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LATTICE DEFECTS IN QUENCHED p-TYPE GaAs

S. Marić and M. Stojić
Institute of Physics, Faculty of Science, Sarajevo
"Boris Kidrič" Institute of Nuclear Sciences, Belgrade

Abstract: Thermal defects in p-type GaAs (free carrier concentration 2.2×10^{16} cm^{-3}) have been studied. Defects created by quenching from temperatures below 790 K, with formation energy of E_F^A=(0.6-0.8)eV, act as acceptors. By quenching from temperatures above 790 K thermal defects are donors with the formation energy of E_F^D=1.5eV. The acceptors induced below 790 K are considered as Cd atoms rearranged in crystals during the heating. Donors are explained as vacancy-impurity complex having different electrical activities in p-type GaAs (donor) and n-type GaAs (acceptors).

1. Introduction

Physical properties of III-V semiconductors, particularly of GaAs, have been studied extensively because of their application which increases rapidly. However, the effects of lattice defects on the properties of GaAs are far less known. For example, there are various explanations for the influence of Ga vacancies and As vacancies on the electrical properties, which are often considered to be acceptors or donors[1,2,3]. Because of such an uncertainty and having in mind how important it is to know the real nature of defects we have taken the study of thermal defects in p-type GaAs as the aim of the present work.

2. Experiment

Single-crystals of Cd doped p-type GaAs (free carrier concentration 2.2×10^{16} cm^{-3}) have been used in this work. The specimens of rectangular shape (18x2x1 mm^3) have been prepared by standard technique (mechanical polishing and etching by solution of H_2O: 30%H_2O_2:conc.H_2SO_4=1:1:3). The same quenching procedure and measuring technique have been used as in the case of n-type GaAs (4). To prevent sample contamination during thermal treating the heating was performed in high vacuum (better than 10^{-6} mmHg). The maximum quenching temperature was

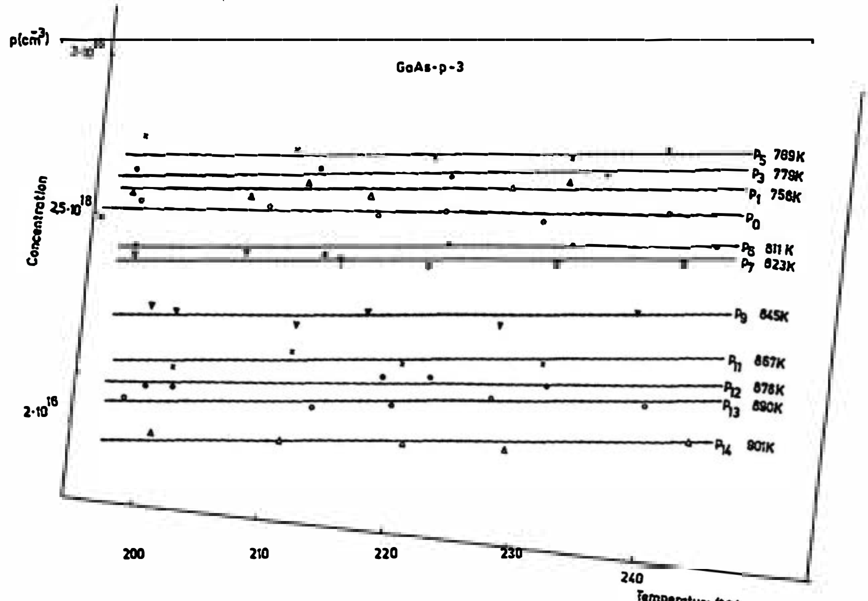

Fig. 1. The concentration of free carriers as a function of measuring temperature for various quenching temperatures.

900 K, a few degrees below the decomposition temperature of GaAs (910 K).

3. Results

From Fig. 1 it is clear that the concentration of free carriers increases with increasing the quenching temperature up to 790 K. Above this temperature the concentration of free carriers decreases.

The concentration of thermally induced defects, assumed to be equal with the change in free carrier concentration, as a function of reciprocal quenching temperature, T_q^{-1}, is shown in Fig. 2.

From the slopes of these curves the formation energies of thermal defects have been determined. For donor-like defects induced

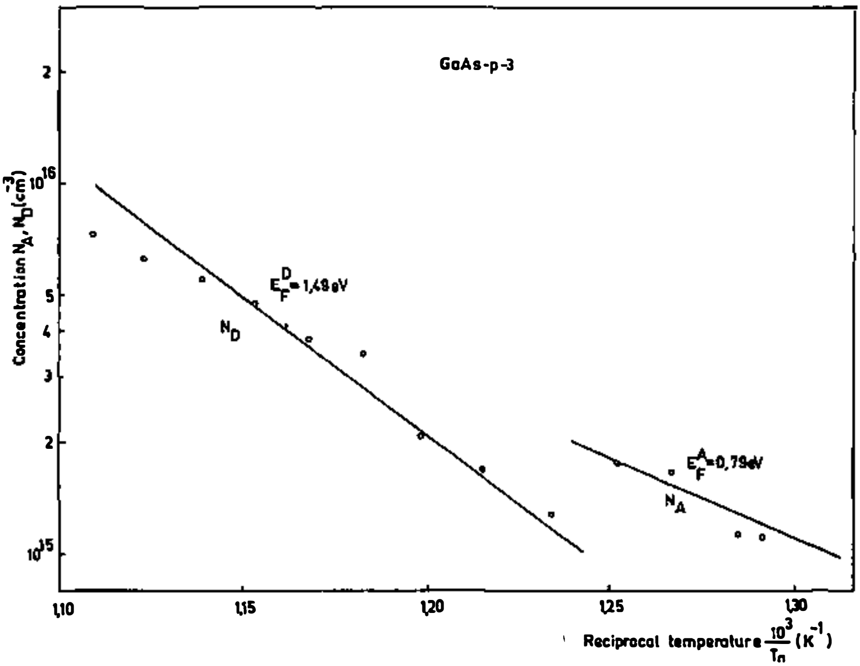

Fig. 2. The equilibrium concentration of thermal acceptors and donors as a function of quenching temperature.

by quenching above 790 K the formation energy is determined as E_F^D=1.50±0.1 eV, and acceptor-like defects created below 790 K is estimated as E_F^A=0.6–0.8 eV.

The isochronal annealing of quenched samples has been performed in the temperature range of 650–780 K and three annealing stages have been discovered. These results are shown in Fig. 3 and they are nearly the same for the quenched n-type GaAs obtained earlier[5].

4. Conclusions

According to the experimental results above, concerning the lattice defects study in quenched p-type GaAs, the following conclusions can be drawn.

By quenching of GaAs from temperatures of 750-900 K, nearly equal concentrations of defects are induced in both n-type and p-type GaAs (10^{14}-10^{15} cm^{-3}).

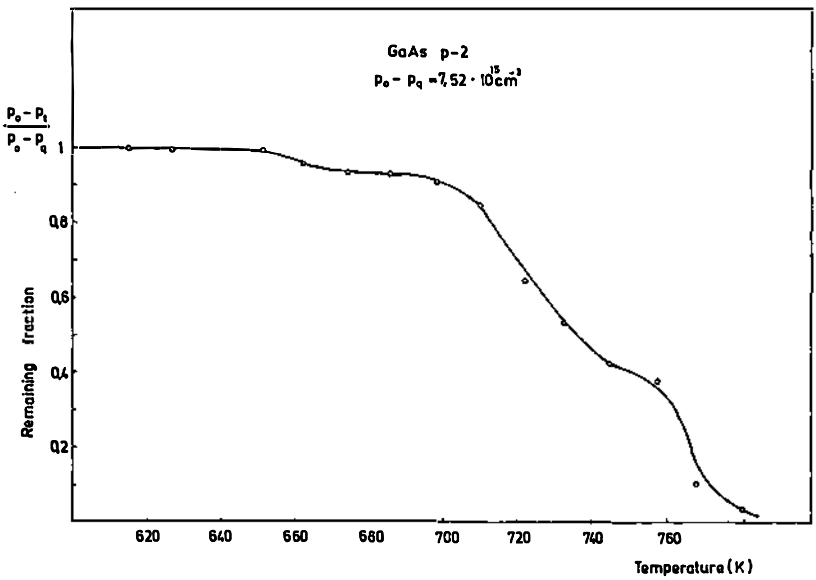

Fig. 3. Remaining fraction of defects-$(p_o-p_t)/(p_o-p_q)$ plotted versus annealing temperature where p_o is the initial concentration of carriers, p_q-conc. after quenching, and p_t-conc. after each cycle of annealing. Time interval was 10 min.

Quenching of p-type GaAs from temperatures below 790 K results in acceptor-like defects formation with the formation energy estimated to be 0.6-0.8 eV. Such a low formation energy suggests that the increasing of acceptor concentration is due to the certain ordering of the crystals during the heating. Probably atoms of Cd, which was the main impurity introduced during the crystal growth, are replaced from electrical inactive to the active places becoming acceptors.

Above 790 K it was established that the donor-like defects are formed. Their formation energy of E_F^D=1.50 eV is comparable to formation energy of acceptors in quenched n-type GaAs. These values and the annealing data support the idea that in p-type and n-type GaAs the same defects are created such as vacancy-impurity complex which are different in electrical activity. They are donors in p-type GaAs and acceptors in n-type GaAs.

5. References

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