OPTOELECTRONIC PROPERTIES OF CERAMIC SEMICONDUCTOR FILMS

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ABSTRACT

The optoelectronic properties of screen-printed Cadmium Sulfide (CdS) films have been studied by the Van der Pauw method. The dependence of the electronic properties with the preparation condition, as sintering temperature and atmosphere have been investigated. The optimum conditions for improving the electronic properties of the ceramic CdS have been identified.

1. INTRODUCTION

The term ceramic material refers to inorganic non-metallic materials whose formation is due to the agglomeration of powders by action of heat. There are a number of ceramics that are semiconductors. Most of these are transition metal oxides, but also other materials as the II-VI semiconductors, such as Cadmium Sulfide, can be prepared in ceramic form. In recent years the II-VI materials cause interest for technological use due to their very interesting opto-electronic properties. [2,3]

The ceramic thick-film can be defined as a sequential screen-printing and firing at elevated temperature of a conductor, resistor, dielectric, or semiconductor, onto a suitable substrate. These films are broadly used in different processes, due their low cost of production, and application on a large scale.

This paper is related exclusively to the electrical properties of Cadmium Sulfide. CdS is of interest, mainly for applications in photoelectric devices, photosensors, solar cells, heterojunction diodes, electroluminescent layers and surface acoustic wave devices [6,7].

The temperature of sintering influences directly in the conductivity of the material. By the increase the sintering temperature, we identify a considerable increase in the conductivity of the samples under previously illumination conditions defined. The change in the conductivity with the sintering conditions are correlated with structural studies by X-ray diffraction [1], and indicates the effect of grain size as well of the sintering atmosphere in the electronic properties of these films.

2. EXPERIMENTAL DETAILS

The production of the film starts with the preparation of a paste constituted by CdS powder, 20% of $CdCl_2$ and glycerin. This paste is applied by silk-screen on ceramic substrates. The thick film is fired during 4 minutes in temperatures ranging from 500°C to 700°C under air or dry nitrogen.

The electrical measurements were performed in the Van der Pauw configuration [4,5], under an illumination of 100 lux. The contacting to the samples was done by silver painting. The samples were approximately 6x6 mm dices cut from the original ceramic disc.

The measurements were performed with a Keithley 220 Programmable Current Source and a 617 Programmable Electrometer.

The mean value of the thickness of the CdS film was obtained directly by Scanning Electron Microscope (SEM) of transversal section of these samples, as shown in Fig.1. We considered a thickness of (6.6 ± 0.7) µm.

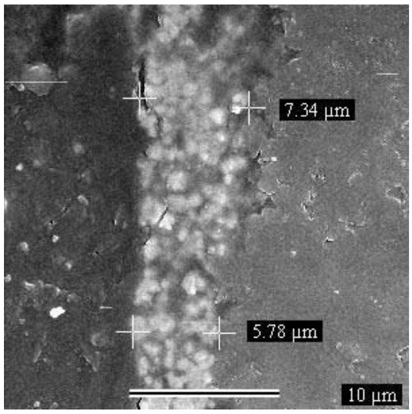

Figure 1: SEM image of transversal section of our CdS film.

3. RESULTS AND DISCUSSION

In Figure 2 we show the resistivity as a function of the sintering temperature. The results for both films sinterized in air (SGA) and nitrogen (GNA) are depicted. The CdS film resistivity for the SGA condition decays initially reaching a minimum in the range 550-580°C, and increases after, probably due to oxidation of the CdS film with increasing sintering temperature. The resistivity for GNA conditions presents also a decrease after 550°C, reading a minimum around 600°C. There is also a small increase for higher sintering temperature but lower than the obtained for the previous case.

The strong changes in the resistivity observed around 525°C for the SGA case are probably related to the action of the $CdCl_2$ flux, what promotes the adhesion of the CdS grains [3]. The $CdCl_2$ sublimates at 525°C, and the strong change in the film resistivity at 525°C is probably caused by it.

The GNA case also presents the strong change in resistivity, but shifted in temperature by around 30°C. This shift can be related to the effect of the gas flow in the temperature of the sample, since the temperature control thermocouple was not in contact with the sample but its vicinity. In order to show it, we plot the GNA curve shifted of 30°C (GNA shifted).

The lowest resistivity for GNA is 6.3x10² Ω.cm and the lowest of SGA is 13.0x10² Ω.cm.

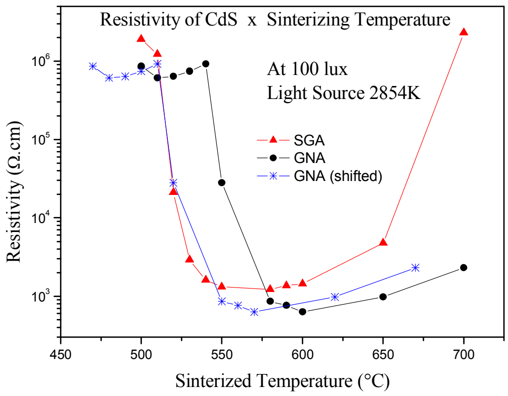

Figure 2: The electrical resistivity of ceramic CdS as a function of the sintering temperature, for an illumination of 100lux.

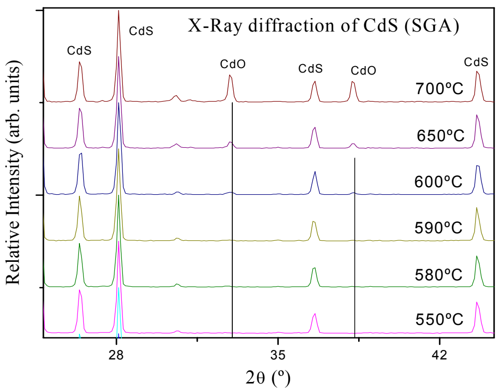

Figure 3: Presence of peaks of CdO in the diffractograms of the samples of CdS sinterized without the flow of nitrogen gas for temperatures above 600°C.

In Figure 3 and 4 we show the diffractograms of the CdS films for increasing sintering temperatures. The peaks associated to cadmium oxide are visible above 600°C for the sinterization in air. But no oxide peak can be seen in the diffractograms of the in nitrogen sinterized samples. Further x-ray analyses of these films indicate the presence of stress [1]. The increase of the resistivity with sintering temperature cannot be directly associated to the oxidation of the grain boundary, but rather to the residual strain in the films. Further studies to corroborate it are in course.

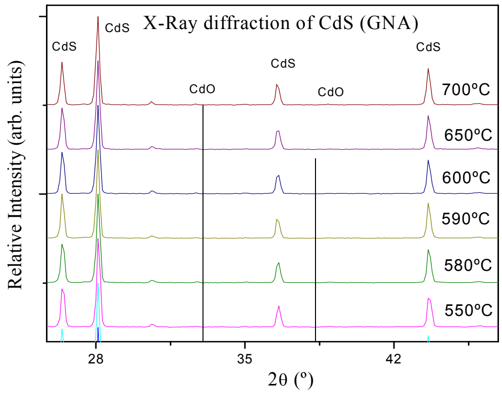

Figure 4: Absence of peaks of CdO in the diffractograms of the samples of CdS sinterized with gas flow nitrogen.

4. CONCLUSION

The sintering conditions for preparation of CdS ceramic semiconductors were studied by resistivity measurements and x-ray diffraction. The conductivity of our samples varied strongly with the sintering temperature around the wetting point of the $CdCl_2$ flux to the CdS. The uses of a protective atmosphere does not change significantly the resistivity, despite the clear suppression of oxidation. The role of the strain in the films is now under investigation.

5. REFERENCES

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