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Determination of Intrinsic Defects in High-Purity Semi-Insulating 4H-SiC by Discharge Current Transient Spectroscopy

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1. Introduction

We have investigated X-ray detectors operating at room temperature using semi-insulating SiC. For making use of semi-insulating semiconductors as an active layer in electronic devices as well as a substrate for lateral power microwave devices, the properties of intrinsic defects in them should be investigated in details because they strongly affect the electric properties of the devices.

Although powerful methods to characterize traps in low-resistivity semiconductors are transient capacitance methods, e.g., deep level transient spectroscopy [1], it is difficult for the methods to be applied to semi-insulating semiconductors. Thermally stimulated current (TSC) [2] is suitable for characterizing traps in semi-insulating semiconductors. However, TSC is available only in the case of thermionic emission processes, and it is difficult to analyze the experimental TSC data when traps with close emission rates are included in the film. Moreover, because the influence of the pyroelectric currents and the temperature dependence of the steady-state leakage current should be considered in the analysis, an isothermal measurement is more suitable for characterizing traps than TSC.

A graphical peak analysis method using the isothermally measured transient current (DCTS: discharge current transient spectroscopy) [3] is here applied to high-purity semi-insulating 4H-SiC, besides SiN_X films [4], $Pb(Zr,Ti)O_3$ films [3], and high-resistivity Si pin diodes [5].

2. Discharge Current Transient Spectroscopy

DCTS can determine the densities and emission rates of traps in semi-insulating SiC using the transient current $i(t)$ of a Schottky barrier diode at a constant temperature. In DCTS [3-5], the following function is defined using the experimental $i(t)$;

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

where i_{s} is the steady-state leakage current at a reverse bias voltage (V_{R}), q is the electron charge, S is the electrode area, and e_{ref} is the peak-shift parameter [3]. From each peak value and time, we can determine the density and the emission rate of the corresponding trap accurately.

3. Experiment

A 0.37-mm-thick high-purity semi-insulating 4H-SiC wafer was purchased from Cree Inc., and Ni electrodes with a radius of 1.25 mm were evaporated onto both sides of the sample. $i(t)$ for V_{R} of –100 V was measured in the temperature range from 303 K to 373 K. The densities and emission rates of traps in semi-insulating 4H-SiC were determined by DCTS.

4. Results and Discussion

The transient current at 343 K, which was measured when a bias voltage was changed from 0 V to –100 V, was denoted by circles in Fig. 1. The DCTS signal was calculated with $e_{\mathrm{ref}} = 0$ s^{-1}, and denoted by the solid curve in Fig. 2. From the peaks of DCTS signal for different e_{ref}, four types of traps were detected. Using the density (N_{ti}) and emission rate (e_{ti}) for each trap determined by DCTS, the component of DCTS for the corrsponding trap was simulated using

$$D_{\mathrm{ti}}(t, e_{\mathrm{ref}}) = N_{\mathrm{t}i}\, e_{\mathrm{t}i}\, t \exp\left[-\left(e_{\mathrm{t}i} + e_{\mathrm{ref}}\right)t + 1\right], \tag{2}$$

which is denoted by each line in Fig. 2. The energy level for each trap was determined from an Arrhenius plot shown in Fig. 3. The detail investugation of intrinsic defects in high-purity semi-insulating 4H-SiC are in progress.

5. Summary

It was elucidated that DCTS is applicable to semi-insulating semiconductors. DCTS could determine the densities and emission rates of intrinsic defects in high-purity semi-insulating 4H-SiC. From the temperature dependence of the emissin rate of each intrinsic defect, the energy level could be determined.

References

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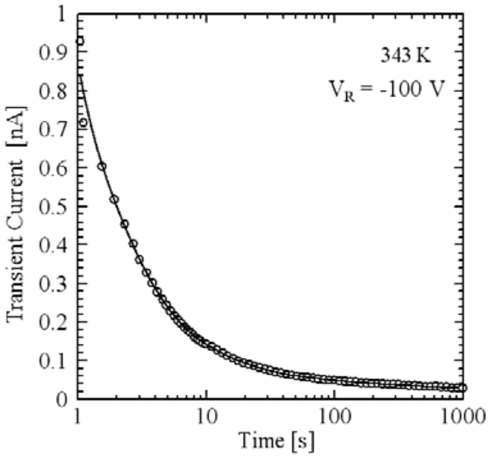

Fig. 1 Transient current.

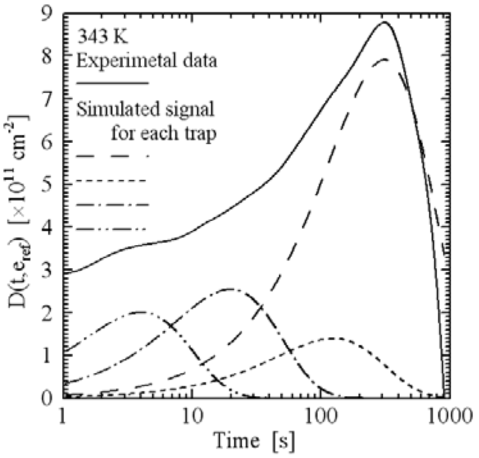

Fig. 2 DCTS signal and simulated signals for traps with $e_{\mathrm{ref}} = 0$ s^{-1}.

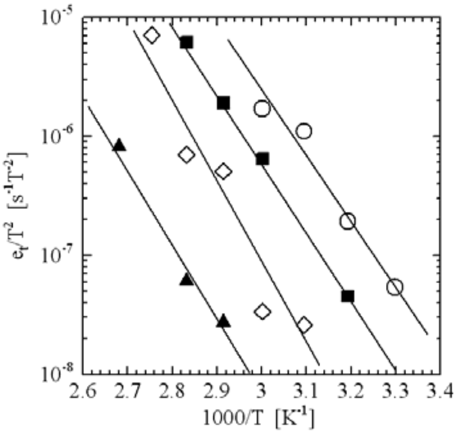

Fig. 3 Temperature dependence of emission rate.