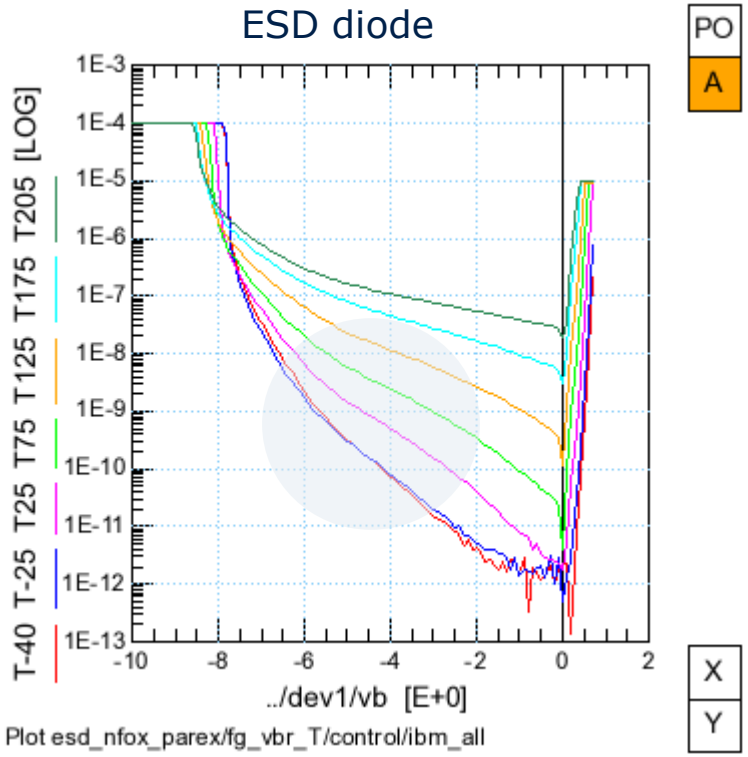
How to model the temperature dependence of a diode tunnel current

Joerg Berkner
ATV PTP TD EDA DCM

Tunnel current
for a reverse biased ESD diode

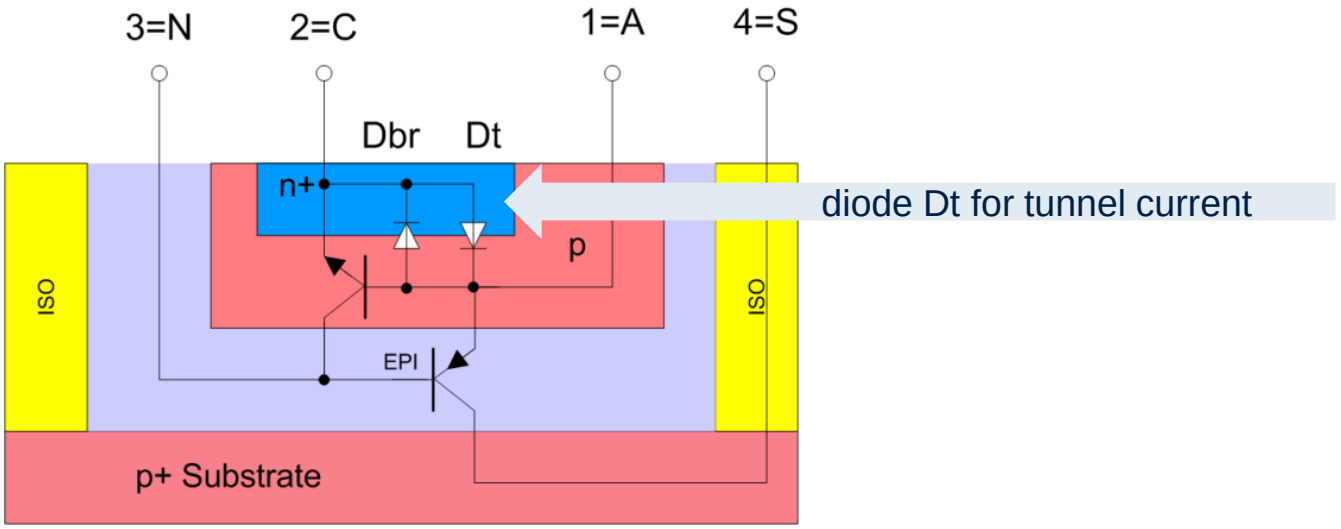


A typical curve for a ESD diode
The increasing current up to Vbe= -6V is called “tunnel current” here*, whereas at -8V the avalanche effect takes place

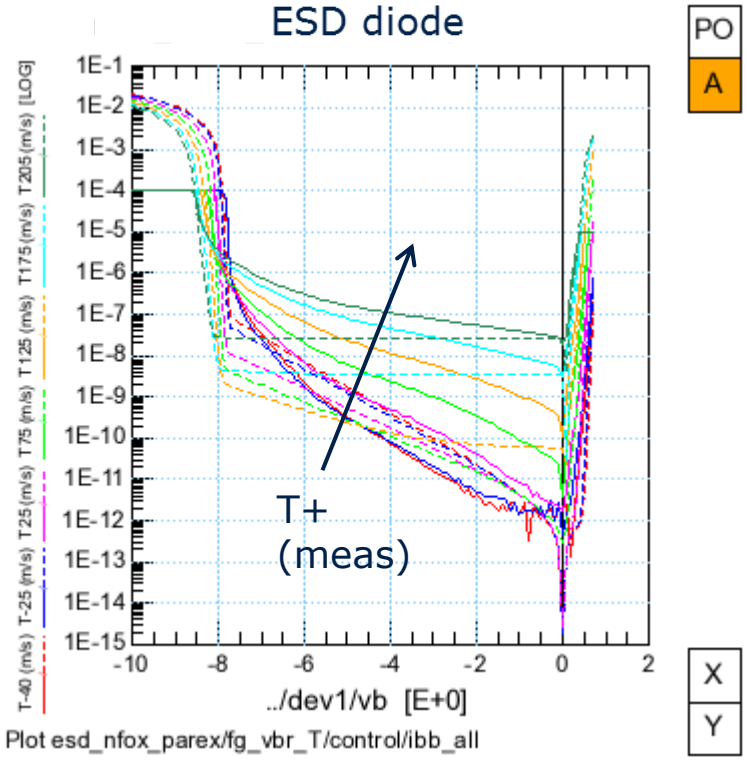
*according to Ashburn: SiGe HBTs, p.65

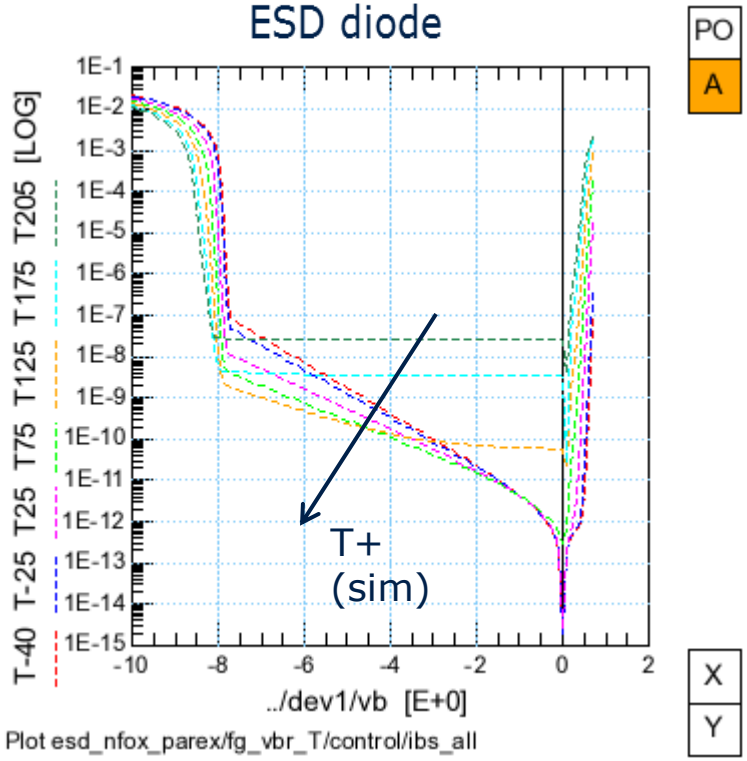
Tunnel current modeling using antiparallel diode Dt1

- Diode tunnel current may be simulated at room temperature using an antiparallel diode Dt1
- A very large emission coefficient value is necessary, e.g. N=40
- However, for such high N-values the temperature dependence of the current inverses!



Tunnel current modeling using antiparallel diode Dt

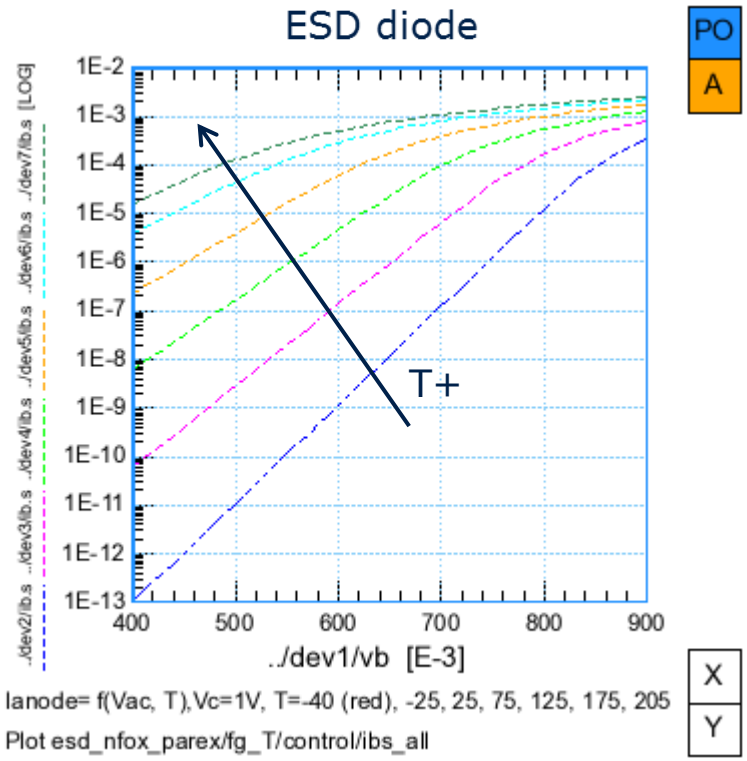


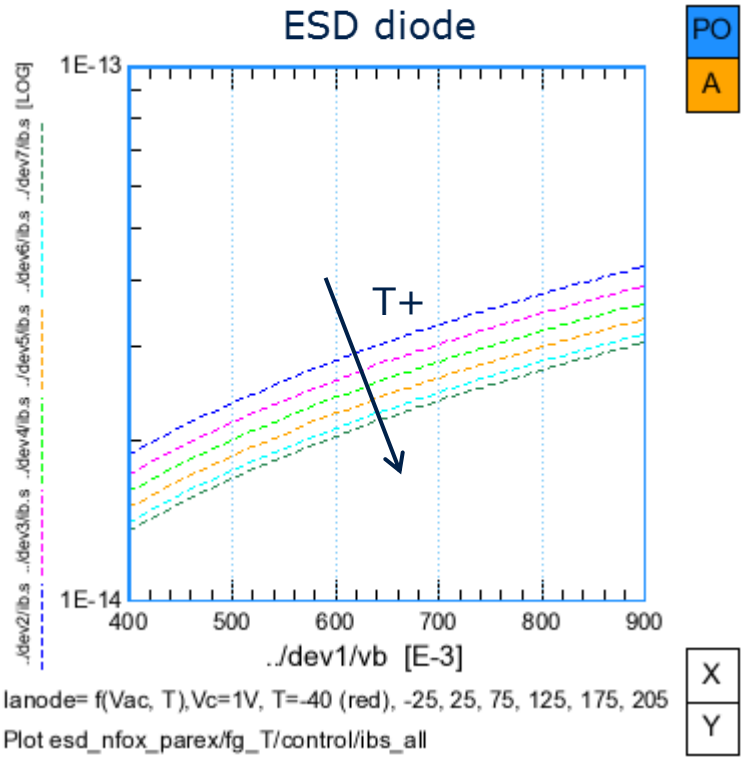


- Problem: antiparallel diode creates wrong temperature dependence in the tunnel current range
- Why?

Reason(1)
Simulation Id(T) forward

- Comparison: Id(T) @ N=1 and Id(T) @ N=10





- Model parameters for simulation:
  IS=10a, N=1, EG=1.11, XTI=3

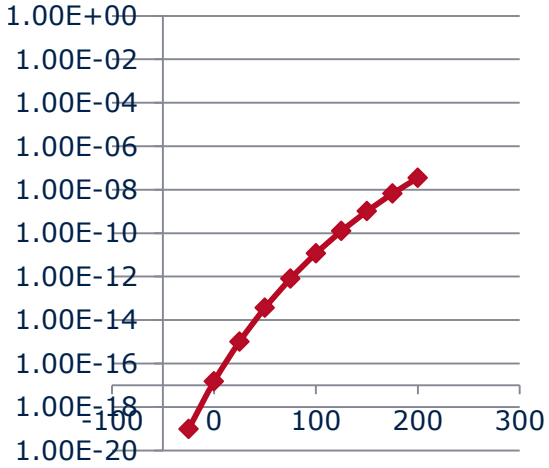
- Model parameters for simulation:
  IS=10a, N=10, EG=1.11, XTI=3

Reason(2)
Id(T) for N=1

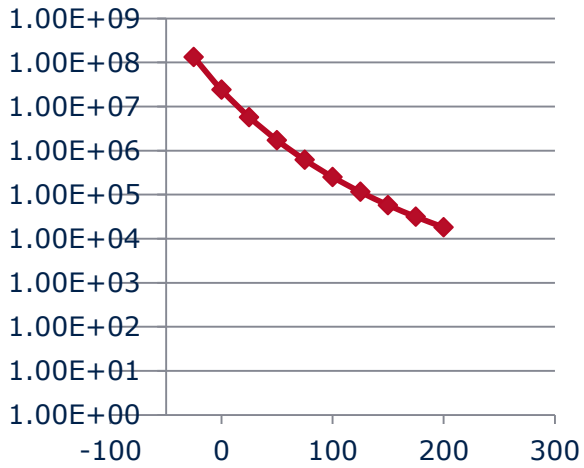
$$IS(T) = \underbrace{IS(T_0)\left[\frac{T}{T_0}\right]^{XTI/N}}_{IS(T)} \cdot \underbrace{\exp\left[\frac{EG}{N \cdot V_T(T_0)}\left(1-\frac{T_0}{T}\right)\right]}_{IS-Multiplier}$$

$$I_D(T) = IS(T) \cdot \left[\exp\left(\frac{EG}{N \cdot V_T(T_0)}\right) - 1\right]$$

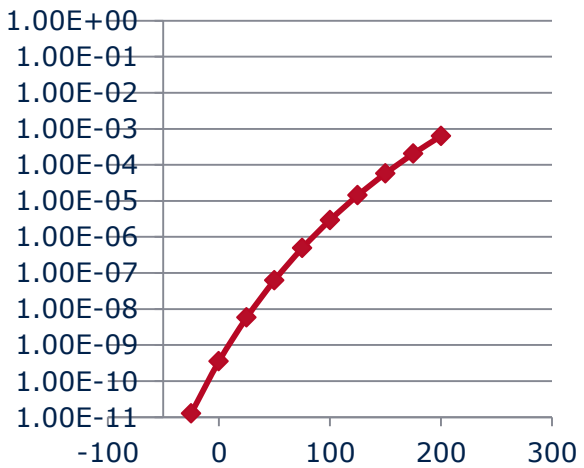
IS(T)



IS-Multiplier



Id(T)



Simulation using IS=1a, EG=1.11, XTI=3, N=1

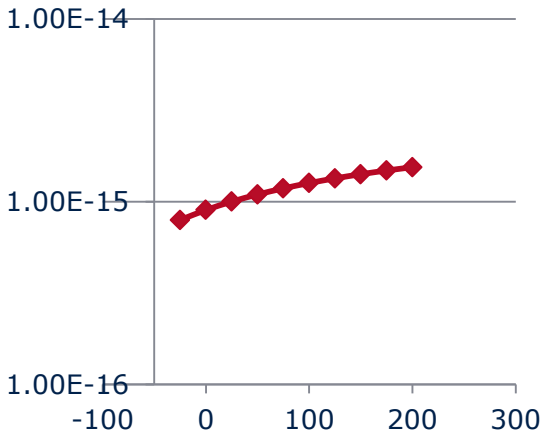
- Result: positive TC of Id for N=1

Reason(3)
Id(T) for N=40

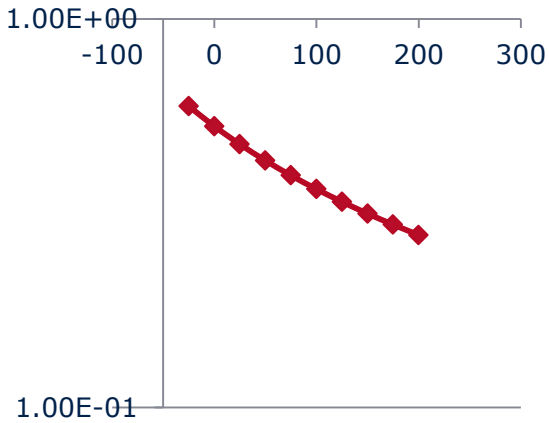
$$IS(T) = \underbrace{IS(T_0)\left[\frac{T}{T_0}\right]^{XTI/N}}_{IS(T)} \cdot \underbrace{\exp\left[\frac{EG}{N \cdot V_T(T_0)}\left(1-\frac{T_0}{T}\right)\right]}_{IS-Multiplier}$$

$$I_D(T) = IS(T) \cdot \left[\exp\left(\frac{EG}{N \cdot V_T(T_0)}\right) - 1\right]$$

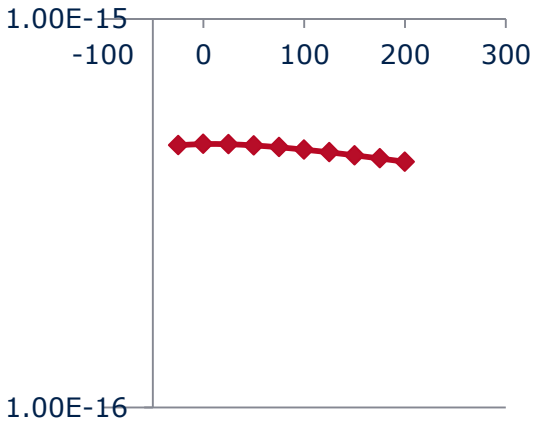
IS(T)



IS-Multiplier



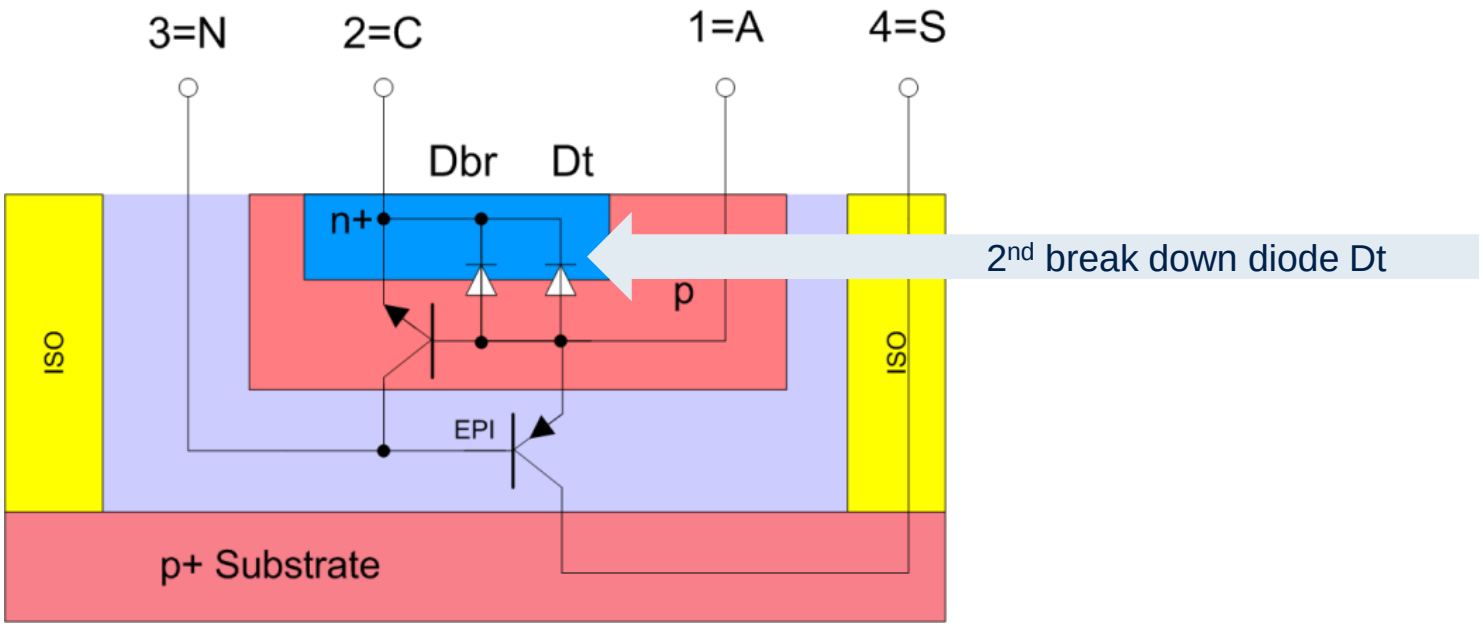
Id(T)



calculated using IS=1a, EG=1.11, XTI=3, N=40

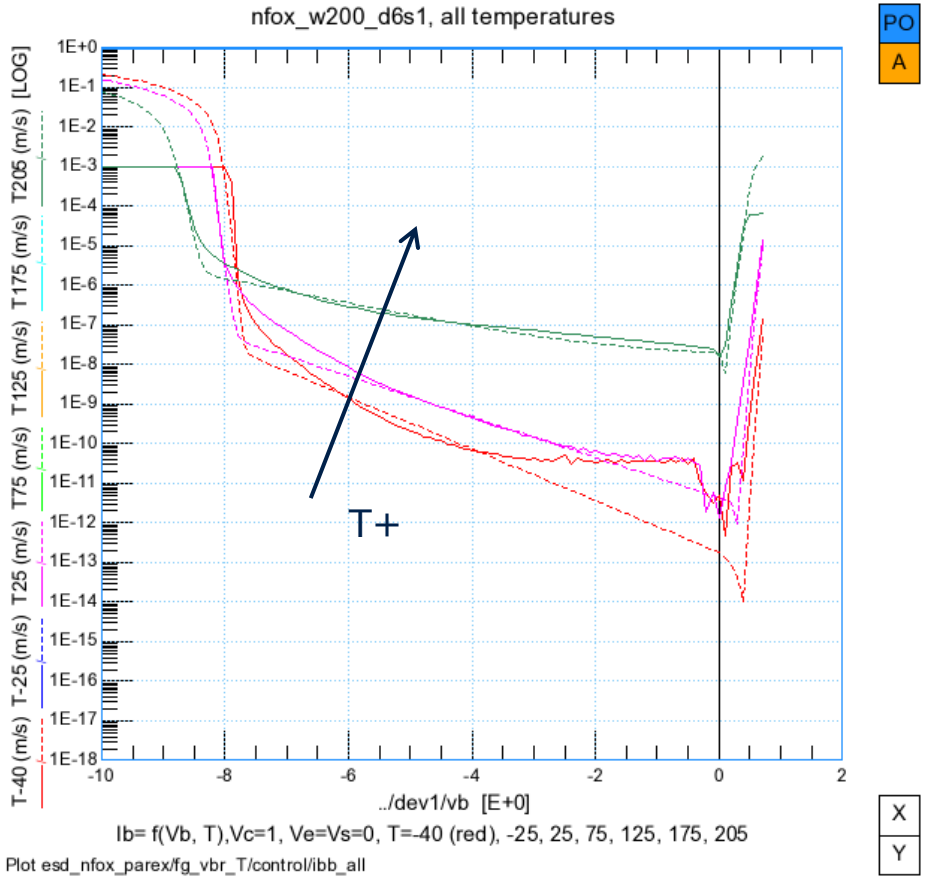
- Result negative TC of Id for N=40

Tunnel current modeling using 2nd parallel break down diode Dt



- Tunnel current may be better modelled using a 2nd breakdown diode Dt, if some conditions are taken into account

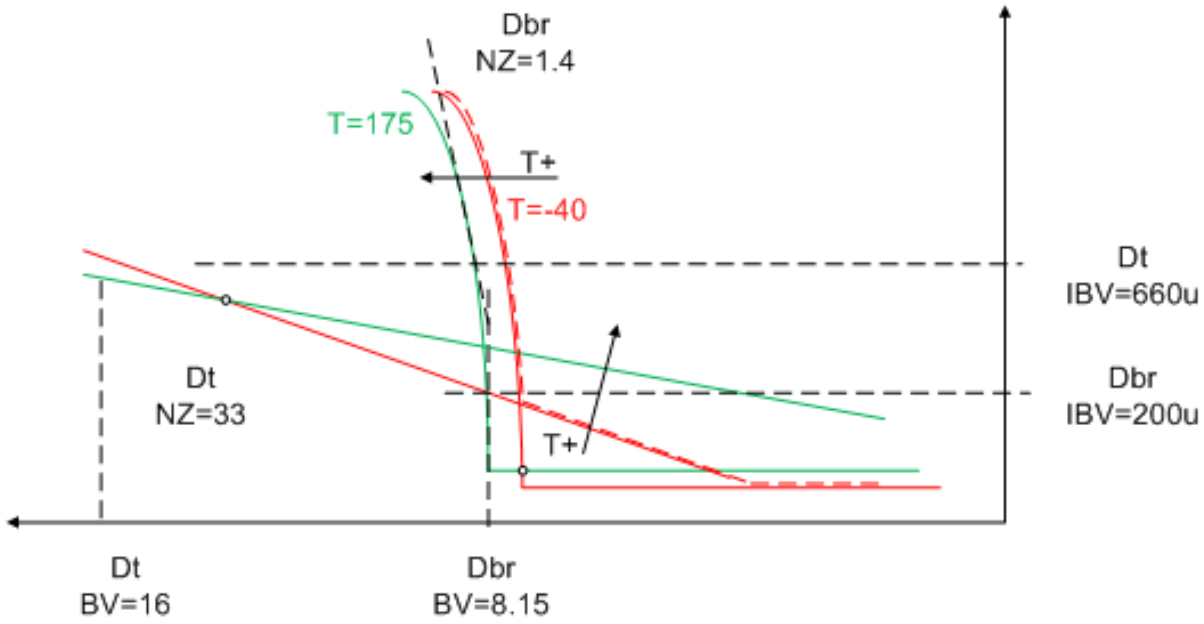
Tunnel current modeling using 2nd parallel break down diode Dt



T=-40 T=25 T=205

- 2nd breakdown diode Dt allows to model the right temperature behaviour of the tunnel current

Tunnel current modeling using How to choose the model parameters?



- How to choose the model parameters:
- Use $BV_{Dt} \approx 2BV_{Dbr}$ and $IV_{BDT} > IBV_{Dbr}$
- Use $NZ_{DT} >> 1$
- Note: Cross section point of the temperature dependent curves of Dt must be shifted to the left

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