Characterization of deep centers in semi-insulating SiC and HgI_2: Application of discharge current transient spectroscopy

Hideharu Matsuura, Miyuki Takahashi, Shunji Nagata and Kazuo Taniguchi
Osaka Electro-Communication University, 18-8 Hatsu-cho, Neyagawa, Osaka 572-8530, Japan
e-mail: matsuura@isc.osakac.ac.jp

Abstract

Semi-insulating HgI_2 has been used in X-ray detectors operating even at room temperature, and we have investigated semi-insulating SiC X-ray detectors. For making use of semi-insulating semiconductors as an active layer in electronic devices, however, the properties of deep centers in them should be known very well because they strongly affect the electric properties of these devices.

Powerful methods to characterize deep centers are transient capacitance methods, e.g., deep level transient spectroscopy (DLTS)1) and isothermal capacitance transient spectroscopy (ICTS)2) for low-resistivity semiconductors, and the heterojunction-monitored capacitance (HMC) method3) for high-resistivity semiconductors. However, it is difficult for those methods to be applied to semi-insulating semiconductors.

Thermally stimulated current (TSC)4) is suitable for characterizing deep centers 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 deep centers 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 deep centers than TSC.

One of the authors has proposed a graphical peak analysis method using the isothermally measured transient current (DCTS: discharge current transient spectroscopy),5) and has applied it to SiN_x films,6) $Pb(Zr,Ti)O_3$ films,5) and high-resistivity Si pin diodes.7)

In this study, we report on our investigation of the properties of deep centers in semi-insulating 4H-SiC and HgI_2 using DCTS. 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. A 0.53-mm-thick semi-insulating HgI_2 wafer was obtained from Constellation Technology, and carbon electrodes with 3×2.5 mm^2 were formed.

The transient current $i(t)$ was measured at -100 V at 300 K, and denoted by circles in Fig. 1. The DCTS signal

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

was calculated with $e_{\mathrm{ref}}=0$ s^{-1}, and denoted by the solid curve in Fig.1, where i_{s} is the steady-state leakage current at -100 V, q is the electron charge, S is the electrode area, and e_{ref} is the

peak-shift parameter.5) The density and emission rate of the deep center corresponding to this peak were determined as 2.2×10^{13} cm^{-3} and 2.4×10^{-2} s^{-1}, respectively. From the peak of $D(t,0.16)$, these of another deep center were evaluated as 1.5×10^{13} cm^{-3} and 7.2×10^{-2} s^{-1}, respectively. Therefore, two types of deep centers were found in the 4H-SiC under this measurement condition. In the HgI_2, four types of deep centers were detected.

In summary, it was elucidated that DCTS is a powerful method for semi-insulating semiconductors.

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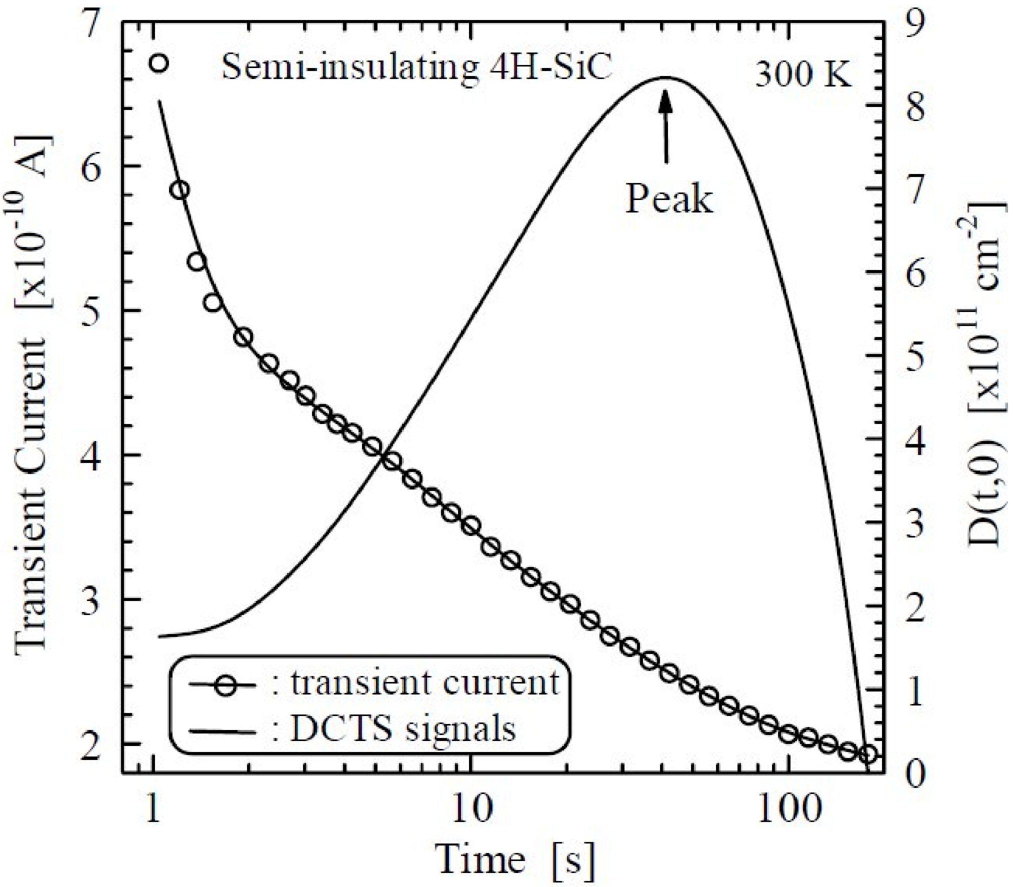

Fig. 1 Transient current and DCTS signal for high-purity semi-insulating 4H-SiC.