Determination of Indium Concentration in GaAs : In Semiconductor by PIXE

II. 5. Determination of Indium Concentration in GaAs : In Semiconductor by PIXE

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Introduction

Impurity doping is often used for control of the various properties of semiconductor materials. For example, indium impurity is known to be effective for the improvement of crystal perfection Usually, the concentration of impurity is determined satisfactorily by wet chemistry and ICP.

Recently, Liu et. al.[1] studied the determination of dopant elements in GaAs by NAA, where they have to remove as so as to measure the radioactivity after the chemical decomposition. Though high detection limits in an order of ppb was achieved in NAA for some elements, NAA is not a rapid determination method.

In the present paper, we report the non-destructive determination of the trace concentration of In impurity doped in GaAs crystal by PIXE method.

Experimental

GaAs: In semiconductors crystals were provided by Sumitomo Electric Industry Ltd. and Mitsubishi Monsanto Chemical Company. Plates of 0.3 mm thickness were cut by a diamond cutter from the crystals and were polished with a reagent of $3H_2SO_4$: $1H_2O_2$: $1H_2O$ at 70 - 80 °C following mechanical polishing. The plate was used as a self-supporting target pasting on the aluminum frame.

In the case of powder target, several milligrams of GaAs : In crystal were ground into the fine powder using an agate pestle and mortar. The target was prepared by scattering a few milligram of GaAs : In powder onto 10 mm Mylar film and using a drop of 0.1 ml of polyvinyl acetate diluted with acetone as adhesive.

3 MeV proton from 40 MeV AVF cyclotron, Tohoku University Cyclotron Radioisotope Center, was used as a bombardment particle and 100 mm Mylar film with 50 mm copper foil was inserted as the absorber in the front of Si (Li) detector.

Results and Discussion

The large X-ray peaks emitted from Ga and As matrix appear in the central region of X-ray spectrum. They make it difficult to measure X-ray from In which is in very low concentration and which has the low X-ray production cross-section compared to the matrix elements. Thus, in the present work, the copper absorber was used to decrease the X-rays from the matrix. Fig.1 shows the X-rays spectrum obtained from GaAs: In with the copper absorber. Though, while X-rays from the matrix elements decrease, the Cu K_α and K_β X-rays excited by scattered proton appeared, the X-ray peaks from In were apparently observed.

The spectrum was mainly analyzed by the computer program of EMCA (Seiko Co.). As seen in Fig.1, GaK_β and AsK_α X-rays were in the doublet which was separated by PESCAL 5 program which is composed of the Gaussian fitting.

Fig.2 shows the linear relationship between the ratios of $InK_\alpha/(GaK_\beta+AsK_\alpha)$ and the concentration of In for GaAs: In crystal, where the concentrations of In were separately determined by the usual method of wet chemistry and ICP. The concentration of In in the range from 0.1 to 0.01 wt.% in GaAs: In matrix was possible to determine by PIXE.

In Fig.2, the powder targets were employed to eliminate the channeling effect in measurements. Table 1 shows the concentration of In determined in the plate target of GaAs:In crystal in comparison with that using the powder target of crystal. Since the ratios of $InK_\alpha/(GaK_\beta+AsK_\alpha)$ observed in both types of targets were identical, the channeling effects are not essential in these experimental conditions.

Thus, we conclude that using a plate target of crystal, the concentration of impurity in GaAs can be determined non-destructively.

The authors acknowledge Mr. Junji Iihara for his guide to PESCAL 5 program.

Reference

1) R. S. Liu., P. Y. Chen., Z. B. Alfassi. et al., J. Radioanal. Nucl. Chem. Articles **141** (1990) 317.

Table 1. The concentration of In determined in the plate target of GaAs:In crystal in comparison with that using the powder target of crystal.

	E1031		E1032	
	GaAsIn-powder		GaAsIn-plate	
	PESCAL5	EMCA	PESCAL5	EMCA
GaK β	761		1,330	
AsK α	3,343		4,035	
AsK β	5,181	5,184	6,967	6,948
InK α	2,109	2,087	3,039	2,926
InK β		547		594
AsK α +GaK β		4,001		5,195
InK α /AsK β	0.407	0.402	0.436	0.421
InK α /GaK β	2.770		2.285	
InK α /AsK α +GaK β		0.521		0.563

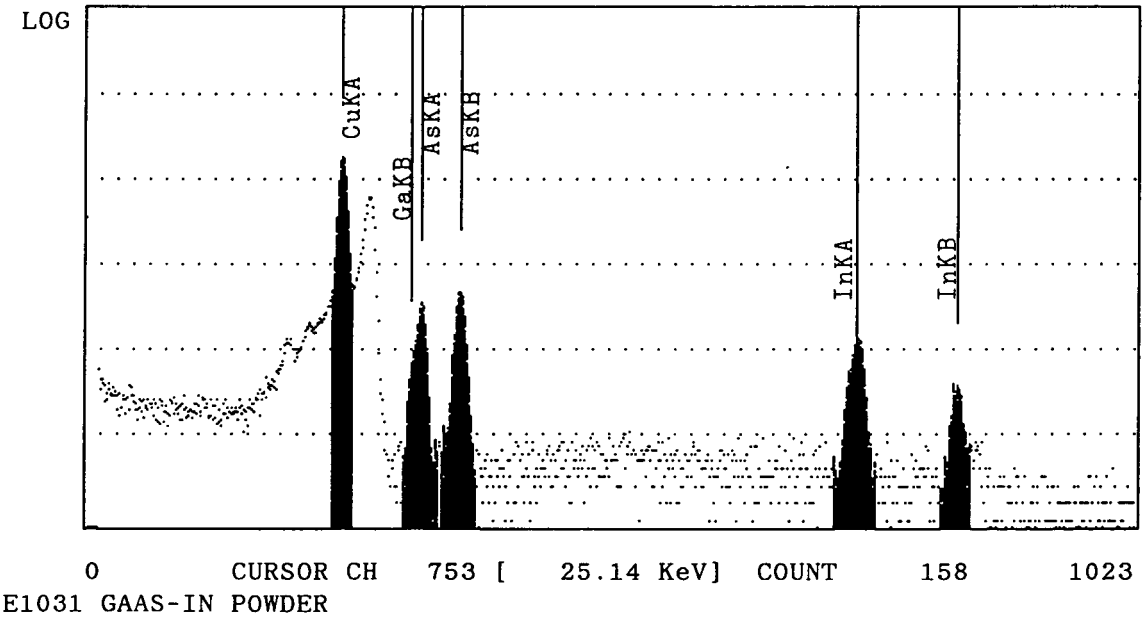

Fig. 1. X-ray spectrum of GaAs: In semiconductor using copper absorber.

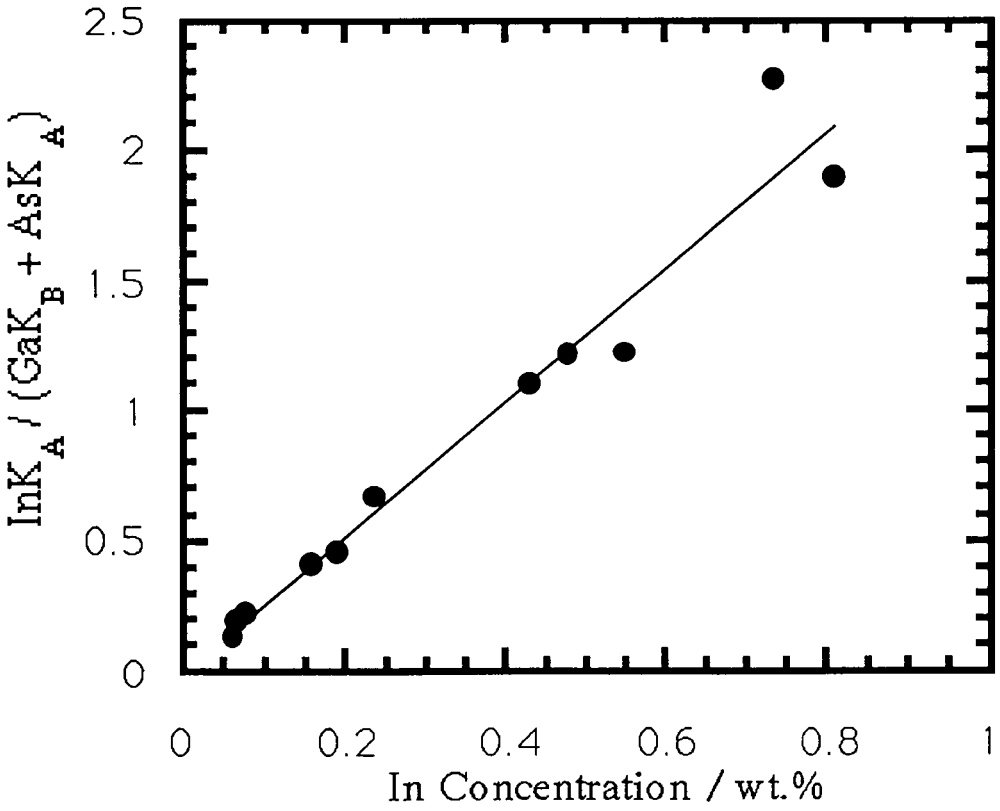

Fig. 2. Determination of In concentration in GaAs semiconductor by PIXE.