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CAPACITANCE TRANSIENT SPECTROSCOPY (DLTS) OF EXTENDED DEFECTS IN SEMICONDUCTORS

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Deep level transient spectra of extended defects show significant differences from those of point defect. Experimentally well established are the logarithmic capture characteristics, i.e.

$C_m \sim \ln(t_p)$ (C_m : line amplitude, t_p : filling pulse length), and a significant line broadening, which is strongly asymmetric in some cases, nearly symmetric in others. As has been shown by several authors, the unusual capture law is associated with the existence of a capture barrier, whose height varies with the charge of the extended defect. But it has been also shown, that this barrier is not responsible for the line broadening.

Recent experiments have shown up a significant difference in the DLTS characteristics of different kinds of extended defects. The temperature $T_{\max}$ of the line maximum may (I) either stay unchanged with variation of t_p or (II) may decrease. The behaviour (I) is well known from the first studies of dislocations in silicon, while case (II), i.e. a decreasing $T_{\max}$ with increasing t_p has been found recently by us for thin NiSi_2 -platelets. The cases (I) and (II) may be also recognized from typical differences in the line shape.

Using computer simulations we show in this work that the line shape and the $T_{\max}(t_p)$ -relation is strongly influenced by two properties of the extended defect: (1) its density of states, and (2) the carrier exchange rate r_{xc} within it. We have studied in some detail the two limiting cases that (2a) r_{xc} is large compared to electron capture rate at the defect, and that (2b) r_{xc} small

compared to the electron emission rate from the defect.

In the first case the occupation of the extended defect at any time during emission can be approximated by one occupation probability f or one quasi-Fermi level E_{0F} . In the rate equation the emission term is an integral taken over the product of the defect density of states $N_d(E)$, their occupation probability $f(E)$ and the emission rate $e_n(E)$. It turns out that in this case (2a) the DLTS-line maximum shifts with t_p .

In the second case the emission of any state E_i of the extended defect occurs independently of all the others and $f(E_i)$ is obtained as solution of the rate equation for state i . The total number of electrons emitted during the small time interval dt is obtained as a sum over all i of the changes of $f(E_i)$ during the time interval dt considered. The simulation shows that in this case (2b) the line maximum T_{max} does not shift with t_p .

The results of the simulation establish a clear relation between the physical criteria (2a) and (2b) and the experimentally established cases (I) and (II).

Case (2a) is shown to apply to the DLTS of small $NiSi_2$ -platelets in silicon, whose line shape is consistent with the density of states of a two-dimensional system. Case (2b) is observed in the DLTS of edge-type dislocations in silicon. A possible density of states in this case results from a point defect cloud in the compression field of the dislocation.