ShanghaiTech GaNology Lab
氮化镓电子器件实验室

Trap properties of SiC SBD studied by DLTS

ShanghaiTech

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Outline:

1. Fresh SiC diode DLTS test:

Capacitance-DLTS (C-DLTS)

2. Irradiated SiC diode DLTS test:

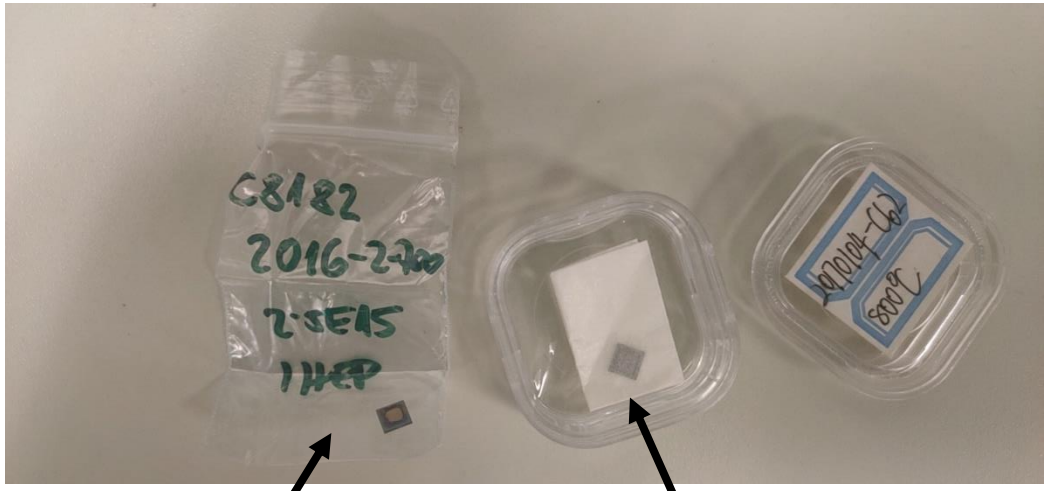
I-DLTS temperature scan

3. Comparison

- Trap properties of Fresh and irradiated SiC SBD
- Using I-DLTS and C-DLTS test for fresh SiC SBD

1. Fresh SiC SBD





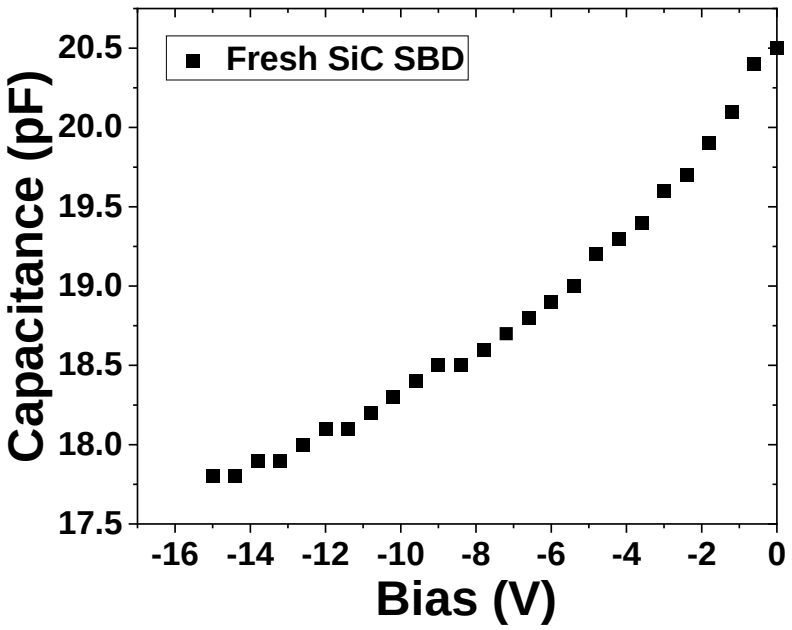
Irradiation Sample

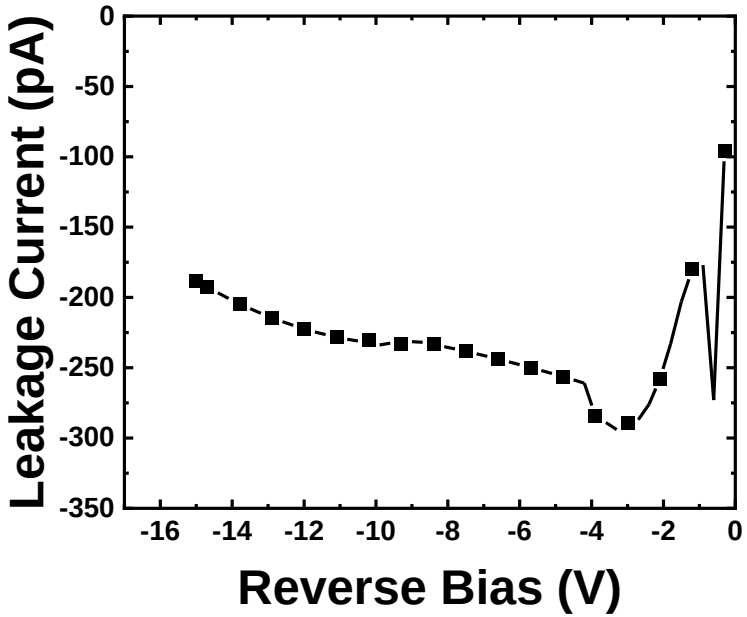
Fresh sample

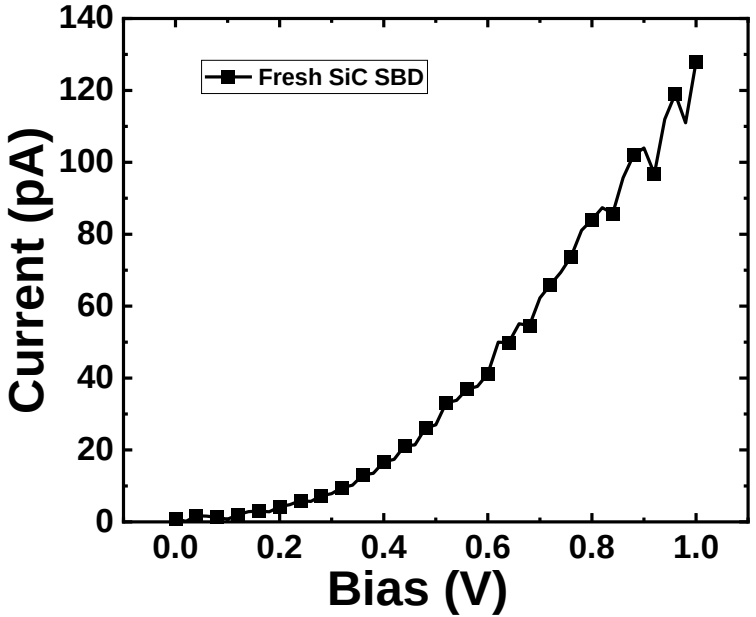
Sample Area： 5mm x 5mm
Anode Area: 4mm x 4mm

Ns=1E14cm^{-3}

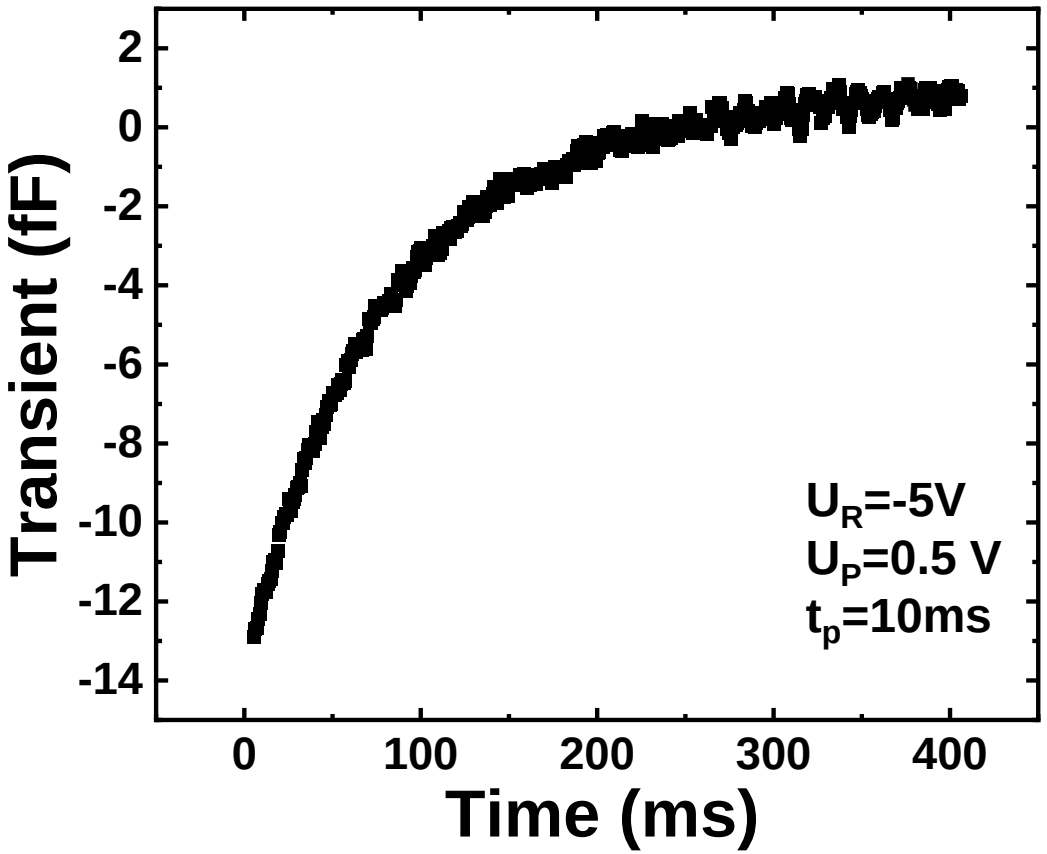
CV and IV tests at RT for fresh SiC SBD







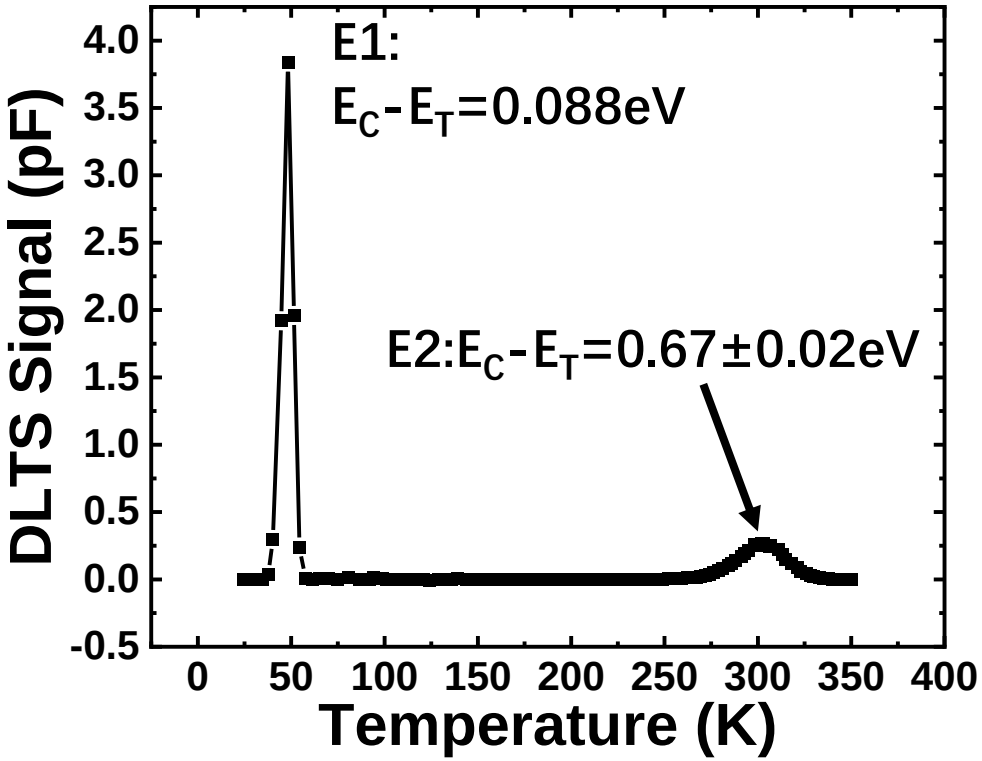
Fresh SBD capacitance transient (1MHz) at 300K

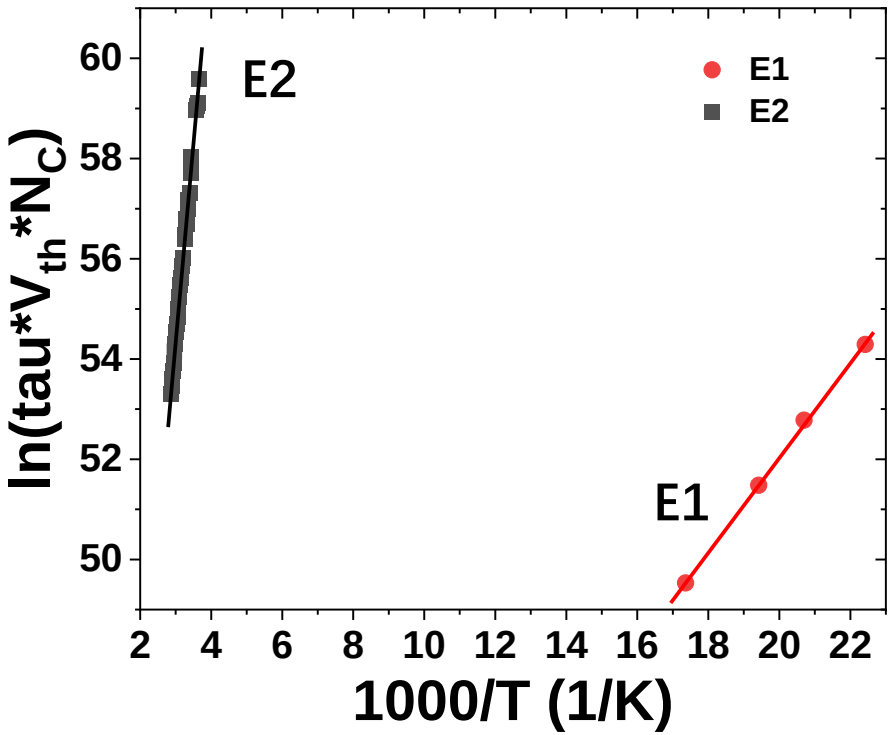


- The capacitance transients of fresh SiC SBD were tested under 1MHz.
- The transient direction indicating the type of traps is majority carrier trap

----electron trap

C-DLTS test of SiC fresh SBD （50-350K）





DLTS conditions:
U_R=-6V
U_P=-0.1V
t_p=100ms

Level	Activation energy （eV）	Capture cross section (cm^2)	N_T(cm^{-3})
E1	0.088	1.60E-14	4.61E+13
E2	0.67	3.53E-14	3.08E+12

- Two electron traps were observed by C-DLTS and have similar capture cross section .
- Around 300K, the activation energy of E2 is 0.67eV.
- The trap concentration(N_T) of E1 is higher than E2.

2. Irradiated SiC SBD

Irradiation parameter：
1MeV Neutron irradiation

Irradiation dose:2.5E15 Neq/cm^2



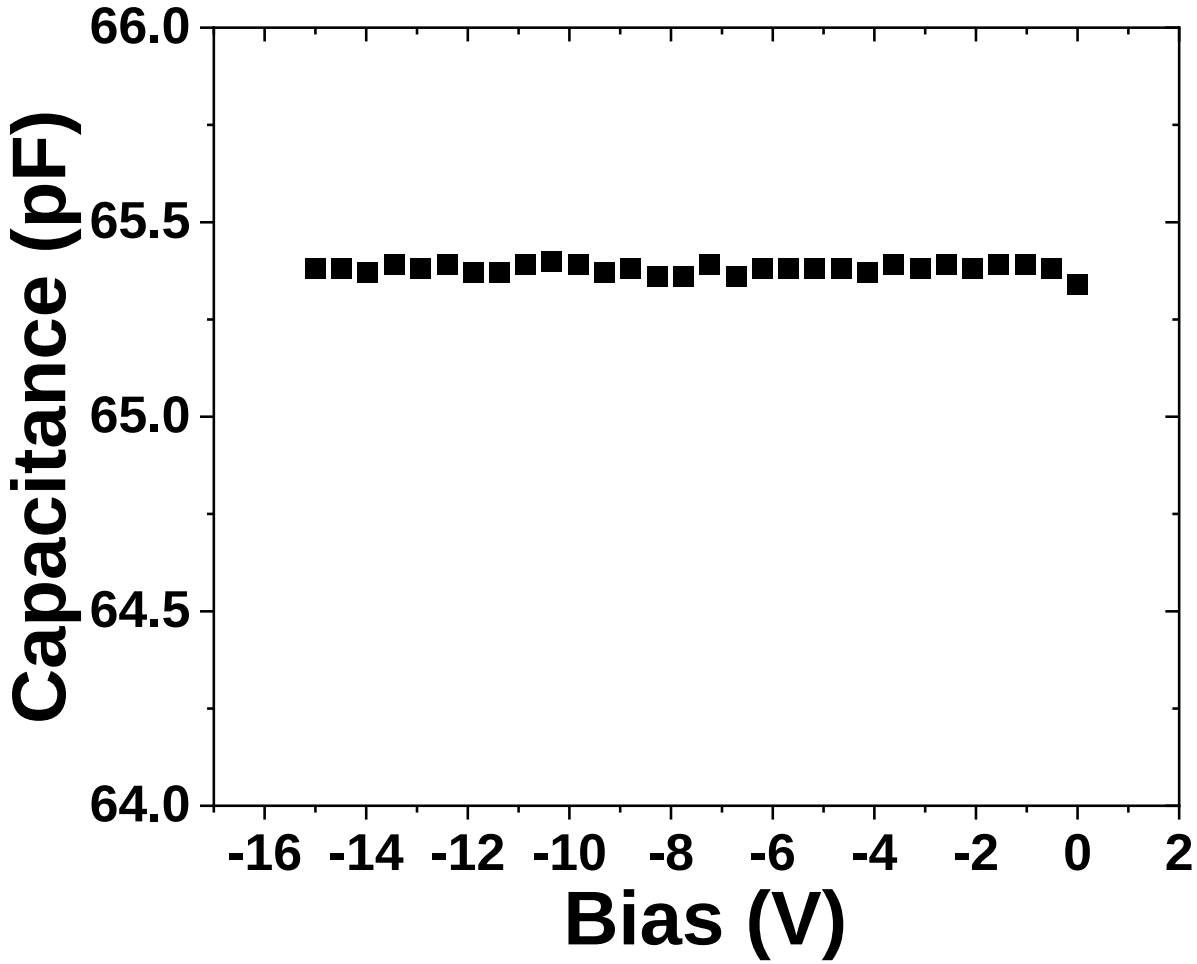


Sample anode



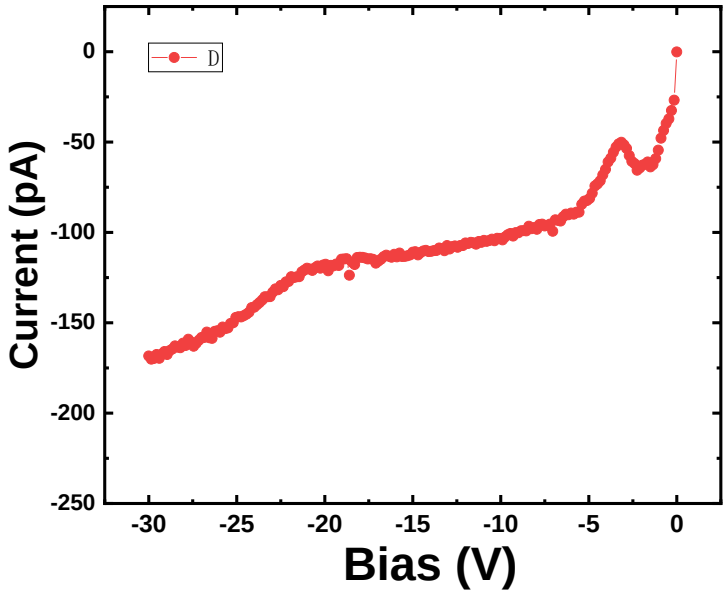
Sample cathode

C-V test at RT （300K）

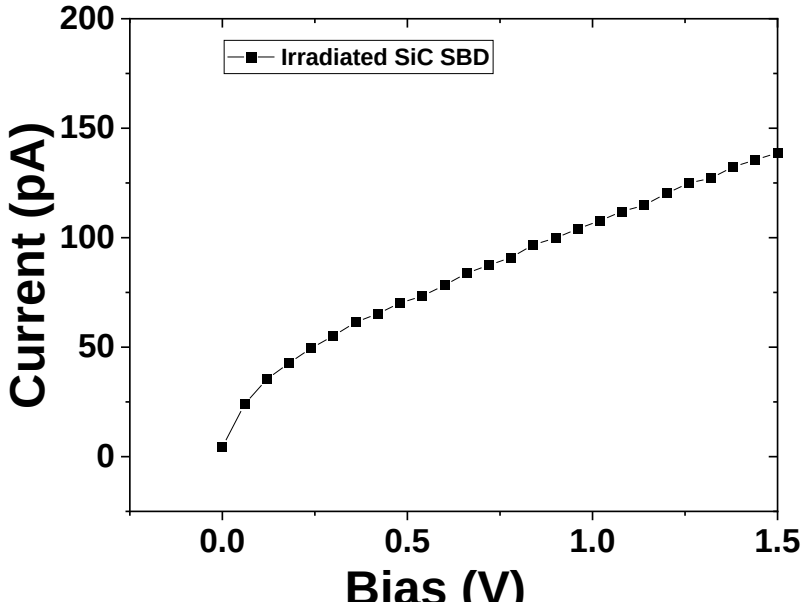


After irradiation，the capacitance of SiC SBD is nearly independent with reverse bias.

I-V test at 300K

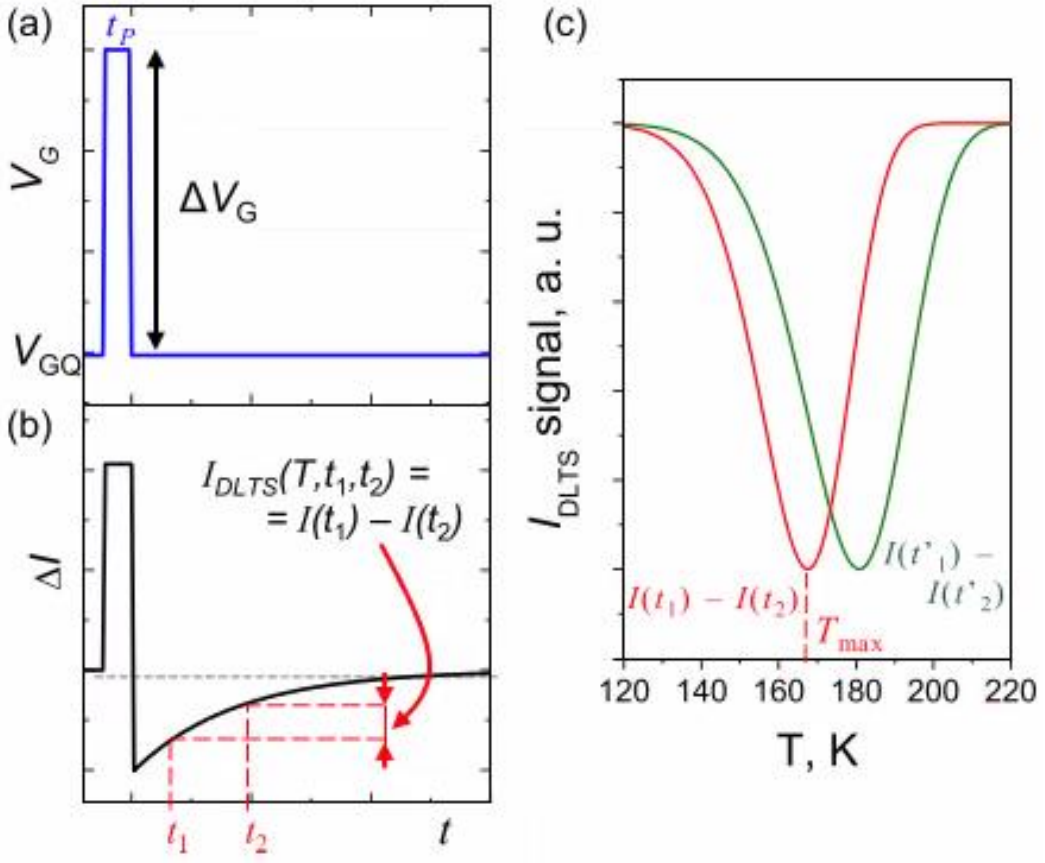


- Because traditional Capacitance DLTS transient is not good, we try to use current-DLTS to test.



At same bias, the forward current is lower than fresh SBD.

Current DLTS features



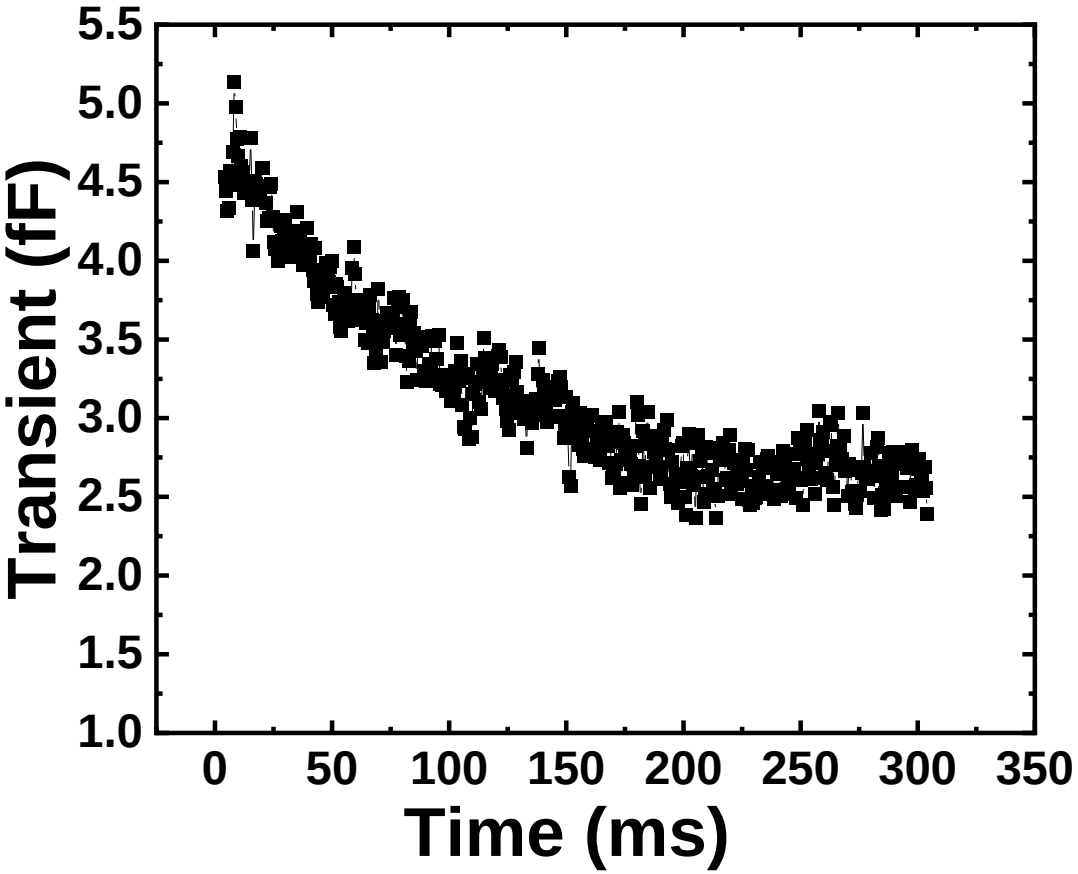
[1] Isakov, Ivan JAP, 2017.

- In current DLTS, the integrated current over time represents the total charge released by the traps.
- The sensitivity of current DLTS is also temperature depending because the amplitude depends on the temperature. An additional disadvantage is the approximation for NT.
- The current produced by holes and by electrons is of the same sense, so current DLTS cannot distinguish between hole and electron emission.
- The rate of carrier emission e_n from the deep traps can be expressed as:

$$e_n \propto \sigma_0 \exp(-E_{dl}/k_B T)$$

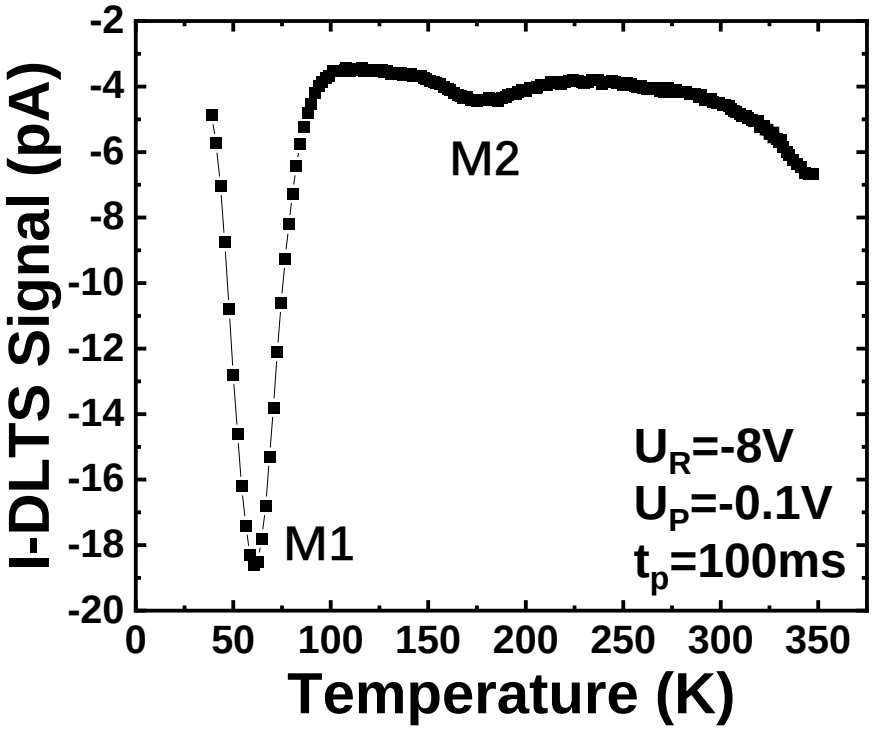
where Edl is the deep trap activation energy, δ_0 the trap cross-section, and k_B Boltzmann's constant. Hence, the emission rate will vary with temperature T.

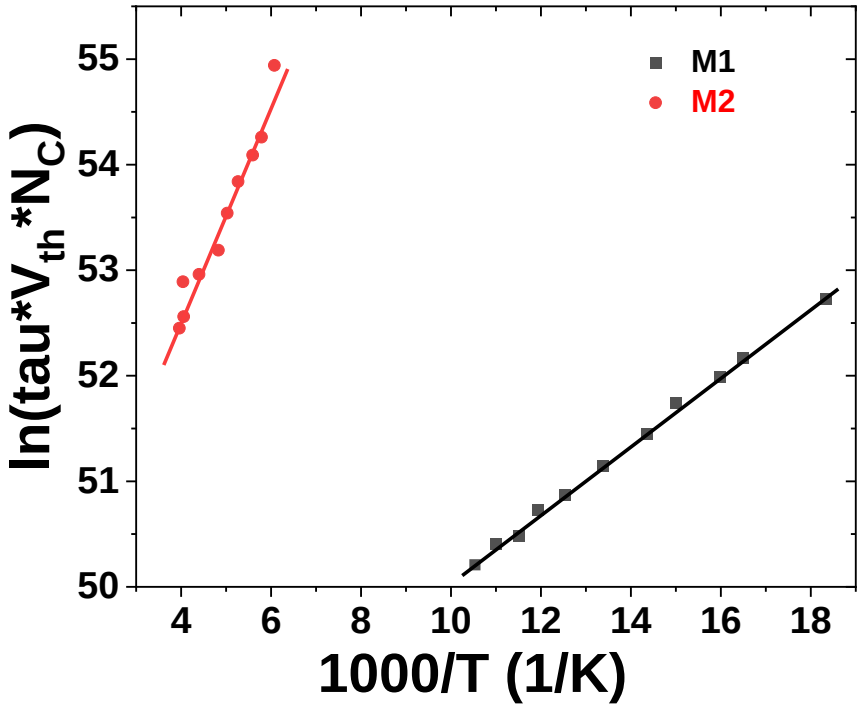
No invert transient of irradiation SiC SBD



- The direction of transient indicating the type of traps are minority traps.
- The amplitude of capacitance transient is small.

Irradiated SiC SBD I-DLTS test （20K-350K）



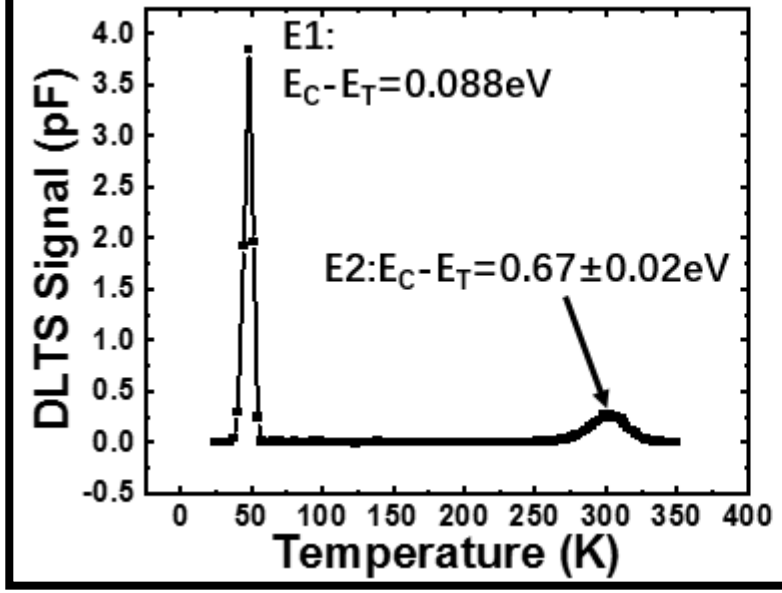


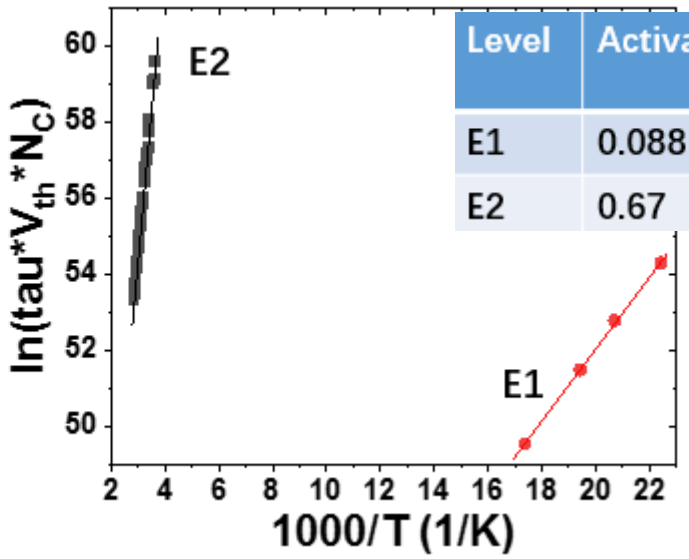
After irradiation, two minor carrier traps (hole traps) were observed.

Level	Activation energy （eV）	Capture cross section (cm^2)	N_T(cm^{-3})
M1	0.028	4.7E-21	2.8E+10
M2	0.104	2.7E-21	6.7E+09

3. Comparison

Fresh SiC SBD

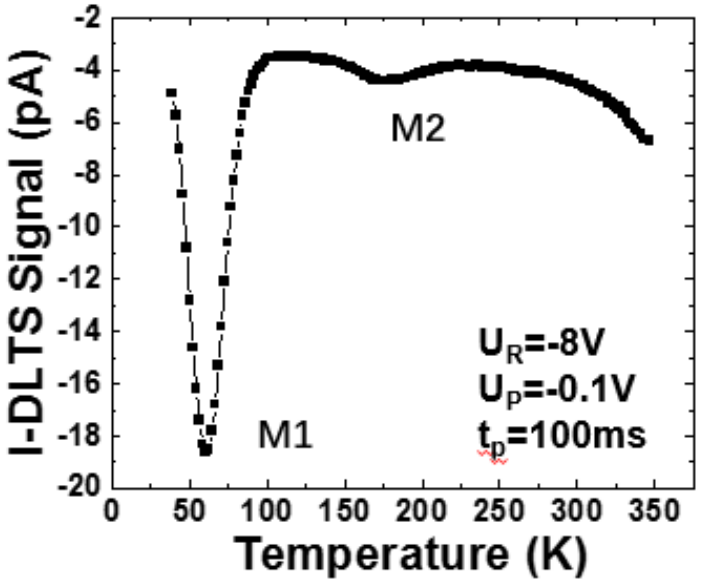


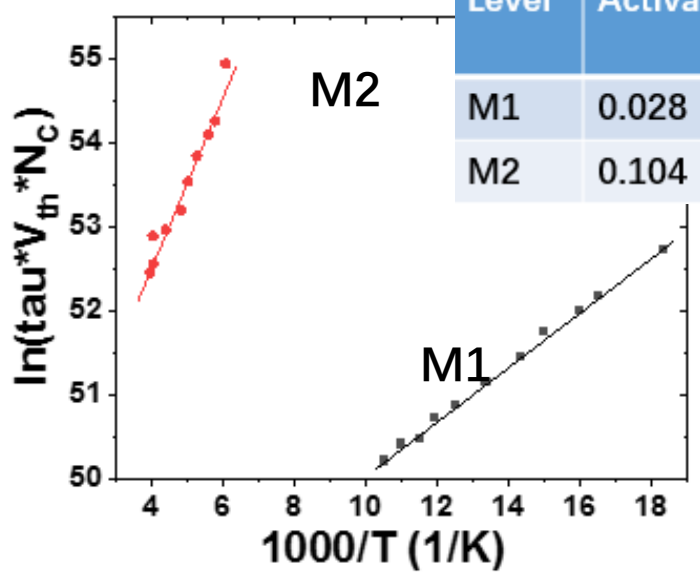


Level	Activation energy (eV)	Capture cross section (cm^2)	N_T(cm^{-3})
E1	0.088	1.60E-14	4.61E+13
E2	0.67	3.53E-14	3.08E+12

C-DLTS conditions:
U_R=-6V
U_P=-0.1V
t_p=100ms

Irradiated SiC SBD

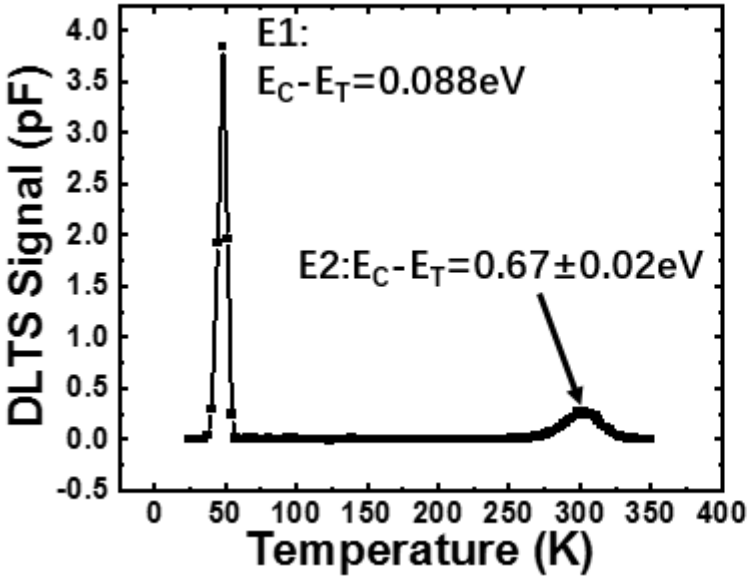


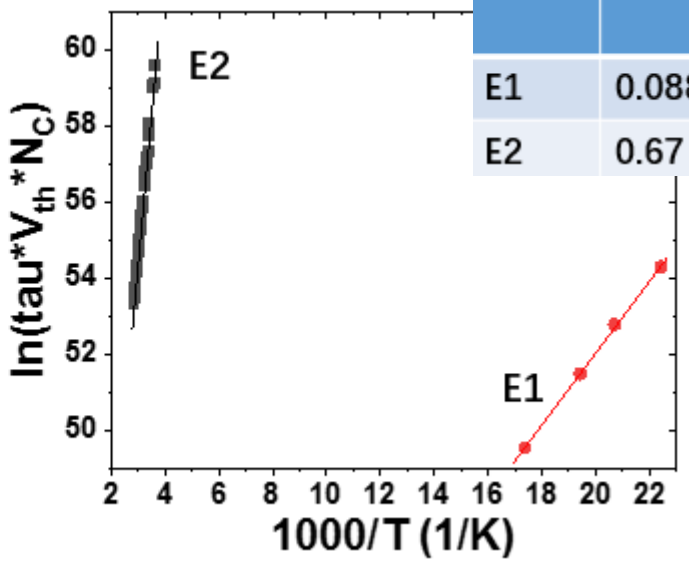


Level	Activation energy (eV)	Capture cross section (cm^2)	N_T(cm^{-3})
M1	0.028	4.7E-21	2.8E+10
M2	0.104	2.7E-21	6.7E+09

Comparison by C-DLTS and I-DLTS for fresh SiC SBD

Capacitance based DLTS (C-DLTS)

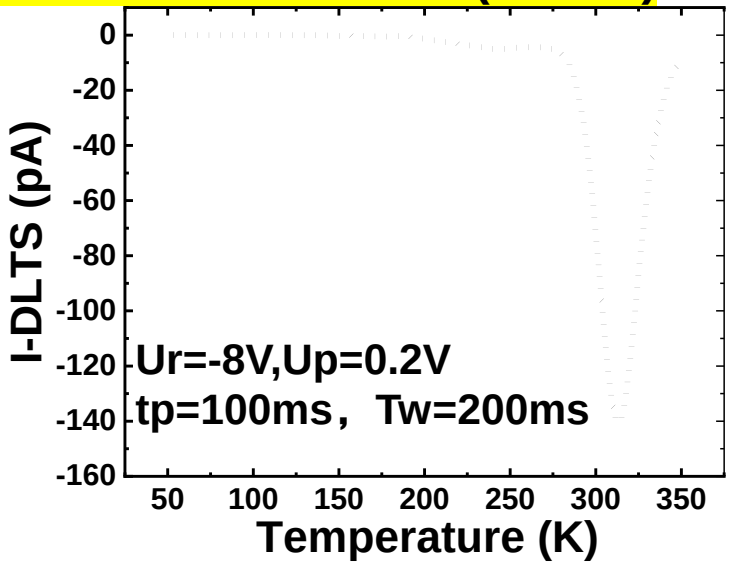


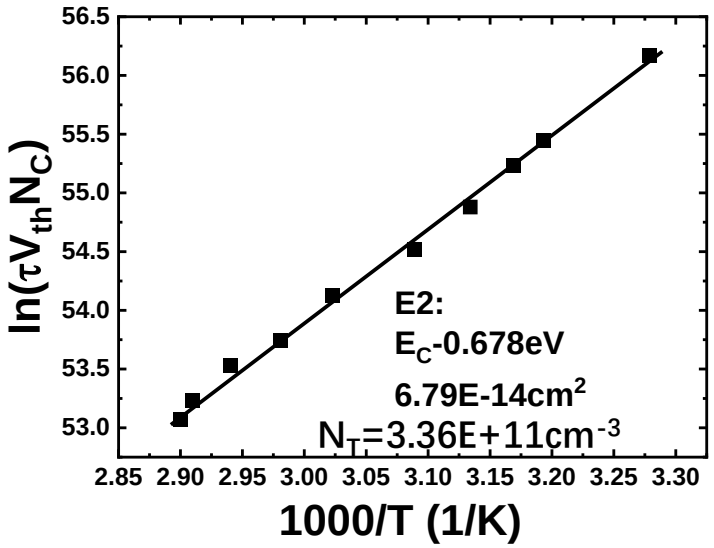


Level	Activation energy (eV)	Capture cross section (cm^2)	N_T(cm^{-3})
E1	0.088	1.60E-14	4.61E+13
E2	0.67	3.53E-14	3.08E+12

Test conditions:
Ur=-6V,Up=-0.1V, tp=100ms

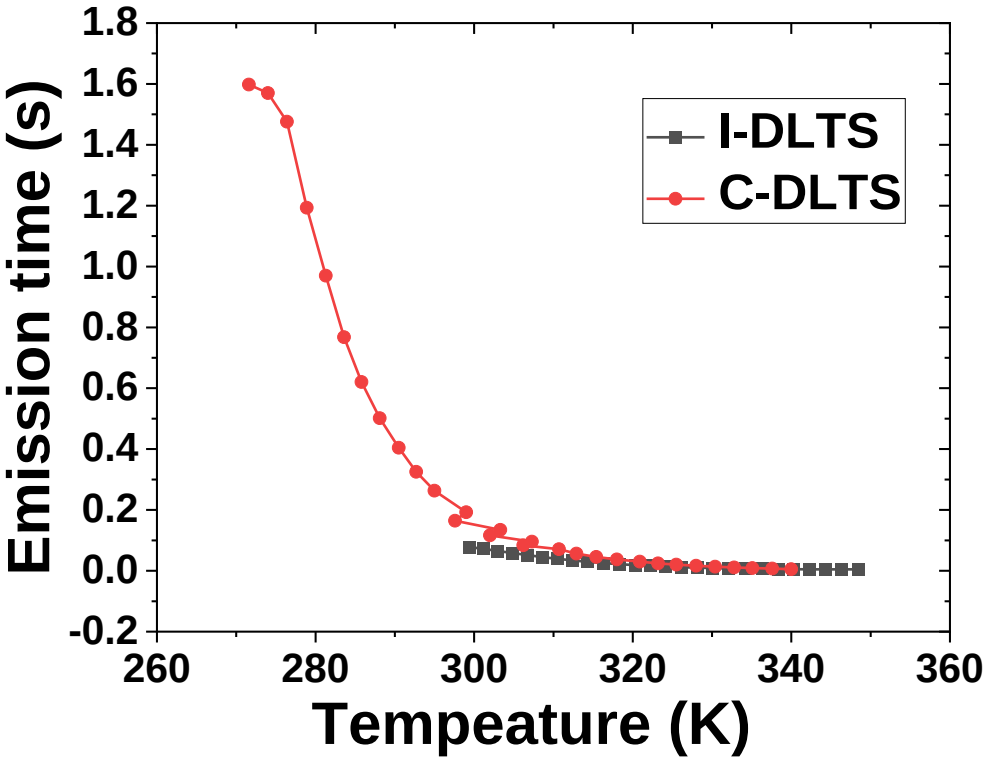
Current based DLTS (I-DLTS)

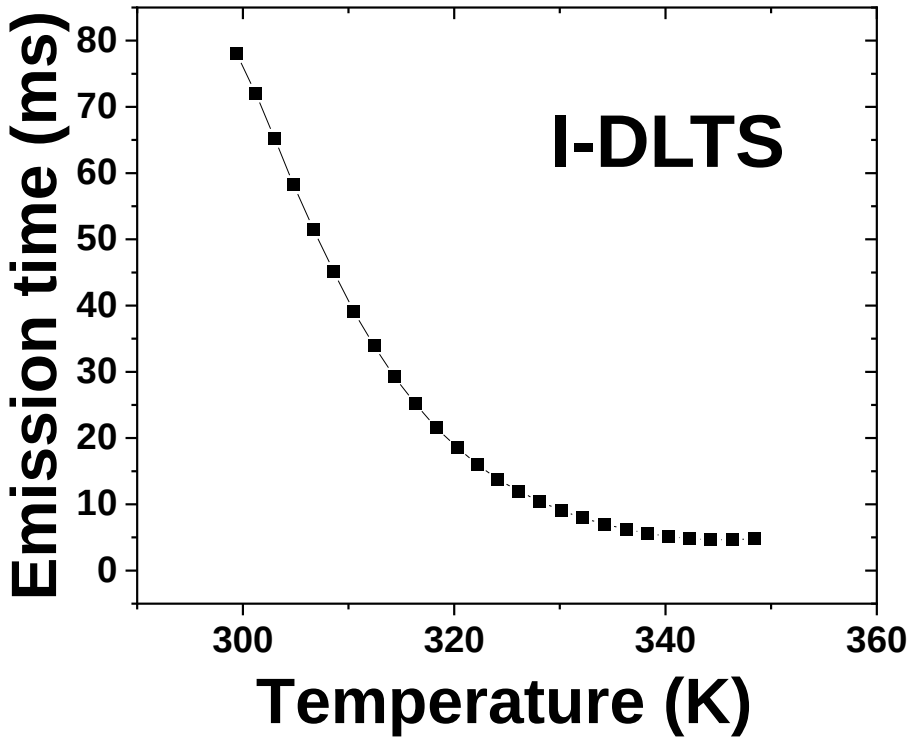




- The trap **E2** have been found and have similar trap energy and capture cross section using C-DLTS and I-DLTS.

Temperature dependent trap emission time of E2 in fresh SBD by two ways





- By two DLTS methods, we could obtain the temperature dependent emission time constant of E2 (E_C-E_T=0.67eV) above 300K.
- The emission times of E2 mainly are dozens of milliseconds around RT and are accelerated by temperature increasing from 300K (80ms) to 350K (4.5ms).

Conclusion:

- Fro fresh SiC SBD, electron traps E1 (E_C-E_T=0.088eV) and E2 (E_C-E_T=0.67eV) were observed using C-DLTS. And E2 also has been observed by I-DLTS.
- For irradiated SiC SBD, the capacitance is nearly independent with reverse bias and two shallow hole traps (M1,M2) were observed using I-DLTS.
- The trap concentration and capture cross section of irradiated SBD are less than fresh SiC SBD.
- The forward conductive ability of irradiated SiC SBD has degradation.
- The temperature dependent trap emission time constant of E2 in fresh SiC SBD have been demonstrated by C-DLTS and I-DLTS.
- The emission time of E2 is nearly 80ms at 300K and are accelerated to 4.5ms at 350K.