Multiple dose He ion implantation into n-GaN for electrical isolation

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Abstract

In this work, Wurtzite GaN films were implanted with 15KeV, 55KeV and 150KeV He ion respectively with various doses at room temperature. One of the groups of samples were annealed at 750 ^{0}C for 20 min before ion implantation. We found that the mobility increased and reduced corresponding to the low and high dose, respectively, by the measurements of double crystal X-Ray and Hall Effect.

Introduction

Recently, great progress in the technology of ion implantation has made it possible to fabricate photoelectric device simply [1, 2]. In fabrication of GaN-based devices, ion bombardment is one of the most commonly used processes in semiconductor technology, such as doping, dry etching and electrical isolation [3,4]. Kahn et al. were the first to report the use of ion implantation to modify the electrical properties of GaN[5]. In this letter, we report on changes of mobility under multiple doses He ions implantation into n-GaN by the investigation of Ω scan (rocking curve) of X-Ray and Hall effect, which contribute to understanding the behaviors of He ions and defects in n-GaN.

Experimental

About 2.5μn-thick wurtzite n-GaN layer was grown on c-plane sapphire substrate by low press metal-organic chemical vapor deposition (MOCVD). Multiple dose He ions implanted into n-GaN with overlapping energy to achieve uniform electrical isolation throughout the GaN film. Table 1 lists the implanted doses.

Unannealed Samples	annealed samples	doses (10^{14} cm^{-2})		
1	A1	0.255	0.600	1.0
2	A2	0.51	1.20	2.00
3	A3	1.30	3.00	5.00
4	A4	2.0	4.8	8.0

Table 1 the implanted doses at room temperature with the overlapping energy at 15KeV, 55KeV and 150KeV separately.

X-ray diffraction was carried out on X'pertMRD，when X-ray is scattered from a crystal lattice, constructive interference happens when Bragg's Law is:

$$2d\sin\theta = \lambda \qquad (1)$$

where λ is the wavelength of the X-ray, which is 0.154056nm, the 2θ is diffraction angle, the angle between incident beam and the diffracted beam, d is the spacing of the reflection planes, which is determined by Miller indices of the family of planes, for wutzite GaN, the d is written as:

$$d = \frac{1}{\sqrt{\frac{4}{3}\frac{h^2+hk+k^2}{a^2}+\frac{l^2}{c^2}}} \qquad (2)$$

where a=0.3189nm and c=0.5185nm.

Results and discussion

We investigated symmetric rocking curve scan (reflection plan is (002)) in this letter, from Eq. (1) and (2), the sharp (002) GaN peak should be at 17.28^0, Fig 1 shows that the X-Ray curve of the sample before ion implantation, and sample 2 was annealed at 750 ^{0}C for 20 min. From the Fig1, the peak of as-grown GaN is 17.70^0, and the annealed sample is 17.06^0, in this case, the as-grown sample is elongated along c-direction and the film is under compression stress, while the annealed sample is tension stress.

All ion implantation experiments presented in this letter were carried out with LC-4 High-energy Ion Accelerator. Ion ranges and atomic displacements produced in GaN by ion bombardment can be calculated using the TRIM (Transport of Ions in Matter) code, a Monte Carlo computer simulation program. The sample during the room temperature implantation was tilted 8^0 relative to the ion beam to avoid ion channeling. Fig2 shows that the X-Ray curve of implanted sample 1,2,3 and 4 compared with the as-grown sample, all these sample were not annealed before ion implantation, from the Fig2, the d_{002} decreases at the begin of ion bombardment according to Eq.(1) compared with the as-grown sample, however, the d_{002} increases with overlapping implanted doses increasing further.

Fig3 shows the rocking curve of implanted samples A1, A2, A3 and A4 compared with the annealed as-grown sample. All the d_{002} of these samples decreases compared with the annealed as-grown sample. The sample A1 is similar to the sample A2, the d_{002} of sample A3 decreased with implanted doses increasing, however, the value of d_{002} increased with more ion bombardment compared with the sample A4.

Fig4 shows that, to the samples without annealed before ion implanted (curve 1), the mobility increases with the ion-implanted doses initially, however, it decreases with the high dose ion implantation. In another way, to annealed samples (curve2), the mobility decrease at the beginning, the peak happens with increasing the ion implantation, then the mobility decrease with increasing the ion doses further. Such an increase in mobility at the first region (the lowest doses) is typically caused by the trapping of carriers at defects created by ion irradiation and damage-induced degradation of carrier mobility [6]. When increasing the ion implantation furthermore, the densities of carriers decrease dramatically, which result in decrease in mobility. From the Fig4, the lowest mobility was achieved though the samples without being annealed before ion implantation.

In conclusion, we investigated He implantation into wurtzite n-GaN. Under symmetrical (002) rocking scan, the varieties of d_{002} has been studied, though comparing with samples under different doses with overlapping energy at 15KeV, 55KeV and 150KeV separately. We obtained the influence of mobility, depending on the doses of ion implantation by measurements of Hall Effect, and achieved the lowest mobility by the samples without being annealed. We believe that the He ion implantation is viable method for electrical isolation for GaN-based devices.

Acknowledgements

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References

[1] G.G.DeLeo,G.D.Watking, Ogts.Rew.B 23 (1981) 1851.

[2] M.J. Howes, D.V.Morgan, Gallium Arsenide: Materials, Devices,and Circuits, Wiley, Norwich,1985.

[3] C.Ronning , Ion implantation into gallium nitride, Physics Reports, 351, 345-385, 2001.

[4] S.Nakamura, M.Senoh, N.Iwasa, Jpn.J.Appl.Phys, Part2 34(1995) L797.

[5]M.A.Khan, et al., Appl.Phys.Lett. 74 (1999) 2161.

[6]S.J.Pearton, “Ion implantation for isolation of Ⅲ-Ⅳ semiconductors,”Materials Science Report 4(8), 313-367, 1990

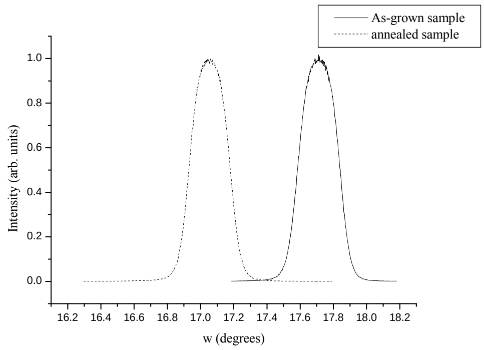

Fig 1 X-Ray curve for GaN film, the as-grown sample (solid) and the annealed sample (dotted)

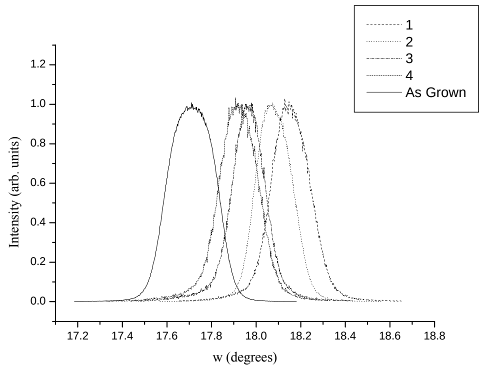

Fig2 the X-Ray curve of unannealed sample 1(Dash), 2(Dotted), 3(Dash Dotted) and 4(Short Dash) compared with the as-grown sample (solid)

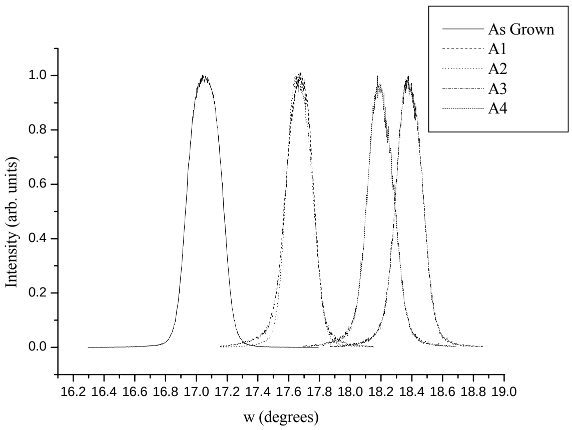

Fig3 the X-Ray curve of annealed sampleA1 (Dash), A2 (Dotted), A3 (Dash Dotted) and A4 (Short Dash) compared with the as-grown sample (solid)

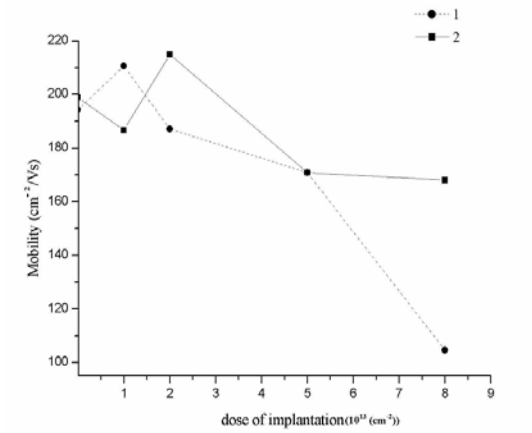

Fig 4 the mobility Variety with the ion-implanted doses