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ANALYSIS OF CRYSTALLOGRAPHIC AND SOME OPTICAL PROPERTIES OF SINGLE CRYSTAL $InSb_{1-x}As_x$ AND $InSb_{1-x-y}As_xBi_y$ ALLOYS

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Single crystal alloy samples of $InSb_{1-x}As_x$ and $InSb_{1-x-y}As_xBi_y$ were made using the Bridgeman technique. The lattice parameters for $InSb_{1-x}As_x$ were determined using X-ray diffractograms and the composition of the samples was obtained comparing the calculated parameters with the literature data. Far infrared optical reflectivity measurements were done for both alloys. The experimental data were analysed and the values of the optical parameters and the susceptibility mass were calculated.

INTRODUCTION

There are only a few reports published on the properties of $InSb_{1-x}As_x$ alloys. They were first obtained by melting the required amount of the element in sealed and evacuated quartz capsules, which were then annealed for several months (1). These alloys were also made by a directional freezing procedure and their electrical and some optical properties were examined (2,3).

The photoconductivity properties of these alloys were studied more than ten years ago (4), using samples obtained by a directional freezing method.

In this work the Bridgeman technique wasused and single crystal alloy samples were produced with a content of 5 mol% and 8 mol% InAs, and 95 mol% or 92 mol% InSb respectively. These and $InSb_{1-x-y}As_xBi_y$ samples were used for far infrared optical reflectivity measurements, and plasma frequency and ionic resonance were observed.

SAMPLE PREPARATION AND MEASUREMENT

Alloy specimens weighing five grams were prepared from the two compounds by melting together the required amount of both InSb and InAs in sealed evacuated quartz ampoules. Single crystals were obtained using the Bridgeman technique by lowering the quartz ampoule

at 0.8 mm/h into a furnace with a suitable temperature profile.

The lattice parameters were determined using X-ray diffractograms. The composition of the samples was confirmed by comparing the obtained lattice parameters with those given by Woolley and Smith (1), for $InSb_{1-x}As_x$ alloys.

The samples for the reflectivity measurements were obtained by cutting slices from the obtained ingot. Then, the slices were polished on one face using diamond compound first and then 0.1 micron alumina (Al_2O_3).

Far infra red measurements were made between 40 and 400 cm^{-1} using a Beckman FS 720 Fourier transform spectrometer. The near normal incident far infrared reflectivity spectrum of $InSb_{.95}As_{.5}$ is shown in Fig. 1. A reststrahlen band was observed in the range between 180 and 210 cm^{-1}. Also a plasma edge was observed at the range of about 90 cm^{-1} which was due to free electron absorption. All the obtained samples were N type with a rather low carrier concentration - between 1 and 3 . 10^{16} cm^{-3}

ANALYSIS AND DISCUSSION OF RESULTS

The experimental reflectivity data were analysed using both Kramers Krönig integration and computer curve fitting procedures

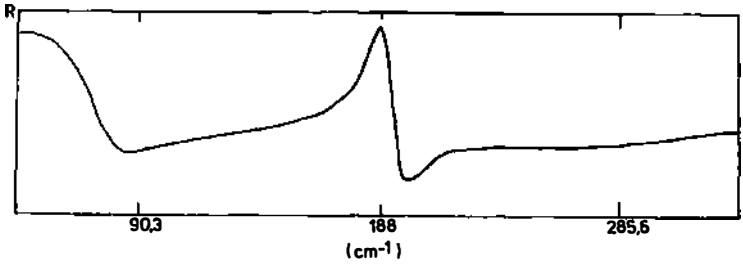

Fig. 1. Far infrared reflectivity of $InSb_{0.95}As_{0.5}$

in the first case the classical expression for the complex dielectric constant was used.

$$\varepsilon = \varepsilon_\infty + \varepsilon_{FC} + \varepsilon_{LV} = \varepsilon_\infty - \frac{\varepsilon_\infty \omega_p^2}{\omega^2 + j\gamma\omega} + \frac{\varepsilon_\infty(\omega_{LO}^2 - \omega_{TO}^2)}{\omega_{TO}^2 - \omega^2 - j\omega\Gamma}$$

where ε_∞ is the dielectric constant at high frequency; ε_{FC} and ε_{LV} are the free carriers and lattice contributions; ω_p is the plasma frequency; γ is the plasma damping constant; ω_{TO} and ω_{LO} are the transfer and longitudinal optical phonon frequencies and Γ is the phonon damping constant. Kramers Krönig analysis was used for obtaining a qualitative value of the optical parameters which were then used as a first set of parameters for a better-fitting procedure. In this work a four parameter model, introduced by Gervais and Piriou (5) has been used, where damping factors are separated for both

$$\varepsilon = \varepsilon_\infty - \frac{\varepsilon_\infty \omega_p^2}{\omega^2 + j\gamma\omega} + \varepsilon_\infty \prod_i \frac{\omega_{iLO}^2 - \omega^2 + j\gamma_{iLO}\omega}{\omega_{iTO}^2 - \omega^2 + j\gamma_{iTO}\omega}$$

longitudinal and transverse optical modes.

Theoretical and experimental curves for a typical sample with composition of $InSb_{0.95}As_{0.5}$ are given in Figs. 2 and 3. The full lines represent the theoretical curves which were obtained using the values of the parameters given in Table 1. The experimental values are given with dotted lines. In the same Table are also given

T A B L E 1.

	95%molInSb 5%molInAs	92%molInSb 8%molInAs	InSb-InAs-InBi	InSb Sanderson (6)	InSb Hass and Henvis (5)
$\omega_p (s^{-1})$	$0.153.10^{14}$	$0.155.10^{14}$	$0.154.10^{14}$		
τ (s)	$28.11.10^{-14}$	$36.3.10^{-14}$	$22.4.10^{-14}$		
$\mu_{opt} (m^2/Vs)$	4.474	4.429	4.270	5.005	
m*	$0.011m_o$	$0.014m_o$	$0.009m_o$	$0.0174m_o$	
$\sigma_{opt} (\Omega m)^{-1}$	16392	20550	20248		
$N (m^{-3})$	$2.9.10^{22}$	$2.9.10^{22}$	3.10^{22}	2.10^{22}	
$\lambda_p (\mu m)$	121.2	121.3	121.8		
$\omega_{TO} (cm^{-1})$	185	185	189	179	184.7
$\omega_{LO} (cm^{-1})$	195	196	201		197.2
$\gamma_{TO} (cm^{-1})$	0.3	0.5	6.5		
$\gamma_{LO} (cm^{-1})$	4.0	5	8		

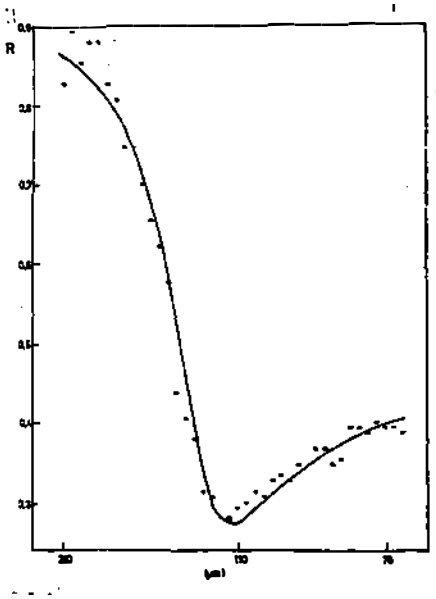

Fig.2. Experimental far infrared reflectivity for $InSb_{0.95}As_{0.5}$ versus wavelength in the plasma range (points). The solid line was calculated using the oscillator parameters given in table 1.

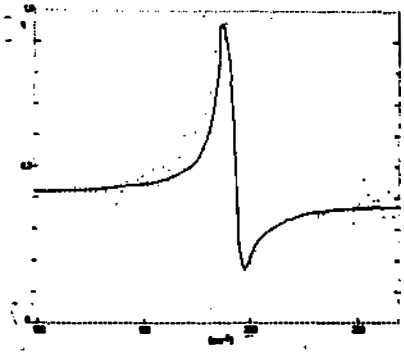

Fig.3.Far infrared reflectivity of $InSb_{0.95}As_{0.5}$ versus wavenumbers in the reststrahlen range. Experimental points and curve obtained using the parameters given in table 1.

the calculated values of the parameter for the samples with 92 mol% InSb and 8 mol% InAs, together with a typical sample of In(SbAsBi) alloy, with a content of 50 mol% In, 41.3 mol% Sb, 6.46 mol% As and 2.26 mol% Bi. Finally, in Table 1 some literature data for pure InSb (5,6) are presented.

It is obvious that the values for optical transfers and longitudinal modes of $InSb_{1-x}As_x$ alloys are similar to those for pure InSb (5). The damping factors of those modes for In(SbAsBi) alloy are much bigger than the equivalent value for $InSb_{1-x}As_x$ alloys. In our opinion this is the consequence of a higher fluctuation of the microsurrounding because various atom couples exist.

The calculated values for the effective mass for $InSb_{1-x}As_x$ alloys are a little bit smaller than for pure InSb and that is in agreement with the literature data (7). The explanation for this is that the change of effective mass follows the decreasing of the energy

gap when the content of InAs is increased in the In(SbAs) alloys. When Bi atoms are added to the studied alloys then the effective mass decreases by almost 50% which means that when alloying In(SbAs) with Bi one should expect a further decrease of the energy gap. This was experimentally confirmed by Bugarinović (8) when the edge of photoconductivity was measured and a value of Eq = 0.078 eV obtained.

Concerning the mechanism of scattering for In(SbAs) and also for In(SbAsBi) alloys one could expect them not to change compared with pure InSb because the obtained values for the optical mobility for the studied alloys are very similar to the known literature data for pure InSb.

In conclusion one can say that In(SbAsBi) alloys can probably be used in making infrared detectors for instance for radiation of CO_2 lasers. This is reasonable to expect because the energy gap and the effective mass for In(SbAsBi) decrease enough so that the limit wavelength is moved sufficiently into the infrared range.

REFERENCES

1. Woolley, J.C. and Smith B.A., 1958, Proc.Soc.London 72, 214.
2. Woolley, J.C., Warner, J., 1964, J.Electrochem. Soc. 111, 1142
3. Woolley, J.C., Warner J., 1964, Canadian Journal of Physics, 42, 1879.
4. Nikolić, P.M., 1967, Proceedings XIth Conf. ETAN, Niš, 383-7.
5. Hass, M., Henvis B.W., 1962, J.Phys.Chem.Solids, 23, 1099.
6. Sanderson, R.B., 1965, J.Phys. Chem. Solids, 26, 803-10.
7. Berolo, O., Woolley, J.C., Van Vechten J.A. 1973, Physical Review B, 8, 3794-9.
8. Bugarinović, Dj. (to be published).