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ISOTHERMAL RELAXATION CURRENTS IN ARSENIC CHALCOGENIDES

G.J. Adriaenssens, H. Michiel and M. Hamman


Abstract.- The transient response to step voltage excitation was investigated for bulk As$_2$S$_3$ and As$_2$Se$_3$ material and in evaporated As$_2$Se$_3$ films. Au and Al were used as electrodes. While in general the response proved to be relaxational, for all As$_2$S$_3$ samples and for the Au/As$_2$Se$_3$/Al substrate cell some additional structure was observed which points to the transit of a finite amount of charge through the sample.

Introduction.- It is a well-known fact that when a voltage is applied to one of the arsenic chalcogenides, polarization of the sample takes place and goes on for anything from minutes to hours. Hence the frequent references in the literature to either waiting a sufficiently long time to allow for steady state conditions, or measuring immediately after voltage application to avoid distortion of the applied field. Since, to our knowledge, the polarization process itself, and the relaxation currents that go with it, have not been fully investigated so far, the present study was undertaken.

Experimental.- As$_2$S$_3$ and As$_2$Se$_3$ bulk material was obtained by quenching from the melt. Samples with thicknesses from 500μm to 800μm were prepared by slicing the material with a wire saw and subsequent polishing of the surfaces. We also used As$_2$S$_3$ disks purchased from Servo Corporation and material from an As$_2$Se$_3$ rod kindly provided by Dr. P. Nagels of SCK/CEN, Mol. Thin layers (typically 100μm to 200μm) of bulk As$_2$S$_3$ and As$_2$Se$_3$ were prepared by heating it to the softening point and pressing between aluminium and quartz disks. Evaporated As$_2$Se$_3$ samples were obtained by open boat evaporation of the bulk material onto either glass or aluminium substrates. Films of 20μm to 50μm thick were deposited at about 1μm per minute. No evaporated As$_2$S$_3$ samples were examined. Except for some samples where the aluminium substrate was used as one of the electrodes, gold or aluminium electrodes were evaporated to form a sandwich type configuration.

Relaxation currents after step voltage application were measured by way of a Bio mation 805 transient recorder when times up to 2 seconds were being examined; they were plotted directly on a chart recorder after passing through a Keithley 427 current amplifier for times between 1s and 1200s. Current response in theμs range was briefly examined by preceeding the transient recorder with a guarded current sensing resistor and high-speed buffer stage to eliminate the influence of cable and stray capacitances. No special features were observed on this time scale. A Fluke 415B high voltage power supply with reversible polarity was used as voltage source. Samples were switched to either supply voltage or reference potential by means of a mercury relay. The sample temperature was held constant within 0.1K during the relaxation measurements for temperatures between 290 K and 410 K.

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RESULTS AND DISCUSSION

General behaviour.- With the exception of some specific instances noted below, all samples exhibit a featureless polarization current when the voltage is applied and a depolarization current which is nearly the inverse of the polarization current when the voltage is switched back to zero after a polarization time of at least 30 minutes.

Fig. 1 illustrated this behaviour at three different temperatures for a 540µm thick As₂S₃ gold-electroded sample subjected to an applied voltage of 1000V.

The "universal" power-law dependence on time(1) of the relaxation currents is obvious from fig. 1. All observed As₂S₃ relaxation currents are well represented by an expression of the form

\[ I(t) = I(\infty) + D t^{-n} \]

where

- \( n = 0.75 \) is essentially temperature independent,
- \( D \) is thermally activated with \( E_D = 0.3 \) eV,
- \( I(\infty) \) is the steady state dark current when polarizing, or zero when depolarizing. As activation energy for the As₂S₃ dark current we obtain \( E_d = 1.12 \) eV.

While the same general behaviour was observed for the As₂Se₃ samples, values for \( D \) and \( n \) have not yet been extracted. Here we can only use the depolarization currents for that purpose. Since the steady state dark current is much larger in As₂Se₃ with respect to the polarization current than is the case in As₂S₃, temperature fluctuations induce variations in \( I(\infty) \) which already at 350 K equal the \( D t^{-n} \) term soon after the onset of the polarization process.

Aside from the general agreement with a \( t^{-n} \) relaxation behaviour, As₂S₃ and As₂Se₃ polarization currents can also be understood in terms of the formation of a depletion layer at the metal-semiconductor contact such as described by for instance Matthews and Warter(2) or Simmons and Taylor(3).

Fig. 1. Polarization (full symbols) and depolarization currents (empty ones) in bulk As₂S₃; \( E = 1.85 \times 10^4 \text{V/cm} \)
The $E_D = 0.3$ eV activation energy then represents the trap depth of those traps which are being emptied in building up the depletion layer. The polarization curves were also fitted to a model which coupled a release-out-of-traps source function to a dispersive transport mechanism. It was found that only a source with the time dependence of the actual relaxation current gave acceptable results, indicating that the observed currents are emission limited. Details of these and other investigations into the nature of the relaxation currents and the depletion region will be presented in a later report.

Deviations from the power-law behaviour. We observed departures from the $t^{-n}$ decay on one type of As$_2$Se$_3$ sandwich cells, and for some parameter values on all measured As$_2$Se$_3$ samples. The As$_2$Se$_3$ case has been observed and discussed before by Abkowitz and Scher(4).

A thick evaporated As$_2$Se$_3$ film (= 45um in our case) on an aluminium substrate and with an evaporated gold top electrode, when subjected to step voltage excitation, exhibits transients of the type shown in fig. 2. The first transient (positive voltage to the Au contact) is the one studied by Abkowitz and Scher. They showed that the current maximum is related to the transit of a finite amount of charge through the sample. The gold electrode was assumed to be the source of that charge. Our samples show the same field and temperature dependence of the peak position as the published results. As is evident from fig. 2., depolarization currents differ strongly here from the corresponding polarization curve, and the two reverse shapes upon voltage reversal. The featureless transient following a downward voltage step shows a markedly faster decay than is observed in samples which obey the general relaxation power law.

We were not able to obtain comparable results with either bulk or pressed layer As$_2$Se$_3$ samples, or for that matter with films which were taken off the substrate and where an evaporated gold or aluminium film was put on as back electrode. In all those cases we observed the general power-law decay described above. It is clear therefore that a gold contact by itself cannot account for the transients of fig. 2.

Deviations from the power-law decay, as illustrated in fig. 3, were observed for all As$_2$S$_3$ samples at lower fields and temperatures. At room temperature the devia-

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Fig. 2. Transients following switch-on and switch-off of +80V and -80V to the Au contact of a 45um sample of the type shown.
Fig. 3. Relaxation currents for 0.8mm As$_2$S$_3$ with Au/Au, Au/Al on Al/Al electrodes (300V at 300 K).

tions can be resolved up to $= 10^4$V/cm, at 370 K they are only seen up to $= 3 \times 10^3$V/cm. Such field and temperature dependence is consistent with a transit-time phenomenon since at higher fields or temperatures a shorter transit time will cause the extra feature to be submerged in the main relaxation peak. It may be noted that the same thing happens to the current maximum of fig.2. The asymmetry between polarization and depolarization currents, and the reversal with voltage that was observed in the Au/As$_2$Se$_3$/Al-substrate cell is also found in fig. 3, again accentuating the similarity of the two data sets. Ascribing the As$_2$S$_3$ feature to the transit of some finite amount of charge in analogy with the As$_2$Se$_3$ results, one is led to hole transit times in the seconds range, which is reasonable for our 0.1mm to 0.8mm thick samples under the field and temperature conditions noted above. In order to better characterize the indicated transit phenomenon, it will be necessary to subtract the superimposed relaxation current, or to find an experimental arrangement where, analogous to the As$_2$Se$_3$ case, a distinct maximum can actually be resolved.

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References
4. ABKOWITZ M. and SCHER H., Phil. Mag. 35 (1977) 1585.