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Nanostructures of ITO Thin Films Induced by Low Energy Ion Beam

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Abstract. This paper presents a novel method that using low energy hydrogen ion beam at normal incidence to deal with indium tin oxide(ITO) thin films.The surface structure of ITO thin films are controlled by changing parameters of ion source(IS),such as ion energy,ion beam current,substrate temperature and processing time.In this paper,the ion energy is set at 300 eV, the ion beam current ranges from 60 mA to 100 mA,the substrates are heated to 120 ℃ and 150 ℃,the processing time is from 5 min to 25 min.Setting the ion source parameter at 300 eV,120 ℃ and 60 mA,with the growing of time,the nanoparticles(NPs) on the surface of ITO layer appears,and the diameter of nanoparticles is reduced as the treating time is beyond 15 min.In addition to,transforming the ion beam current from 80 mA to 100 mA,other parameters,such as maintaining the ion energy at 300 eV, substrate temperature at 150 ℃ and conducting time at 15 min,it demonstrates that the nanoparticles size of ITO layer is more uniform and dense nanostructures at 100 mA ion beam current than at 80 mA ion beam current.It means that altering the ion beam current could affect the nanoparticles size distribution and,furthermore,control the surface nanostructure of ITO layer.

1 Introduction

One Dimension(1D) nanomaterials show various electrical and optical properties[1,2] compared to their bulk materials.For instance,metallic NPs have quantum confinement effect,surface effect and tunneling effect when the particles diameter are confined 1 to 100 nm[3,4].Besides,metallic nanoparticles exhibit higher light absorption than their bulk counterpart due to surface plasma effects and form many nano-electrodes to increase efficient potential contact.ITO thin film[5] is one kind of transparent conducting oxide with high conductivity,high transmittance in visible light region and good chemical stability,it is regarded as a transparent electrode materials widely used in LCD,PDP,touch screen and solar cells[6,7].

Using hydrogen plasma[8,9] to handle ITO thin films in Plasma Enhanced Chemical Vapor Deposition(PECVD) has been reported in recent years.As our knowledge,using Ar^+

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[10] or Xe^+[11] ion beam to treat the surface of Si, Ge and GaAs has been reported in previous researches.However,it is seldom to see someone to utilize low energy hydrogen ion beam to treat ITO thin films.Unlike the principle of generating hydrogen plasma in PECVD,which needed high H_2 flux and produced hydrogen plasma by means of an unaccelerated electrical field, the IS could not only produce high density of H^+ ions with specific direction and large ions momentum,but require smaller H_2 flux than in PECVD.Apart from above advantages,the equipment charges of PECVD is more expensive than IS devices and it is not easy to maintain in comparison to IS equipment.

In this paper,the formation of nanostructure on ITO layer by employing IS to produce hydrogen ions to treat ITO thin films.Besides,the influence factor of surface nanostructures, such as ion beam current value or ion beam current density,substrate temperature,ion energy and processing time has been studied in details.

2 Experimental Details

The ITO thin films were deposited on the glass substrate,the thickness of ITO thin films were around 25 nm and the size were 15 mm×25 mm.Subsequently,the glass substrates coated ITO thin films were cleaned by washing-up liquid for wiping off surface contaminants.Then,the substrates were cleaned by ultrasonic devices in the mingle solution of ethanol,NaOH and deionized(DI) water for 5 min,Finally, the substrates was rinsed several times by DI water and blowed by N_2. The cleaned ITO glass substrates were rapidly placed in the vacuum chamber,the reaction pressure was 2.5E-2 Pa,the ion beam current changed from 60 mA to 100 mA,the IS energy was 300 eV, the reaction time was increased from 5 min to 25 min and the substrates were heated to 120 ℃ and 150 ℃,the H_2 flux maintained in 3.5 sccm.

The IS type was Kaufman IS(KFM-12),the max ion beam current of this IS was 150 mA and the max ion energy was 600 eV.The surface morphology of ITO thin films was detected by scanning electron microscope(FEI INSPECT F SEM).

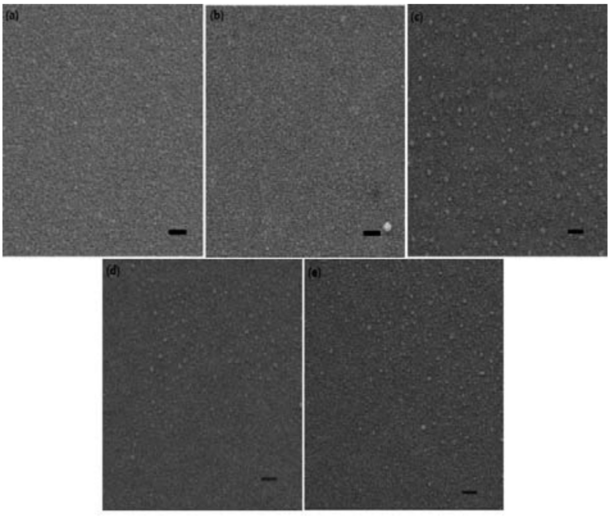

Fig. 1 SEM images of ITO thin films on glass substrate treated by hydrogen ions at 60 mA ion current beam,120 ℃ substrate temperature,300 eV ion energy and different treating time,all scale bars = 200 nm,(a)5 min,(b)10 min,(c)15 min,(d)20 min,and (e)25 min.

3 Results and Discussion

Fig. 1 shows SEM images of ITO thin films on glass substrates treated by hydrogen ions,the ion beam current is set at 60 mA,the density of ion beam is around 0.531 mA/cm^2 ,the ion energy is 300 eV, and the processing time changes from 5 min to 25 min.With the growing of time,uniform distribution of NPs are emerged when processing time is beyond 15 min.Besides,the diameter of NPs is becoming smaller with the increase of treating time,the average diameter in Fig. 1(c),(d),(e) is respectively ~50 nm,~35 nm and ~25 nm.This phenomena is mainly due to the consisting hydrogen ions,especially H^+ reduction[12,13] of ITO thin films.When the treating time is below 15 min, the reduction reaction is not dominated, physical reaction,mainly is ion bombarding sputtering, plays an important role in the formation of surface nanostructure.Nevertheless,the mass of hydrogen ions is relatively smaller than oxygen atoms, and the momentum of hydrogen ions is so tiny that it could not bombard oxygen atoms effectively and peeling oxygen atoms off ITO thin films, thus not leading to formation of obvious nanostructures on the ITO thin films.When processing time exceeds 15 min,however,the reduction reaction acts as a major role,and the reducing capacity of H^+ is stronger than atom hydrogen[14],the ions beam contains numerous H^+ ions.Therefore, it is easily to obtain on NPs on the surface of ITO layer,and the diameter of NPs becomes smaller with the extension of time.As the treating time reach to 25 min,the average diameter of ITO layer is the smallest one and the density of surface NPs is sparsest in all pictures of Fig. 1.

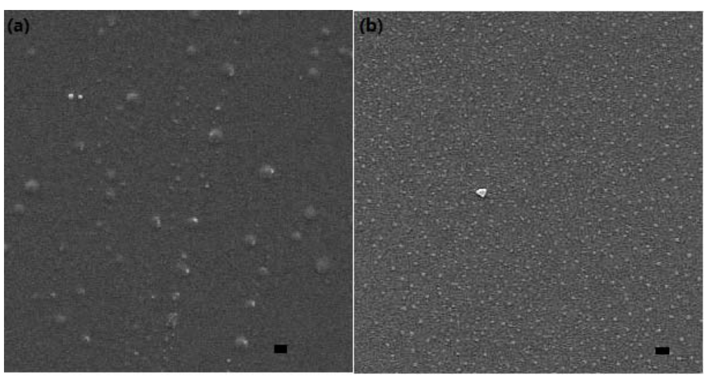

Fig. 2 SEM images of ITO thin films on glass substrates treated by hydrogen ion at 150 ℃ substrate temperature,300 eV ion energy and different ion current beam,all scale bars=200 nm,(a)80 mA,15 min and (b)100 mA,15 min.

Fig. 2 displays SEM images of ITO thin films treated by hydrogen ion at 300 eV of ion energy,150 ℃ of substrate temperature,15 min of handling time and different ion beam current,the ion beam current in Fig. 2(a) is 80 mA and in Fig2(b) is 100 mA,respectively,the density of ion beam current in Fig. 2(a) is 0.707 mA/cm^2 and in Fig2(b) is 0.884 mA/cm^2 .the obtainment of surface nanostructures in Fig. 2(b) is more uniform size and intensive surface density than in Fig. 2(a).It indicates that the size of surface nanostructure depends on the density of ion beam current.The ion beam current somewhat represents the concentration of hydrogen ions.Accompanied with high hydrogen ions concentration,the reduction effect of ITO thin films is good.It has been demonstrated in Fig. 2 that much denser and smaller NPs at 100 mA ion beam current in Fig. 2(b) than at 80 mA ion beam current in Fig. 2(a). Meanwhile,the reacting time selects to 15 min because of optimized reducing effect of ITO thin films and good distribution of NPs in Fig. 1.

4 Conclusion

In this study,the homogeneous NPs distribution on the surface of ITO thin films were obtained successfully via utilizing low energy IS.The suitable treating time of hydrogen ions is 15 min as well as ion beam current at 60 mA.When treating time is less than 15 min,any evident nanostructures could not observed on the surface of ITO thin films.On the contrary,sparse and symmetrical NPs distribution is on ITO layer.The best treating time at 60 mA is distinct at 15 min.With the growing of ion beam current and substrate temperature, the more uniform distribution and smaller size of NPs acquired at 100mA ion beam current,thus the best experiment parameter of getting well-organized dots nanostructures is setting the ion beam current at 100 mA and the substrate temperature at 150 ℃ in our study.However,altering other parameters,such as ion energy and substrate temperature remains to be studied further.

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