CHAPTER – 4

GENERAL INFORMATION ON InBi

CHAPTER – 4

GENERAL INFORMATION ON InBi

Existence of InBi was first reported by Anosov and Pogodin[1] in 1947, as a berthollide type intermetallic compound. It is one of the three equilibrium phases, occurring at 50 at.% Bi in the In – Bi alloy system (Fig. 1)[2]. It has a narrow homogeneity range[3,4] and does not form solid soultions with either indium or bismuth and thus it is a daltonide phase[5,6]. Subinski[7] has reported InBi as an 'imaginary' chemical compound not existing in pure form and always having an excess of In or Bi. However, Giessen et al[2] had performed quenching experiments to investigate metastable phases in the In- Bi system and revised the earlier phase diagram[3,4]. They found that InBi has a very sharp homogeneity range without any detectable stoichiometric deviation and can be considered as a true compound. Its melting point is $109.0 \pm 0.5\ ^{0}C$[2-4] and its density 8.84 gm cc^{-1} [5,6].

InBi crystal has a tetragonal unit cell in the ditetragonal – bipyramidal point symmetry group (i.e. 4/ mmm), having space group P4/nmm with a = b =5.000 Å and c = 4.773 Å, i.e. c/a = 0.9546[8].

The crystal structure of InBi (Figure.2), contains two InBi molecules per unit cell with In position coordinates (0,0,0) and

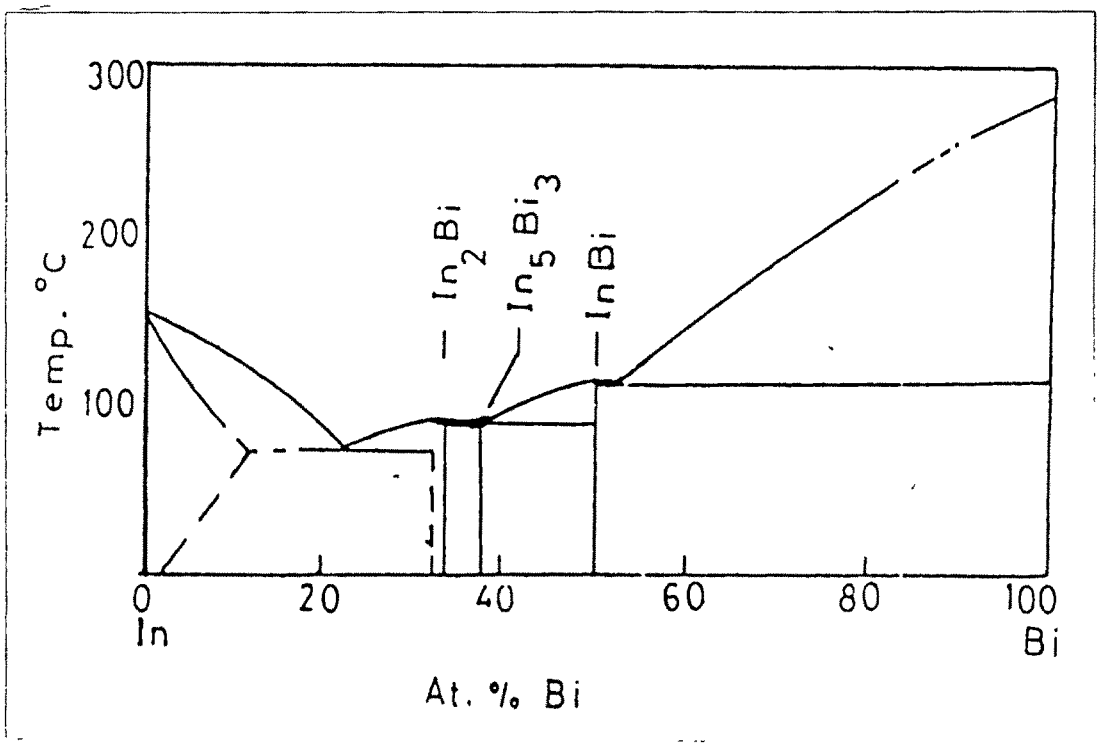

Fig.1

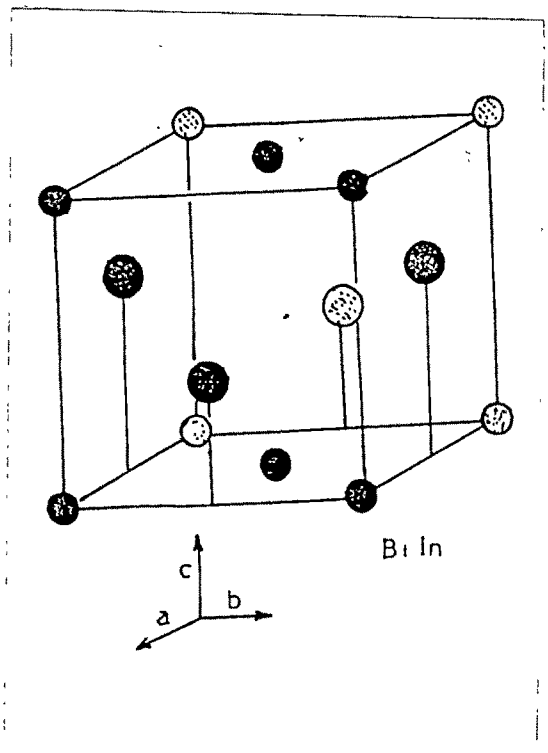

Fig.2

(1/2, 1/2, 0) and Bi coordinates (0, 1/2, Z) and (1/2, O, Z) where Z = 0.393. The interatomic separations are as under.

In ..... Bi = 3.13 Å

Bi ..... Bi = 3.68 Å and

In ..... In = 3.54 Å

Since the position of the bismuth atoms with respect to the c – axis are +1.876 Å and – 1.876Å, two sublayers of Bi exist. Each In layer is in first coordination with the bismuth layer on either side of it and thus the closest spacing of atoms in neighboring bismuth layers is 3.68 Å. This is larger than the spacing of atoms in the adjacent layers of metallic Bi (3.47 Å), so an easy cleavage exits between two bismuth sublayers along (001) plane[9]. The slip systems of InBi single crystals are {110} [001] – primary and {100} [001] – secondary[10].

ELECTROPHYSICAL PROPERTIES OF InBi:

The intermetallic compound InBi behaves as a divalent metal and it is the most diamagnetic material with the magnetic susceptibility ~ - 50 emu/mole at room temperature[11]. Its electrical resistivity is of the order of 10^{-4} ohm-cm[12,13]. Its work function is about 4.15 eV[14] and its Fermi energy is ~ 0.4 eV[15].

The linear compressibility of InBi is highly anisotropic. It has been observed to be a factor of 10 greater in the C direction than in the

C-Plane[16]. Also, at room temperature, the thermal expansion coefficients parallel and perpendicular to the c- axis are, respectively,

$\alpha \sim -80 \times 10^{-6}\ ^{\circ}K^{-1}$

$\alpha \sim +60 \times 10^{-6}\ ^{\circ}K^{-1}$

$\Delta\alpha \sim 140 \times 10^{-6}\ ^{\circ}K^{-1}$

The crystal expands along c-axis and contracts perpendicular to it with decreasing temperature. Hence this intermetallic compound InBi is even more anisotropic than the hexagonal selenium and tellurium.

The elastic stiffness constants of InBi at normal atmospheric pressure, as obtained from the data of Fritz[17], are (in terms of 10^{11} dyne cm^{-2}):

$C_{11} = 5.10$

$C_{12} = 3.75$

$C_{33} = 3.50$

$C_{13} = 3.25$

$C_{44} = 1.98$

$C_{66} = 1.60$

Thus InBi differs widely from the other III – V compounds like GaAs, InSb, GaP etc. in the structural and electrophysical properties.

Fletcher et al[18] have reported Bi precipitates in the InBi crystals grown by the horizontal gradient freeze method. Lal et al[19] have studied conductivity and Seeback coefficient and their temperature dependence in

InBi. Leonov et al[20] have studied the effects of annealing on creep of In – Bi and calculated diffusion coefficients. Powell[21] has studied the tensile strength of [100] filamentary cleavage crystals of InBi. I – V characteristic curves of self oscillation characteristics of In – Bi system have also been studied in its superconducting phase by Chiang et al[22]. Anisotropy of carrier density and its composition dependence in $Bi_{2-x}In_xTe_3$ has been studied by Kutasov et al[23], Horak et al[24] and Pancir et al[25]. Jansa et al[26] have studied reflectivity and transmission of $Bi_{2-x}In_xTe_3$ crystals in infrared region. Horak et al[27,28] studied relation between structure, bonding and nature of point defects in layered crystals of $In_xBi_{2-x}Te_3$. They have also reported work on electrical conductivity, Hall constant, concentration of antisite defects and free carriers. The preparation, characterization and photoelectrode behavior of semiconducting polycrystalline $InBi_2Te_4$ was studied by Subramanian et al[29]. It is interesting to note that because of the low melting point of InBi, it was selected as a member material for the study of the effect of absence of gravity on crystal growth in the experiments conducted by NASA in its Appollo flyback missions and skylab.

REFERENCES :

1. Anosov V.Y. and Pogodin S.A., Fundamentals of Instr. Analysis (Izd AN ASSR), (1947) 423
2. Giessen B.C., Morris M. and Grant N.J. Trance. AIME, 239 (1949) 883
3. Peretti E.A. and Carapella S.C., Trans.ASM, 41 (1949) 947
4. Henry O.H. and Badwick E.L. Trans. AIME, 171 (1947) 389
5. Makarov E.S., Doklady AN ASSR, 59 (1948) 899
6. Makarov E.S., Doklady AN ASSR, 68 (1949) 509
7. Subinski S.A., Dissertation, IONKH AN SSSR, Moscow, (1957)
8. Binnie W.P., Acta Cryst., 9 (1956) 686
9. Walter, H.U., J. Cryst. Growth, 19 (1973) 351
10. Roy U. and Glassco D., J. Cryst. Growth, 16 (1972) 227
11. Setty D.L.R. and Mungurwadi B.D., phys. Rev., 183 (1969) 387
12. Hashimoto K., J. phys. Soc. Jap., 12 (1957) 1423
13. Krivov M.A., Malisov E.V. and Presnov V.A., Sov. Phys. J. (IZV VUZ Fiz. No. 6, (1967) 152)
14. Korol'kov V.A., Malov Y.I. and Markov A.A., Fiz. Met. Metalloved, 40 (1975) 1312
15. Schirber J.E. and Van Dyke J.P., Phys. Rev., B15 (1977) 890
16. Akgoz Y.C., Farley J.M. and Saunders G.A., J. Phys. Chem. Solids, 34 (1973) 141

17. Fritz I.J., Solid State Commun., 20 (1976) 299

18. Fletcher M.A., Young M.S.S., Geyling F.T., Nakahara S. and Parsey J.M., Jr. Metall. Trans. A (USA), A15, 11 (1984) 1963 - 7

19. Lal R.B., Davis J.H. and Walter H.U., Phys. Status Solidi A (Germany), 100 , 2(1987) 583 – 8

20. Leonov V.V. and Bryukhanov A.V., Phys. Chem. Mater. Treat.(U.K.), 21, 3 (1987) 301 – 2

21. Powell B.E., Mater. Lett. (Netherlands), 6 , 10(1988) 356 – 8

22. Chiang Yu. N. and Shevchenko O.G., Fiz. Nizk. Temp. (Ukrainian SSR), 16, 11 (1990) 1398 – 403

23. Kutasov V.A. and Luk'yanova L.N., Sov. Phys. Solid State (USA), 28, 3 (1986) 502 – 3

24. Horak J., Cermak K. and Koudelka L., J. Phys. & Chem. Solids (GB), 47, 8 (1986) 805 – 9

25. Pancir J., Horak J. and Stary Z., Phys. Status Solidi A (East Germany), 103, 2 (1987) 517 – 26

26. Jansa L., Novotny R., Lostak P. and Klikorka, J., Phys. Status Solidi B (East Germany), 146 (1988) K 75 – 80

27. Horak, J., Stary, Z. and Kilkorka, J., Phys. Status Solidi B (East Germany), 147, 2 (1988) 501 – 10

28. Horak, J., Stary, Z. and Matyas, M., J.Solid State Chem. (USA), 93, 2 (1991) 485 – 96

29. Subramanian V., Ramprakash Y., Krishnakumar R., Lakshmanan A.S. and Venkatesan V.K., J. Mater. Sci. Lett. (UK), 7, 12(1988) 1321 –3