SOME TRANSPORT AND OPTICAL PROPERTIES OF $Pb_{0.97}Hg_{0.03}Te$

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ABSTRACT: Single crystals of $Pb_xHg_{1-x}Te$ were obtained using two methods Bridgeman and Czochralsky. The transport properties of these samples were measured at room and liquid nitrogen temperatures. The reflectivity was measured in the far infrared range at room temperature. It was also shown that the plasma frequency of the $Pb_{0.97}Hg_{0.03}Te$ alloy was moved further into the infrared range compared with PbTe. The experimental optical results were numerically analysed and the susceptibility mass and dielectric constant were obtained for this alloy.

1. INTRODUCTION

Lead-telluride is widely used for making photoconductive detectors and emitters for the range between 2 and 4 microns. Alloyed with tin telluride, it is often used for production of infrared detectors for the range between 8 and 14 microns.

The main disadvantage of both pure PbTe and the $Pb_xSn_{1-x}Te$ alloys is that they have a relatively high free carrier concentration which is usually about 10^{18} cm^{-3} at room temperature. There have been several attempts to decrease the free carrier concentration in this material. Linden /1/ had some success when he doped PbTe with Cd or Zn. This method requires long annealing in an atmosphere of either Cd or Zn.

Up to now only one paper /2/ has been published about the optical properties of $Pb_xHg_{1-x}Te$. The possibility of decreasing the free carrier concentration by alloying PbTe with HgTe was discussed. HgTe is a semi-metal with a very small effective mass /3/.

In this work the physical properties of the semiconducting material $Pb_{0.97}Hg_{0.03}Te$ obtained using Bridgeman and Czochralsky methods was analysed. The transport and optical properties were measured at room and liquid nitrogen temperatures. In addition, far infrared reflectivity was measured and the plasma frequency of free carriers observed. The experimental optical results were numerically analysed and the susceptibility mass and dielectric constant were obtained.

2. EXPERIMENTAL

Lead mercury telluride crystals were obtained using the Bridgeman and Czochralsky methods. Alloys were obtained with 1 and 3 mol % of HgTe. Single crystal samples made by the Bridgeman technique were oriented (422) as determined using x-ray analysis. The single crystal obtained by the Czochralsky procedure had the orientation (111). Specimens for both transport and optical measurements were made from ingot by cutting slices which were about 1.5 mm thick. One side of these samples was polished using a standard technique. The same samples were used for both transport and optical measurements.

A typical single crystal sample obtained using the Czochralsky procedure is given in Fig. 1.

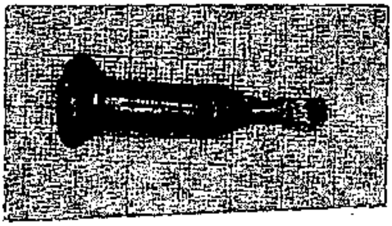

Fig.1. A single crystal of $Pb_{0.97}Hg_{0.03}Te$ obtained using the Czochralsky procedure.

Fig.2. Reflectivity of $Pb_{0.97}Hg_{0.03}Te$ as a function of wavenumber for the samples produced using both Bridgeman (a) and Czochralsky methods.

Far infrared reflectivity was measured using a Fourier spectrometer (Beckman FS 720) in the range between 40 and 400 cm^{-1}. In figure 2 are given two curves of reflectivity versus wavenumber for the two typical samples of $Pb_{0.97}Hg_{0.03}Te$ obtained by the Bridgeman and Czochralsky procedures. For the former the plasma frequency was about 225 cm^{-1} while it moved much further into the far infrared range for the sample obtained by the Czochralsky procedure and the plasma frequency was about 12o cm^{-1}.

For the same samples the transport properties were also measured at room and liquid nitrogen temperature using Van der Pauw's /4,5,6/ and Green's /7/ methods. Room temperature resistivity (ρ), carrier concentration (p) and mobility (μ_p) for the sample obtained by the Bridgeman procedure were: $\rho = 6xlo^{-3}\Omega cm$; $p = 1.06 \ x \ lo^{18} \ cm^{-3}$; $\mu_p = 930 \ cm^2/Vs$.

The specimen obtained by the Czochralsky procedure was n-type and the room temperature transport properties were:

$\rho = 3.9 \ x \ lo^{-3} \ \Omega cm$; $n = 1.08 \ x \ lo^{18} \ cm^{-3}$; $\mu_n = 180 \ cm^2/Vs$.

The experimental reflectivity data were analysed using a computer curve fitting procedure beginning with the expression of the classical oscillator

$$\varepsilon = \varepsilon_\infty \left| 1 - \frac{Ne^2}{\varepsilon_o m_s \varepsilon_\infty} \ \frac{1}{\omega(\omega + j\gamma)} \right| \qquad (1)$$

where "N" is the free carrier concentration; m_s the susceptibility mass and γ is the plasma damping constant; ε_∞ is the high frequency dielectric constant.

Plasma frequency was $\omega_p = \left(\frac{Ne^2}{\varepsilon_o \varepsilon_\infty m_s}\right)^{1/2}$ (2)

Both experimental data, with open circles and the theoretical curve obtained for the parameters calculated during the fitting procudure are presented in Fig. 3.

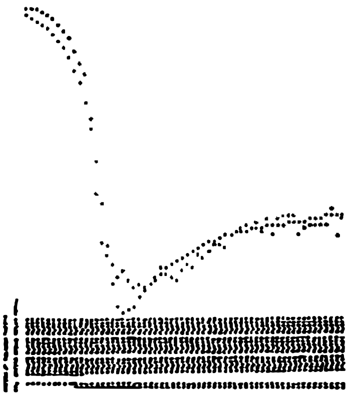

Fig.3. Experimental data (open circles) and the theoretical curve obtained for the parameters calculated and given in Table 1.

The values of the calculated parameters are given in Table 1 together with the values of the transport room temperature properties.

Table 1

	ω_p	ρ (Ωcm)	n (cm^{-3})	ε_∞	λ_p	m_{eff}	μ_{opt}	μ_{Hall}
Bridgeman	$2.8x10^{13}$	$6x10^{-3}$	10^{18}	26	66	$0.15m_o$	1080	930
Czochralsky	$2.3x10^{13}$	$3.9x10^{-3}$	10^{18}	48	77	$0.12m_o$	2960	1480

3. DISCUSSION

Using Table 1 one can compare the values of the calculated parameters with the literature data. Our susceptibility mass for both "p" and "n" type samples had values which were half those of the literature data, $m_p=0.3m_o$ and $m_n=0.24m_o$. These differences are in our opinion the consequence of the energy band structure change which occurs when PbTe is alloyed with HgTe. Our samples were also of very high quality. In support of these it may be pointed out that our p-type samples had a mobility of about 1000 cm^2 /Vs while the literature values are a bit smaller /8/. For n-type samples our liquid nitrogen mobility was about 27.000 cm^2 /Vs which is almost as high as the mobility of electrons at 4.2K. for PbTe /9/ which was reported to be about 35.000 cm^2/Vs for the sample whose carrier concentration at 4.2K was about 10^{17} cm^{-3}.

For $Pb_xHg_{1-x}Te$ alloys it is very important that the plasma frequency is moved much further into the far infrared range. One should expect that the carrier concentration of alloyed samples is much lower, but that was not confirmed with the measurements of transport properties. It is interesting to see that for n type samples the high frequency dielectric constant increases almost twice as much as with the p-type samples. This is the consequence of filling the Pb vacancies with the Hg so that ionisity increases.

Judging by the shape of the change of the reflectivity curves vs. wavenumber in the far infrared, it is obvious that the mobility should increase as more HgTe is added to PbTe. This is confirmed by the higher values of μ_{nopt} compared with the μ_{opt} which in our case was increased threefold.

In our opinion it would be interesting to do magneto-optical measurements on these samples at liquid helium temperature where this effect should be more emphasized.

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