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Characterization of traps in 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, however, the properties of traps in them should be known very well because they strongly affect the electric properties of these devices.

Powerful methods to characterize traps in semiconductors are transient capacitance methods, e.g., deep level transient spectroscopy (DLTS) [1], isothermal capacitance transient spectroscopy (ICTS) [2] and the heterojunction-monitored capacitance (HMC) method [3]. However, it is difficult for those methods to be applied to semi-insulating semiconductors.

Thermally stimulated current (TSC) [4] 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 must be considered, 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) [5] was proposed, and has been applied to SiN_X films [6], $Pb(Zr,Ti)O_3$ films [5], and high-resistivity Si pin diodes [7].

2. 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[5,6]. 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 [5]. From each peak value and peak time, we can determine the densities and the emission rates of traps 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. $i(t)$ 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 and 323 K.

4. Results and Discussion

The transient current at 373 K was denoted by the solid curve in Fig. 1. The DCTS signal was calculated with $e_{\mathrm{ref}} = 0$ $\mathrm{s^{-1}}$, and denoted by the broken curve in Fig. 1. The density and emission rate of the trap species corresponding to this peak were determined as 1.44×10^{9} $\mathrm{cm^{-3}}$ and

3.09×10^{-1} s^{-1}, respectively. From the peak of $D(t,-0.03)$, these of another trap were evaluated as 1.19×10^{9} cm^{-3} and 1.04×10^{-1} s^{-1}, respectively. In the measurement time range, two types of traps were detected at 323 K. Even at 373 K, DCTS found two types of traps with approximately the same densities as the traps detected at 323K. The details are in progress.

5. Summary

It was elucidated that DCTS is applicable to semi-insulating semiconductors. In the case of semi-insulating 4H-SiC, DCTS could detect two types of traps with close emission rates, and could determine the densities and emission rates of those traps.

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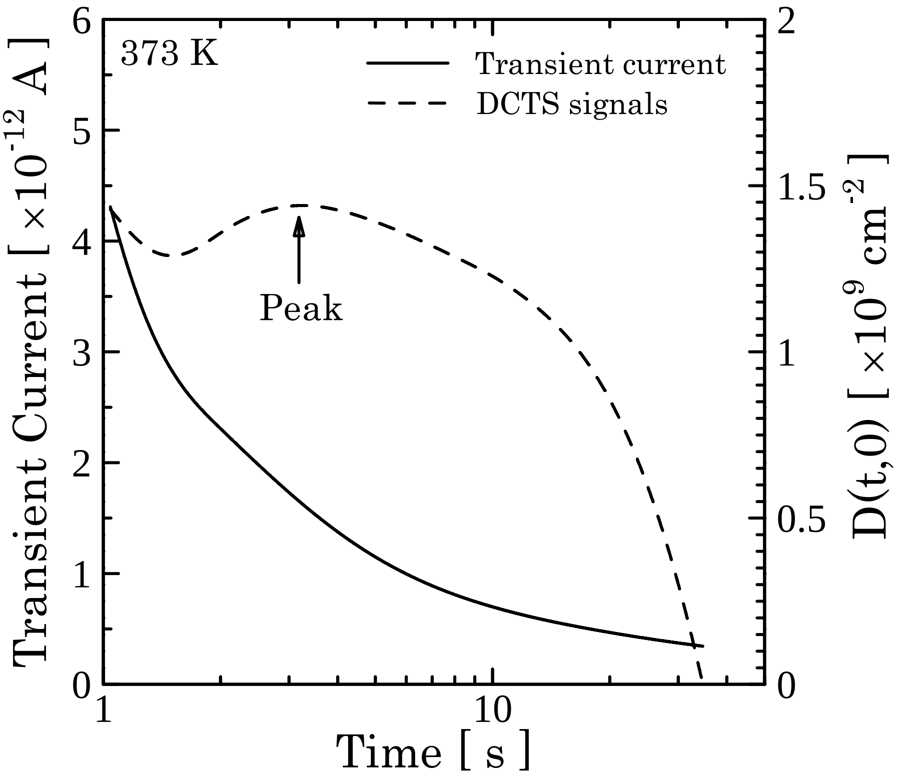

Fig. 1. Transient current and DCTS signal for high-purity semi-insulating 4H-SiC.