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Damage buildup and recovery in III–V compound semiconductors at low temperatures

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Abstract

Results are presented of the RBS/channeling study of the structural defect behavior in ion bombarded $In_xGa_{1-x}As_yP_{1-y}$ ($0 \leqslant x, y \leqslant 1$) compounds at temperatures ranging from 15 K (LT) to 300 K (RT). Experiments consisted of implantation with different ions to fluences ranging from 4×10^{13} to 5×10^{15} at./cm^2 at different temperatures followed by in situ RBS/channeling measurements. Successive measurements of LT implanted samples were performed during warming up to RT.

Broad recovery stage beginning at 100 K for all compounds was revealed. It was attributed to the defect mobility in the group III sublattice. Steep damage buildup up to amorphisation with increasing ion dose was observed. The defect production efficiency is much higher at LT than at RT. The consequences of defect mobility at RT for ion implanted semiconductor structures are discussed.

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Keywords: III–V semiconductor compounds; Defects; Ion implantation; RBS/channeling

1. Introduction

Modification of semiconductor properties by ion implantation is a well-established technological process. For structures based on compound semiconductors it is used for introducing active doping, compositional mixing of quantum wells

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and formation of isolation regions in electronic devices. Point defects and their complexes determine optical and electrical properties of semiconductors, diffusion of impurities as well as the recovery of crystalline lattice after ion bombardment and subsequent annealing.

Broad recovery stage at low temperatures exists for III–V semiconductor compounds [1–5]. It is located between 100 K and 400 K and is attributed to the recombination or reconfiguration of a variety of defects with different activation energy. Thus, the investigation of thermally activated processes can be decisive for identification of defects. On the other hand defect mobility at RT can lead to important effect transformation after RT implantation and subsequent storage. Hence, structure and distribution of radiation defects are of great scientific and technological interest and their reproducible control is crucial for electrical and structural properties of implanted materials.

In this paper we review the results of the study of defect buildup and recovery in arsenide and phosphide semiconductor compounds after ion implantation at temperatures below 50 K and subsequent warming up to RT. This process was monitored by in situ RBS/channeling measurements. Since the main objective of this work was to elucidate the properties of point defects and their complexes light ion bombardment was applied. Light ions produce principally diluted binary collision cascades and are well suited for the study of simple defects.

2. Experimental

$In_xGa_{1-x}As_yP_{1-y}$ ($0 \leqslant x, y \leqslant 1$) binary, ternary and quaternary compound semiconductors were studied. Epitaxial layers of these compounds were grown using the MOCVD technique in the Aixtron AIX200RD reactor at the Institute of Electronic Materials Technology, Warsaw on ⟨100⟩ semi-insulating GaAs and InP substrates. These were: InP, $In_{0.53}Ga_{0.47}As$, $In_{0.82}Ga_{0.18}As_{0.52}P_{0.48}$. Layers of such compositions are lattice matched to InP substrates and consequently they are not strained due to the pseudomorphic growth.

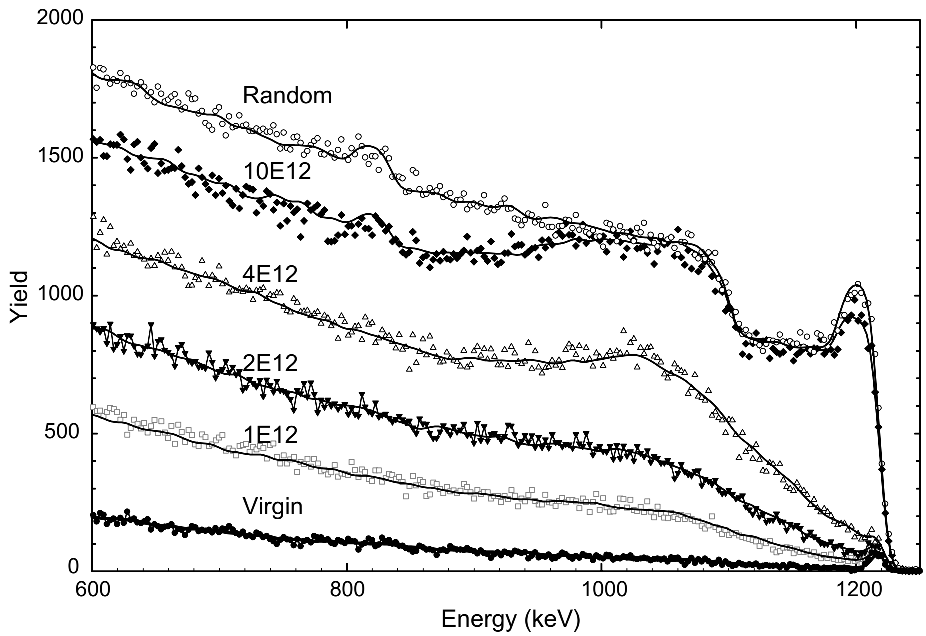

Fig. 1. ⟨100⟩ aligned spectra measured in situ for $In_xGa_{1-x}As_yP_{1-y}$ ($x = 0.82, y = 0.52$) epitaxial layer before and after implantation to different fluences of 150 keV N ions at 15 K. The spectra are labeled with fluences in 10^{13} at./cm^2.