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Study of high background doping in p-type GaAsN grown by chemical beam epitaxy

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I. ABSTRACT

The properties of acceptor states in GaAsN crystal are studied based on the changes of carrier concentration and temperature dependence of the junction capacitance due to annealing. The acceptor state, obtained at 0.165 eV above the valence band maximum (VBM), is responsible for the high background doping in unintentionally doped film, since its concentration has a good relationship with the carrier concentration. The energy level comes closer to the (VBM) with annealing time. Therefore, this defect is not thermally stable and its structure and electrical properties change by the annealing.

II. INTRODUCTION

GaAsN alloy is a potential material for fabricating ultra-high efficiency multi-junction solar cell, aiming to achieve an efficiency of more than 40% under air mass zero (AM0) radiation. One of the serious problems, that decreases the conversion efficiency of GaAsN based solar cell, is attributed to the high carrier concentration in undoped films. The reason of this high background doping is the formation of high density acceptor defects. In this work, we will study the properties of acceptors in GaAsN and show the change of their energy levels and densities with annealing. After that, their relationship with the carrier concentration at room temperature will be discussed.

III. EXPERIMENTAL PROCEDURE

GaAsN films were grown on p-type GaAs [001] 2° off toward [110] substrates by chemical beam epitaxy (CBE). The detail of this growth method is described elsewhere. After the growth, the samples were annealed under N_2 atmosphere. The annealing times were from 1 to 40 min at 500°C. The as-grown and annealed films showed the p-type conductivity.

IV. RESULTS AND DISCUSSIONS

The density of the acceptor state was calculated based on the difference between the junction capacitance before and after its thermal ionization. The densities of the acceptor state in as-grown and annealed samples are summarized. Since $N_{Acceptor}$ in the as-grown sample increases significantly with annealing time, this acceptor is expected to be responsible of an increase of carrier concentration.

The carrier concentration, N_A, at room temperature was calculated from C−V characteristic and its change upon annealing treatments is shown in Fig. 1. By comparing the calculated N_A (taking into account the density of acceptor) with that from the CV measurement (Fig. 1), we found that the acceptor density affect in great part the ionized acceptor density in the film.

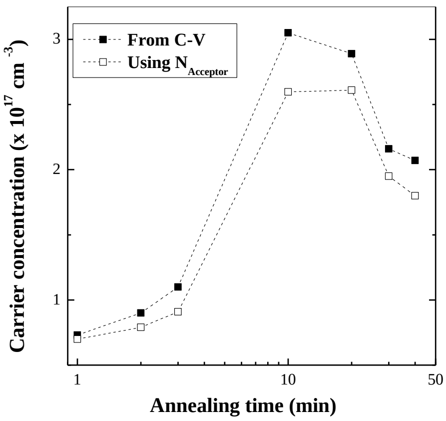

FIG. 1. Annealing time dependence of N_A obtained by C-V measurement and using $N_{Acceptor}$

V. CONCLUSION

The acceptor state, located at 0.165 eV above the VBM of GaAsN, is mainly responsible for the high background doping in unintentionally doped GaAsN. Its energy level comes closer to the VBM with annealing time. Therefore, this defect is not thermally stable and its structure and electrical properties change by the annealing.

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