Molecular Beam Deposition of Low-Resistance Polycrystalline GaAs

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Heavy doping of polycrystalline GaAs (poly-GaAs) with Be is investigated using low-temperature molecular beam deposition. A polycrystal grain size of 50–180 nm, which is appropriate for microfabrication, is obtained at a deposition temperature of 370–530°C. The resistivity of poly-GaAs decreases rapidly with increasing doping level \( N_A \), and it becomes in reverse ratio to \( N_A \) when \( N_A > 2 \times 10^{20} \text{ cm}^{-3} \). Low deposition temperature and high As$_4$ pressure are also found to be effective in reducing resistivity. The minimum resistivity reported to date of $3.3 \times 10^{-3}$ Ω·cm is achieved for Be-doped poly-GaAs with a grain size of 120 nm. These results show that the present poly-GaAs is very promising for applications to compound semiconductor devices.

**Key words:** Be, GaAs, grain size, molecular beam deposition, polycrystal, resistivity

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**INTRODUCTION**

Low-resistance polycrystalline GaAs (poly-GaAs) would have a great impact on compound semiconductor devices by analogy with polycrystalline Si in Si technology. For example, if poly-GaAs can be used for base electrode of AlGaAs/GaAs heterojunction bipolar transistors (HBTs), one-dimensional transistor structure, which is known as SICOS (sidewall base contact structure) for Si bipolar transistors, is expected to be realized by burning SiO$_2$ in the extrinsic collector. However, due to the difficulty of achieving low resistivity, successful application of poly-GaAs has been limited to isolation of planar GaAs devices, such as mixer diodes, laser diodes, and metal-semiconductor field effect transistors.

In order to reduce the resistivity of poly-GaAs, Yang et al. investigated the electrical properties of poly-GaAs using metalorganic chemical vapor deposition. They found that the resistivity decreased with increasing doping level, and they achieved a resistivity of $8 \times 10^{-8}$ Ω·cm at a Zn doping level of $2 \times 10^{19}$ cm$^{-3}$. However, there arise two problems when their results are applied to fabrication of electronic devices. The first is that the grain size of poly-GaAs they obtained was 2–5 μm, which is too large for microfabrication. This large grain size is attributed to the high deposition temperature of 725°C. The second is that the Zn doping level cannot be increased further due to its low sticking coefficient.

The purpose of this work is to realize poly-GaAs with a small grain size (<0.2 μm) and low resistivity (<1 x 10$^{-2}$ Ω·cm) for the application of poly-GaAs to base electrode of AlGaAs/GaAs HBTs. Low-temperature molecular beam deposition is used in order to reduce the grain size of poly-GaAs, and heavy doping of poly-GaAs with Be, whose sticking coefficient is unity, is investigated for the further reduction of the resistivity.

**EXPERIMENTAL**

Poly-GaAs was deposited on (100) GaAs substrates coated with 400 nm thick SiO$_2$ using conventional molecular beam epitaxy apparatus. The deposition
RESULTS AND DISCUSSION

Electrical Properties of Poly-GaAs

The dependence of the resistivity of poly-GaAs on the p-type doping level is shown in Fig. 1. The triangles are the results of Zn-doped poly-GaAs deposited at 725°C by Yang et al. and the circles are the present results of Be-doped polycrystalline GaAs with a grain size of about 0.1 μm deposited at 450°C. 

The resistivity of poly-GaAs was determined by the van der Pauw method. The alloying temperature of In electrodes was 350°C, which was lower than T_d. Thus, the resistivity change during the alloying is considered negligible. Structural analysis of poly-GaAs was made by scanning and transmission electron microscopes whose acceleration voltages were respectively 5 and 300 kV. X-ray diffraction with Cu Kα radiation was also used to evaluate the distribution of crystallographic orientations of poly-GaAs. For x-ray