

# CHARACTERIZATION OF PHOTSENSITIVITY OF ELECTRICAL RESISTANCE OF NANOSTRUCTURE POROUS TIN OXIDE FILMS DEPOSITED FROM SPRAY METHOD

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## INTRODUCTION

Tin dioxide ( $SnO_2$ ) films possess interesting structural and electronic properties that suggest a number of new and useful applications, such as electronic gas sensors [1], [2], flat display devices [3], [4], transparent electrodes [5] and photovoltaic cells [6], [7].

Thin-films of  $SnO_2$  may be produced with unique properties, such as low electrical resistivity, high optical transparency, high or low porosity and high chemical stability. However, the photosensitivity properties of  $SnO_2$  have not been investigated in detail. In this work, we show the dependency of the electrical resistance of  $SnO_2$  films on the light intensity.

This work describes the intensity light-dependency of the photosensitivity of electrical resistance of nanostructure porous tin oxide films deposited from spray method on *Si* substrates. The experimental results show a strong influence of the deposition temperature and characterization temperature of the photosensitivity properties. The morphological and chemical structure of the samples, revealed by atomic force microscopy (AFM) and Raman spectroscopy are discussed.

## EXPERIMENTAL PROCEDURES

The samples were deposited on the surface of a substrate using a spray pyrolysis system described by [8]. The experimental set-up consists of a reservoir of liquid *Sn* solution that feeds by gravity a jet gas nozzle. The nozzle is induced by the flow of hydrogen through a small orifice to the atmosphere. Control valves are placed to independently adjust the hydrogen and the *Sn* solution flow rates. The substrates were mounted horizontally over a steel hot-plate placed below the jet nozzle in order to receive an uniform spray coating. A 0.2 M solution of pentahydrated stannic chloride ( $SnCl_4 \cdot 5H_2O$ ) in ethanol ( $C_2H_5OH$ ) was used in the feed reservoir. Hydrogen flow was kept at  $7 \text{ l min}^{-1}$  at 1520 Torr pressure and the solution spray rate was around  $1 \text{ ml min}^{-1}$ . Deposition temperature, measured by a chromel-alumel thermocouple, were controlled via the power supplied to the hot-plate, and were set in  $350 \text{ }^\circ\text{C}$ . After establishing the stability of the deposition parameters described, the substrates were introduced in the reactor for 60 s. N-type *Si* substrates were used. Prior to the deposition, they were ultrasonically degreased in acetone, ethyl alcohol, rinsed in distilled water and dried in hot nitrogen. Surface morphology of the grown layers was examined by AFM using a ThermoMicroscopes AutoProbe CP. Micro-Raman

spectroscopy were carried out at ambient temperature using a RENISHAW - inVia Raman Microscope, employing the output of an Ar+ laser (5mW power) for excitation at  $\lambda = 514.5 \text{ nm}$ .

## RESULTS AND DISCUSSION

Figure 1 shows the dependency of electrical resistance on light intensity for a  $SnO_2$  film. It can be noted that for the range within 0 and 200 lux the film presents a higher sensitivity. In addition, it has been verified that the electrical resistance is also dependent on the temperature. We suggest that this effect is related to the temperature needed for efficient thermal decomposition of the hydroxides to form n-type  $SnO_2$  nanocrystals.

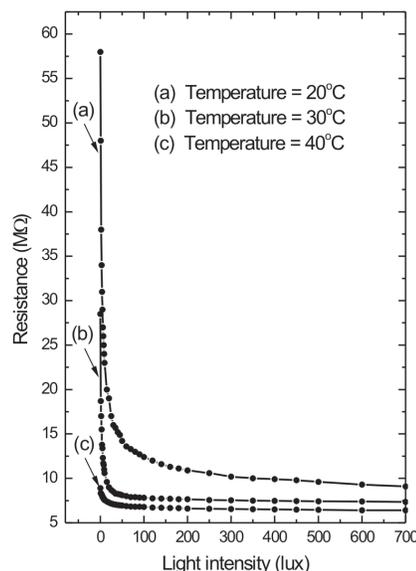


Figure 1. Electrical resistance behavior with light intensity and temperature.

Figure 2 shows the three-dimensional morphology of the sample deposited at  $350 \text{ }^\circ\text{C}$ , which represents the typical morphologies of the samples revealed by AFM. The particle size at  $350 \text{ }^\circ\text{C}$  is around  $50 \text{ nm}$ . All the samples exhibit a granular morphology with uniform particle sizes and good surface coverage. A higher deposition temperature contributes to the increase in film roughness and also increased the lateral particle size. The heights of the particles are nearly equal to their diameters [9].

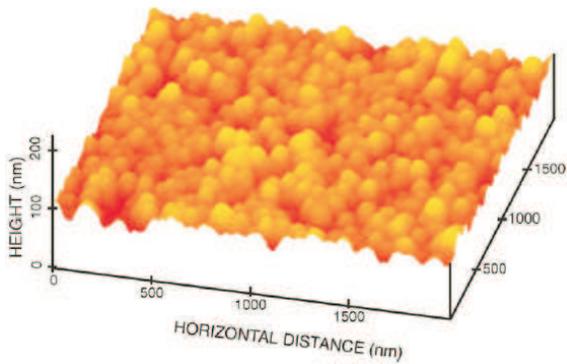


Figure 2. AFM image of the sample deposited at  $350^{\circ}\text{C}$ .

Figure 3 shows the typical room temperature Raman spectrum of the *Si* substrate (curve a) and three similar  $\text{SnO}_2$  samples (curves b, c and d). This result complies to the one obtained by [10], which identified that the Raman spectrum peaks of nanometer  $\text{SnO}_2$  can be divided into two groups. In the first group, Raman peaks are the same as that from single-crystal or polycrystalline  $\text{SnO}_2$ . The three Raman peaks are located at  $472$ ,  $632$ , and  $773\text{ cm}^{-1}$ . In the second group, the peaks are located at  $358$  and  $572\text{ cm}^{-1}$ . These two peaks are not observed in Raman spectra of single-crystal and polycrystalline  $\text{SnO}$ , and they are only observed in nanometer  $\text{SnO}_2$  with small grain size. Others Raman peaks shown in Figure 3 are probably explained by the interaction tin/silicon or tin/silicon oxide. Therefore, these Raman peaks are not associated to neither tin oxides subproduct.

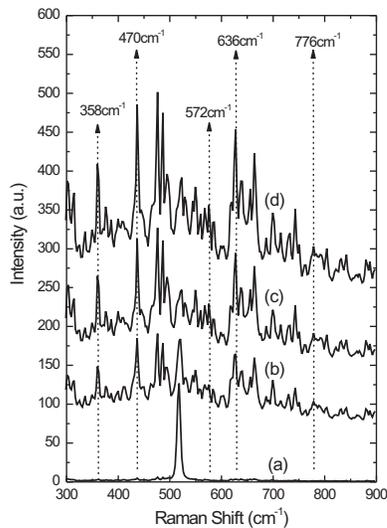


Figure 3. Typical room temperature Raman spectra of *Si* substrate (curve (a)) and  $\text{SnO}_2$  samples (curves (b), (c) and (d)).

## CONCLUSION

In this paper, it was presented a study of the photosensitivity of the electrical resistance of nanostructure porous tin oxide films deposited from spray method on *Si* substrates. In addition, it was verified that the electrical resistance is also dependent on temperature. Finally, the effectiveness of the film deposition process was shown by means of a Raman spectrum analysis. The results encourages more investigation in order to make feasible applications such as frequencimeters, encoders, counters, etc.

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