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SOLID SOLUTION OF GALLIUM IN ANTIMONY PRODUCED BY RAPID QUENCHING

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Abstract. As part of an investigation of solid solutions of III-V compounds, we studied these solutions prepared by rapid quenching /1/. It has also been reported /2/ that in the InSb system metastable phases having a simple cubic structure can be produced by rapid freezing. Since the phase diagrams of In-Sb and Ga-Sb systems are very similar, we examined the metastable phases obtained by rapid quenching in Ga-Sb. While a new metastable simple phase was not detected in this system, the solid solubility of Ga in Sb has been observed. Namely from the lattice parameter of rapidly quenched alloys we deduce that up to 7 at% Ga is in solid solution in Sb. In the equlibrium structure Ga is practically not soluble in Sb /3/.

1. Introduction

In a search for the ordering of the semiconductor alloys of III-V compounds, we have turned our attention to the GaSb-InSb system, and we showed earlier /1/ that single phase GaSb-InSb solid solutions can easily be prepared by very rapid solidification.

Using the same technique, i.e. by rapid cooling from the melt, a single phase simple cubic structure (one atom per unit cell) has been obtained in the In-Sb system /2/. As the phase diagrams of Ga-Sb and In-Sb are similar, it seemed to us that a similar phase could be produced in the Ga-Sb system by rapid freezing. The purpose of this paper is to record evidence of metastable phases in the Ga-Sb system, obtained using the technique of the fast quenching from the melt.

3. Experimental procedure

The ingots of master alloys of the two compositions, Ga-68 at.% Sb and Ga-88 at.% Sb were prepared by direct synthesis of pure elements (Ga: 5N, Sb: 6N) in an evacuated silica tube. The ingots were then crushed into fine powders and used in the second step of preparation - the quenching.

About 1 g of powders were used in each quenching experiment. Details of the method used (the two-piston quenching technique) were described earlier /4/. Cooling rates of about 10^7 K/s can be achieved by this method /5/. In the present experiment the melt was quenched from about 750 ^{o}C.

Quenched samples, obtained in the form of very fine flakes, were examined by means of a Nonius Guinier-de Wolf quadruple focusing camera with crystal-monochromated Cu K radiation from a tube operated at 35 KV and 16 mA, and exposure times ranged from 6 to 10 hours. X-ray diffraction patterns of quenched samples of Ga-68 at.% Sb and Ga-88 at.% Sb, and of the stable phases of identical concentrations, were detected on the same film. No new line appeared on the patterns of the rapid quenched phases. Comparing the patterns of the rapid quenched phases with those of the stable phases of identical concentrations, the shift of Sb lines towards bigger angles was evident. This indicated the solubility of Ga in Sb. As the lattice parameter of the intermetallic compounds GaSb is precisely determined (a=0.609612 nm) /6/ we used the GaSb diffraction lines as internal standard to calculate the lattice parameters of SbGa solid solutions, and thus the concentrations of Ga in Sb by means of Vegard´s law.

3. Results and discussion

Although the phase diagrams of In-Sb and Ga-Sb are similar, the metastable phases obtained by rapid quenching from the melt are different. Patterns taken from the rapidly frozen alloys in In-Sb system showed no change from the equilibrium structures at 28 and 50 at.% Sb, but at 58 at.% Sb a pattern which could be indexed as a simple cubic lattice was found together with the pattern of InSb, and at 69 at.% Sb the pattern obtained was entirely that attributed to a simple cubic lattice. At 79 and 89 at.% Sb the pattern again showed the same phases in both normally frozen and rapidly frozen alloys, but a small shift in the spacing of the Sb lines appeared, but a small shift in the specing of the Sb lines appeared, indicating that some solid solution of In in Sb may have been produced by the rapid quenching /2/.

A concentration of 69 at.% Sb corresponds approximately to the eutectic concentration in the system InSb-Sb. Thus we chose the corresponding eutectic concentration (88 at.% Sb) in the GaSb - Sb system, expecting similar results of quenching in GaSb as in InSb system. However, no new metastable simple phase was detected in the GaSb system, but some solid solution of Ga in Sb has been produced by the rapid quenching.

The quantitative investigation gave the parameters of both (88 at.% Sb and 68 at.% Sb) SbGa solid solutions to be a=0.4200 nm, c=11.273 nm, i.e. at both concentrations the same amount of Ga is in solution.

Although Vegard's law, the expected linear dependence on composition of lattice spacing trends, is never quite true in metallic systems, nevertheless we attempted to observe trends in lattice--spacing versus composition curve in the Ga-Sb system. In Fig.1 are plotted the calculated mean atomic volumes (V_{at}) given by Vegard's law and actual atomic volume of SbGa solid solution. From this figure follows that about 7 at.% Ga is in solution.

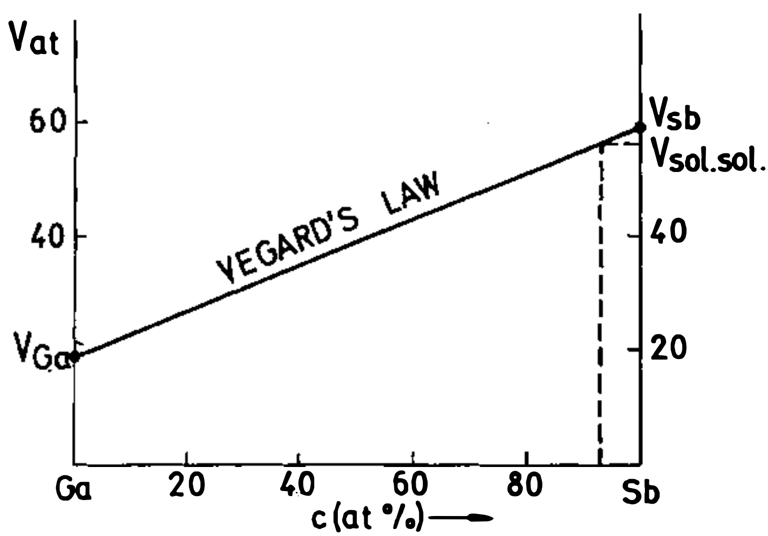

Fig.1: V_{at} - mean atomic volumes
V_{Ga} - mean atomic volume of gallium
V_{Sb} - mean atomic volume of antimony
$V_{sol.sol.}$ - mean atomic volume of solid solution Sb-Ga.

References

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