Study the native oxide layer on the surface of semiconductor material GaAs before and after hot-implanted Al ion by RBS/NR method

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MOTIVATION

The electrical characteristics and functionality of semiconductor devices are greatly influenced by this native oxide layer. Studying the formation and growth of the native oxide layer on GaAs surfaces is crucial for improving the performance, reliability, and integration of GaAs-based devices [1]. The GaAs samples were subjected to irradiation with 100 keV-Al ions at a fluence of 4 x 10^{16} ions/cm^2 with various temperatures. Rutherford backscattering spectroscopy with nuclear reaction analysis (RBS/NR) method was used to determine the thickness and atomic composition of elements in the samples [2].

Reference

[1] A.G. Baca, C.I.H. Ashby, Fabrication of GaAs Devices, The Institution of Engineering and Technology, London, 2005
[2] W.K. Chu, J.W. Mayer, M.A. Nicolet, Backscattering Spectrometry, Academic Press, New York, San Francisco, London, 1978.
[3] J.R. Cameron, Elastic scattering of alfa-particles by oxygen, Phys. Rev. 90 (1953) 839–844.…

Abstract

This work examined the native oxide layer on the GaAs material's surface both before and after hot-implanted aluminum (Al) ions. Rutherford backscattering spectroscopy with nuclear reaction analysis (RBS/NR) method was used to determine the thickness and atomic composition of elements in the samples [2]. The nuclear reaction $^{16}O(\alpha,\alpha)^{16}O$ exhibits elastic resonance at around 3.05 MeV. This resonance provides a useful method for expanding RBS techniques to investigate the concentration of oxygen in oxides [3].

SAMPLES

For the purpose of research, the GaAs samples were subjected to irradiation with 100 keV-Al ions at a fluence of 4 x 10^{16} ions/cm^2. Ion implantation was performed at temperatures of 25^0 C (room temperature), 300^0 and 500^0 Celsius.

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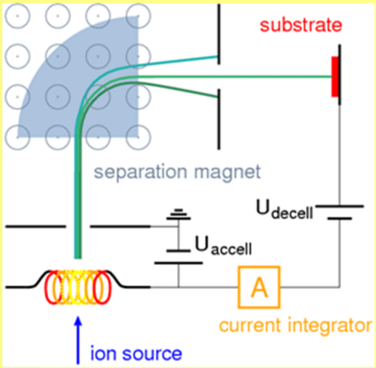
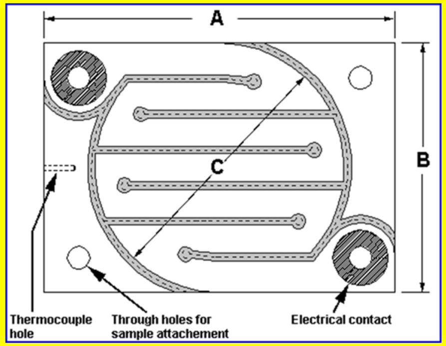
ION IMPLANTATION

Al^+ implantation was performed with the UNIMAS implanter. The ion beam scanned each sample across a 5 cm square side. The ions current density did not exceed 0.8×10^{-6} A cm^{-2}. Implantation was performed at 23°C, 300°C, and 500°C The dose equal 4×10^{16} He^+/cm^2 for the each samples. The ion energy was 100 keV.



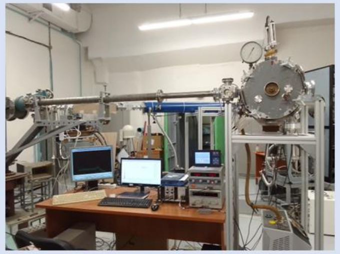
Hot implantation of Al^+ ions into GaAs

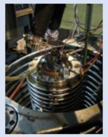
Heater of Samples
Boralectric (Tectra)
I = 16A, P = 1440 W (Max.)

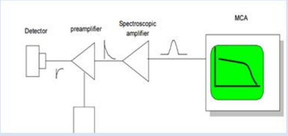


The ceramic heating plate
(graphite covered with borium nitride). Max t =800 °C
The temperature at the heating holder was stabilized within +- 1°C .

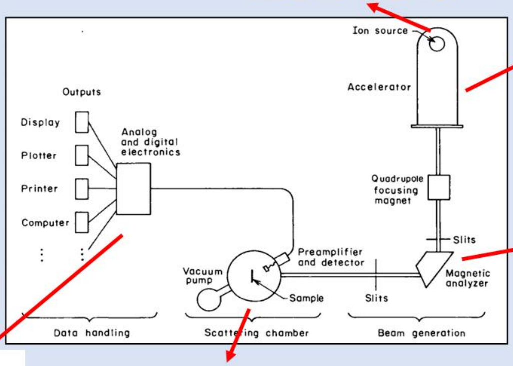
Rutherford backscattering spectroscopy (RBS)

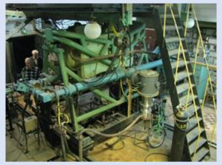


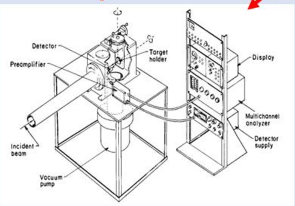


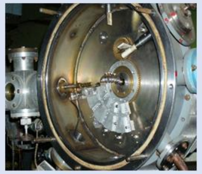


The basic set-up of the electronic system







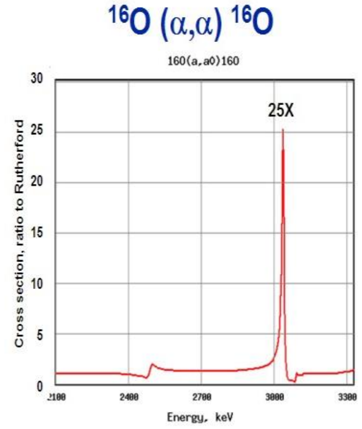


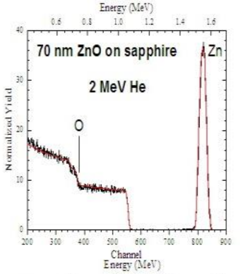
Experiment's parameter:

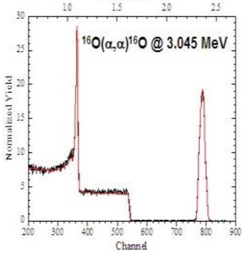
- E_α: 3.03 ÷ 3.08 MeV
- Incident angle: 15^0
- Scattering angle: 170^0

Nuclear reaction analysis (NR)

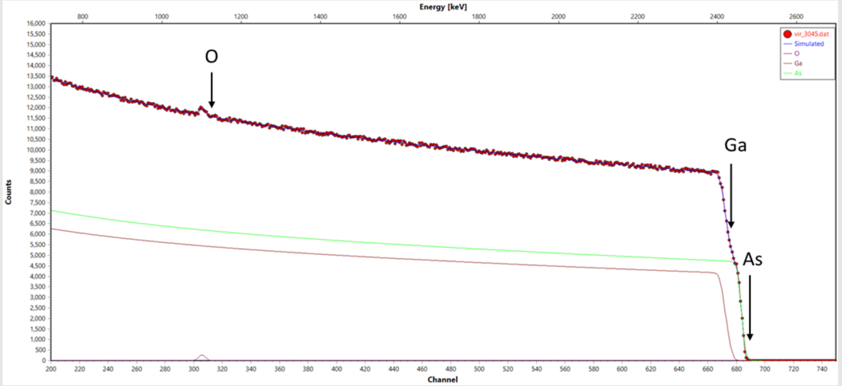
The nuclear reaction $^{16}O(\alpha,\alpha)^{16}O$ exhibits elastic resonance at around 3.05 MeV. This resonance provides a useful method for expanding RBS techniques to investigate the concentration of oxygen in oxides [3]. This represents a distinct resonance that exhibits a backscattering cross-section close to the resonance energy, which is up to 25 times larger than the Rutherford cross-section.



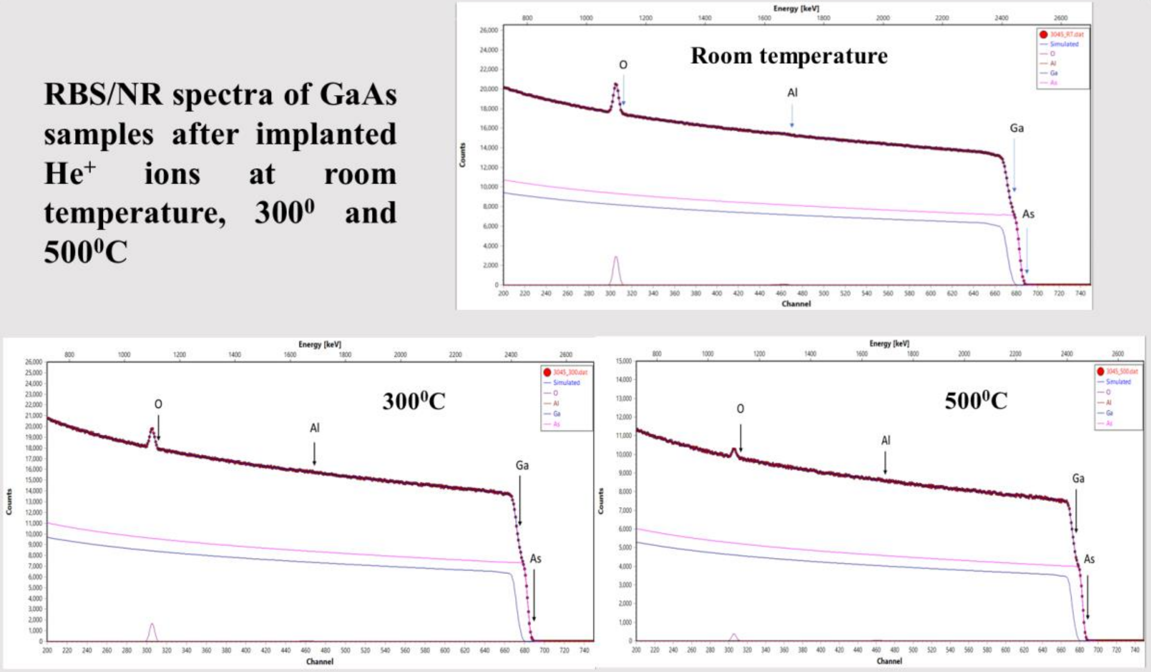




RBS/NR spectrum of GaAs sample before implanted He$^+$ ions



RBS/NR spectra of GaAs samples after implanted He$^+$ ions at room temperature, 300^0 and 500^{0}C



Conclusion

- The RBS/NR approach's conclusion indicates that the surface of GaAs samples contains an oxygen-enriched layer.
- The thickness of native oxide layer increase when GaAs samples implanted He$^+$ ions at room temperature.
- When the temperature of the Al-implanted process rises, the thickness of this layer decreases.

Samples	Layers	Thickness 10^{15} atoms/cm^2	Elements concentration			
			O	Ga	As	Al
Virgin	1	15	0.33	0.35	0.32	0
	2	20000	0	0.5	0.5	0
Room temperature (23)	1	20	0.55	0.24	0.2	0.01
	2	40	0.6	0.2	0.16	0.04
	3	200	0	0.46	0.49	0.05
	4	300		0.48	0.5	0.02
	5	20000	0	0.5	0.5	0
300	1	15	0.5	0.25	0.2	0.05
	2	27	0.36	0.3	0.3	0.03
	3	500	0	0.45	0.5	0.01
	4	20000	0	0.5	0.5	0
500	1	10	0.5	0.21	0.23	0.06
	2	10	0.35	0.31	0.32	0.02
	3	500	0	0.49	0.5	0.01
	4	20000	0	0.5	0.5	0