AC Conductivity Studies on Eectron Irradiated ZnO: Li thin films

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***Abstract* - In this article, we report the AC conductivity studies on electron irradiated Li doped Zinc Oxide thin films. The thin films in the geometry Al/LZO/Pt-Si were irradiated with 8 MeV electrons at different fluence viz. 3x10^{12}, 3x10^{13} and 3x10^{14} electrons/cm^2. The conductivity of pristine and irradiated thin films was measured in the temperature range 300–350K. Conductivity increased with fluence. The order parameter 's' was found to decrease with fluence. The activation energy value calculated from Arrhenius plot increased with fluence. It increased from 0.15 to 0.55 eV for the highest fluence.**

Keywords:
Li doped ZnO thin films, electron irradiation and ac conductivity

I. INTRODUCTION

Zinc oxide is a wide band gap oxide semiconductor with hexagonal crystal structure (P6_3mc). It finds application in solar cells, gas sensors, LCDs, heat mirror and SAW devices because of its versatile properties [1]. The charge transport and dielectric relaxation phenomena are the vital characteristics for the thin film devices, in lieu of both practical and scientific reasons. It is known that material properties are essentially controlled by the inherent defects or charge carriers, which are created during the synthesis itself. Therefore, it is significant to investigate the charge carrier transport mechanism in these materials. The defects may also come from the electron irradiation when such devices are exposed to such radiations. The radiation induced charges will affect the charge distribution and thereby alter the local fields near the defects, the interface and the localized charges, which will be echoed as changes in device properties. It is of vital importance to understand the precise influence of irradiation induced charge carriers on the properties of the materials in the presence of the inherent charge carriers [2]. ZnO is considered to be the radiation hard material; there are several reports on irradiation induced changes in the properties of ZnO [3-5]. Zn_v, Zn_i, O_V and O_i types of defects may be formed. To the best of our knowledge, there are no reports on the AC conductivity studies on electron irradiated Lithium doped ZnO thin films. Hence, an attempt was made to study the conducting properties of LZO thin films.

II. SYNTHESIS AND e-IRRADIATION

The synthesis of the thin films was reported elsewhere [6]. The thin films were in M-I-M configuration (Al/Li: ZnO/Pt-Si). The deposited films were characterized for AC conductivity measurements using a KEITHLEY 3330 LCZ Meter. The well characterized films were exposed to 8 MeV electron irradiation in air at room temperature with fluence of 3x10^{12}, 3x10^{13} and 3x10^{14} electrons/cm^2 by using Microtron Accelerator. Post irradiation characterizations of the LZO thin films were carried out.

III. RESULTS AND DISCUSSION

A. AC Conductivity

Variation of AC conductivity with frequency of LZO thin films before and after irradiation is presented in fig.1. Before e-irradiation (Fig.1a), the AC conductivity had very weak frequency dependence at measured temperatures. However, it increased with temperature. After e-irradiation, it increased with an increase in fluence as shown in fig.2-I, at any given temperature. Material loses its dielectric/insulating behavior exhibiting enhanced conducting nature. The frequency dependence of AC conductivity is given by the power law,

$$\sigma_{ac} = A_n(T)[\sin(n-1)/2]\omega^s$$

where A_n is a constant. The frequency dependent s is a characteristic parameter that represents the many body interactions of the electrons, charges and impurities. It depends on the material temperature (T) and varies from 0 to 1. For ideal Debye type samples, it is equal to 1. fig.2-II shows the variation of s parameter for both the unirradiated and irradiated LZO thin films, which was obtained from the linear regions of the corresponding plots in fig.1. Before irradiation, the exponent s decreased with increase in temperature. We anticipate that the temperature increase could lead to the increase in the contribution from deep traps and when the temperature is high enough for the band-to-band transition to govern the conduction process, s approaches zero, as electronic conduction is frequency independent. This may be attributed to the greater interaction between the dipoles participating in the polarization process. After irradiation, the *s* parameter decreased with an increase in the delivered fluence; it could be due to the enhancement in the contribution from many body interactions, because of the creation of large number of radiation induced defects.

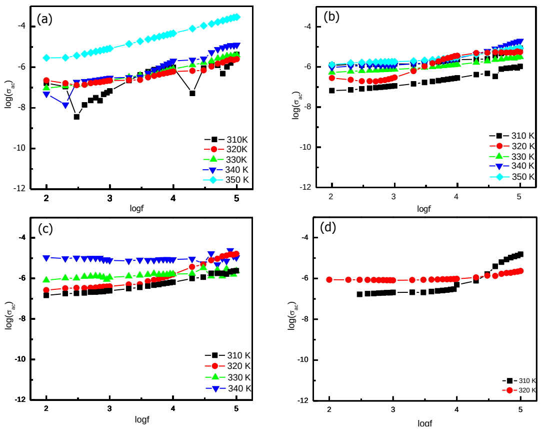

Fig. 1. Variation of AC conductivity with frequency at room temperature of $Zn_{0.93}Li_{0.07}O$ thin film before and after electron irradiation at 10 kHz (a)Unirradiated (b) 3 X 10^{12} (c) 3 X 10^{13} (d) 3 X 10^{14} electron/cm^2 fluence.

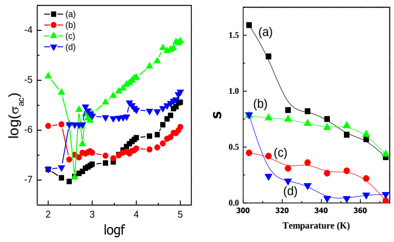

Fig. 2. I) Variation of AC conductivity with electron fluence. II) Variation of s parameter with temperature for $Zn_{0.93}Li_{0.07}O$ thin film before and after electron irradiation at 10 kHz (a) Unirradiated (b) 3 X 10^{12} (c) 3 X 10^{13} (d) 3 X 10^{14} electron/cm^2 fluence.

B. Arrhenius plot

In order to understand the obtained results in terms of the activation energies, the Arrhenius plot (lnσ_{ac} vs. 1000/T) at three selected frequencies of 1, 10 and 100 kHz are shown in fig. 3 for both unirradiated and irradiated LZO thin films. The activation energy for the LZO thin films increased after irradiation as follows: for unirradiated film it was 0.15eV, after irradiation with the fluence 3 x 10^{12} and 3 x 10^{13}electrons/cm^2 it got increased to 0.50 eV and for the fluence 3 x 10^{14} electrons/cm^2 it increased to 0.55eV, corresponding to the shallow traps. The increase in the activation energy after irradiation was due to the trapping of charge carriers by the radiation induced defects/shallow traps.

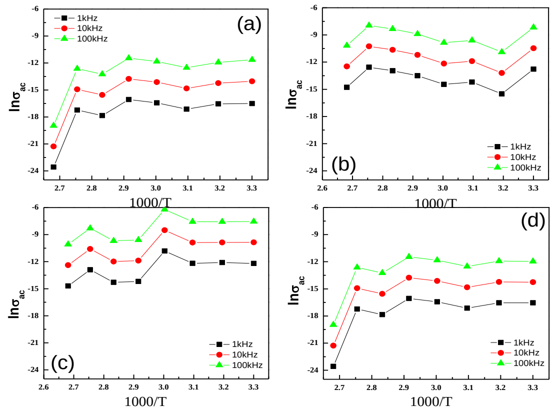

Fig. 3. Arrhenius plot, before and after electron irradiation at 10 kHz (a) Unirradiated (b) 3 X 10^{12} (c) 3 X 10^{13} (d) 3 X 10^{14} electron/cm^2 fluence.

IV. CONCLUSIONS

The AC conductivity of the thin films increased with an increase in the fluence and it was ascribed to the presence of radiation induced trapped charges in the LZO thin film. The order parameter 's' decreased after irradiation. The activation energy values indicated the creation of shallow type defect levels after e-irradiation.

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