Opto-electronic application of AgInSe$_2$

D. K. Shukla, Manohar Lal * and Navdeep Goyal

Centre of Advanced Study in Physics,
Panjab University, Chandigarh-160014 (India).

Abstract

The paper reports a possible application of AgInSe$_2$ for opto-electronic switching. Material has been studied over a wide range of frequencies (5Hz to 1MHz), through measurements of conductance and capacitance, at different temperatures and illumination levels. The results indicate that there is an increase in capacitance (C) as well as conductance (G), when sample is exposed to light radiations at a given temperature. The switching/recovery time has been analyzed in terms of time constant ($\tau = C/G$) and found to be of the order of microseconds for this material. It has been further observed that $\tau$ decreases with increasing illumination levels and temperature. It is understandable, because higher the rate of recombination of optically/thermally generated carriers, lesser should be the value of $\tau$. 

*Permanent Address: G.G.D.S.D. College, Sector 32, Chandigarh.
1 Introduction

The semiconducting I-III-VI$_2$ and II-VI compounds are of great practical interest in fabrication of opto-electronic device. I-III-VI$_2$ compounds normally crystallize into diamond like structure and have attracted considerable attention [1-3] of many workers. Most of these compounds can be made to have both $n$–type and $p$–type conduction and are useful in the field of photovoltaics [4,5]. Copper-III-VI$_2$ compounds have been studied by many investigators [5-8]. The use of these compounds in the development of photoconductive, photovoltaic and other devices has been established [6-8]. We report in this paper some investigations made on a silver based chalcopyrite semiconductor (AgInSe$_2$). AgInSe$_2$ is a material of special interest, because it is a ternary analogue of CdS, with direct energy gap of 1.19 eV [1]. The study of AgInSe$_2$ communicated from the author’s laboratory [9], indicate the existence of gap states in this material. Present investigations provide clear indication of suitability of AgInSe$_2$ for use as opto-electronic switches. The switching time is of the order of microseconds for planer AgInSe$_2$ samples.

2 Experiment

AgInSe$_2$ was prepared by sealing a desired quantity of constituent elements (99.99% pure) in an evacuated quartz ampule, which was heat treated in a rocking furnace [9]. EDAX analysis of the prepared material provides the following percentage compositions: Ag: 24.982 At%, In: 25.014 At%, Se: 50.004 At%. The X-ray diffraction pattern of the sample shows that the material is polycrystalline in nature [9]. The sample, in the form of pellets was prepared by finely grinding the ingots and then compressing the powder in a die under hydraulic pressure. The samples were annealed at 80 degree celsius for 24 hours. Sheet measurements on planer configuration were made by exposing a narrow slit of material ($\approx$ 1mm) in between two electrodes obtained by coating a conducting layer of silver paste on one face of pellet.

Measurements were made on modular a.c. impedance and C.V system (EG & G, PARC, USA) shown schematically in Fig. 1.

The real and imaginary components of a.c. impedance were obtained over a frequency range 5Hz to 100kHz by using dual lock-in amplifier. Plots of capacitance versus time and conductance versus time were obtained at 1MHz on a C-V system coupled with an X-Y recorder. The sample was illuminated by using optical fibre bundle connected to Ealing (UK) optical illumination set with a light source (Tungsten Halogen Sylvania Lamp, 150W) of variable intensity.
3 Results and Discussion

A.c. measurements are reported here, over a wide range of frequencies (5Hz -1MHz) under dark and illuminated conditions for AgInSe$_2$. Figure 2 shows the variation of conductance with time at a fixed temperature (T= 285 K) by switching the light ON and OFF for a particular interval. It is evident from figure that there is an increase in the conductance when sample is exposed to light radiations at a higher temperature. Similar measurements were obtained on capacitance versus time plot and it was observed that the capacitance of the sample increases when light radiations are shone on the sample. Similar behaviour were observed at other temperatures, frequencies and illumination levels. It is observed from the measurements under illumination that there is a considerable increase in a.c. conductance and the material is said to be in the ON (low resistance) state. It goes back to OFF (high resistance) state, as soon as illumination is turned off. Figures 3 and 4 show the effect of illumination on conductance and capacitance respectively. It is clear from the figures that the material is sensitive to light over a wide range of frequencies and the sensitivity of the material to illuminations increases with the increasing frequency therefore, higher frequencies are preferable for operations. The switching/recovery time of the sample for OFF-ON-OFF states was estimated by determining the RC-time constants ($\tau = C/G$) at different frequencies. Table 1 shows the

Table 1: Variation of time constant $\tau$ ($\times 10^{-6}$ Seconds) at different illumination levels ($I_0=0.00$, $I_1=5.05$, $I_2=12.5$, $I_3=26.5$, measured in arbitrary units)

| Frequency in kHz | $I_0$ | $I_1$ | $I_2$ | $I_3$ |
|-----------------|------|------|------|------|
| 1.00            | 0.129| 0.102| 8.44 | 6.12 |
| 3.98            | 0.111| 8.54 | 7.40 | 5.35 |
| 10.00           | 9.40 | 7.25 | 6.80 | 4.50 |
| 39.80           | 6.81 | 5.23 | 4.44 | 3.45 |
| 100.00          | 5.04 | 4.02 | 3.36 | 2.62 |

value of $\tau$ at different levels of illuminations and frequencies. It is clear from the table that the switching/recovery time ($\tau$), is of the order of microseconds for AgInSe$_2$. It is also clear from the table that switching response is faster at higher frequencies. Figure 5 shows the frequency dependence of time constant $\tau$ at different temperatures. It is clear from the figure that the dependence of switching time on temperature decreases at higher frequencies.
4 Conclusion

The response of AgInSe$_2$ to optical and thermal stresses demonstrates the suitability of AgInSe$_2$ as an opto-electronic switch over a wide range of frequencies. The switching/recovery time for planer sample has been found to be of the order of microseconds.

Acknowledgments

The authors are grateful to University Grants Commission for providing funds under COSIST programme for purchase of a.c. impedance and C.V. system. The authors are thankful to Professor K.K.Srivastava for useful discussions.
References

[1] J. L. Shay, B. Tell, H. M. Kasper and L. M. Schiavone, Phys. Rev., B7, 4485 (1973).

[2] B. Tell, J. L. Shay and H. M. Kasper, J. Appl. Phys., 43, 2469 (1972).

[3] S. Wagner, Int. Phys. Conf., S.No. 35, Institute of Physics, Bristol (1977).

[4] R. McConnel, J. Stone, E. Witt, T. Surek and T. Basso, Solar 88, Pro- ceeding of 1988 annual meeting of Solar Energy Society, Cambridge, MA, USA. June 1988.

[5] L. L. Kamareski, Int. Mater. Rev., 37, 185 (1989).

[6] L. L. Kamareski, M. Hallendt, J. J. Ireland, R. A. Mickelson and W. S. Chen, J. Vac. Sci. Technol., 2, 395 (1983).

[7] R. W. Birkmise, B. E. McCandless, Appl. Phys. Lett., 53, 140 (1988).

[8] V. Ramanathan, T. Datta and R. Noufi, Appl. Phys. Lett., 51, 746 (1988).

[9] Navdeep Goyal, Pramana. J. Phys, 40, 97 (1993).
## List of Figures

| Figure | Description                                                                 | Page |
|--------|------------------------------------------------------------------------------|------|
| 1      | Schematic diagram of computer assisted a.c. impedance and CV system set-up   | 7    |
| 2      | Computer plot of conductance against time at $T=285$ K                       | 8    |
| 3      | Variation of conductance with illumination of sample (illumination level 26.5 arbitrary units) | 9    |
| 4      | Variation of capacitance with illumination of sample (illumination level 26.5 arbitrary units) | 10   |
| 5      | Effect of frequency on time constant $\tau$ at different temperatures       | 11   |
Figure 1: Schematic diagram of computer assisted a.c. impedance and CV system set-up
Figure 2: Computer plot of conductance against time at T=285 K
Figure 3: Variation of conductance with illumination of sample (illumination level 26.5 arbitrary units)
Figure 4: Variation of capacitance with illumination of sample (illumination level 26.5 arbitrary units)
Figure 5: Effect of frequency on time constant $\tau$ at different temperatures