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Pyroelectric and Photosegnetoelectric Phenomena in Segnetoelectric Semiconductor SbSI Thin Films

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Abstract

In this work, pyroelectric properties of SbSI thin films have been investigated. Under a constant current, thin films were obtained by the magnetron powdering method and the thin film thickness was about 4.5 μm. These films had policrystal structures and their structure decay temperatures were observed to be dependent on their dimensions. These measurements were carried out in both the planar and the sandwich configurations, which are perpendicular and parallel to the c-axis, respectively.

Keywords : Thin film, pyroelectric, segnetoelectric

Ferro-Elektrik Yarı İletken SbSI İnce Filmlerinde Piro-Elektrik ve Foto-Ferroelektrik Olgusu

Özet

Bu çalışmada, SbSI ince filmlerinde piro-elekltrik özellikleri incelendi. Sabit bir akım altında, ince filmler magnetron tozlama metodu ile elde edildi ve ince film kalınlığı 4.5 μm civarında oldu. Filmler poli kristal (çoklu kristal) yapıda idiler ve bunların yapı bozunma sıcaklıkları boyutlarına bağlı olarak gözlendi. Bu ölçümler, sırayla c-eksenine dik ve paralel olan düzlemsel ve sandiviç yapılanmalarda gerçekleştirildi.

Anahtar Kelimeler: İnce film, Piro-elektrik, Ferro-elektrik

Introduction

Since A^{V}, B^{VI} and C^{VII} composites are semiconductors and they also have segnetoelectric properties, the interest in them is increasing gradually. The existence of the first and the second phase transformations in SbSI was proved years ago [Hamano, et al., 1965; Bets and Polik, 1977] and it was determined that both of the transformations had segnetoelectric properties. According to Iwasaki [1969], SbSI has the first and the second phase transformations at 295 K and at 233 K, respectively [Bets and Polik, 1977]. Compared to some other known segnetoelectric materials, SbSI is superior in view of some parameters. Especially among the segnetoelectric items SbSI has the largest piezomodul and it is a very sensitive crystal against external pressure. It was reported that it has high photoelectric sensitivity and nonlinear polarizebility [Gavryushin et al.,1993]. In principle those properties are important for making some physical measurement equipment like piezoelements, optical modulators, counters etc. Beside the practical use, SbSI is quite important for fundamental research. In a resent research an interest to the SbSI compounds is stimulated by their semiconductor and ferroelectric properties [Kallaev et al., 2004]. Some papers concerning the SbSI are related to the thermal annealing effect on the structural properties of glassy alloy [Rubish, 2001] and the characterization of nanocrystalline material produced by ball milling [Voynarovich et al.,] Although its optical, photoelectrical and insulating properties have been adequately investigated, few investigations have been performed on its pyroelectrical properties.

Experimental Results

A resistor made of the ethanol which has a resistance 1-2 times lesser than that of the sample was connected parallel to the sample to avoid the charge leakage onto it. In the measurement studies, a constant current supply (U 5-6) and a printer (XV Recorder Endim 620.02) were used and during the measurement electrometer input resistance was observed as 10 Ω. Over the Curie temperatures a high coherent and constant electric field was applied to the sample. At the moment, in the existence of the external electric field, the sample was cooled to the liquid nitrogen. After the cooling process the external field was turned off and then the sample was warmed up in the rate of 0.2 K/sec. At the moment of warming instant the pyrocurrent versus time (min.) plot was obtained.

In the final course of the pyroelectric research conducted on the film samples, pyrocurrents were observed only in the direction of the c-axis only. From the emergence of the pyrocurrent, dependency on the temperature, it can be understood that SbSI thin film pyrocurrents have two maximums at T_1 = 225 K and T_2 = 325 K (Fig. 1. a). According to this figure the full weights at half maximums are ΔT_1 = 15 K and ΔT_2 = 25 K respectively.

It was determined that when the external field changed its polarity, the pyrocurrent obeyed that changing and they changed their directions too, but there was no changing with their temperature dependency states. The presence of the spontaneous polarization was attributed to being of the phase transformation of the segnetoelectric in the investigated sample.

The current at the c-axis direction shows that the [001] is the polarization, Ps(T), axis for the SbSI and the investigated sample is a semiconductor in one direction which means that it is a segnetoelectric. It must be noted that in the planar configurations the pyrocurrents did not occur.

The measurement of the pyrocurrents makes it possible to investigate the spontaneous polarization's temperature dependency (Fig. 2). According to this investigation Ps(T) has constant value at the interval of 200-220 K temperatures. In this interval the magnitudes of the Ps(T) are 13 and 10 C/cm^2 between 200 and 275 K respectively. After 275 K degrees the Ps(T) decays gradually and at T > 300 K degrees disappears.

To compare these results, the piezoelectric measurements were also performed on the same sample, SbSI. The results of the experimental investigations showed that the plots of the piozeelectric appeared almost similar to the Ps(T) on the temperature dependencies but in a value of the Ps(T) there is a current leakage only. Non-polarization in the plane perpendicular to the c-axis means that the [001] axis is a polar axis of the SbSI and is also its crystallographic axis.

Here the effect of the white light on the SbSI thin films' pyroelectric properties have also been investigated. As Fridkin [Fridkin et al., 1966] showed that the state of the electronic subsystem is very effective on phase transformation of semiconductors. The existent of the surface charges on the poles cause an increase in the polarization brought about by the transformation from the paraphase into the segnetoelectric phase. The measurement of the pyrocurrent were continuously made in the dark and beside this treatment the surface of the sample was illuminated for five minutes. Furthermore the rate of heating and the other experimental necessary conditions were always the same. It was noted that, when the surface of the sample was illuminated the pyrocurrent's maximum shifted to the lower temperature zone (Fig. 3.).

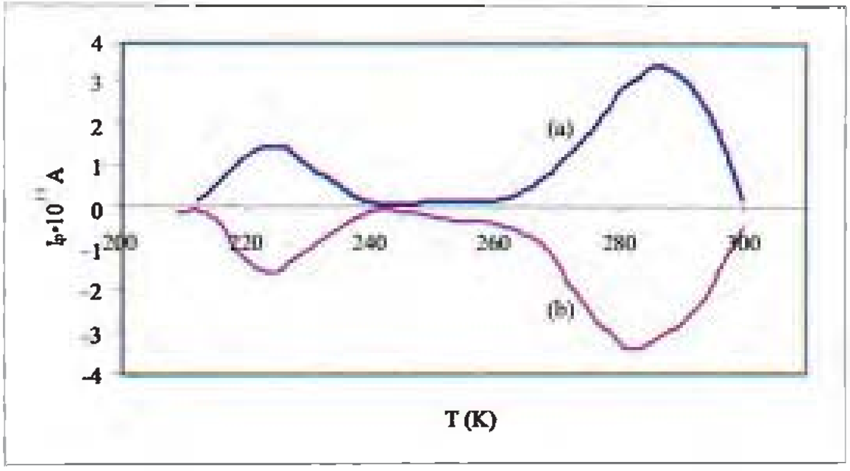

Figure 1 Temperature dependence of the pyrocurrents in the SbSI thin films (a) in the sandwich configuration, (b) in the changing of the polarity..

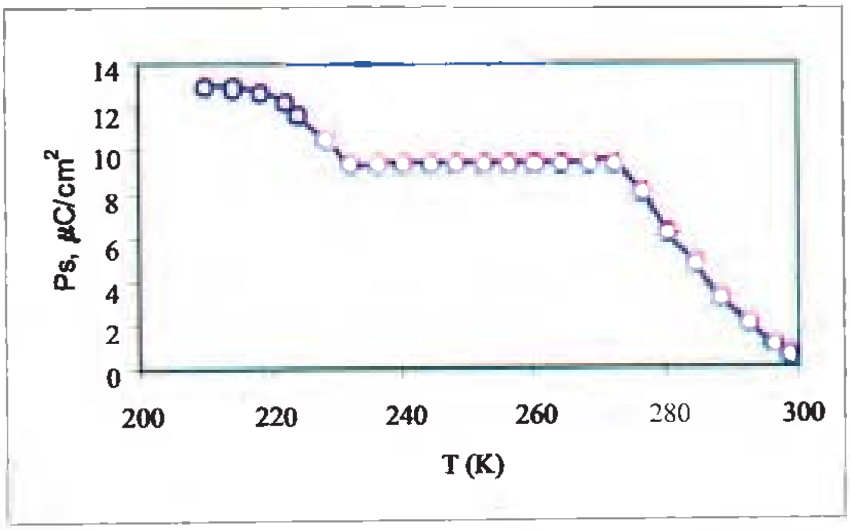

Figure2 Temperature **dependency of the SbSI thin film's spontaneous polarization in the sandwich** configuration.

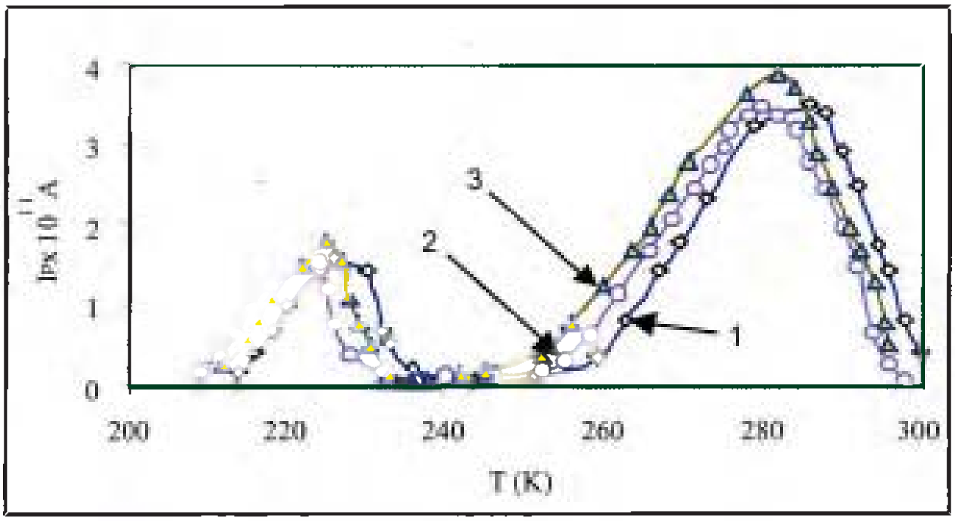

Figure 3. The effect of the white light on the pyrocurrent in the SbSI thin films; 1- without illumination, 2- when the surface of the sample illuminated 3- when the electron of the sample illuminated.

Conclusion

The shift in the pyrocurrent can be interpreted as thus: The charge occurred as a result of the illumination of the spontaneous polarization of the sample under liquid nitrogen temperature is associated with the screening of the carrier when the negative part of the sample is illuminated an increase in pyrocurrent maximum was observed. The maximum was observed to have shifted to low temperature zone. As for the elevation of pyrosignal, it is most probably associated with the emergence of negative layers resulted from electron accumulation on the surface zone of the sample.

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