AFRL-RQ-WP-CP-2023-0004

INTENTIONAL IRON DIFFUSION IN BETA-Ga_2O_3

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FEBRUARY 2019
Interim Report

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REPORT DOCUMENTATION PAGE

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1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED	
		START DATE	END DATE
05022019	Interim	02052017	08072019

4. TITLE AND SUBTITLE
Intentional Iron Diffusion in Beta-Ga_2O_3

5a. CONTRACT NUMBER	5b. GRANT NUMBER	5c. PROGRAM ELEMENT NUMBER
In-house		62203F
5d. PROJECT NUMBER	**5e. TASK NUMBER**	**5f. WORK UNIT NUMBER**
3145		Q11S

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8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Aerospace Systems Directorate
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Air Force Materiel Command
Wright-Patterson Air Force Base, OH 45433-7542

10. SPONSOR/MONITOR'S ACRONYM(S)
AFRL/RQQE

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-RQ-WP-CP-2023-0004

12. DISTRIBUTION/AVAILABILITY STATEMENT
DISTRIBUTION STATEMENT A. Approved for public release. Distribution is unlimited.
Cleared 7 August 2019.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This report details efforts to selectively dope Beta-Ga2O3. Doping was achieved through diffusion source layers containing Mg, Fe, Sn, and indium. SIMS analysis is presented to show the depth of diffusion of the different species. Experiments showed that diffusion is a viable method to selectively dope gallium oxide.

15. SUBJECT TERMS
Beta gallium oxide, iron diffusion, selective area doping,

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES
a. REPORT	b. ABSTRACT	C. THIS PAGE	SAR	4
Unclassified	Unclassified	Unclassified		

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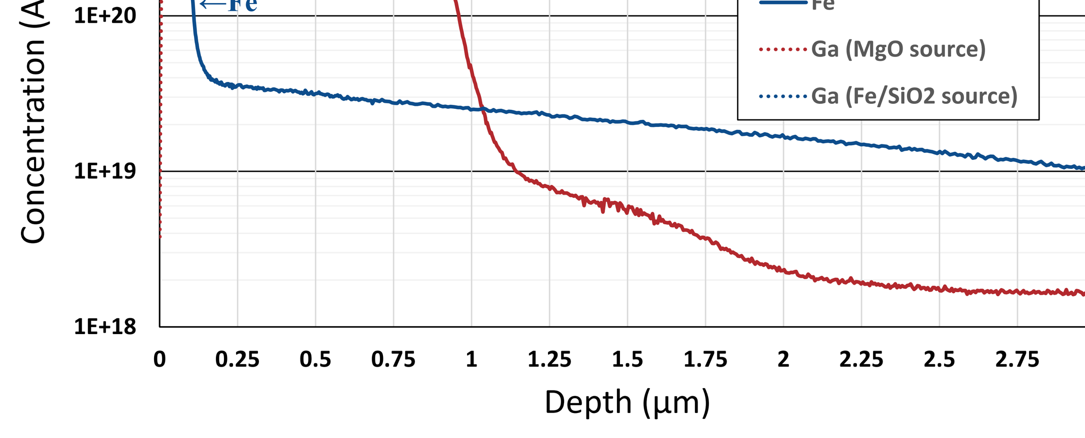
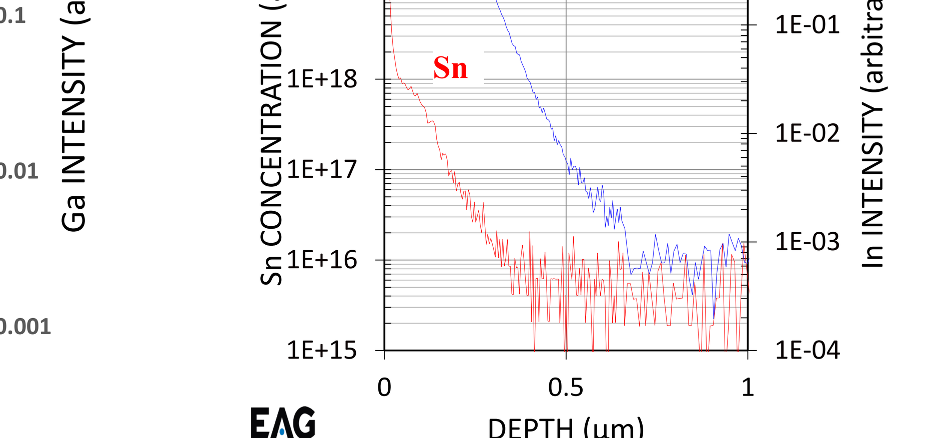
PREVIOUS EDITION IS OBSOLETE.

STANDARD FORM 298 (REV. 5/2020)
Prescribed by ANSI Std. Z39.18

Sn/SiO_2	10/500	Fe-doped (0,1,0)	RF sputter	1240	15*	~2 min BOE, ~1 min 1:3 HCl:H_2O	Sn < 1e18, < 0.5 µm Si detected but not quantified
Sn/ITO	10/1500	Fe-doped (0,1,0)	RF sputter	1240	15*	~5 min 1:3 HCl:H_2O	Sn < 1e18, < 0.5 µm Indium detected but not quantified
MgO	2000	UID (0,1,0)	e-beam	1240	15*	~2 min H_2SO_4	>1e18 out to 3 µm 0.8 µm region with 3e21 Mg and reduced Ga
SiO_2:Fe	2000	UID (0,1,0)	RF sputter, co-dep, 20% O_2	1240	15*	~2 min BOE, ~1 min 1:3 HCl:H_2O	>1e19 out to 3 µm 0.1 µm region with 3e21 Fe and reduced Ga





1240 °C Conclusions: Sn possible with Sn/ITO or Sn/SiO_2, but not very efficient. Fe and Mg showed promise with Fe b
Source layer concentration appears to be too high – possible ternary formed with Mg and Fe.

2nd Pass: Focus on Fe diffusion without alloying with surface

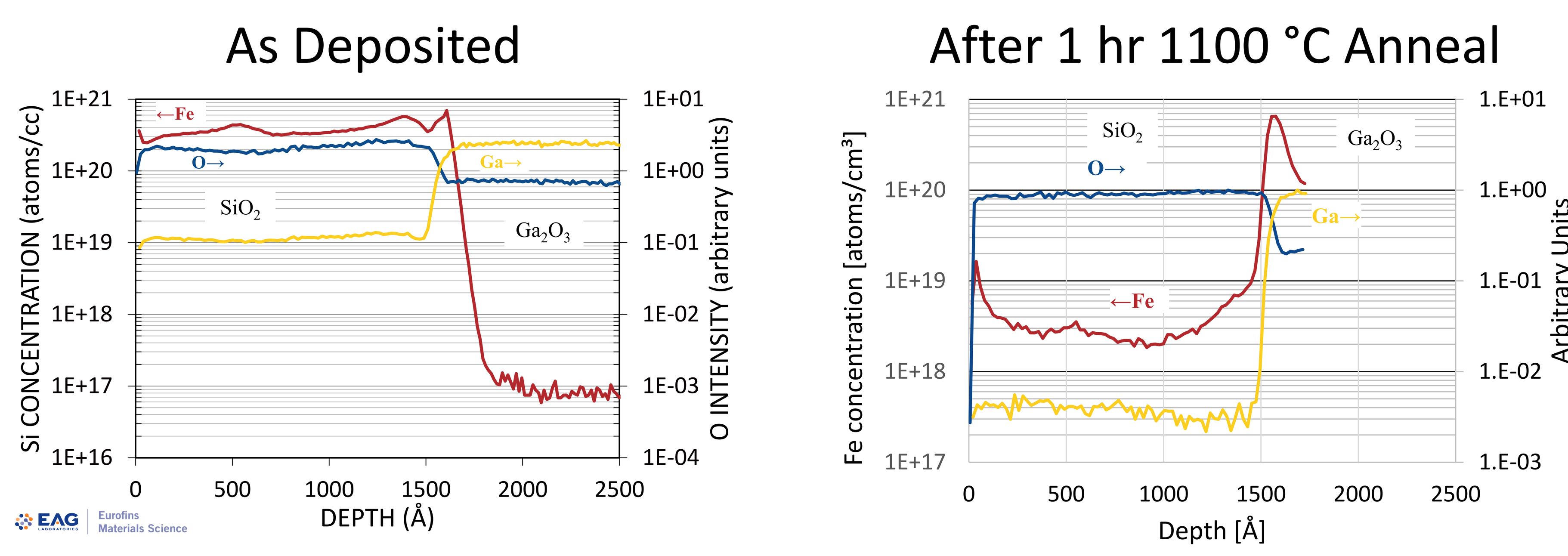
- reduce Fe in source layer: targeted 4e20 Fe/cm³ in SiO_2
- reduce temperature to reduce stress on furnace and sample

Experimental details

- Deposited source layer on Sn-doped (0 1 0) and (
- Wet etched source layer from ~ half of sample su
- Four anneals performed in purified Ar with one o
  - 1100 °C for 1 hr
  - 1100 °C for 3 hr
  - 1175 °C for 3 hr
  - 1175 °C for 6 hr

SIMS of Fe-doped SiO_2 source layer

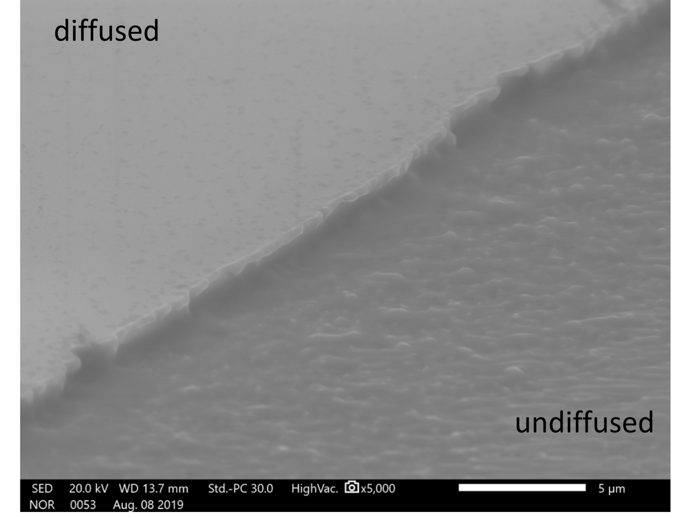
As Deposited | After 1 hr 1100 °C Anneal



Fe/SiO_2 cosputtered (Fe ~ 4e20), ~ 1500 Å, uniform Fe distribution

Effect of diffusion on substrate

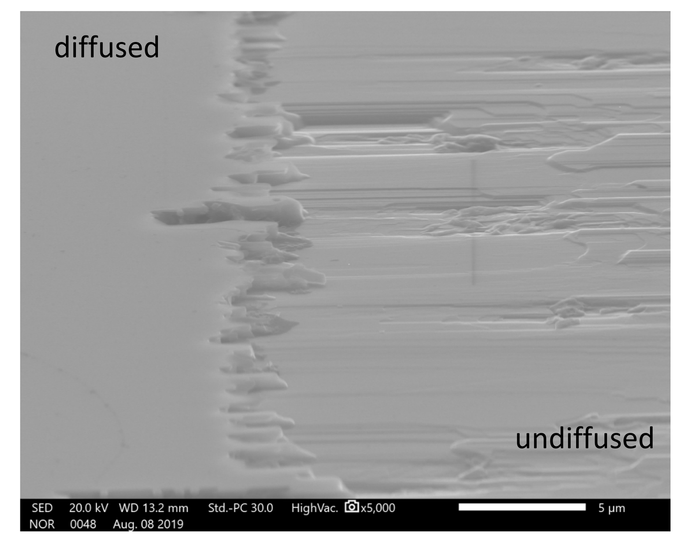
1175 °C
6hr anneal (010)



All (0 1 0) samples showed no surface roughening in diffused region

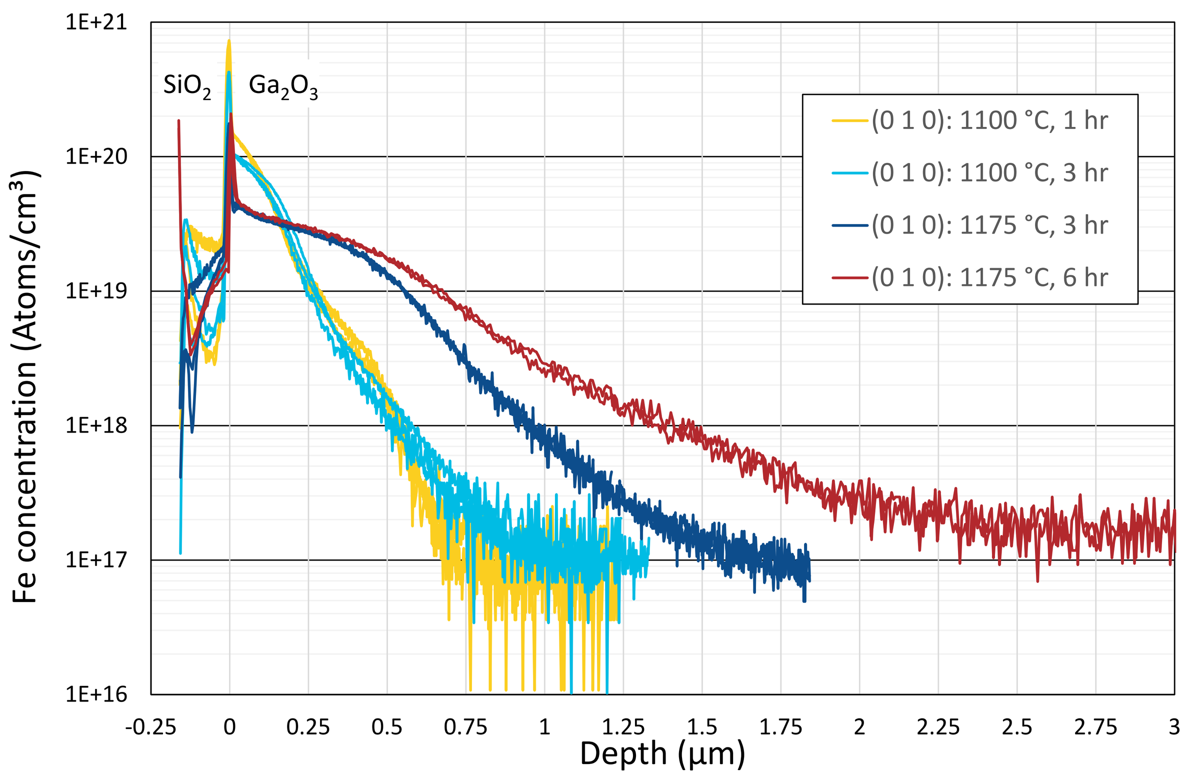
(-2 0 1) samples showed mostly smooth surface with some pitting in diffused region. Pitting grew larger at longer/higher temperature anneals

1175 °C,
6hr anneal (-201)



Both orientations showed roughening of the undiffused/uncapped regions

SIMS analysis of (0 1 0) samples Through SiO_2 layer into Ga_2O_3



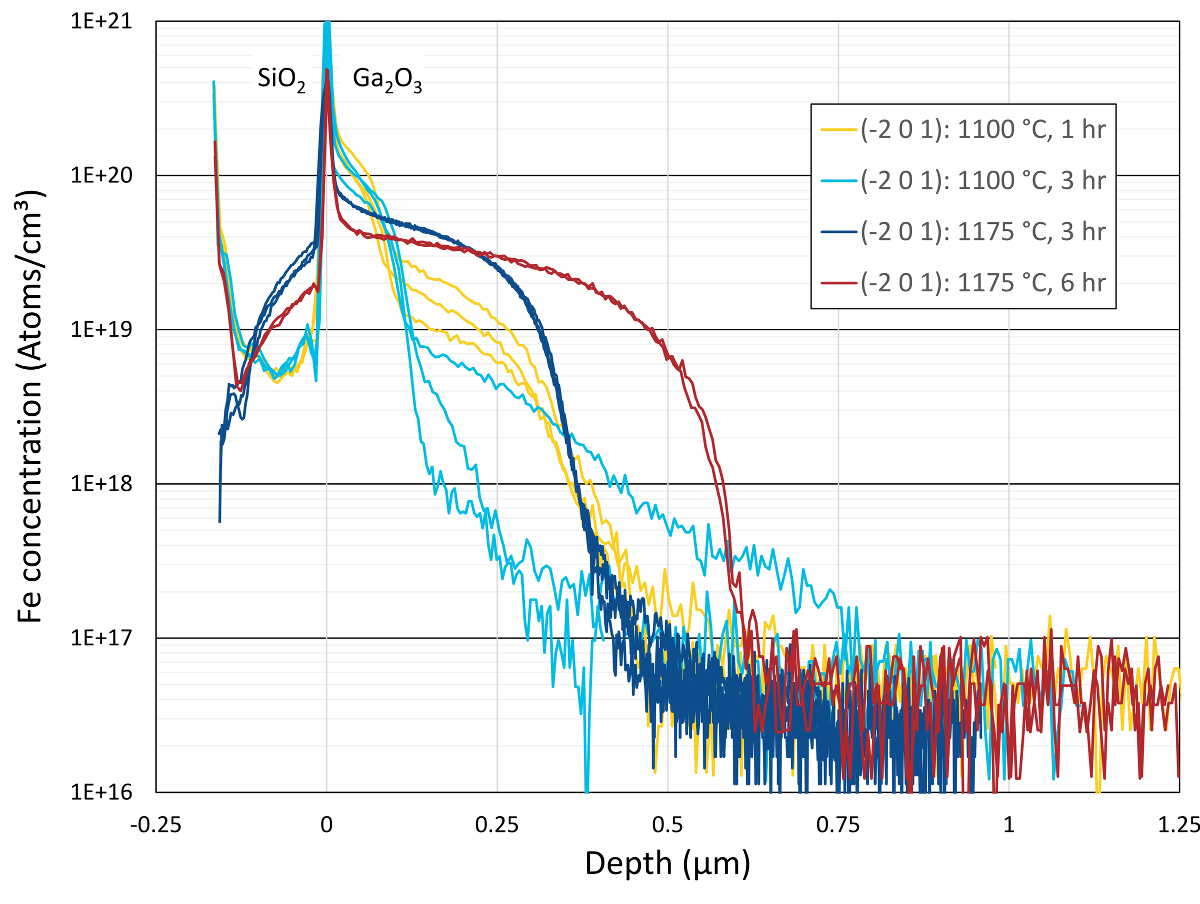
At 1100 °C, not a large difference between 1 hr and 3 hr anneals

For 3 hr anneals, increasing from 1100 to 1175 °C increased depth of profile by almost 0.5 µm.

At 1175 °C, increasing the time from 3 to 6 hr had a significant effect on the depth

Note: These scans were not calibrated for SiO_2. Therefore the Fe concentration in SiO_2 is unreliable.

SIMS analysis of (-2 0 1) samples Through SiO_2 layer into Ga_2O_3

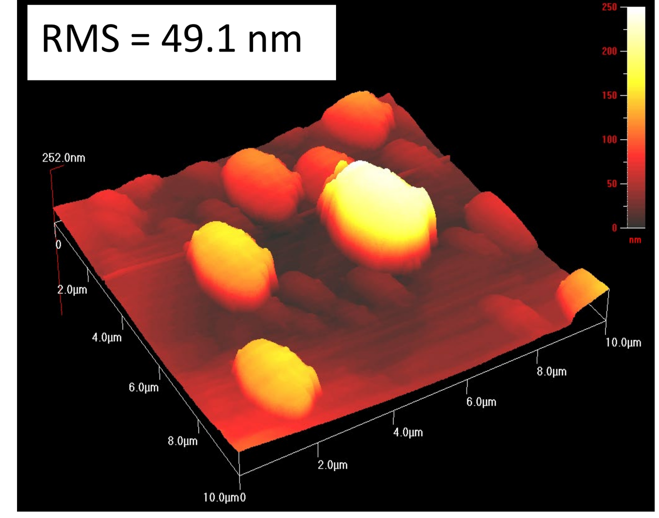


At 1100 °C, multiple scans on each sample produced varied profiles.

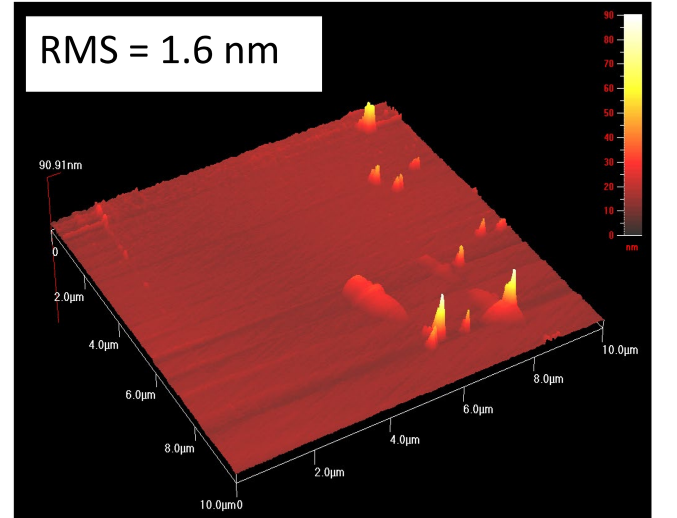
1175 °C samples were more consistent. Concentration dropped sharply below 1e19.

Note: These scans were not calibrated for SiO_2. Therefore the Fe concentration in SiO_2 is unreliable.

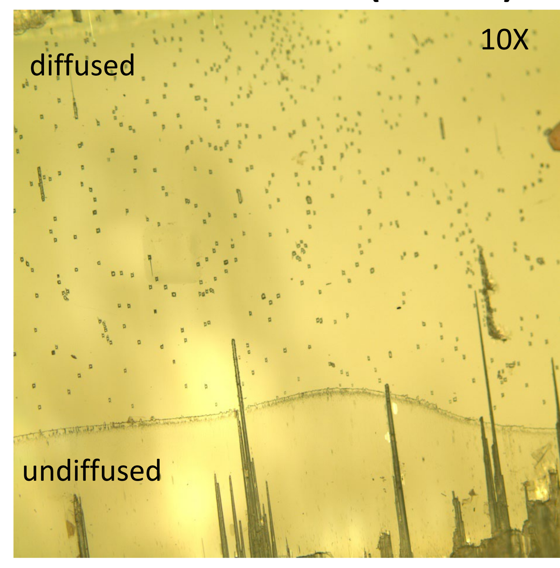
Undiffused, 1175 °C, 6hr anneal (-201)



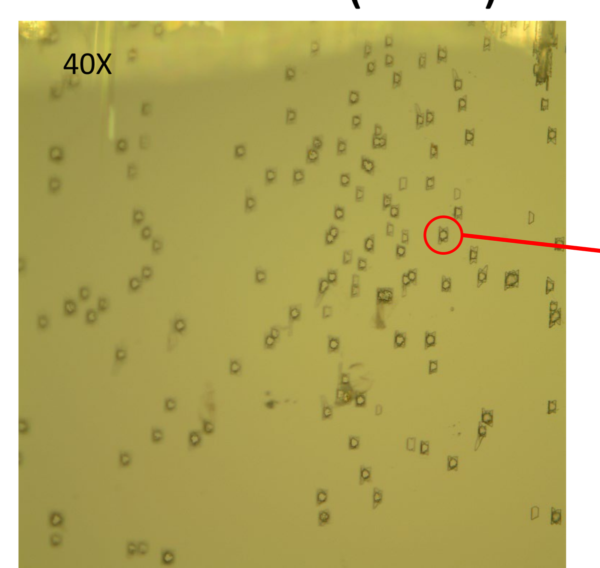
Diffused, 1175 °C 6hr anneal (-201)



1175 °C, 6hr anneal (-201)



Diffused, 1175 °C 6hr anneal (-201)



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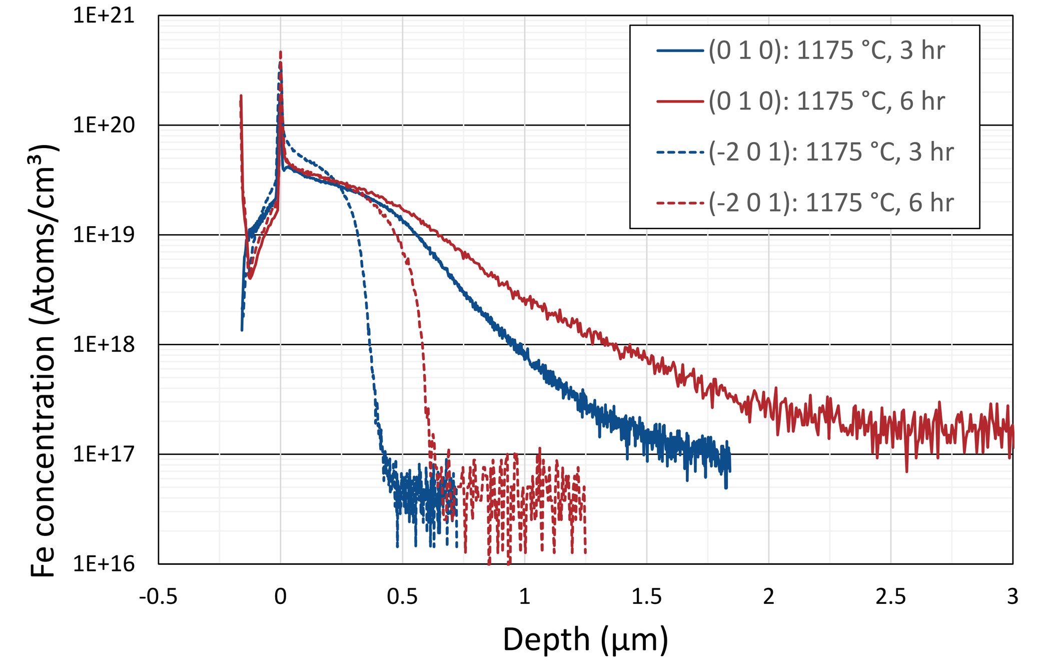
(0 1 0) vs (-2 0 1) at 1175 °C



Conclusions

- Fe is promising material to thermally dope β-Ga_2O_3
- Smooth diffused surface on (010)
- Pitting observed on diffused surface of (-201)
- Roughening on undiffused regions of both orientations after 3 hr at 1100 °C (entire 1 hr samples were diffused)

Fu

- Cap un change
- Reduce

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