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A temperature independent emission component in the capacitance transients of deep-level defects in germanium

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Introduction

Treatments involving high temperatures, e.g. quenching, may introduce impurities and point defects in Ge, which may give rise to deep levels in the band gap and which may reduce the carrier lifetimes.

An adequate technique to study these defects is Deep Level Transient Spectroscopy (DLTS). In one of the DLTS signals of quenched p-type Ge an additional emission component has been observed when using large time windows. The characteristics of this emission have been compared to those of the recently studied $Co^{+/0}$ level in Co-implanted p-type Ge [1] which also exhibits such behaviour.

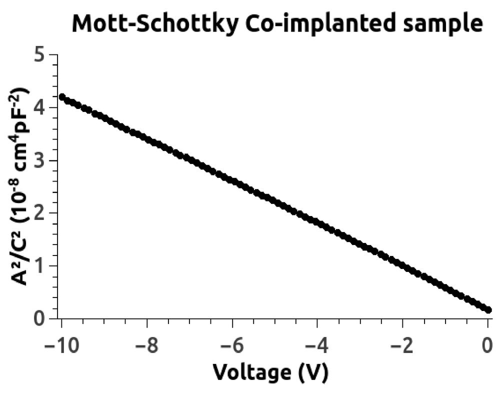
Additional emission component

Experimental

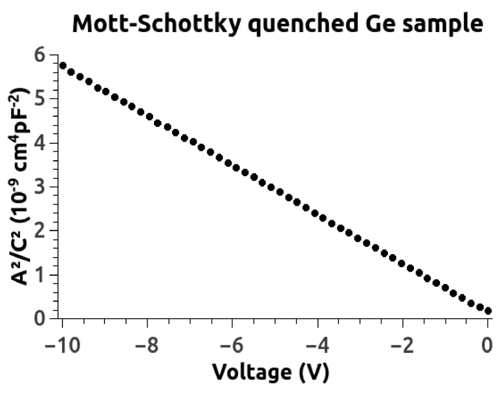
p-type germanium samples (10x10x2mm³).

"Co-implanted": (5.10[13] cm⁻²) at 90 keV + Thermal Annealing at 500°C (5 min).
"Quenched Ge": 30 min in preheated tube furnace (700°C) + quenched in silicon oil (25°C)

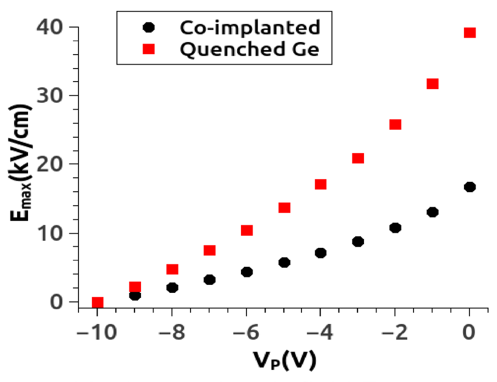
The samples were etched ($HF+HNO_3$) and prepared for DLTS measurements by evaporating In to form Schottky junctions.



Co-implanted Ge (T=15K)
N_S=1.6x10[14]/cm³



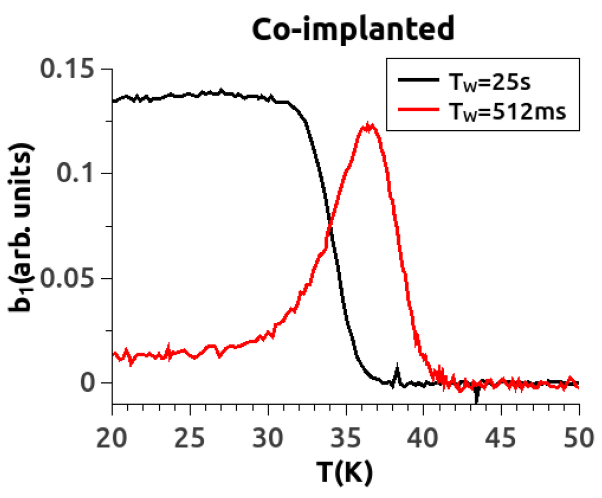
Quenched Ge (T=140K)
N_S=9.8x10[14]/cm³



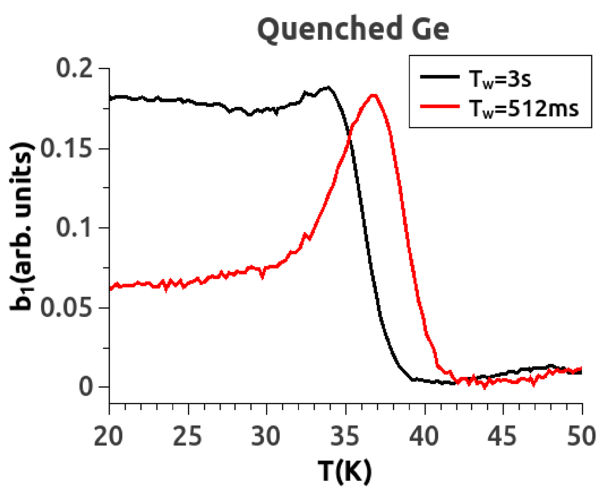
Maximum electric field E_{max} as a function of pulse voltage V_P

Ohmic contacts were prepared using In-Ga eutectic and In foil. Capacitance transients were measured after a pulse from V_R (-10V) to V_P. The DLTS time window is denoted by T_w. A pulse duration of 100 ms was used for T_w < 1s and 200 ms for T_w > 1s.

Observation



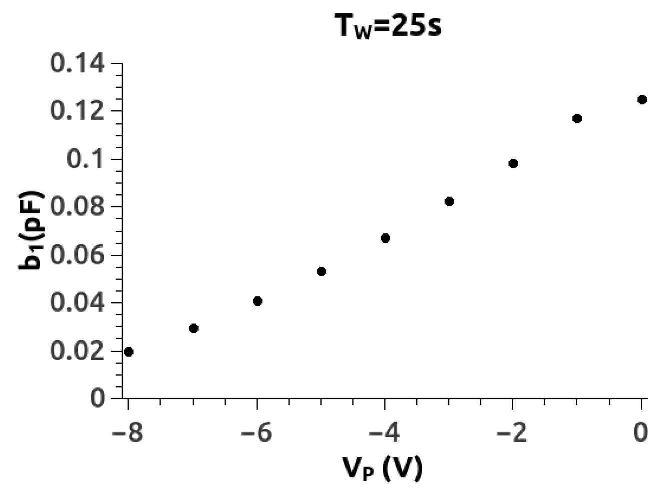
E_T=86 meV

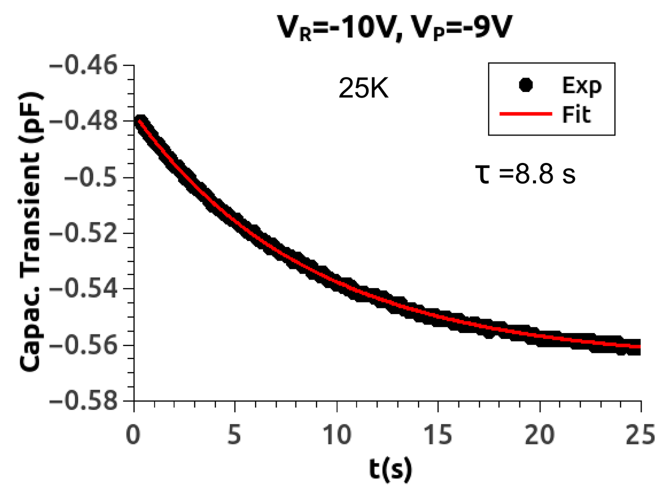


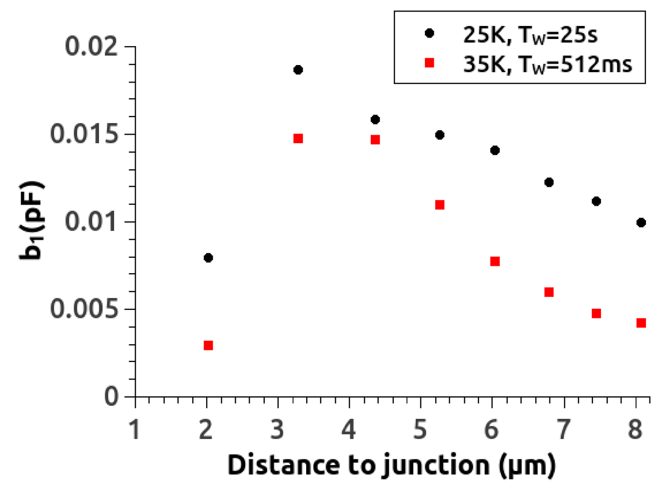
E_T=63 meV

→ "Tunneling"-plateau is "shunted" as soon as the thermionic effect begins [2]

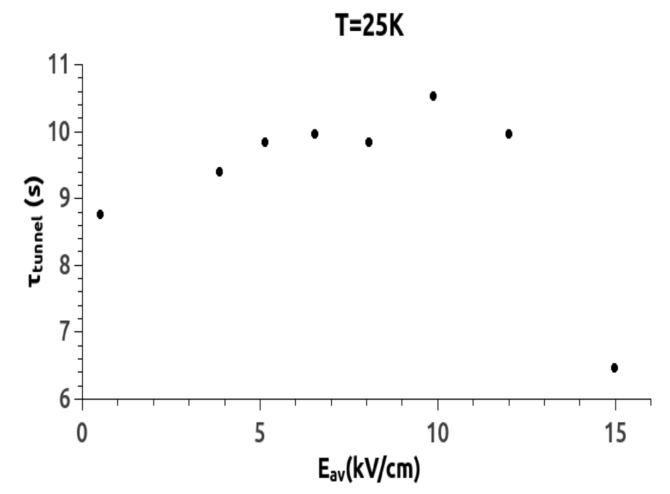
Co-implanted Ge





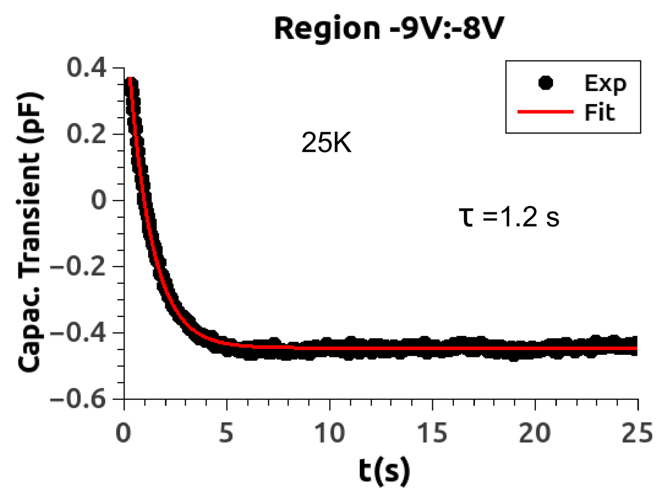


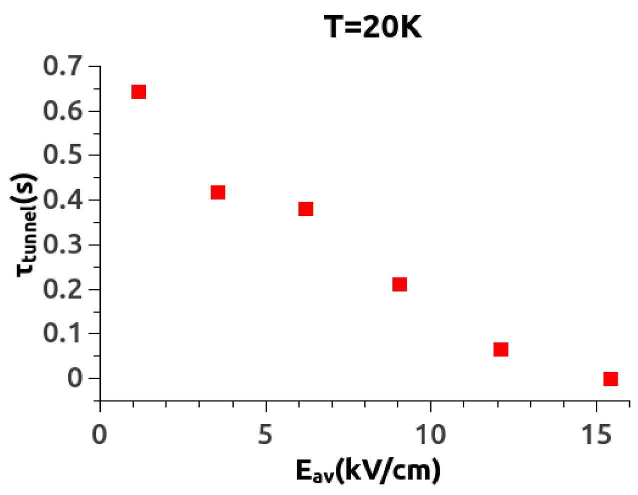
→ The thermal and tunnel emission follow the same profile

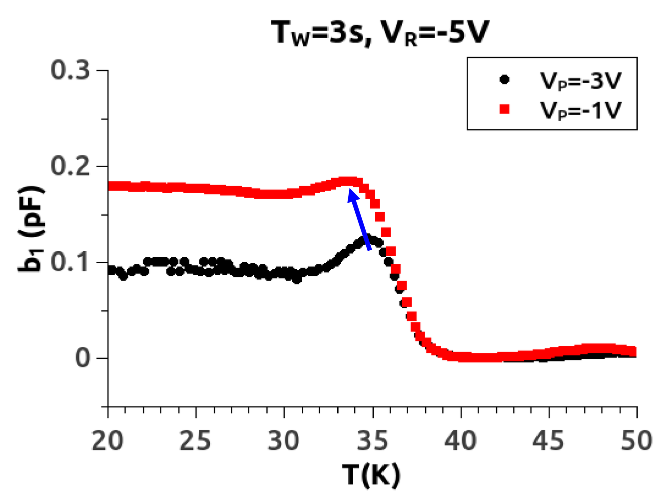


→ τ_{tunnel} practically independent of electric field.

Quenched Ge







→ Attractive center (Poole-Frenkel shift)

→ Peak position dependent on external electric field.

→ τ_{tunnel} depends on electric field

→ Model for attractive potential seems to apply

Simulation

$$C(t)=\frac{a_0}{2}+\sum_{n=1}^{\infty}\left[a_n\cos(n\omega t)+b_n\sin(n\omega t)\right]$$

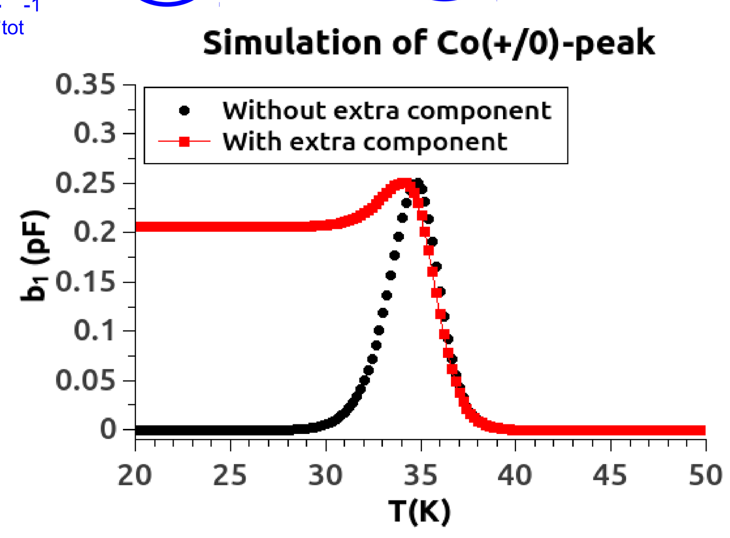
$$\omega=\frac{2\pi}{T_W}$$

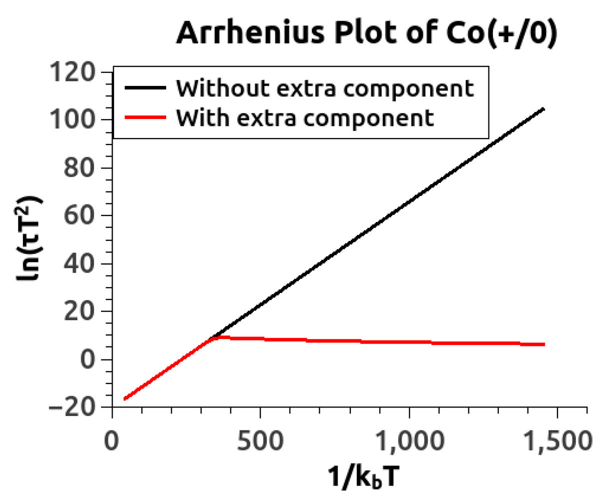
$$b_n=\frac{2}{T_W}\int_0^{T_W}C(t)\sin(n\omega t)\,dt$$

$$b_1=\frac{2A}{T_W}\exp\left(\frac{-t_0}{\tau}\right)\left[1-\exp\left(\frac{-T_W}{\tau}\right)\right]\frac{\omega}{\frac{1}{\tau^2}+\omega^2}$$

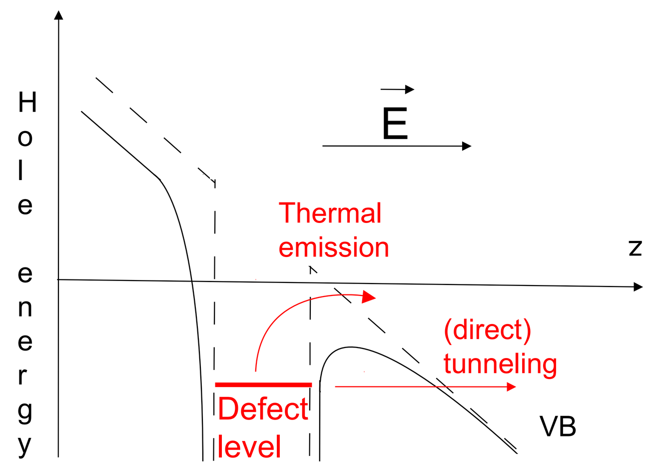
$$e_{tot}=K_T T^2 e^{\frac{-E}{kT}}+e_2$$

τ_{tot}^{-1} ← e_{tot}; e_2 → τ_{tunnel}^{-1}





Model, in case of attractive potential



The potential of a neutral (dashed) or charged (full) deep impurity with external electric field [3]

Conclusions

	Charge	PF-shift	E-dep. τ
Co-implanted	0	X	X
Quenched Ge	-	V	V

→ The two investigated deep defects in Ge exhibit two parallel emission paths, one from thermal emission and a second one attributed to localized level-to-band tunneling.
→ For the "neutral" hole trap level $Co^{+/0}$, the tunnel time was observed to be practically independent of electric field.
→ The quenching induced level (E_T=63 meV) is attractive to holes (Poole-Frenkel effect) and here the tunnel time appears to be electric field dependent.

References

[1] J. Lauwaert, J. Vanhellemont, E. Simoen, H. Vrielinck and P. Clauws, J. APPL. PHYS, submitted (2012)
[2] X. Letartre, D. Stiévenard and M. Lannoo, J. APPL. PHYS **69 (10)** 7336-7338 (1991)
[3] S.D. Ganichev, I.N. Yassievich and W. Prettl, J.PHYS.:CONDENS. MATTER **14** R1263-1295 (2002)

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