Frequency Domain Comparison of GaSe Thin Film Bulk Single Crystal

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Abstract **- Frequency domain measurements in the frequency range 10-2 to 104 Hz and temperature range 300 to 400K have been carried out *for* p-type ε-GaSe single crystal and GaSe thin films. Activation energies for p-type ε-GaSe single crystal and GaSe thin film have been determined from the lateral shift in frequency vs 1/T plots. The obtained values for single crystal are 0.75 ± 0.03 eV for both ‖ c and ⊥c for Au contacts, and for thin films 0.66 ± 0.03eV for Al tape contacts, 0.72 ± 0.03eV for Cu tape contacts, and 0.65 ± 0.03eV for Cu evaporated contacts**.

Index Terms **-** Dielectric Behavior, Gallium Selenide.

1. INTRODUCTION

The layer compounds consists of sheets a few atoms thick which stick to each other to form a three dimensional crystal. The bonding between the atoms of a single layer is predominantly covalent or strongly ionic and each layer forms a self – contained crystalline unit. The bonding between different layers arises from weak forces of the Ven Der Walls type. The interlayer interaction in Gallium Selenide (GaSe) contains an ionic or coulomb contribution [1].

Layer crystals therefore exhibit a large mechanical anisotrophy and mechanical cleavage occurs easily along the basal plane, indicating that the bonding between the layers is relatively weak. This enables the layers to glide easily over each other and to cleave the crystal to very thin layers.

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Gallium Selenide is a III – VI semiconducting layer compound, deep red in colour, corresponding to a band gap of ≈ 2 eV at 300 K.. It crystallizes with the layer structure in the form of thin plates whose faces are parallel to the basal plane of the structure. It can exist in the hexagonal (β and ε) or rhombohedral (γ) modifications[1,2]. The layer structure of GaSe single crystal consists of four closed-packed monoatomic sheets in the sequence Se-Ga-Ga-Se. The interalayer bonding is basically covalent with appreciable ionic contribution [3]. Fragile layers of GaSe single crystal can be cleaved to expose a clean (0001) surface ⊥c. The complete four – fold layers are bound together by much weaker (interlayer) forces of Van der Waals type llc and " coulomb interaction" type[4,5].

There is not much frequency dependence data available on comparative study for bulk GaSe single crystal and thin film. In the present investigation comparative study of single crystal and thin films of GaSe is reported in the frequency range 10^{-2} Hz to 10^{4} Hz and temperature range 300 to 480 K.

The frequency dependence of the real and imaginary components of the complex capacitance and hence complex relative permittivity can be described by, [1, 2],

$$C(\omega) = C'(\omega) - iC''(\omega) = (A/d)\{\varepsilon'(\omega) - \varepsilon''(\omega)\} \quad (1)$$

where $C'(\omega)$ corresponds to ordinary capacitance, $C''(\omega)$ represents the dielectric loss component.
A the surface area of the measuring electrode and d the thickness of the sample.

II. EXPERIMENTAL

GaSe single crystal samples were grown using the Bridgman- Stockbarger (B-S) method [3]. X-ray and electron diffraction analysis confirmed

that the as- grown ε-GaSe single crystal has an excellent crystallographic structure [4]. The ε-GaSe single crystal sample used were p-type [5].

GaSe thin films used for measurements were prepared on three glass substrates in vacuum better than 10–5 torr, with thickness around 4.6 x 10–7m [6]. Three different contacts, Al-tape, Cu –tape and Cu evaporated, were used.

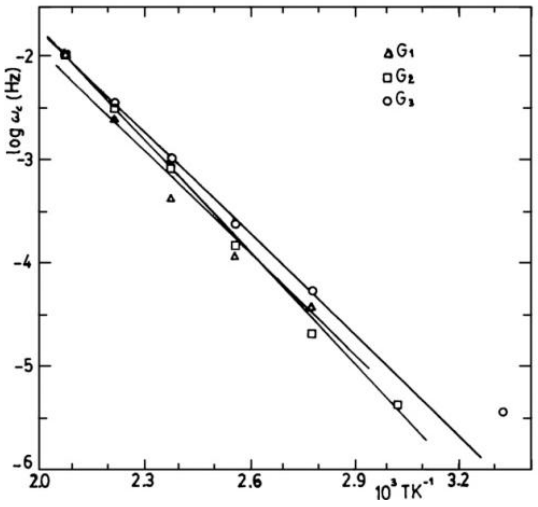

Figure.1. Activation energies for GaSe thin films n determined from the lateral shift in frequency vs 1/T plots. The obtained values for thin films are (G1)0.66 ± 0.03eV for Al tape contacts, (G2) 0.72 ± 0.03eV for Cu tape contacts, and (G3) 0.65 ± 0.03eV for Cu
evaporated contents.

Frequency domain measurements were carried out in the frequency range 10 –2 to 10 4 Hz and temperature range 300 to 480K with 1Vrms under 10 –3 torr. Instrumentation used were Edward High vacuum unit 306A, Oxford DN1704 cryostat, Oxford temperature controller ITC4 and computer controlled Solatron Model FRA 1255 in conjunction with Chelsea dielectric interface. The results were plotted, with a Roland DXY – 880A X-Y plotter, in the form of real and imaginary components of the complex capacitance C/ (ω) and C// (ω) as a function of circular frequency f = ω / 2π in logarithmic coordinates. Detailed experimental procedure has already been reported [6-9].

III. RESULTS AND DISCUSSION

Dielectric spectroscopy of GaSe thin films for different contact materials has been reported [6]. The value of LFD (Low Frequency Dispersion) activation energy for thin film samples are found to be 0.66 ± 0.03 eV for Al tape contacts, 0.72 ± 0.03eV for Cu tape contacts, and 0.65 ± 0.03eV for Cu evaporated contacts.

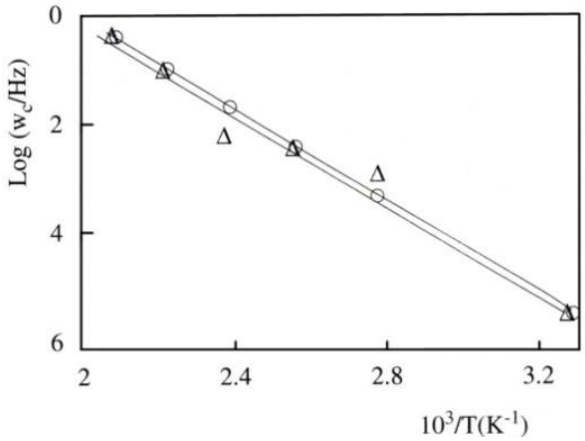

Figure.2. Activation energies for p-type ε-GaSe single crystal have been determined from the lateral shift in frequency vs 1/T plots. The obtained values for single crystal are 0.75 ± 0.03 eV for both ‖ c and ⊥c for Au contacts.

Reported values [6] for GaSe thin films with different LFD activation energies, for different contacts, suggest that the volume may be altered by diffusion of contact material, or that the injection properties for carriers into the material are different [6]. Possible interfacial contribution has been discussed in detail for dielectric spectroscopy of semi-insulating GaAs [10].

GaSe thin film samples have non-crystalline structure with room temperature resistivity between 103 to 104 Ωm [6]. The higher resistivity of thin films may have played a dominant role to suppress the contribution of other processes, e.g. hoping charge carrier, interfacial barrier, etc.

Dielectric spectroscopy of p-type ε-GaSe for different contact materials has been reported [7-9]. The resistivity of GaSe single crystal had been reported to be between 2 to 6 Ωm [11]. Activation energies for p-type ε-GaSe single crystal are determined from the lateral shift in frequency vs 1/T plots for Au contacts are 0.75 ± 0.03 eV for both ‖ c and ⊥c, but in case of indium and silver contacts the values determined were different for ‖ c and ⊥c.

IV. CONCLUSION

In conclusion we can say that the GaSe thin films have shown LFD and the C (ω) behavior with the different values of activation energies

suggests possible contribution of diffused contact material. In case of p-type ε-GaSe single crystal, lack of frequency independent ratio between real and imaginary components of capacitance shows that the LFD behavior is perturbed by the presence of other, related competing processes (e.g. hoping charge contribution etc) . The overall DS response of GaSe single is almost isotropic for both ‖c and ⊥c. The activation energies for GaSe thin films and single crystals appeared to be close, ignoring contact material.

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