QUANTITATIVE ANALYSIS OF GaAlAs COMPOSITION AND ITS DOPANT CONCENTRATION BY Cs CLUSTER ION MASS SPECTROMETRY

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Abstract Quantitative analysis of GaAlAs composition and its dopant (Mg) concentration has been developed using Cs cluster ions for SIMS (secondary ion mass spectrometry). The ratio of AlCs^+ ion intensity to an AsCs^+ ion increased linearly, and the relative sensitivity factor of a $^{24}\text{MgCs}^+$ ion to an AsCs^+ ion showed a constant value with increasing the $\text{Ga}(1-x)\text{Al}(x)\text{As}$ composition x . We can determine an unknown GaAlAs composition and Mg concentration with good precision and sensitivity by detecting Cs cluster ions.

Key Words SIMS, GaAlAs, Mg, Cs cluster ion

INTRODUCTION

It is said that a primary O_2 ion beam in SIMS analysis causes the matrix effect in the quantitative analysis of GaAlAs composition and its dopant concentration. The use of Cs ions as a primary beam decreases this matrix effect, but it also decreases the ionization coefficient for positive charged ions. Gao[1] and Magee et al. [2] showed that no matrix effect is caused when measuring Cs cluster ions made of Cs ions re-emitted from the sample surface and combined with sputtered neutral atoms. This study reports the sensitivity variation of the Cs cluster ions from a series of ^{24}Mg ion implanted $\text{Ga}(1-x)\text{Al}(x)\text{As}$ compounds ranging from $x=0.0$ to 1.0.

EXPERIMENT

A GaAs substrate and $\text{Ga}(1-x)\text{Al}(x)\text{As}$ films (2 μm) on the GaAs substrates were used in this study. The $\text{Ga}(1-x)\text{Al}(x)\text{As}$ composition x , 0.326, 0.524, 0.739, and 1.0, was determined by measuring the lattice constant with a double crystal X-ray diffractometer[3]. ^{24}Mg ions with an accelerated energy of 190 KeV and a dose of $9.4 \times 10^{14}/\text{cm}^2$ were implanted into all the samples except $x=1.0$. The measurements of Cs cluster ions ($^{69}\text{GaCs}^+$, AlCs^+ , AsCs^+ , $^{24}\text{MgCs}^+$) were carried out with a CAMECA IMS-4f SIMS using Cs ions with a primary energy of 5.5 KeV and a current of 10 nA.

RESULT & DISCUSSION

The ratio of the AlCs^+ ion intensity to AsCs^+ increased linearly against the GaAlAs composition x , as in Fig.1. Using this relation, we can determine an unknown composition of GaAlAs accurately by measuring the AlCs^+ and AsCs^+ ion intensities. The linearity of the calibration line indicates that the AlCs^+ ion intensity is not affected by the matrix effect because AsCs^+ ion intensity normalized by the sputtering rate (monolayer/sec) shows a constant value with changing x .

The relative sensitivity factor of a $^{24}\text{MgCs}^+$ ion to an AsCs^+ ion, $S_{\text{As}}(^{24}\text{Mg})$, was calculated by Eq. (1) [4], and these values are plotted against the $\text{Ga}(1-x)\text{Al}(x)\text{As}$ composition x in Fig.2.

$$S_{\text{As}}(^{24}\text{Mg}) = \frac{I(^{24}\text{Mg})/C(^{24}\text{Mg})}{I(\text{As})/C(\text{As})} = \frac{4 \cdot I(^{24}\text{Mg}) \cdot \text{Depth}}{I(\text{As}) \cdot \text{Dose} \cdot \text{LC}^3} \quad (1)$$

where 'I' and 'C' indicate the Cs cluster ion intensity and the concentration of each element, respectively, 'Depth' is the depth of the sputtered crater, 'Dose' is the dose of implanted ^{24}Mg ion, 'LC' is the lattice constant of GaAlAs, and '4' is the number of As atoms in a unit cell of GaAlAs. This sensitivity factor showed a constant value with changing x. This result reveals that the $^{24}\text{MgCs}^+$ ion intensity is also not affected by the matrix effect. This means that we can evaluate the Mg concentration by measuring only one Mg implanted standard sample, even if the GaAlAs composition varies within the sample.

The detection limit of Mg concentration in GaAlAs using a $^{24}\text{MgCs}^+$ ion was of the order of 10^{15} atoms/cm³, which shows a better sensitivity than that for $^{24}\text{Mg}^+$ ion detection under Cs ion bombardment.

Fig. 1 Variation of ion intensity ratios against GaAlAs composition x (AlCs⁺ ion intensity to AsCs⁺ and ⁶⁹GaCs⁺ to AsCs⁺)

Fig. 2 Variation of relative sensitivity factor of $^{24}\text{MgCs}^+$ ion to AsCs⁺ ion against GaAlAs composition x

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