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Short Note

Effect of Stray Carriers on the Separation of Electron and Hole Traps in TSC

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Separation of the electron and hole traps in semi-insulating GaAs by changing the polarity of bias voltage in the thermally stimulated current measurement is done more distinctly when the photo excitation for initialization is confined to the thinned region of the improved specimen, rather than illumination over the whole front surface as previously reported. It was found that this rambling component of the transient current was suppressed by applying an electric field in the order of 10^3 V/cm.

KEYWORDS: thermally stimulated current, semi-insulating GaAs, stray carriers, separation of electron and hole traps

We have been improving the classical method of thermally stimulated current (TSC) spectroscopy to study defects, particularly in semi-insulating GaAs at extremely low temperatures.[1-3] Reduction in noise current, high sensitivity, and quantitative analysis capabilities are our main concerns.

Basically we adopted a parallel electrode structure with a guard ring, as previously reported.[1] A deep hole with a diameter of about 3 mm is etched down to give a narrow spacing between the electrodes. Over the etched hole semitransparent metal film is formed serving as the front electrode through which excitation light is introduced to generate carriers in the semiconductor. Surrounding the surface electrode, a guard ring electrode is formed, which suppresses the surface leakage, especially above 200 K. The back electrode is formed with thick metal film.

The specimen is mounted onto a finger of a cryostat and cooled. After it reaches a desired temperature, the specimen is illuminated on the front surface to generate carriers, which fill traps or flow out to cause photocurrent. This is the process of "initialization."[3] Then the temperature of the specimen is raised, and the trapped carriers are released causing the thermally stimulated current. In the previous papers[1,3] we simply assumed that only the thinned central portion contributed to TSC. We report here that our previous assumption should be corrected.

The sample was first initialized at 30 K for 180 s by illuminating the whole front surface with a defocused light beam from a 5 mW He–Ne laser. During the illumination, the initialization potential, $V_{\rm init}$, was applied to the back electrode. After the initialization, the sample temperature was raised and the TSC spectrum was plotted with the measuring potential, $V_{\rm meas}$. Figure 1A shows the TSC spectrum thus obtained for (a) $V_{\rm init}=V_{\rm meas}=+10$ V, and (b) $V_{\rm init}=V_{\rm meas}=-10$ V. This is essentially the same as in the previous publications[2,3] demonstrating the viability of the TSC spectrum in separating electron and hole traps. Though observable, the effect was not distinct and the spectrum peaks were dull, to our disappointment.

When the focused beam was employed to excite only a small area within the thinned region, the peaks became much sharper and their shapes changed more distinctly with the polarity in Fig. 1B, than in Fig. 1A.

The difference between the spectra in Fig. 1A and 1B is caused by the different distribution of the trapped charges. The carriers are generated over the whole surface in the former, while in the latter they are generated only in the thinned region.

The dull spectra for the whole front surface excitation (Fig. 1A) are apparently due to carriers rambling outside the thinned region. In the thinned (30 μm) region, electrons and holes could be separated by a strong electric field of $10/3\times10^{-3}=3$ kV/cm. But in the thick (300 μm) region the drifting field was one order of magnitude less and not strong enough to divert rambling carriers. Thus, both electron and hole traps are well filled in the surrounding region outside the thinned region. Since the volume is far larger in the surrounding region than that in the thinned region, the total number of trapped carriers in the surrounding region could be much larger than that in the thinned region, for instance, by a factor of 10^2.

In principle, the intensity of TSC is a strong function of the electrode spacing with reference to the drift length[1,4] of the carrier. However, this disadvantage could be compensated by the larger number of trapped carriers

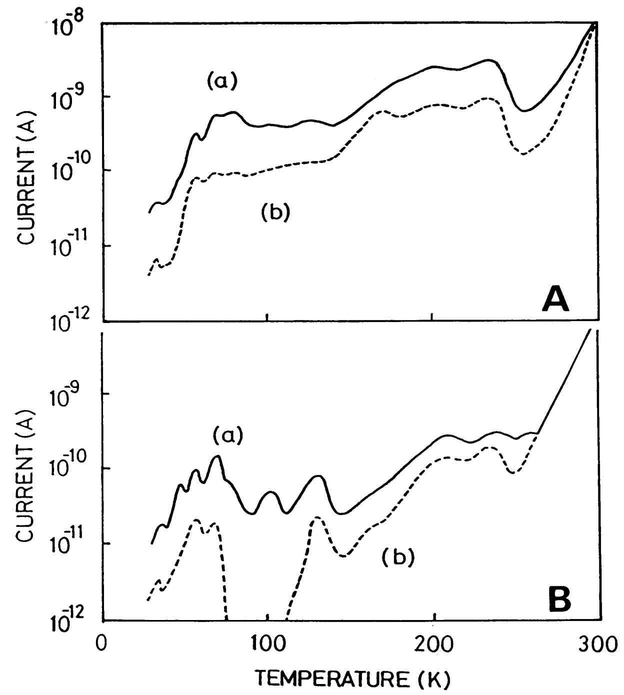

Fig. 1. (A) TSC Spectra for (a) $V_{\rm init}=V_{\rm meas}=+10$ V, and (b) $V_{\rm init}=V_{\rm meas}=-10$ V, by illuminating the whole front area, and (B) TSC spectra for (a) $V_{\rm init}=V_{\rm meas}=+10$ V, and (b) $V_{\rm init}=V_{\rm meas}=-10$ V, by excitation of the small area within the thinned region.

in the surrounding region. The dull shape of the spectrum could be attributed to the cycle of the retrapping and detrapping of carriers. Thus it is important not to spill carriers outside the thinned region. Figure 1B is the result of this precaution.

In Fig. 1B, by applying positive potential to the back electrode, the traveling carriers are electrons, so the electron traps are filled. Conversely, when the potential polarity is reversed, the number as well as the height of the peaks is reduced. Since the photocurrent shows a preference for holes, the electron traps are not completely filled. By comparing the response to the polarity change, we think that the peak around 240 K is caused by a hole trap.

In conclusion, we showed that the separation of electron and hole traps by means of TSC becomes easier by suppressing the rambling component of carriers.

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