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FAR INFRARED TRANSMISSION SPECTRA OF THIN LAYERS OF GeS

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ABSTRACT

Transmission measurements in the range between 40 and 400 cm^{-1} were performed for layered single crystal GeS samples whose thicknesses were between 4 and 140 microns. The change of index of refraction and other optical parameters was determined in the far infrared range for this semiconductor.

1. INTRODUCTION

There has been increasing interest in the layered $A^{IV}B^{VI}$ compounds and especially in GeS during the last few years. This distinctly layered compound can be easily obtained in the form of single crystals which can be readily cleaved so that very thin samples with thicknesses of only a few micrometers can be obtained[1,2)]

First the optical properties of GeS were examined in the range of the absorption edge[3,4)], followed by the behavior of GeS in the far infrared range[1,5,6)]. The reflectivity measurements were done using polarised light when the direction of the electrical field was parallel to the direction of each crystallographic axis of the orthorhombic system in which this compound crystallises. Raman scattering was studied in the same frequency region. Also, using group theory Raman and infrared active modes were predicted and the ratio between the intralayer and interlayer force constants was calculated[5,6)].

In this work the far infrared transmission coefficient of polarised light through thin GeS samples has been determined and some interesting information has been obtained.

2. SAMPLE PREPARATION AND EXPERIMENTAL

Single crystal GeS samples were obtained using the Bridgeman technique as described elsewhere[2,4)]. Thin samples whose thicknesses were between 4 and 140 micrometers were obtained using a cleavage procedure.

Using X-rays it has been shown that the cleaved plates were parallel to x-y plate ie their Miler indexes were (001). The obtained samples were very homogenous in thickness and they were shiny like a mirror. Transmission measurements were performed when the light beam was brought normal to the surface, that is the direction of its expansion was parallel to the $\vec{c}$ axis. GeS is a highly anisotropic compound so the incident light was brought to be parallel to the $\vec{a}$ or $\vec{b}$ axis.

In figure 1 the change of transmission coefficient as a function of the wavenumber is given for a sample which was 35.7μm thick, when $\vec{E}||\vec{b}$. A similar diagram is shown in figure 2 when $\vec{E}||\vec{a}$. For both diagrams interference fringes were very well exposed and they were not disturbed at all only when $\vec{E}||\vec{b}$. For $\vec{E}||\vec{a}$ (fig.2) it is obvious that, besides interference fringes, a strong absorption band exists at about 124 cm^{-1}.

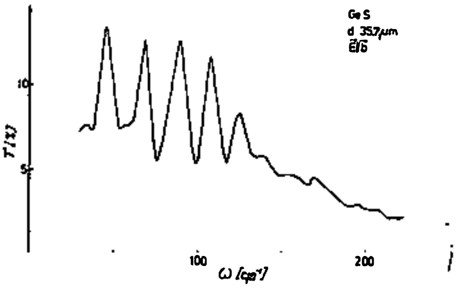

Fig.1. Transmission coefficient when $\vec{E}||\vec{b}$.

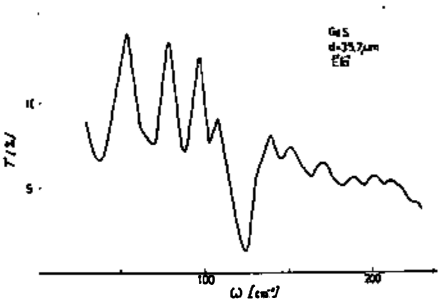

Fig.2. Transmission coefficient when $\vec{E}||\vec{a}$.

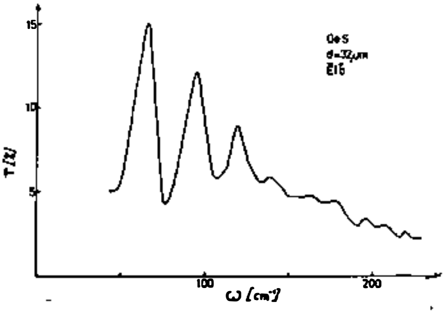

Fig.3. Transmission coefficient as a function of wavenumber for a sample which was 32 μm thick when $\vec{E}||\vec{b}$.

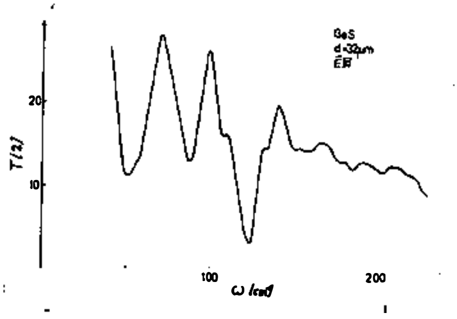

Fig.4. Transmission coefficient for a sample which was 32 μm thick when $\vec{E}||\vec{a}$.

In figures 3 and 4 are given similar diagrams for both polarisations for a slightly thinner sample. There one can also distingwish a strong absorption peak at about 124 cm^{-1}. In figure 5 a reflectivity diagram as a function of wavenumber is given for all three polarisations of the electric field. A strong resonance appearance for $\vec{E}||\vec{a}$ is readily apparent at about 120cm^{-1} while the same resonance does not exist in the case $\vec{E}||\vec{b}$.

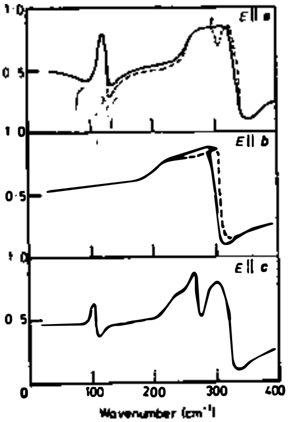

Fig.5. Reflectivity of GeS in the far infrared for the three polarisations. The full line corresponds to room temperature data and the broken line shows the 77 K results where they differ from the former.

Dielectric constant and index of refraction (n) change a lot near the resonance appearance, so it is very important to know if and how n changes in the range where the interference fringes are observed. In our case we have determined the change of index of refraction (fig.6) as a function of the wavelength using the reflectivity diagrams given in fig.5.

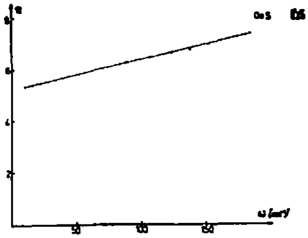

Fig.6. Index of refraction as a function of the wavenumber.

Then a well known equation has been used to analyse the interference fringes

$$2nd = m\lambda \qquad (1)$$

where "d" is the thickness of the sample; m is the order of the interference fringe and λ is the wavelength for the maximum value of the transmission.

3. ANALYSIS AND DISCUSSION OF RESULTS

Using equation (1) we have first determined the order of the interference fringe and then the values of the index of refraction. For the sample given in figure 1, m=2,3,...,6 beginning with the smallest values of the wavenumber and then approaching 150 cm^{-1}. The correct values of m can be calculated more easily using the correct relation $n=f(\omega)$ which we obtained previously by analysing the reflectivity coefficient. When "m" is determined then one can easily calculate the thickness of the sample. That means that this method can be used, above all, to determine rather precisely the thicknesses of thin layer samples whose thicknesses are between 20 and 100 micrometers.

GeS is a semiconducting materials which can be used in holography[7,8], so the explained method may be useful. Transmission measurements should be done in the far infrared range because only in that range are the distances between the maxima of the interference fringes big enough to be easily measured. When transmission measurements are performed in the far infrared range it is possible to find out if there is any ionic resonance in the observed range or not. This is especialy important when the signal to noise ratio is very small for the reflectivity measurements,

If there is only one oscillator in the far infrared range, as is the case for $\vec{E}\,||\,\vec{b}$ then one can gain some impression of the oscillator strength (S) using the equation:

$$\omega_{TO}^{2}(\varepsilon_{0}-\varepsilon_{\infty}) = S \qquad (2)$$

In our case ω_{TO} is equal to 124 cm^{-1}, and that is the frequency of the transverse optical mode. ε_{∞} can usually be obtained by analysing the reflectivity curve. The difference between ε_0 and ε_{∞} can be calculated using $\varepsilon_0 = n^2$.

In conclusion we can say that the measuremed interference fringes can be used first of all to gain information about the thickness of the samples employed. Then very reliable information can be also obtained about the existance of ionic resonance in the measured range.

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