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Effect of sputtering power on the properties of dc magnetron sputtered Au-SnO_2 films

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Abstract: In this work, Au-SnO_2 films were deposited on glass substrates by dc reactive magnetron sputtering under various sputtering powers. The structural, surface morphology, electrical and optical properties of as deposited films were investigated. Au-SnO_2 thin films were deposited on unheated glass substrates by dc reactive magnetron sputtering at various sputtering powers from the 100 to 400 W in the presence of Ar gas and O_2 gas atmosphere. From the XRD results, the as deposited films grew preferentially to the (101) orientation of SnO_2 with tetragonal structure. The increasing of the grain size was observed with sputtering power, it indicating that increasing sputtering power could promote crystallite growth. The RMS roughness varied from 1.1 to 2.3 nm as the sputtering power was increased from 100 to 400W. The optical transmittance of the films decreased from 82 % to 71 % (λ=640 nm) with increasing of the sputtering power from 100 to 400 W. The electrical properties of the Au-SnO_2 films were strongly influenced by sputtering power. The electrical resistivity of the films was sharply decreased at higher sputtering powers.
Keywords: tin oxide, sputtering, sputtering power, optical properties, electrical properties.

Introduction and Experimental

In recent decade's tin oxide (SnO_2) attractive in a wide range of applications, e.g., sensors, laser diode, thin films resistors, antireflection coatings in solar cells, because of its low cost, due to their unique properties of high optical transparency in the visible region with low electrical resistivity (1-4). SnO_2 is often modified with silver (Ag), gold (Au), copper (Cu), and platinum (Pt), to enhance the gas sensing properties. The doping of Au might be a potential method to decrease the operating temperature of the gas sensor. There are several physical and chemical thin films deposition methods for the production of SnO_2 thin films. DC reactive magnetron sputtering is one of the most useful technique having high deposition rates, uniformity over large areas of the substrates and easy control over the composition of the deposited films. In this work, Au-SnO_2 films were deposited on glass substrates by dc reactive magnetron sputtering under various sputtering powers. The structural, surface morphology, electrical and optical properties of as deposited films were investigated.

Au-SnO_2 thin films were grown on Corning 7059 glass substrates using dc reactive magnetron sputtering. The sputtering system is capable of creating an ultimate vacuum of $5x10^{-4}$ Pa. A continuously variable dc power supply of 1000 V and 1 A was used as a power source for sputtering. A 100 mm diameter and 3 mm thick pure Sn (99.99% purity) with some high purity Au-strips attached was used as sputter target. Pure argon was used as sputter gas and oxygen as reactive gas. Au-SnO_2 thin films were deposited at various sputtering powers from 100 W to 400 W by keeping the other deposition conditions such as substrate temperature, oxygen partial pressure and sputtering pressure as constant. The crystallographic structure of the films was analyzed by X-ray diffractometer. The surface morphology and surface roughness was studied by atomic force microscopy (AFM). The optical properties of the films were determined by UV-Vis-NIR double beam spectrophotometer. The electrical resistivity of the films was studied by four-point probe method.

Results and Discussion

Figure 1 shows the XRD patterns of as deposited Au-SnO_2 films at different sputtering powers. It can be clearly observed that they all grew preferentially to the (101) orientation of SnO_2 with tetragonal structure (JCPDS Card No. 88-0287). No diffraction peak from Au phase was found suggesting that the Au is present either in the form of very small clusters (with sizes bellow the limit of detection of the apparatus i.e. <1-2 nm) – probably positioned in the grain boundaries of the SnO_2 nanocrystals or distributed atomically within the SnO_2 lattice, e.g. by occupying the central positions of the tetrahedral arrangement or by substituting some Sn atoms in their lattice position. Cabot et al. (5) studied by XPS the impregnation of SnO_2 crystals with Au, Pd and Pt and found that the formation of metallic clusters only occurred for samples annealed above 600ºC. At low sputtering power of 100 W the films exhibited amorphous nature. When the films deposited on unheated substrate at low sputtering power, the sputter ejected species has low kinetic energy and it is not sufficient for the arrangement and crystallization of the films resulting amorphous nature. The broad peaks were appeared at the sputtering power of 200 W, and the broadness of the films decreases and the intensity of (101) peak of SnO_2 films gradually increases with increase of sputtering power upto 400W.

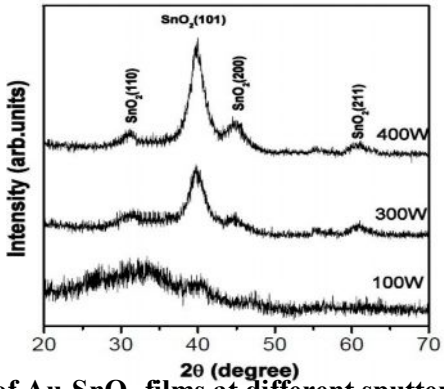
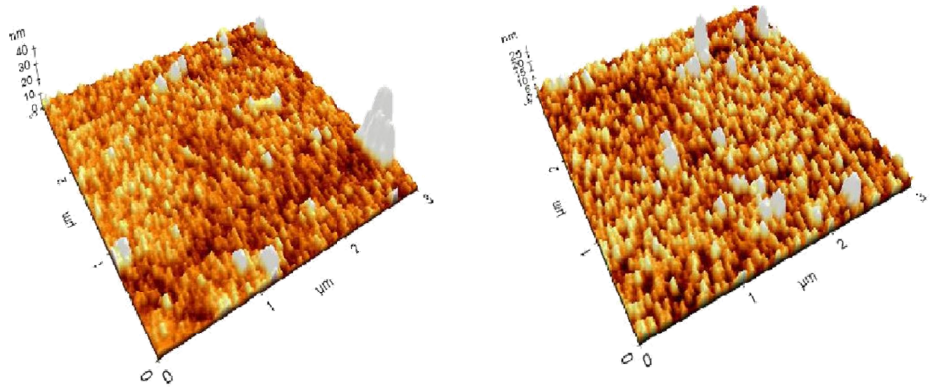


Fig.1. XRD pattern of Au-SnO_2 films at different sputtering powers

The average crystallite size of Au-SnO_2 films at different sputtering power was estimated from the XRD spectrum by using Scherrer formula (6). The obtained values are 3.1, 4.3 and 6.7 nm for the films deposited at 200, 300 and 400 W respectively. The increasing of the grain size indicating that increasing sputtering power could promote crystallite growth.

Atomic force microscopy is used to examine the influence of the sputtering power on the surface morphology and the surface roughness of as deposited Au-SnO_2 films. The three dimensional AFM images indicate that the surface grain size tends to be bigger when sputtering power increases (Fig.2). A larger grain size may induce to a higher surface roughness. The roughness is assumed to influence the optical properties and the resistance of the films. The AFM investigations reveal that the surface roughness of the films increases with increasing of sputtering power. The RMS roughness varied from 1.1 to 2.3 nm as the sputtering power was increased from 100 to 400W.



(a) **(b)**

Fig.2. AFM images of Au-SnO_2 films at various sputtering powers: (a) 200 W and (b) 400 W

The electrical resistivity of the films decreased from $1.3x10^{1}$ to $1.87x10^{-3}\Omega cm$ gradually with the increasing of sputtering power from 100 W to 400W, which may be attributed to the increasing of substitutional doping, decreased interstitial atoms, and improved the crystallinity.

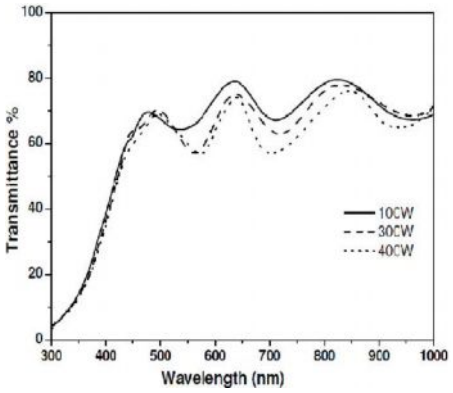


Fig.3. Optical transmittance spectra Au-SnO_2 films at various sputtering powers

The optical transmittance spectra of Au-SnO_2 films as function of sputtering power are shown in Fig.3. The optical transmittance of the films decreased from 82 % to 71 % (λ=640 nm) with increasing of the sputtering power from 100 to 400 W. The absorption edge of the Au-SnO_2 films is shifted to longer wavelength as the sputtering power increases, it ascribed to decrease in optical band gap. At low sputtering powers the films surface was smooth and the light scattering is less hence the films exhibited high transmittance.

In conclusion, Au-SnO_2 nanocrystalline thin films were prepared on glass substrates by dc magnetron sputtering at different sputtering powers. The properties of the films significantly depend on the sputtering power. XRD results revealed that the very low sputtering powers inhibit the crystal growth of the films. The average crystalline size of the films was about 6.7 nm and has a surface roughness of 2.3 nm at the sputtering power of 400 W. The electrical resistivity of the films decreased with increasing the sputtering power. The highest transmittance was obtained about 82 % at sputtering power of 100 W.

References

1. Caina Luan, Jin Ma, Zhen Zhu, Lingyi Kong and Qiaoqun Yu, Preparation and characterization of single crystalline SnO2 films deposited on TiO2 (0 01) by MOCVD, Journal of Crystal Growth, 2011, 318, 599–601.
2. Sivasankar Reddy A., Figueiredo. N.M. and Cavaleiro A., NanocrystallineAu:Ag:SnO_2 films prepared by pulsed magnetron sputtering, Journal of Physics and Chemistry of Solids, 2013, 74, 825–829.
3. Karslıoglu R., Uysal M. and Akbulut H., The effect of substrate temperature on the electrical and optic properties of nanocrystalline tin oxide coatings produced by APCVD, Journal of Crystal

Growth, 2011, 327, 22–26.
4. Korotcenkov G., Cho B.K., Nazarov M., Do Young Noh and Kolesnikova E.V., Cathodo luminescence studies of un-doped and (Cu, Fe, and Co)-doped tin dioxide films deposited by spray pyrolysis, Current Applied Physics, 2010, 10, 1123–1131.
5. Cabot A., Arbiol J., Morante J.R., Weimar U., Barsan N. and Gopel W., Analysis of the noble metal catalytic additives introduced by vimpregnation of as obtained SnO_2 sol–gel nanocrystals for gas sensors, Sensors and Actuators B, 2000, 70, 87–100.
6. Cullity B.D., Elements of X-ray Diffraction, 2nd ed., Addison Wesely, London,1978.

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