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Short Comminication

ELECTRICAL PROPERTIES OF $Cu_xZn_{1-x}S$ NANOCOMPOSITE THIN FILM

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ABSTRACT

Thin dielectric films are widely studied because of their applications in the field of micro- electronics. The basic and applied solid state research have resulted in the production of dielectric thin film components which are extensively used as computer memory, inductance coupling elements, in parametric circuits, wave isolators, in solar cells etc. The dielectric constant ε_r and loss factor tan δ are not absolute constants for an actual dielectric. Both these constants depends on many factors namely the temperature, the frequency, the magnitude of the alternating voltage, the humidity of air etc. The frequency dependence of tan δ in thin film is a very important factor. In these view, in the present study $Cu_xZn_{1-x}S$ Nanocomposite thin films were prepared for various values of x, viz. 0, 0.2, 0.4, 0.6, 0.8 and 1 by SILAR method. The Capacitance and loss factor of all the films were measured using the instrument LCRZ Digital meter of model TH2816A TONGHUI for various temperatures ranging from 40 -120°C in the steps of 10°C at different fixed frequencies viz. 1, 2, 5, and 10 kHz. Loss factor, Dielectric constant and A.C Conductivity were determined from the available methods. The variation of loss factor and dielectric constant with temperature and frequency were also studied. They show normal dependence with temperature and frequency. The search for new materials with low dielectric constant in the microelectronics industry has and will continue feverishly into the future as the demand of faster processing speeds increases. In the present study, the prepared films have low dielectric constant values so, it can be concluded that dielectric layers are used for the fabrication of both thin film capacitors and resistors.

Keywords: Thin film, Dielectric Constant, Dielectric loss, CuS, ZnS and Nanocomposite

1. INTRODUCTION

Thin film preparation is the fascinating field of research in the Nano world today. Thin film technology is widely used in solid state electronics, photo voltaic solar cell etc. Especially dielectric thin films are widely used because of their applications in the field of micro- electronics. The basic and applied solid state research have resulted in the production of dielectric thin film components which are extensively used as computer memory, inductance coupling elements in parametric circuits, wave isolators, in solar cells, radiation detectors, interference filters, reflection and antireflection coatings, hypersonic transducers etc. Only few works have been carried out on the dielectric behaviour of CuS and ZnS thin film. Suresh Sagadevan and Priya Murugasen [1] have studied the dielectric behavior of CuS thin film. They showed that the dielectric constant and dielectric loss decrease with an increase in frequency. Zainab et al [2] have studied the temperature and frequency dependence of the dielectric behaviour of ZnS thin film. They observed that the dielectric constant increases with increase in temperature and decreases with decrease in frequency.

In the present research work $Cu_xZn_{1-x}S$ nanocomposite thin films were prepared for various values of x viz. 0.2, 0.4, 0.6, 0.8 and 1 by SILAR method. The capacitance and loss factor were measured for various temperatures at different frequencies and dielectric constant, loss factor, A.C. Conductivity and activation energy were determined.

2. MATERIAL AND METHODS

$Cu_xZn_{1-x}S$ nanocomposites thin films were prepared by SILAR method as discussed. AR grade Copper Sulphate, Zinc Sulphate and thiourea were used for the preparation of the thin film.

Pre-cleaned ITO glass substrate of size (1cm×1cm) was used for the deposition of the film. For the preparation of the film, the cationic and anionic precursor solution was maintained at pH 12 by adding ammonium hydroxide solution and the anionic precursor was maintained at 70°C for all cases. 0.1 M mixed Cationic solution ($(CuSo4)_x$ + $(ZnSo4)_{1-x}$ for various values of x via 0.2, 0.4, 0.6, 0.8 and 1 were prepared and the pre-cleaned substrate was immersed in the cationic precursor solution for 20 sec. followed by immersion in the distilled water for the same time, for removing the excess ion and then the substrate was immersed in the anionic thiourea solution for the same 20 sec. and finally the substrate was immersed in the double distilled water for the same 20 sec. to remove excess of ions. The cycle of the process was repeated for 50 times, totally 6 films including pure CuS and ZnS were prepared. CuS and ZnS films were prepared for comparison purposes. The film dried and silver paste was coated on the film. The film was placed between two copper electrodes and a parallel plate capacitor was formed. The capacitance and loss factor were measured for various temperatures ranging from 40 to 120°C in steps of 10°C at different fixed frequencies viz. 1 kHz, 2 kHz, 5 kHz and 10 kHz using LCRZ Digital meter (TH2816A TONGHUI)

The air capacitance (C_0) has also been determined. Dielectric constant of the film was determined using the general relation

$$\varepsilon_r = C/C_0$$

A.C Conductivity was calculated using the relation [3-7]

$$\sigma_{ac} = \varepsilon_0 \varepsilon_r \, \omega \tan\delta$$

Activation energy was also calculated using Arrhenius equation

$$\sigma = \sigma_0 \exp\,[-E_{ac}/KT]$$

It is customary to plot ln σac versus 1000/T. The activation energy can be determined from the slope of the line of best fit.

3. RESULTS AND DISCUSSION

The temperature dependence of dielectric constant (ε_r) and loss factor (tan δ) for all the six films are shown in the fig. 1 and fig. 2. It has been observed that both dielectric constant and loss factor increase slightly at low temperature and become minimum at nearly 80°C, above 80°C *i.e.* at higher temperature these factors increase rapidly. At any particular temperature, the Gibb's free energy of nanocrystal is minimum when a certain fraction of ions leave the normal lattice. As the temperature rises, more and more defects are produced, which in turn, increases the conductivity. In the high temperature (intrinsic) region, the effect of impurity on electrical conduction will not change appreciably whereas in the low temperature (extrinsic) region, the presence of impurities in the crystal will increase its conductivity. The electrical conduction in dielectrics is mainly a defect controlled process in the low temperature region. The presence of impurities and vacancies mainly determine this region. The energy needed to form the defect is much larger than the energy needed for its drift. The conductivity of the crystal in the higher temperature region is determined by the intrinsic defects caused by the thermal fluctuations in the crystal [8]. The minimum value of dielectric constant at 80°C indicates that the crystal defects are low in the films at 80°C. It reveals that crystallinity increased at 80°C.

Table-1 Activation energy for all the thin films at different fixed frequencies

System	σ_{ac} (eV) 1kHz
CuS	0.02988
$Cu_{0.2}Zn_{0.8}S$	0.04409
$Cu_{0.4}Zn_{0.6}S$	0.02017
$Cu_{0.6}Zn_{0.4}S$	0.04463
$Cu_{0.8}Zn_{0.2}S$	0.03786
ZnS	0.04365

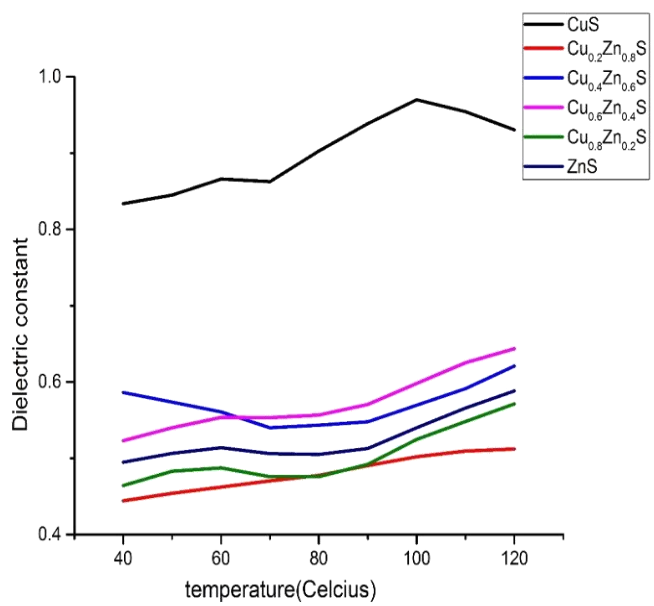

Fig. 1: Variation of Dielectric constant with temperatures at 1kHz for all the thin films

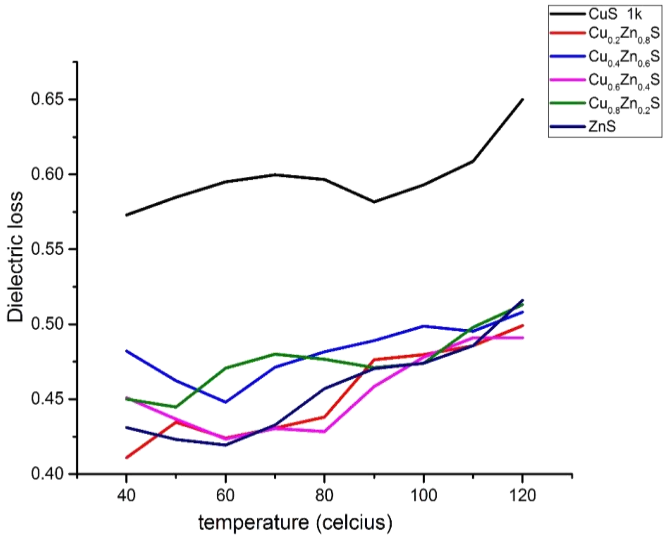

Fig. 2: Variation of Dielectric loss with temperatures at 1kHz for all the thin films

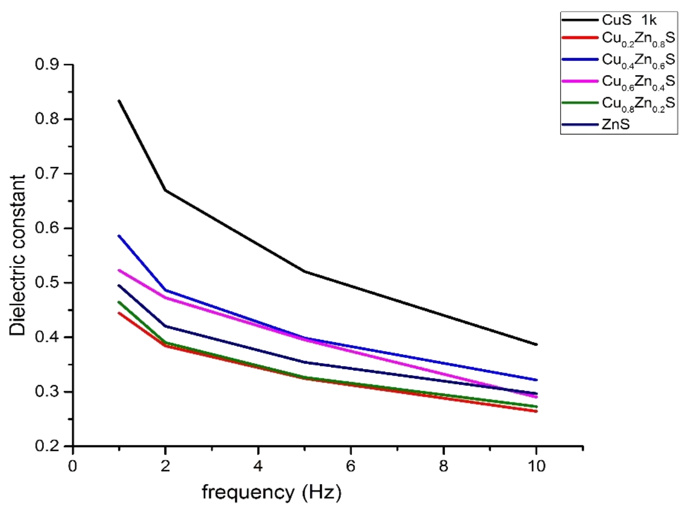

Fig. 3: Variation of Dielectric constant with frequencies at 40°C for all the thin films

The variation of dielectric constant and loss factor with applied A.C. frequency are shown in fig. 3 and fig. 4. It can be seen that both, *i.e.* dielectric constant and loss factor, decreases with increasing frequency. This is due the fact that at higher frequency only electronic polarization exists and all other polarization vanishes. So, at higher frequency the dielectric constant and loss factor decreases.

The variation of A.C Conductivity with temperature and frequency are shown in fig. 5 and fig. 6. It is observed that A.C Conductivity shows non-linear increase with temperature. The conductivity is minimum at 80°C for CuS thin film and at 70°C for composite. This reveals that the free charge carriers are low at these temperature but A.C Conductivity increases linearly with frequency.

The dielectric constant and the loss factor vary non-linearly with bulk composition of the nanocomposites. This non-linear variation may be attributed to the anharmonicity due to mixing [9].

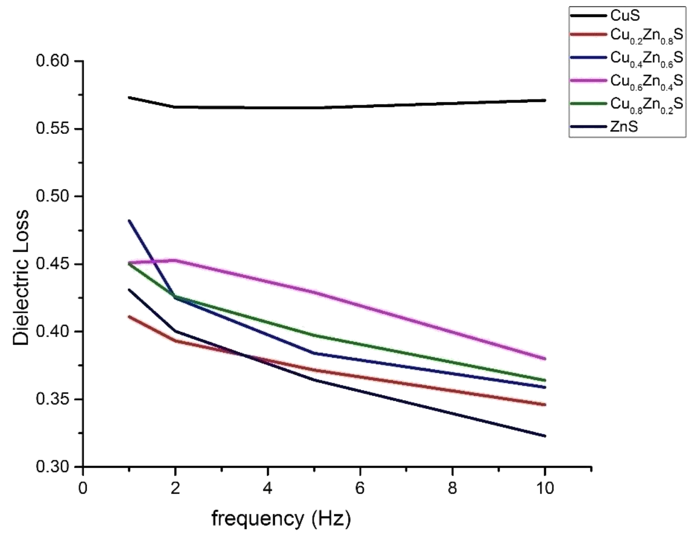

Fig. 4: Variation of Dielectric loss with frequencies at 40°C for all the thin films

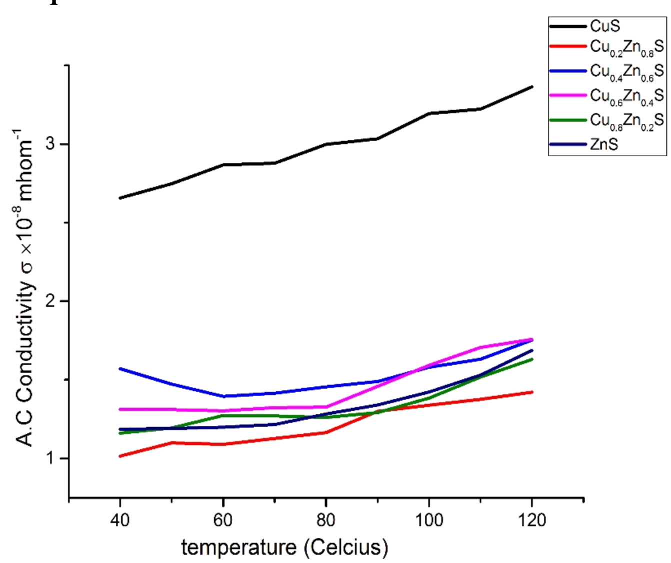

Fig. 5: Variation of A.C Conductivity with temperatures at 1kHz frequency for all the thin films

The variation of ln σac with 1000/T for the composite $Cu_{0.2}Zn_{0.8}S$ is shown in fig. 7 for illustration. The activation energies of all the thin film at 1 kHz are given in table 1. It varies non-linearly with composites. This non-linear variation may be due to anharmonicity. In the present case, activation energy values lie between 0.020 to 0.044 eV. Hill [10] reported that the activation energy of most of the thin film lies between 0.001 to 1 eV.

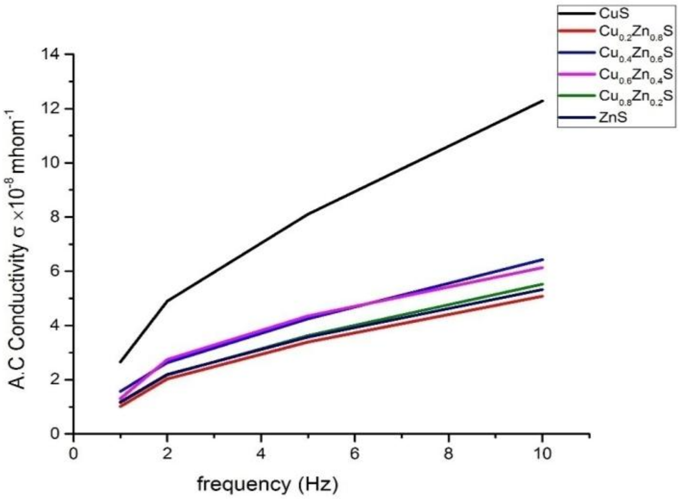

Fig. 6: Variation of A.C. Conductivity with frequencies at 40°C for all the thin films

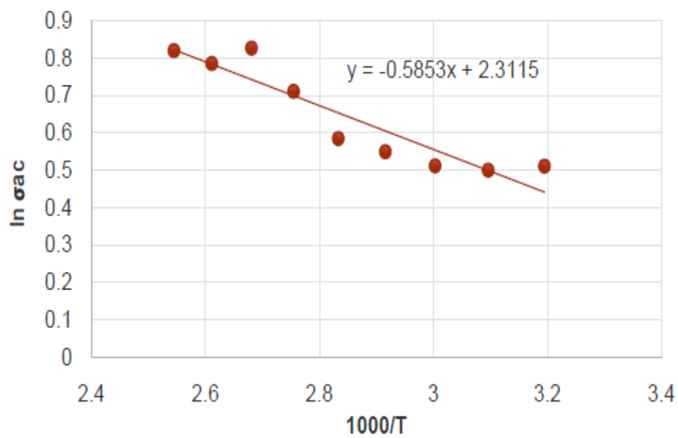

Fig. 7: Variation of ln σac with 1000/T for the composite $Cu_{0.2}Zn_{0.8}S$

4. CONCLUSION

$Cu_xZn_{1-x}S$ nanocomposite thin films were prepared by SILAR method. Dielectric constant and loss factor increases with increasing temperature and decreases with increase in frequency. The dielectric constant, loss factor, A.C Conductivity and activation energy vary non-linearly with composition.

5. REFERENCES

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