Evaluation of damage formation and recovery in ion-implanted β-Ga_2O_3 by low-energy cathodoluminescence

Ion implantation and annealing are important processes in device manufacturing. Low-energy cathodoluminescence (CL) is highly sensitive to the damage caused by ion implantation and suitable for process optimization and failure analysis in b-Ga_2O_3 based devices.

Low-energy cathodoluminescence (CL)

[Advantages]

1. Surface analysis

Low-energy measurement enables surface analysis at nm level.

2. Ultra-wide bandgap materials

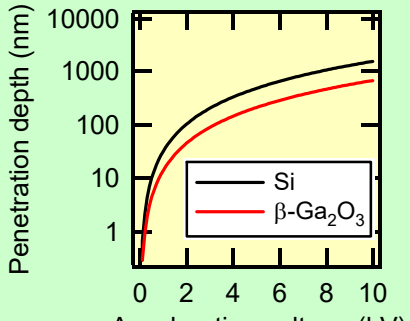
CL can be used for ultra-wide bandgap materials for which photoluminescence (PL) cannot be applicable.

3. Device analysis

AlGaN deep-UV LEDs, GaN HEMTs, SiC MOSFETs, β-Ga_2O_3 transistors etc.

[Application fields]

1. Process damage such as Ion-implantation, dry etching etc.
2. Quality evaluation of thin gate oxide layers
3. Device failure analysis



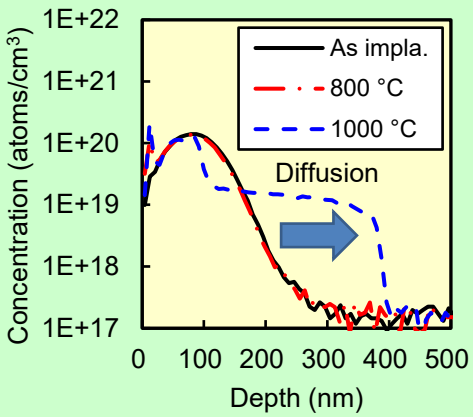
Penetration depth as a function of acceleration voltage

Penetration depth in β-Ga_2O_3
10.0 kV → L = 656 nm
5.0 kV → L = 206 nm
1.0 kV → L = 14 nm
0.5 kV → L = 4.4 nm

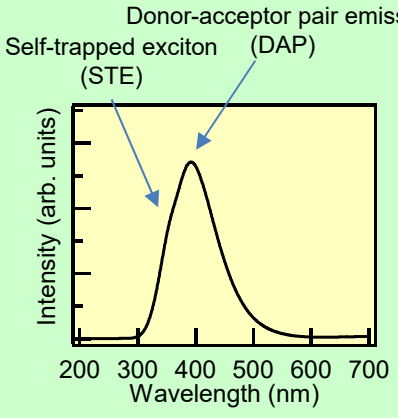
Damage evaluation in ion-implanted b-Ga_2O_3 by low-energy CL[1)]

We implanted Si on β-Ga_2O_3 bare wafers and annealed them at various temperatures. Ion-implantation damage and recovery were evaluated by low-energy cross-sectional CL.

[Sample condition]
Wafer: Unintentionally-doped (-201) wafer
Dopant: Si, Energy: 100 keV
Dose: 1E15 atoms/cm^2
Annealing temperature: 800, 1000 °C

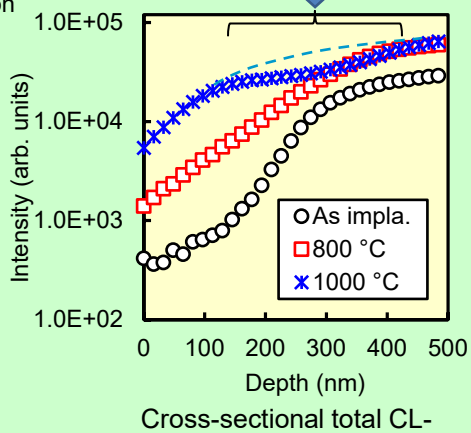


SIMS depth profiles of Si



CL spectrum of bare β-Ga_2O_3 wafer

Insufficient recovery around diffusion region



Cross-sectional total CL-intensity profiles

- Si diffusion was observed after annealing at 1000 °C.
- Total CL intensity increased after annealing. The intensities after annealing at 1000 °C are stronger than those after annealing at 800 °C. However, the CL-intensity profile after annealing at 1000 °C showed insufficient recovery around Si diffusion region. It suggests that the Si diffusion and damage recovery have strong correlation.

1) Appl. Phys. Exp. 13, 126502 (2020).

Toray Research Center, Inc.