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Piezoresistive Response of ITO films deposited at room Temperature by Magnetron Sputtering

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Abstract – Indium tin oxide (ITO) is a degenerate semiconductor with wide band-gap and high conductivity. It exhibits piezoresistivity, which is comparable to n-type single crystal silicon, making it a promising material for strain sensors [1]. In this work, the piezoresistive effect in ITO thin films sputtered on silicon substrates is analyzed by cantilever deflection technique. The samples were cut and glued with epoxy on a stainless steel cantilever. Resistors were fabricated as a resistive-type ITO thin film in the average area of 0.54 mm^2. The figure of merit, defined as the fractional change of the film resistance to the strain has been developed.

ITO films were prepared by RF magnetron sputtering in a high vacuum chamber equipped with a turbo molecular pump and a mechanical vane pump. The residual pressure was down to 5×10^{-6} Torr. A compact ITO target (90% In_2O_3 – 10% SnO_2 in weight) with 6 inch diameter was used. The silicon substrates were placed with a target-to-substrate distance of 10 cm. The pure argon (99.9995%) total flow was kept constant at 24 sccm with a fixed 75 W RF power. The samples were cut and glued with epoxy on a stainless steel cantilever and piezoresistive effect in indium-tin oxide films is analyzed by cantilever deflection technique. The (Fig. 1) shows the values of resistance of an ITO film according to the applied force. The graphic contains points measured during increasing strain and indicates a linear piezoresistive response that was typical of the films measured in this work.

The longitudinal piezoresistive coefficient (π_l) of the samples was then measured and the results are shown in (Fig. 2). We observed that the lower value of the piezoresistive coefficient is -2.44479×10^{-10} Pa^{-1} and the highest is -8.67599×10^{-10} Pa$^{-1,}$ equivalent to a gauge factor of -12 and –23, respectively. We have made a reasonable guess of Poisson coefficient to be 0.25 and value average of the Young modulus was determinate to be 49 GPa. This result is consistent with the data reported by literature [2]. The ITO sensors exhibit relatively large gage factors - GF but as it is typical to semiconductors, they also exhibit a relatively large temperature coefficient of resistance - TCR.

In terms of piezoresistive response, the gauge factor of a conventional metal gauge depends on dimensional changes in the material, but semiconductor gauge, such as ITO, depend largely on the changes in the band structure of the semiconductor as it is deformed. Thus, the large piezoresistive effects observed in semiconductors have been attributed to changes in mobility and carrier concentration in the semiconductor when it is deformed [3].

It was reported in the literature that the gauge factor was the result of the complex competition between the Poisson ratio, wave-function overlap, and activation energy. We have evaluated this energy to the films analyzed and results are shown in (Fig. 3). This curve has a non-linear slope and follows an exponential behavior.

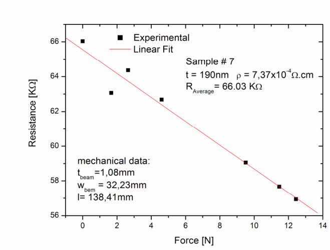

Figure 1: Electrical resistance in function of the mechanical applied force.

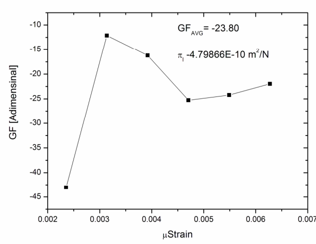

Figure 2: Mechanical sensitivity according to the deformation of the films.

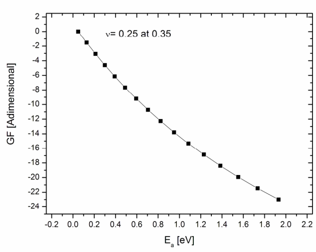

Figure 3: Gauge factor in function activation energy.

We conclude that our ITO layers exhibit decreasing resistance for tensile stress. It was observed that piezoresistive coefficient (absolute value) and resistivity of ITO film increase according to the increase of the oxygen concentration. Piezoresistive gauge factor was determinated at tensile strain using cantilever beam method. We found the GF to be between -12 and -23.

References

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