SOLUBILITY LIMIT OF Ni
IN $Cd_{1-x}Ni_x$Te CRYSTALS

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The $Cd_{1-x}Ni_x$Te crystals were grown by the Bridgman method. The investigated samples were cut from five different ingots with nominal contents of nickel varied from 0.005 to 0.05. The investigations were performed using X-ray powder diffraction method and energy dispersive and wavelength dispersive electron microprobe analysis. The samples were also examined in a scanning electron microscope. Examinations of wavelength dispersive electron microprobe analysis show that the actual contents of nickel differ from the nominal values. The solubility limit of nickel was determined to be $x = 0.005$. The precipitates of NiTe were found in samples of a greater content of nickel. Their dimensions were between 5 to 90 micrometers. X-ray powder diffraction measurements did not reveal any significant change of the lattice constant of investigated crystals in comparison with pure CdTe.

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1. Introduction

Most of the recent studies on II–VI diluted magnetic semiconductors (DMSs) have mainly dealt with Mn so far, which can be incorporated over a large compositions range [1]. The solubility limits for other transition metal ions (TMIs) such as Fe and Co are far below the solubility of Mn [2]. As in the case of Mn, it is a great interest to establish the electronic level structure of other TMIs such as Sc, Ti, V and Cr in II–VI DMSs. The electron paramagnetic resonance and photoluminescence measurements made on vanadium doped CdTe have recently been published [3]. The observations on the infrared absorption lines associated with the localized modes of Ti, Cr, Fe and Co in CdTe and ZnTe have also been reported [4]. However, the localized vibration of Ni in CdTe could not be observed probably due to its low concentration.

In view of the above, we have initiated a systematic study on the incorporation of Ni into CdTe crystals grown from the melt.

2. Crystal growing

$Cd_{1-x}Ni_x$Te crystals were grown by the Bridgman method. The material was grown in a pretreated 18 mm of diameter and 10 cm long fused quartz ampoule coated with a carbon layer to prevent sticking problem and to avoid reaction of melt with quartz. The CdTe and 5N purity of grade Ni were used as starting material. The CdTe was synthesized from 6N Cd and 6N Te, which were already purified further by repeated sublimation under dynamic vacuum of an order of 10^{-6} torr. The stoichiometric mixture of CdTe and Ni was heated up at a rate of 100°C/h to 1150°C and then allowed to homogenize in the molten state for 24 hours. During this stage of the process the charge was held in a temperature gradient of 10°C/cm. Afterwards, the position of the ampoule was changed to reach a temperature gradient of 40°C for further growth. Solidification was achieved by moving the furnace up at a rate of 1 mm/h while the ampoule was kept stationary.

3. Measurements

The composition of the samples was examined using the energy dispersive (ED) and wavelength dispersive (WD) microanalysis, which was performed using a JEOL JXA-50A scanning electron microscope (EPMA) equipped with an automated LINK system. The measurements were done every two millimeters along diameter of the samples. Additionally, the observations included backscattered electrons image in atomic number contrast mode (COMPO) and X-ray area scan mapping of distributions of characteristic X-ray lines for precipitates observations. The X-ray diffraction patterns were obtained by the powders with an automated DRON diffractometer and interpreted using DHN-PDS and SCANIX packages.

4. Results

The results of ED EPMA and WD EPMA measurements given in Table show that the actual Ni contents are lower than the nominal ones in all investigated samples. Those discrepancies are caused by segregation of Ni during the growth process as well as they are related to formation of NiTe precipitates in the solid solution. The NiTe precipitates of circular shapes with dimensions in a range of 5–90 micrometers were seen on scanning electron microscope (using atomic number contrast mode) image picture. Those precipitates were observed at all crystallographic planes of the samples, which indicates that they are probably spheres in three-dimensional view. The quantity of the precipitates was so small that they could not be detected as a second phase by the X-ray powder diffraction method. X-ray diffraction measurements did not reveal any significant differences in the lattice constant in comparison with the value which was observed for pure CdTe. It seems that X-ray powder diffraction is suitable to detect the lattice constant changes in both $Cd_{1-x}Ni_x$Se and $Cd_{1-x}Ni_x$Te when x exceeds an approximate value of 0.025 [5].

Optical absorption studies have provided definite evidence of Ni substitutional incorporation in CdTe as electronic and phonon assisted transitions have

TABLE

Composition analysis of $Cd_{1-x}Ni_xTe$ crystals.

Sample	Ni content [x]		Precipitate dimensions [μm]	Lattice constant a [Å]
	nominal	actual		
P 341	0.005	0.004 ± 0.001	not observed	6.480 ± 0.001
P 429	0.01	0.003 ± 0.001	10–50	6.481 ± 0.001
P 466	0.01	0.003 ± 0.001	5–50	6.482 ± 0.001
P 430	0.03	0.005 ± 0.001	5–50	6.481 ± 0.001
P 384	0.05	0.004 ± 0.001	5–90	6.479 ± 0.001
CdTe-pure	–	–	–	6.481 ± 0.001

been observed. The details of the measurements and their interpretation will be described elsewhere [6].

5. Conclusions

On the basis of the applied methods and the results obtained, it may be concluded that Ni atoms substitute Cd atoms in $Cd_{1-x}Ni_xTe$ alloy for $x \leq 0.005$. For higher Ni contents, NiTe precipitates of dimensions varied in a range of 5–90 μm were observed. It should be also pointed out that the solubility limit of Ni in $Cd_{1-x}Ni_xTe$ is lower than that in the $Cd_{1-x}Ni_xSe$ alloy [5]. The variations of lattice constant within the range of observed solubility limit are comparable with an experimental error. Therefore, the lattice constant variations of the $Cd_{1-x}Ni_xTe$ crystals could not be investigated conclusively with this method.

Acknowledgment

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