Effects of Sacrifice Oxidation on Characterization of Defects in High-Purity Semi-Insulating 4H-SiC by Discharge Current Transient Spectroscopy

Seiji Nishikawa[a], Ryota Okada and Hideharu Matsuura

Osaka Electro-Communication University, 18-8 Hatsu-cho, Neyagawa, Osaka, 572-8530, Japan

[a]m10712@oecu.jp

Introduction

We have investigated X-ray detectors operating at room temperature using semi-insulating SiC. Semi-insulating semiconductors are essential for next-generation semiconductor devices. However, there are electrically active intrinsic defects (i.e., traps) in these devices. Because traps behave as generation centers in the depletion region of the diode and produce a generation current in the reverse-biased diode, they degrade the performance of X-ray detectors. To determine the possibility of semi-insulating SiC being used as a portable X-ray detector operating at room temperature, it is necessary to investigate traps related to the transient reverse current.

Although powerful methods to characterize traps in low-resistivity semiconductors are transient capacitance methods, e.g., deep level transient spectroscopy (DLTS) [1], these are not feasible in semi-insulating semiconductors because the measured capacitance of the diode fabricated using semi-insulating semiconductors is determined by the thickness of the diode, not by the depletion region of the junction [2,3]. Therefore, we proposed discharge current transient spectroscopy (DCTS) , and measured of semi-insulating SiC [4,5].

As a result, in addition to defects in the balk, we found that the effect on the device surface defects.

Discharge Current Transient Spectroscopy

DCTS can determine the densities and emission rates of traps in a semi-insulating SiC from a transient current $i(t)$ in a capacitor consisting of a semi-insulating SiC between two electrodes at a constant temperature [6,7]. In DCTS, the following function is defined using the experimental $i(t)$;

$$D(t, e_{\mathrm{ref}}) \equiv t\left[i(t) - i_{\mathrm{s}}\right]\frac{\exp(-e_{\mathrm{ref}}t + 1)}{qS}, \qquad (1)$$

where i_{s} is the steady-state leakage current at the applied voltage, q is the electron charge, S is the electrode area, and e_{ref} is the peak-shift parameter [8]. From each peak value and peak time, we can determine the densities and the emission rates of traps accurately.

Experiment

A 0.374-mm-thick high-purity semi-insulating 4H-SiC wafer was purchased from Cree Inc., and oxidation furnace at 1273 K, the chip surface was sacrifice oxidation on one side for 2 hours. After sacrifice oxide layers on the chips were removed using HF, Ni electrodes with a radius of 1.25 mm were evaporated onto both sides of the sample. The I-V characteristics of the diodes were measured from 0 to -100 V. $i(t)$ was measured at -100 V. The densities and emission rates of traps in semi-insulating 4H-SiC were determined by the DCTS method at 373 K.

Results and Discussion

Figure 1 shows the I-V characteristics for without sacrifice oxidation and with sacrifice oxidation. The value of the leakage at -100 V, without sacrifice oxidation was -42.8 pA, and with sacrifice oxidation was -16.7 pA. From this, the surface defects were removed by performing a sacrifice oxidation.

Figure 2 shows the DCTS signal and simulated signal for three types of traps. The densities and emission rates of those traps species corresponding to those peaks were determined as 1.68×10^{12} cm^{-2} and 4.68×10^{-3} s^{-1}, 1.71×10^{12} cm^{-2} and 1.95×10^{-2} s^{-1}, 1.16×10^{12} cm^{-2} and 8.24×10^{-2} s^{-1}, respectively.

Summary

The surface defects were removed by performing a sacrifice oxidation. And it was elucidated that DCTS is applicable to semi-insulating 4H-SiC. DCTS could detect three types of traps with close emission rates, and could determine the densities and emission rates of those traps.

References

[1] D. V. Lang, J. Appl. Phys. **45**, 3023 (1974).
[2] H. Matsuura, et al., J. Appl. Phys. **55**, 1012 (1984).
[3] H. Matsuura, et al., J. Appl. Phys. **104**, 043702 (2008).
[4] H. Matsuura, et al., Mater. Sci. Forum **615-617**, pp. 385-387 (2009).
[5] H. Matsuura, et al., Jpn. J. Appl. Phys. **48**, 056504 (2009).
[6] H. Matsuura, et al., J. Appl. Phys. **91**, 2085 (2002).
[7] H. Matsuura, et al., Jpn. J. Appl. Phys. **34**, L186 (1995).
[8] H. Matsuura, et al., Jpn. J. Appl. Phys. **39**, 178 (2000).

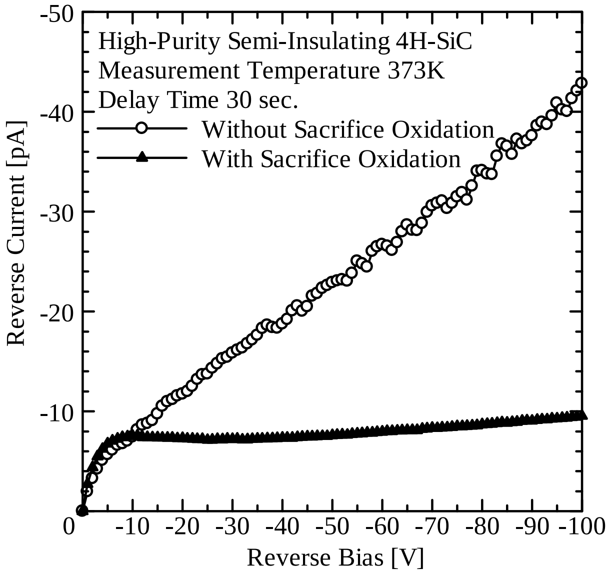

Fig. 1. I-V characteristics for without sacrifice oxidation and with sacrifice oxidation.

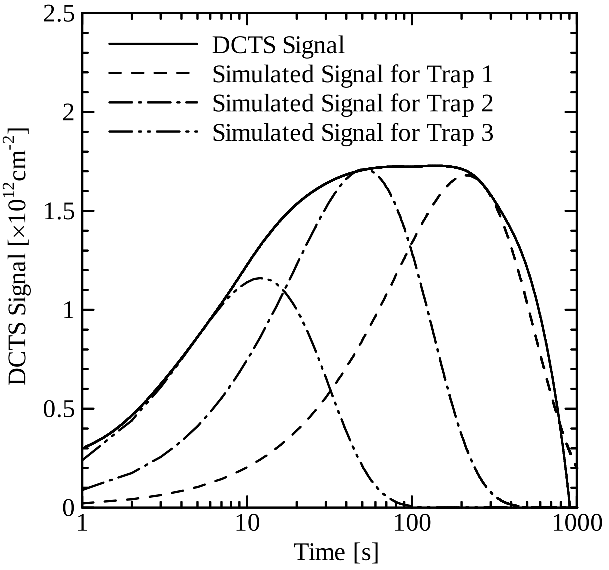

Fig. 2. DCTS signal and simulated signal for three types of traps.