Irradiation damage in sublimation grown 6H-SiC

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SiC is a material with unique abilities:

- Large band gap (3.02eV for 6H-SiC)
- High electrical breakdown field
- High temperature stability
- Chemically inert
- $E_{d\ SiC} > E_{d\ Si}$

E_d is the threshold energy for defect production, defined as the minimal energy needed to produce a Frenkel pair (vacancy + interstitial).

Nitrogen deactivation in 4H-SiC:

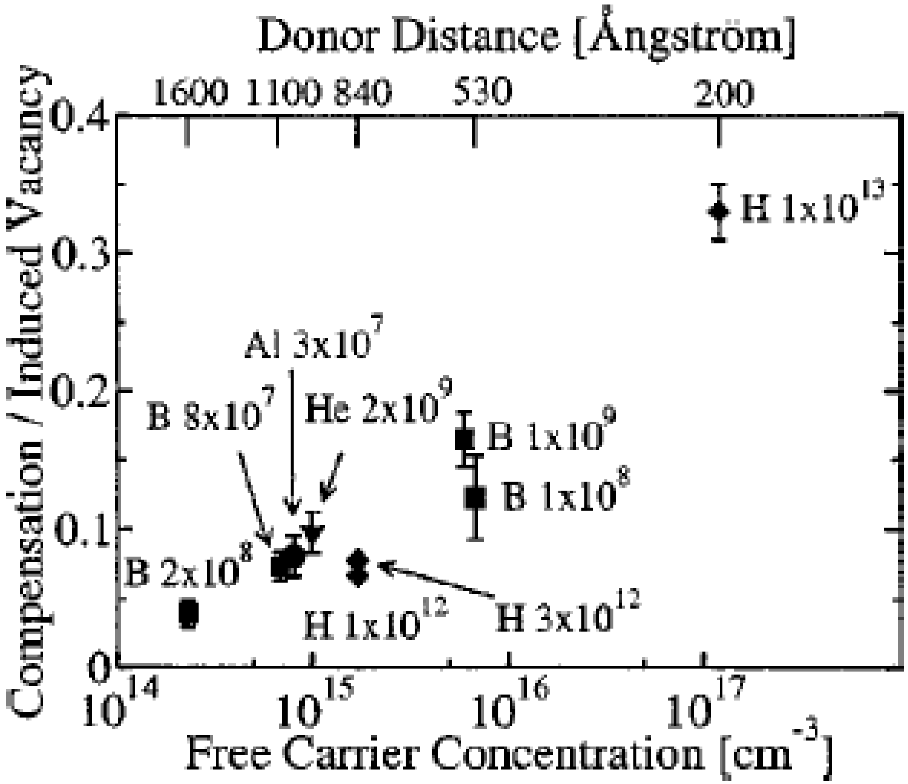
- N is the most important and common dopant in n-type SiC.

- Particle irradiation has shown to reduce the number of free carriers in the semiconductor.

- The reduction of free carriers in 4H-SiC is about one order of magnitude larger than in Si. Most of this reduction is due to dopant deactivation.
  (The figure may vary with type of irradiation, doping, etc. Further investigations are needed!)

- High concentration of N gives a high deactivation rate

Studies on N-deactivation in 4H-SiC:



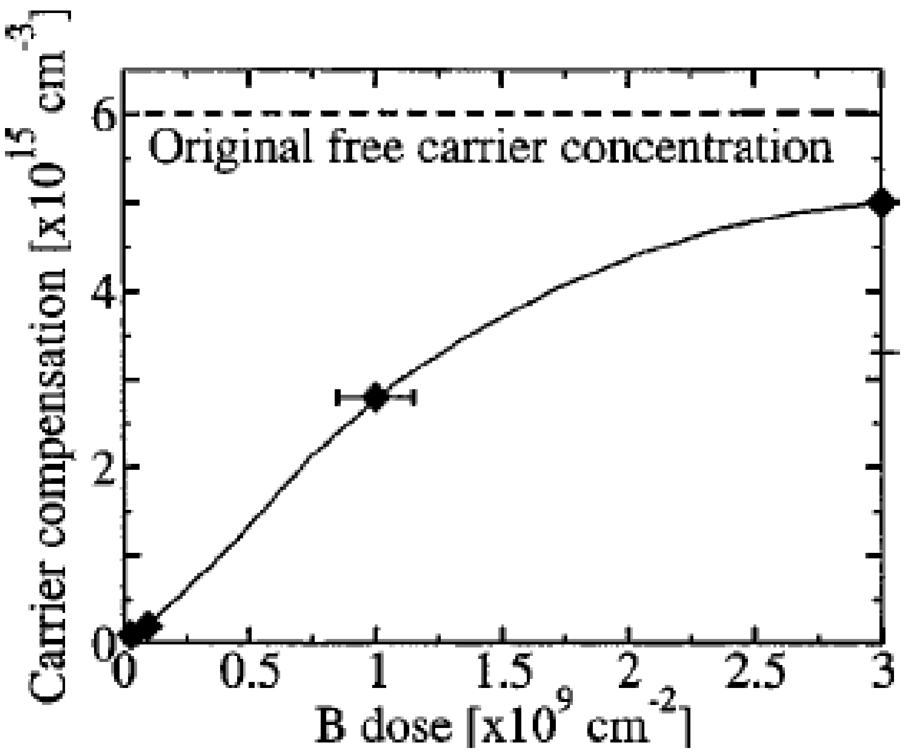


Figure reference:

D. Åberg, A. Hallén, P. Pellegrino and B.G. Svensson. *Appl. Phys. Lett.* **78** (2001), p. 2908.

More facts about nitrogen deactivation:

- The cause of the passivation remains to be found.

- The total concentration of defects detected by DLTS amounts only less than 10% of the measured carrier reduction.

- The carrier reduction is not caused by creation of shallow acceptor dopants in the lower half of the band gap, as these would not saturate, but instead convert the samples to p-type which is not seen.

- It has been suggested (by D. Åberg et al.) that the passivation is caused by a simple defect trapped at the N site. The Si vacancy was suggested as a likely candidate.

Experimental Details:

- n-type 6H-SiC grown with a sublimation technique was studied.
  (The samples where provided by our collaborators at the Ioffe Institute in St. Petersburg.)

- Nitrogen doping ~5E16 cm^{-3}

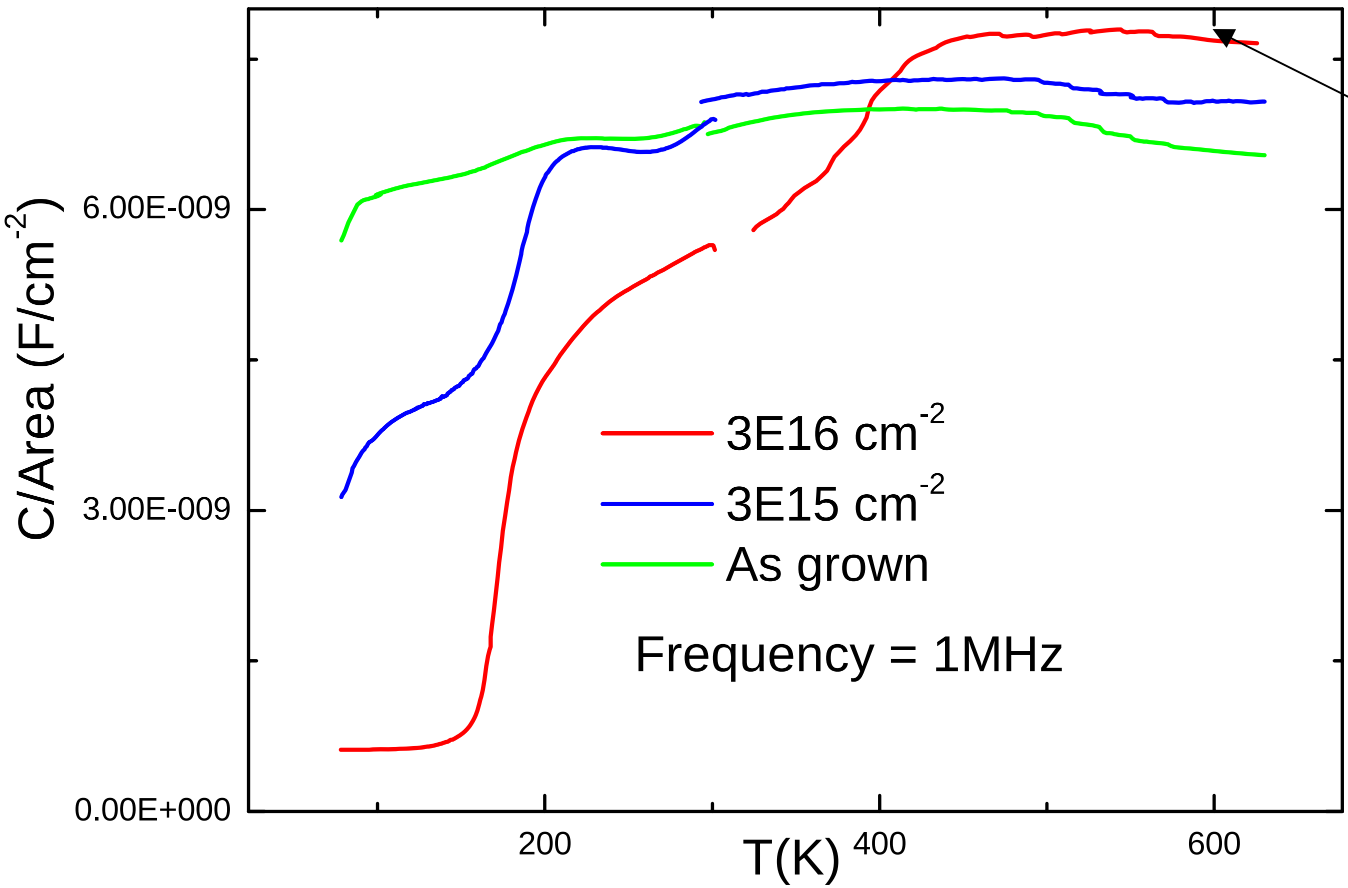
- e- irradiation was performed to doses of 3E15 and 3E16 cm^{-2}.

- The effects of irradiation was studied by with CV, admittance spectroscopy and DLTS measurements.

Irradiation-dose	Carrier-cons at 300K	Carrier-cons at 160K
As grown	5E16	3E16
3E15	3E16	1.5E16
3E16	2E16	Compensated

In regular 4H-SiC (CREE) one would expect the material to be fully compensated here.

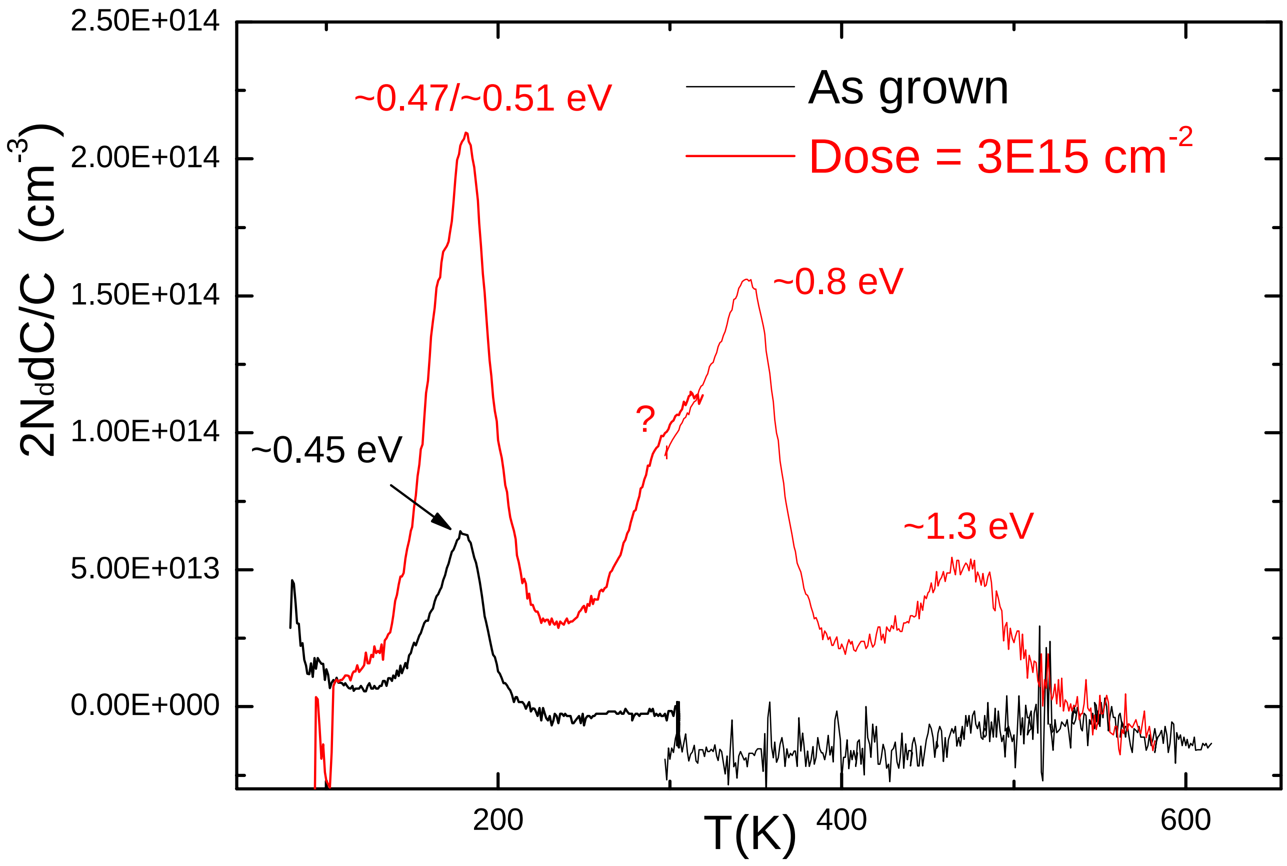
Adspec. results



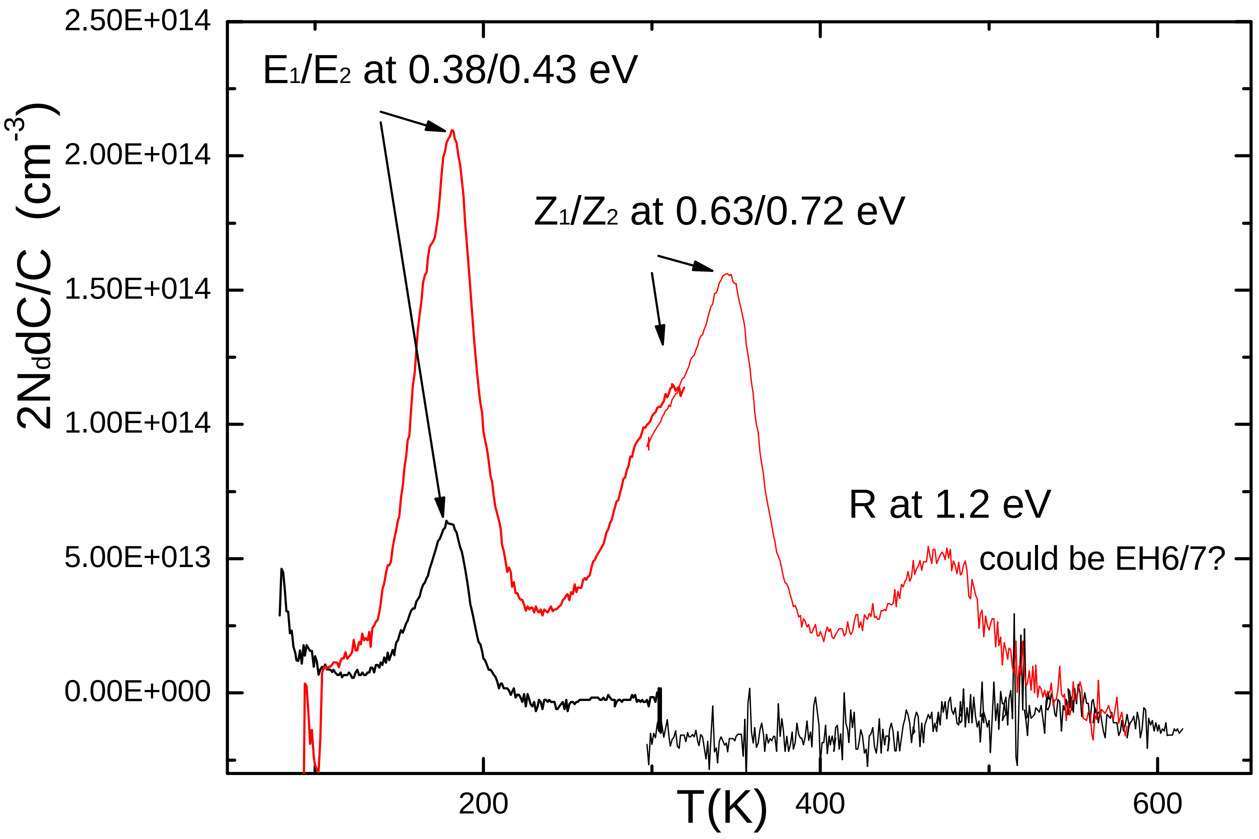
At high temperatures the number of carriers increases with irradiation dose!!

The steps tell us that the compensation at lower temperatures is caused by deep levels. No deactivation observed.

DLTS spectra:

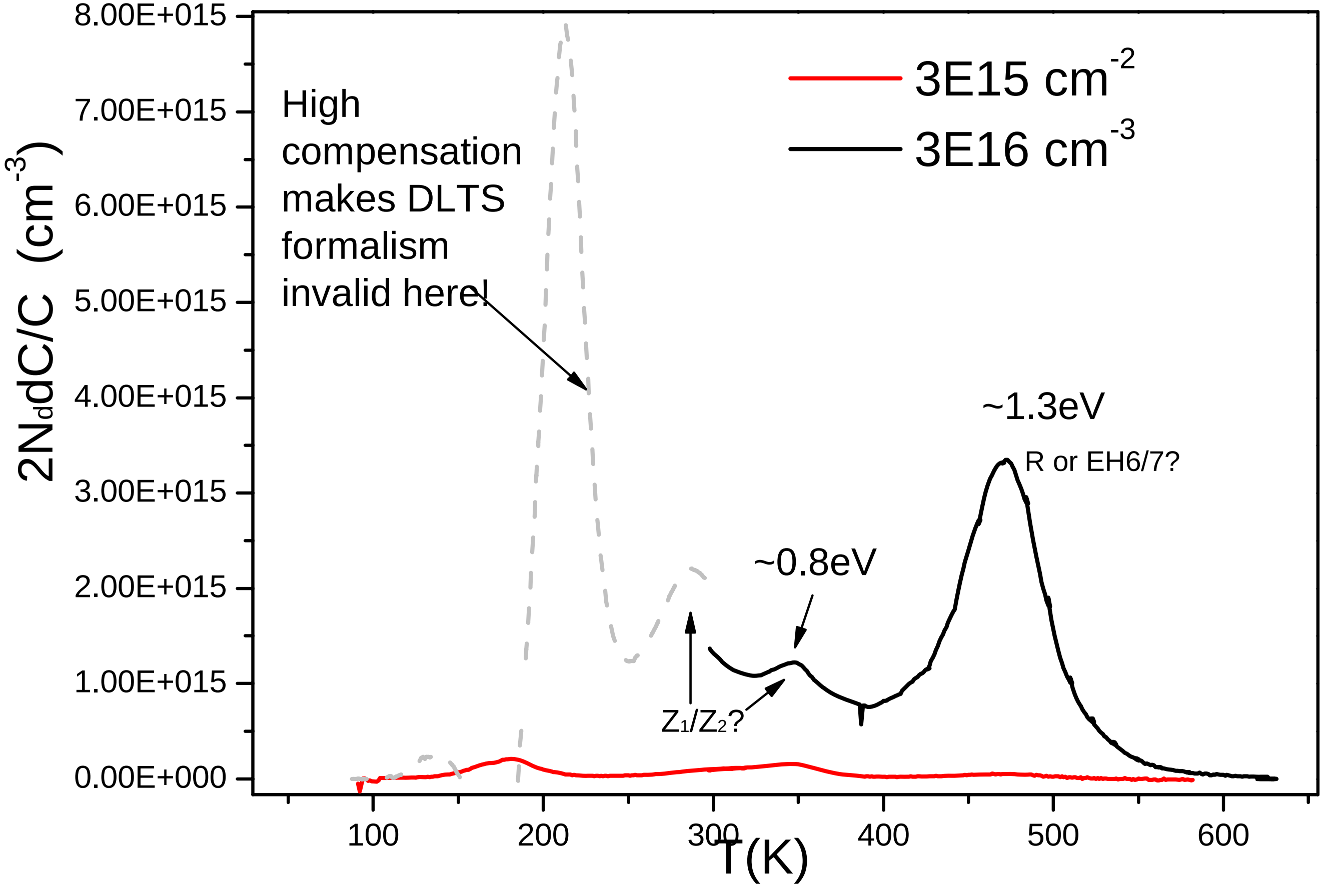


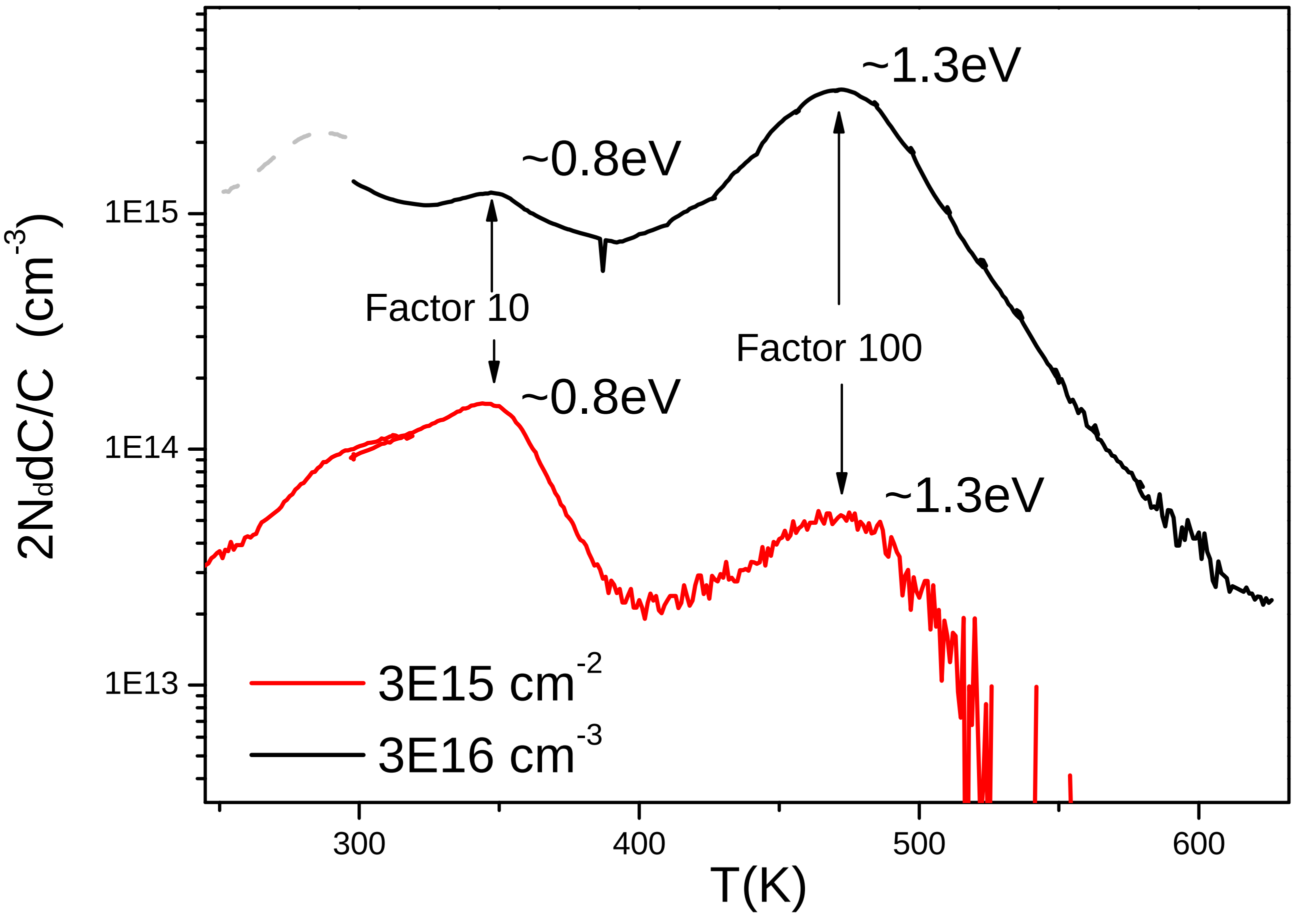
Similar spectra have been seen by other groups, who made the following identifications:



These assignments are uncertain!!!

DLTS spectra:





The ~1.3eV level may have a second order generation rate.
Further studies must be done to confirm this. (2 points is not enough!)

The important point:

Compensation in 6H-SiC grown by sublimation is caused by deep levels, not nitrogen deactivation. This is promising with regards to the radiation hardness of the material.