic α-MoO_3 has 45 optical modes with 24 Raman active, 17 IR active and 4 active modes [11]. All of the MoO_3 thin films examined at the range of 200-1600 cm^{-1} and exhibited the same RAMAN spectrum with determined 14 Raman active peaks belong to α-phase MoO_3. Raman stretching analysis indicated that the most intense Raman lines at 822^{-1} cm give characteristic vibrations peak of the MO-O-MO bonding.

Figure 3 shows the SEM images of cross-sectional and surface morphology of metal oxide semiconductor MoO_3 thin films. The surface morphology of MoO_3 thin films is considerably homogenous, as seen in Fig. 3a., with nano-sized grains roughly. These nano-sized grains dispersed all over the surface and all of them in same dimension. The surface morphology of the MoO_3 thin films as deposited has appeared to be uniform with smaller grains and exhibits a coarse structure. Annealing of the MoO_3 thin films favors growth and agglomeration of small grains. We found to be ~600 nm film thickness from cross-section images in Fig.3b.

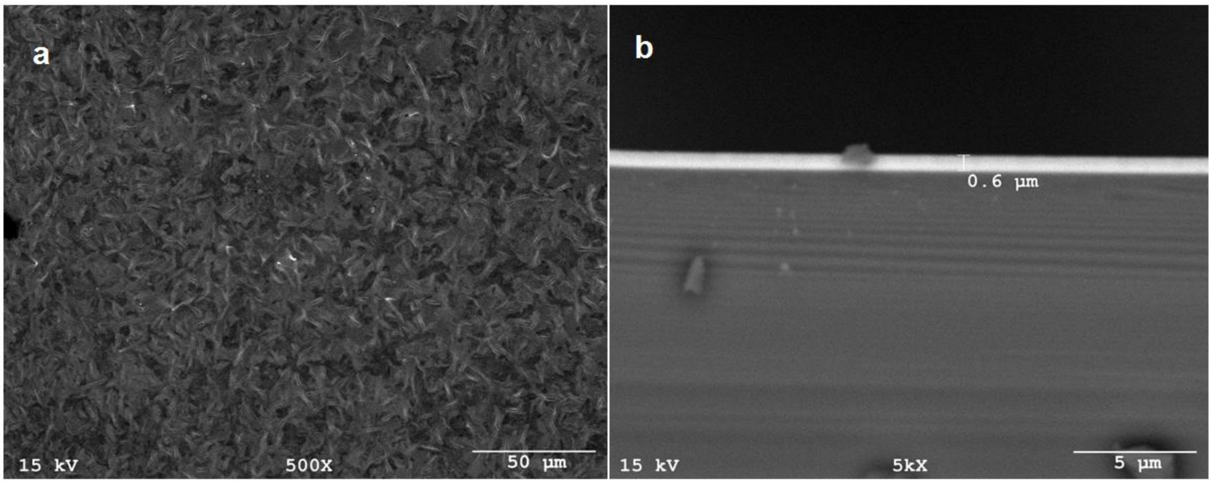

Figure 3. SEM images of cross-sectional and surface morphology of metal oxide semiconductor MoO_3 thin films

Conclusion

Metal oxide semiconductor MoO_3 thin films are successfully growth on c-Si substrates by Magnetron sputtering technique. After the annealing process, XRD analysis indicated that MoO_3 thin films have polycrystalline nature with the orthorhombic α-phase structure. We determine 14 Raman active peaks belong to α-phase MoO_3 with Raman spectrum. Prior to annealing, the surface morphology of the MoO_3 thin films as deposited has appeared to be uniform with smaller grains and exhibits a coarse structure. Annealing of the MoO_3 thin films favors growth and agglomeration of small grains. Magnetron sputtering technique is an effective method to produce MoO_3 metal oxide semiconductor thin film; the film structure was homogeneously, rough and orthorhombic α-phase crystal structure.

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