Annealing Behavior of Ar Implanted GaN

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Due to its outstanding properties GaN is one of the key materials for various electronic and optoelectronic applications. Ion implantation is indispensable in planar selective area doping for making such devices.

Previous studies have shown that GaN is extremely resistant to lattice damage and amorphization (1). However, defects produced by ion implantation are quite stable and cannot be completely removed by the following high temperature annealing. One way to facilitate the annealing process is to reduce the concentration of residual damages (after implantation) by performing the ion implantation at elevated temperatures. Our recent studies have shown that lattice disorder in GaN bombarded with Ar^+ ions in the temperature range from room temperature (RT) to 1000°C demonstrated a characteristic retrograde behavior (2). The amount of disorder decreased with increasing of implantation temperature (T_{imp}) up to 500°C. The irradiation at higher temperatures resulted in an increase of the disorder, which reached maximum at about 700°C and decreased again with further increase of the temperature.

In this work, we present a detailed investigation of the radiation damage removal in GaN implanted with Ar^+ ions at various temperatures after both isochronal and isothermal annealing. The epitaxial GaN films were grown on (0001) 6H-SiC substrates and implanted with 150 keV Ar^+ ions to a dose of 3×10^{15} cm^{-2}. Three sets of samples implanted at RT, 300°C and 600°C were prepared for the annealing experiments. The given implantation temperatures were chosen in such a way that the residual disorder resulting from implantations into hot substrates was both smaller (T_{imp} = 300°C) and larger (T_{imp} = 600°C) than in the room temperature implantation. A sample from each set was annealed in a nitrogen ambient whether isochronally in the temperature range from 600°C to 1000°C for 20 sec or isothermally at 1000°C for times ranging from 2 to 200 sec. Disorder depth distributions before and after the annealing were determined by means of Rutherford Backscattering Spectrometry combined with channeling (RBS/C), using 2.3 MeV He^+ beam.

From the results of annealing experiments we concluded that there is a major difference between the anneal behavior of the damaged layers formed by the bombardment at different temperatures. The integrated damage (the area of the disorder peak, which is proportional to the number of displaced Ga atoms per cm^2) as a function of annealing temperature is shown in Fig. 1. It is clearly seen from this figure that significant damage remains after the anneal. The damage recovery was better for the samples annealed at RT comparing to implantations at the elevated temperatures. In the samples implanted at 300°C there appear to be stable defects which persist to anneal temperatures up to 900°C. Only at 1000°C an insignificant decrease of radiation damages was obtained.

The isothermal annealing behavior of Ar-implanted GaN is shown in Fig. 2. At 1000°C the recovery during the initial 20 sec is fast compared to that which occurs during longer annealing up to 200 sec. Under these conditions the samples implanted at RT demonstrated poor thermal stability for annealing times greater that 20 sec. After annealing at 1000°C for 200 sec the surface deterioration was observed.

The data indicated that the anneal characteristics of the lattice disorder are influenced by the type of defects formed during the implantation, which are in turn determined by the implantation temperature. Thus the anneal kinetics may be governed by the migration and dissociation of these defects.

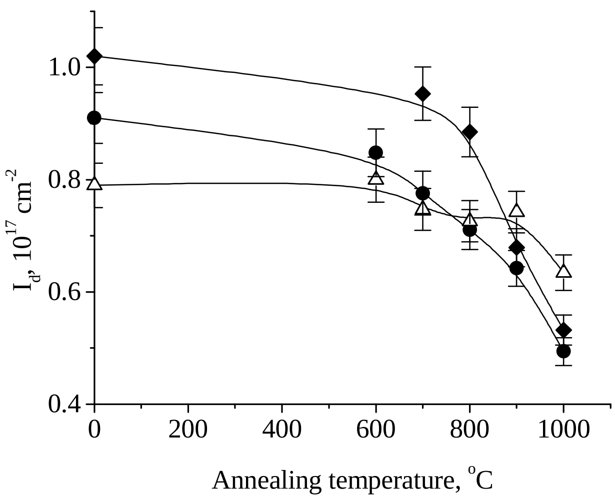

Fig. 1. The integrated damage, I_d, as a function of the annealing temperature for GaN bombarded at RT (•), 300°C (Δ) and 600°C (♦), and annealed for 20 sec.

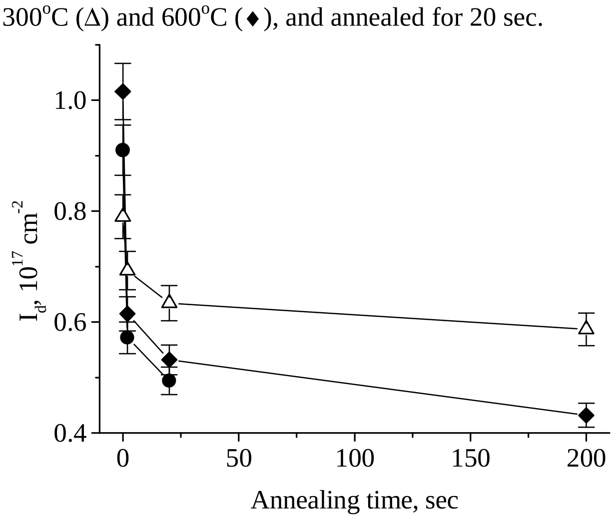

Fig. 2. The integrated damage, I_d, as a function of the annealing time for GaN bombarded at RT (•), 300°C(Δ) and 600°C (♦), and annealed at 1000°C.

REFERENCES

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