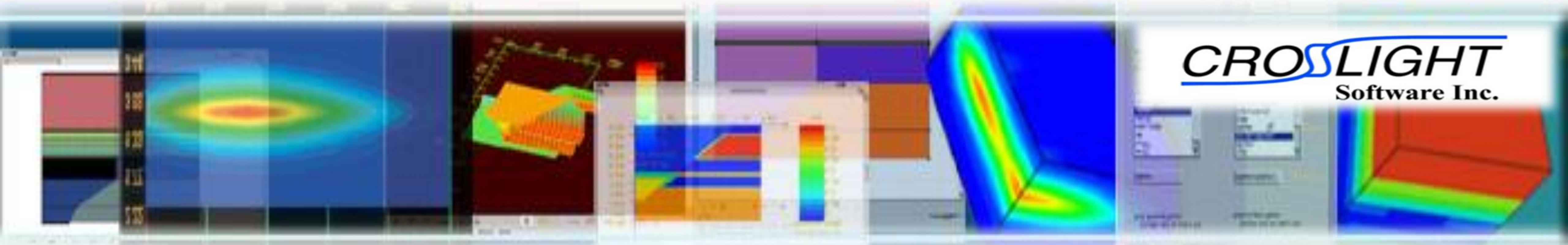


TCAD Simulation of LTPS Hot Carrier Injection Degradation

Contents

- Model
- Demo Simulation
- Summary

Hydrodynamic model for hot carriers:

$$\nabla \cdot S + R_n w - \nabla E_c \cdot J_n + \frac{n(w - w_0)}{\tau_w} + \frac{\partial(nw)}{\partial t} = 0$$

$$S = -\frac{5}{3} J_n w - \frac{10}{9} \mu_n n w \nabla w.$$

where w is the total energy of an electron and $w_0 = 3kT/2$ is the electron energy at equilibrium. S is the electron energy flux intensity and τ_w is the energy relaxation time.

E.M. Azoff. Energy transport numerical simulation of graded AlGaAs/GaAs heterojunction bipolar transistors. *IEEE Trans. ED*, 36(4):609–616, 1989. doi:10.1109/16.22464.

E.M. Azoff. Close-form method for solving the steady-state generalised energy-momentum conservation equations. *COMPEL*, 6(1):25–30, 1987. doi:10.1108/eb010297.

HCI Theory:
Gate injection:
j_HCI=q*v_therm(Te)*n_channel*prob(Te)
where v_therm is the carrier temperature (Te) depedent thermal velocity given by

v_therm=sqrt(k*Te/(2*m*pi))

prob(Te) is the probability of carriers with temperature higher than Te from TCAD simulation.

To calculate prob(Te), we assume Boltzman statistics due to the lack of quantum confinement for high energy hot carriers:

prob(Te)=sum_over_ky_for_E>Eox [B exp(-(E-Ec)/kTe]

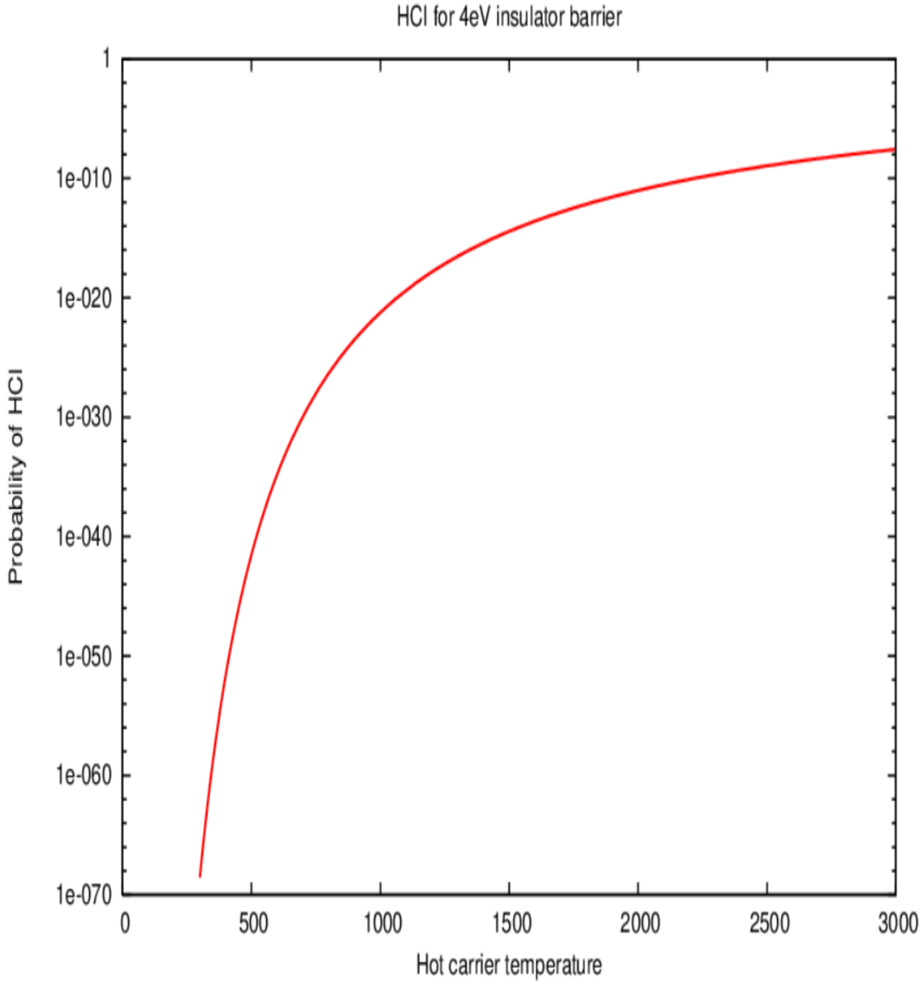
prob(Te)=sum_over_ky_for_E>Eox [B exp(-(E-Ec)/kTe]

where E is carrier energy, B is normalization constant,
Ec is conduction band edge, and Eox is oxide barrier energy.
The sum over ky in k-space can be converted to 1D density of states (DOS) integral and the result can be expressed in erfc() function.

One correction to the above is that hot carrier injecting over the oxide barrier into the poly may not be strictly vertical to the channel and the target may have distribution. Here we assume target of HCI follow a normal distribution of the form:

1/sigma/sqrt(2pi)exp(-0.5*((x-x0)/sigma)**2)

where sigma is the standard deviation and x0 is the target center.



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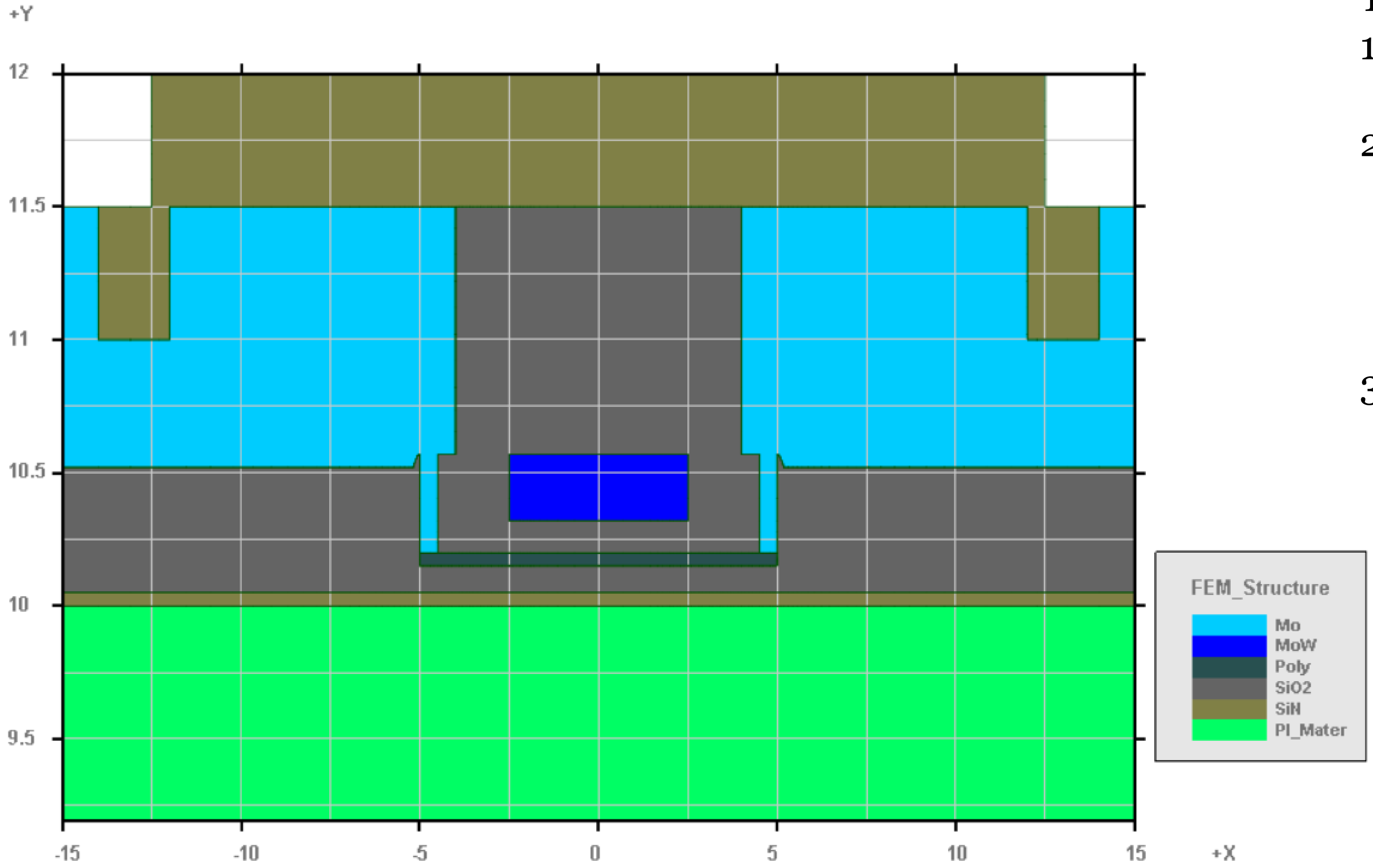
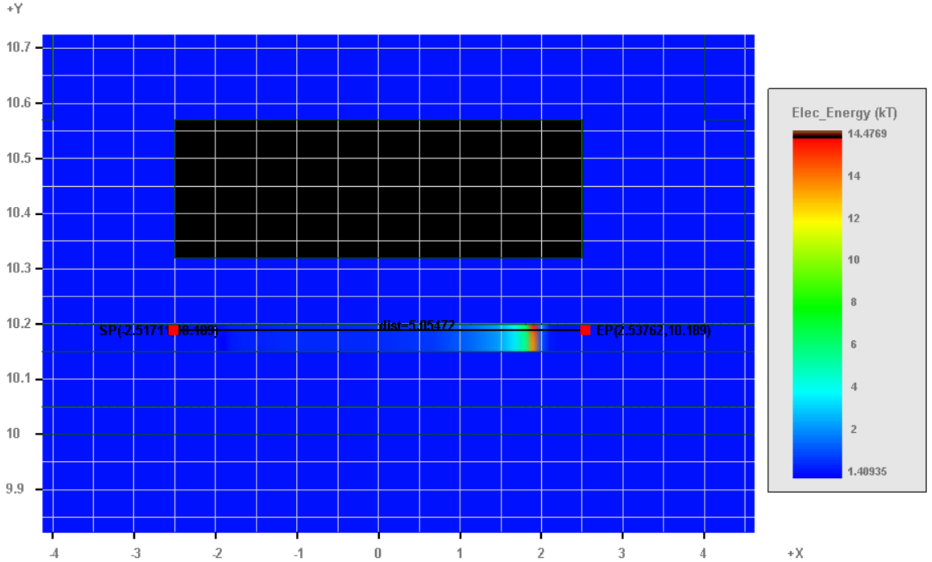
Demo LTPS TFT structure

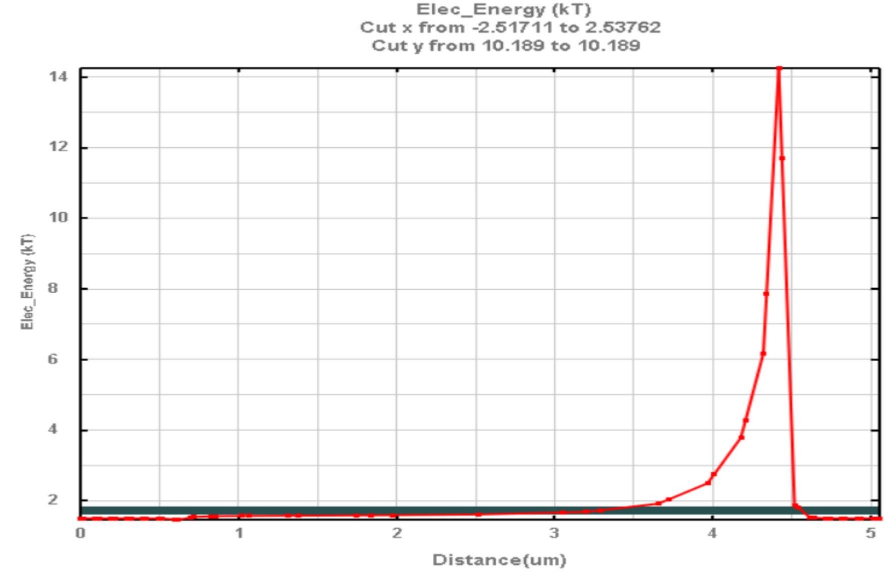


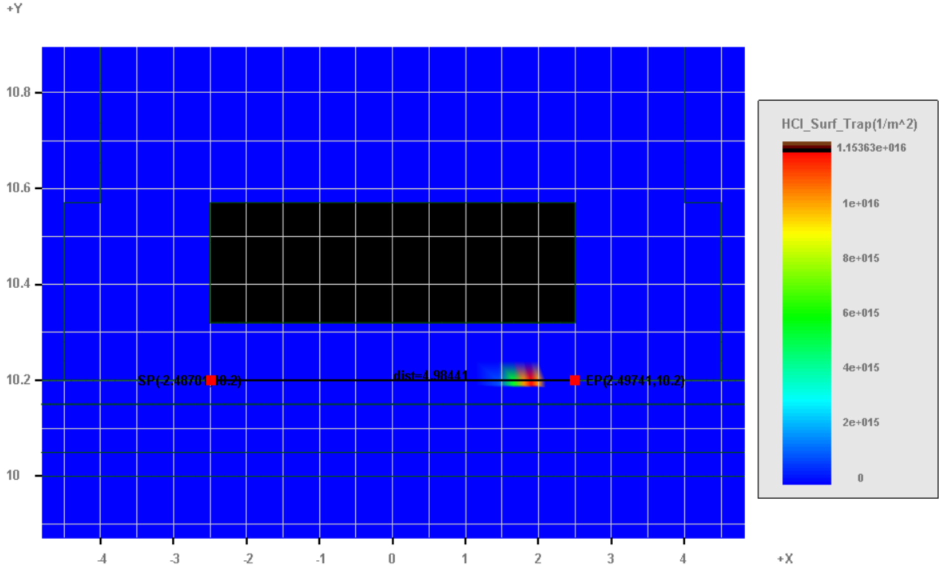
Transient Simulation:

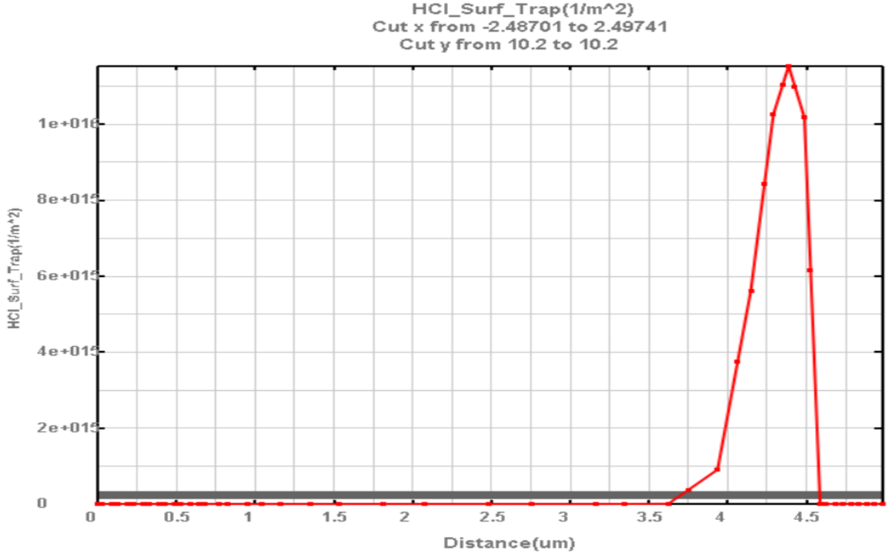
1) Using 1sec to ramp up Vd=10V and Vg=10V.
2) Stay at Vd=10V Vg=10V for one month while studying HCI and HCI generated traps at channel/oxide interface.
3) After one month, use 1sec to ramp down Vd Vg and study IV curve to observe any change in threshold voltage

Before long-term high current stress

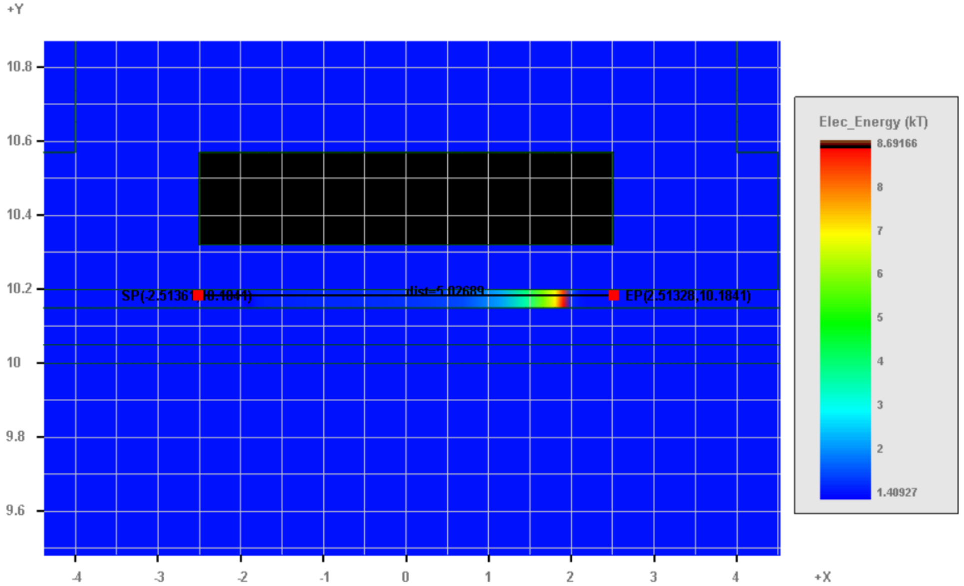


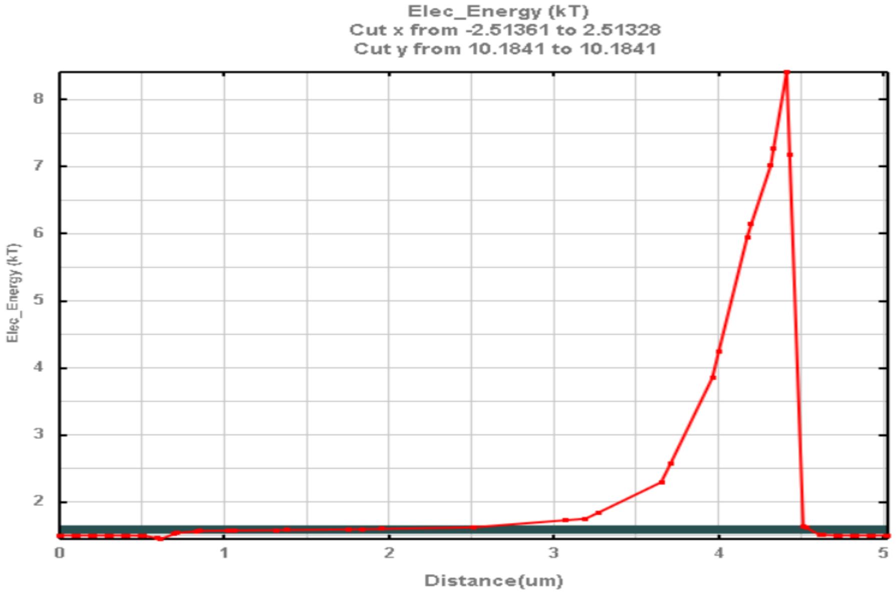


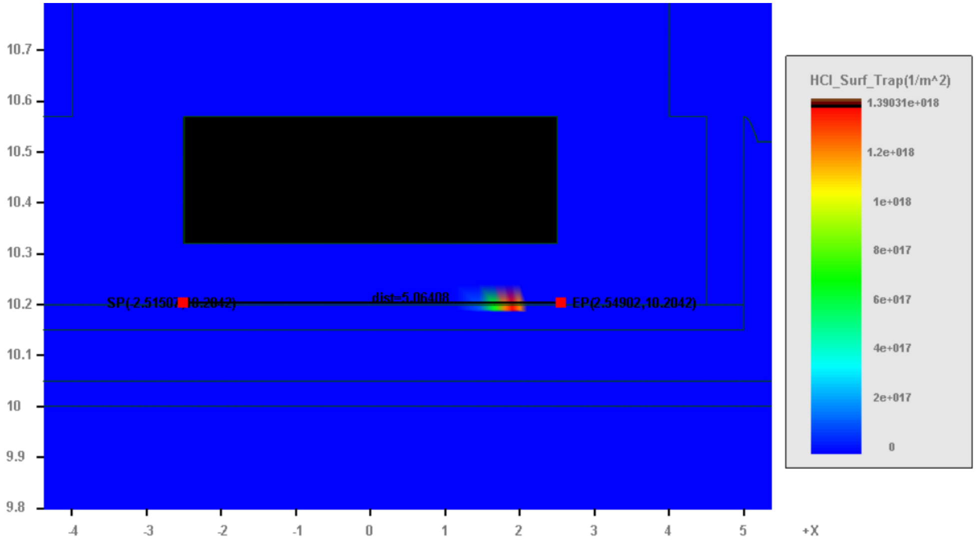


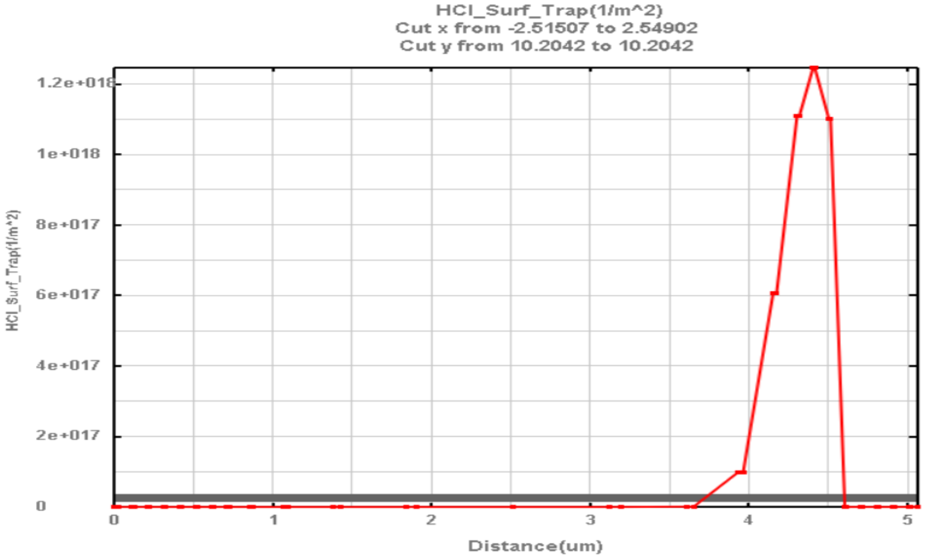


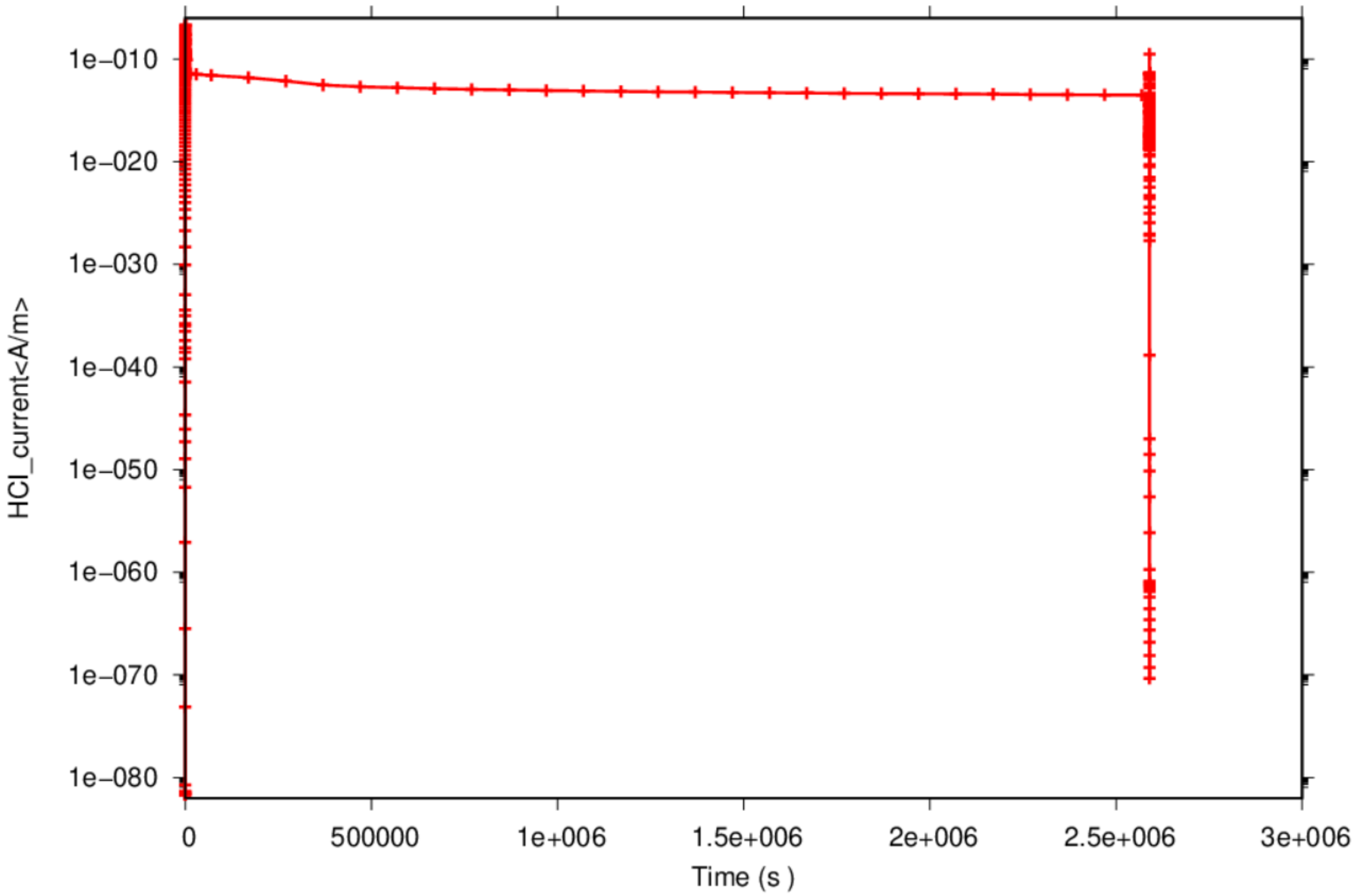
After one-month high current stress



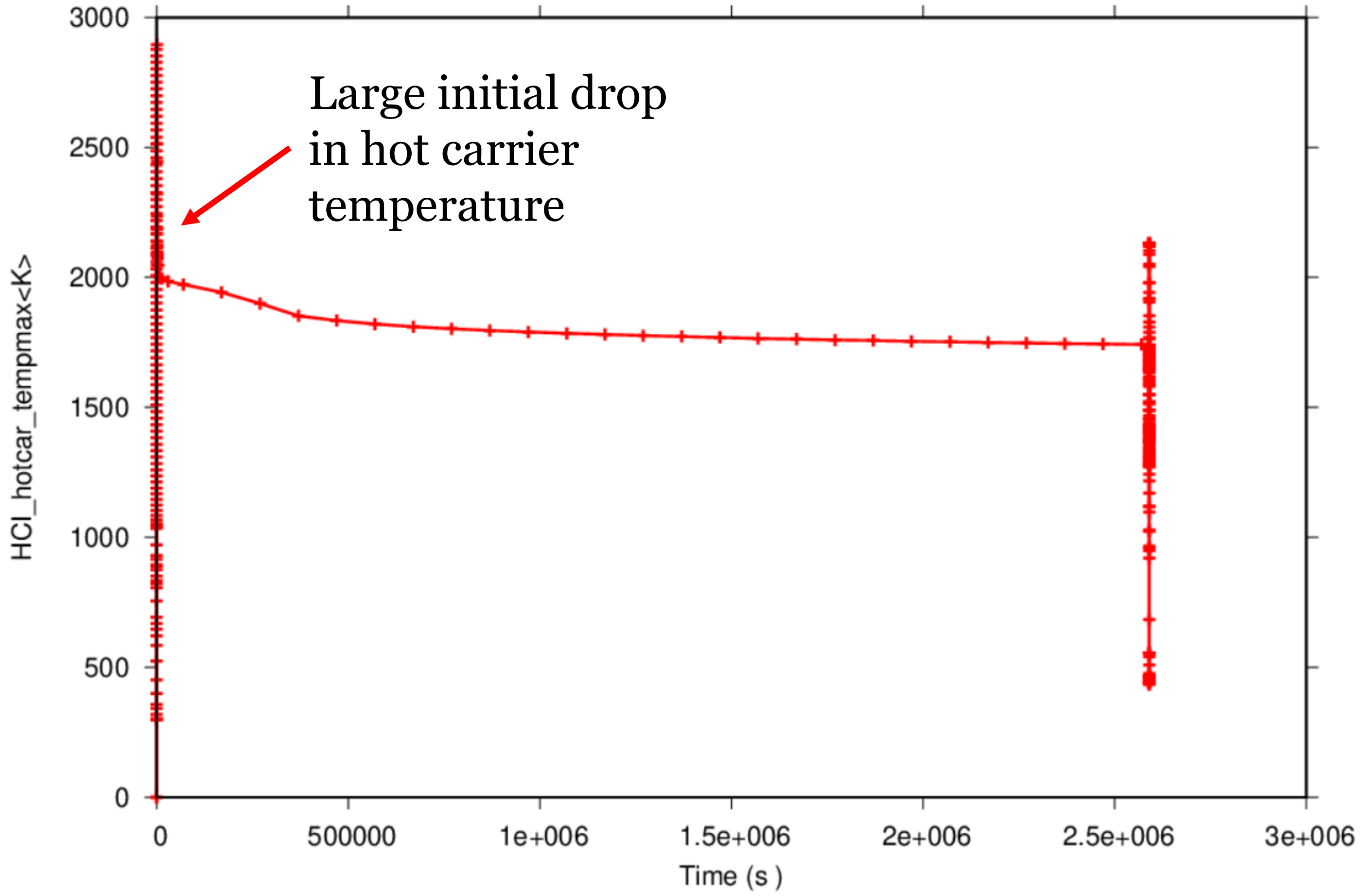






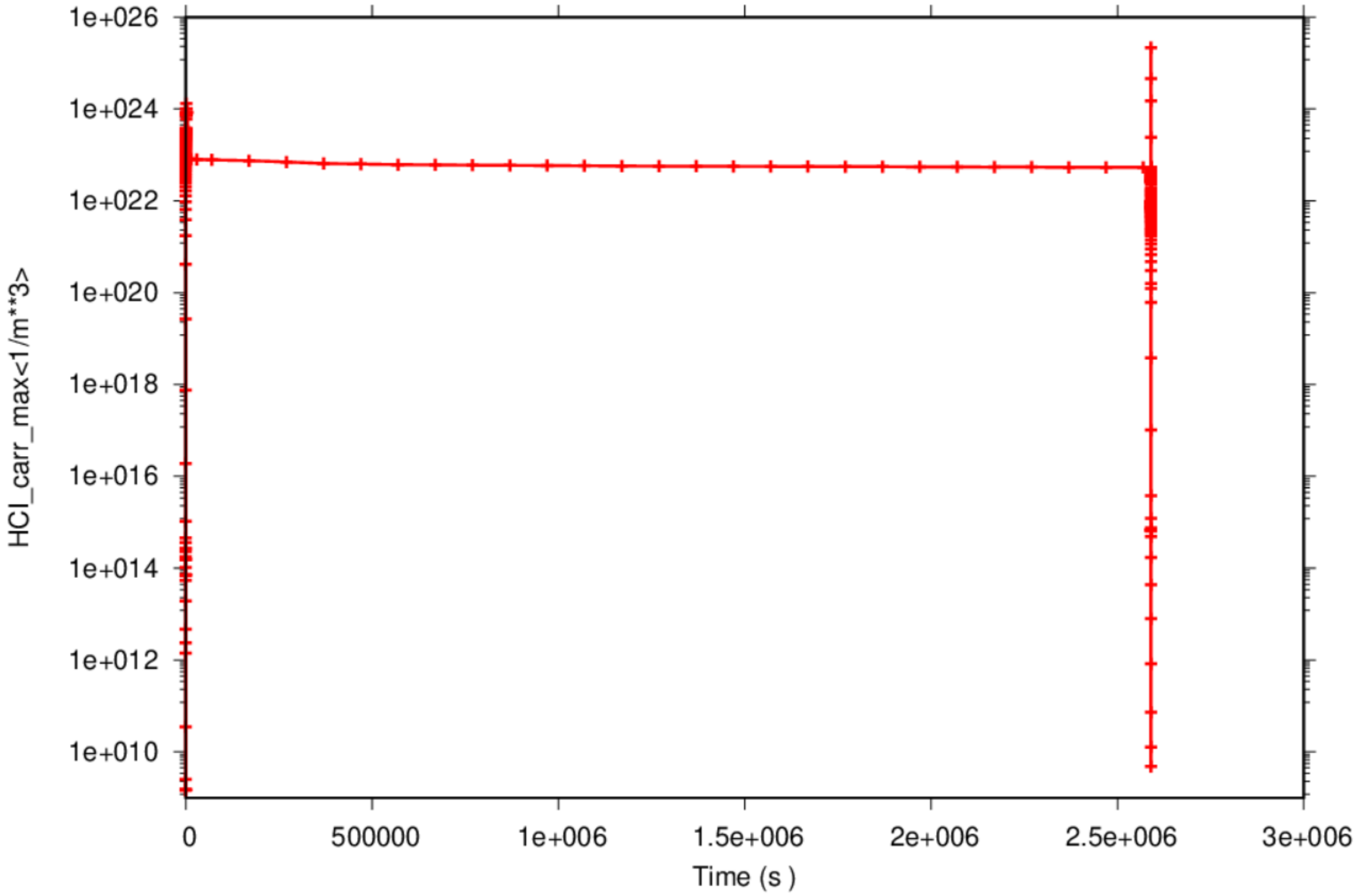


Hot carrier injection (HCI) current into the poly gate varies with stress time, indicating change of electrical potential due to the generation of HCI induced interface defects



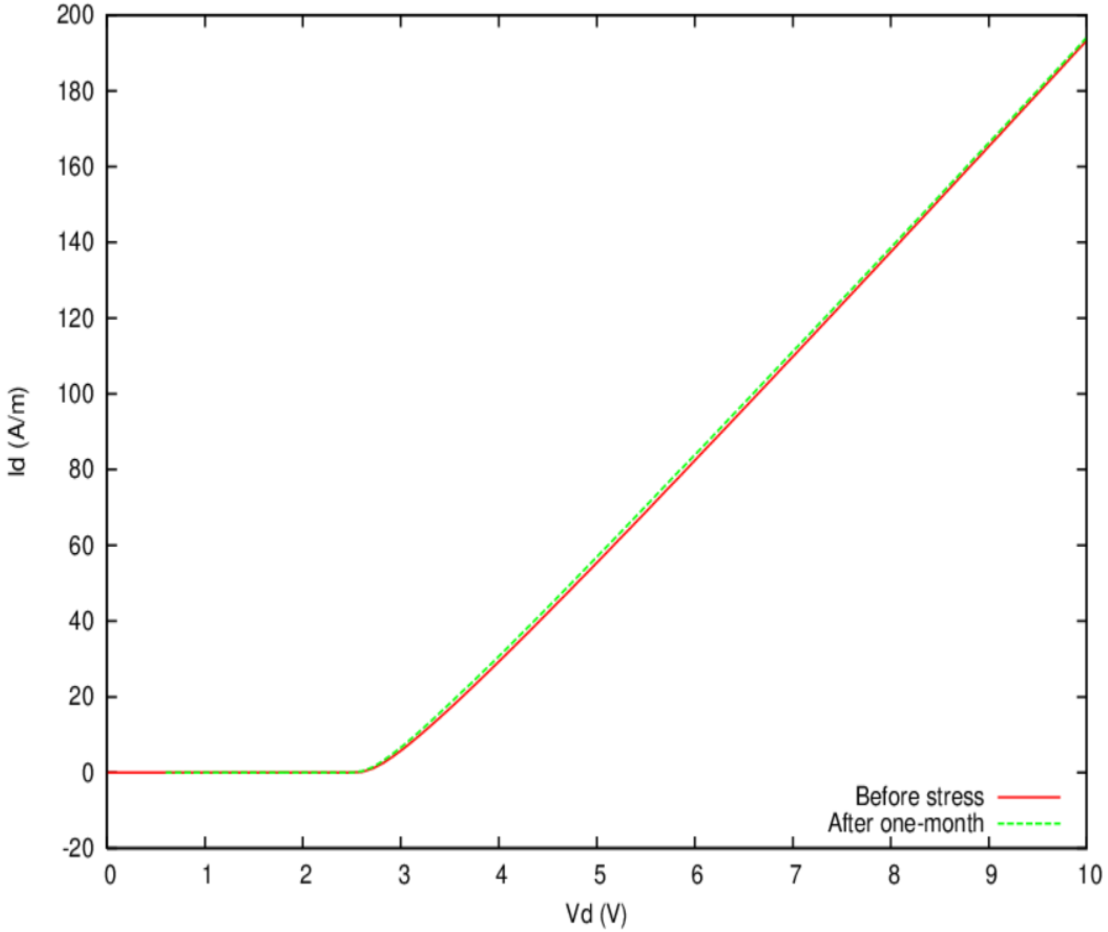
Large initial drop in hot carrier temperature

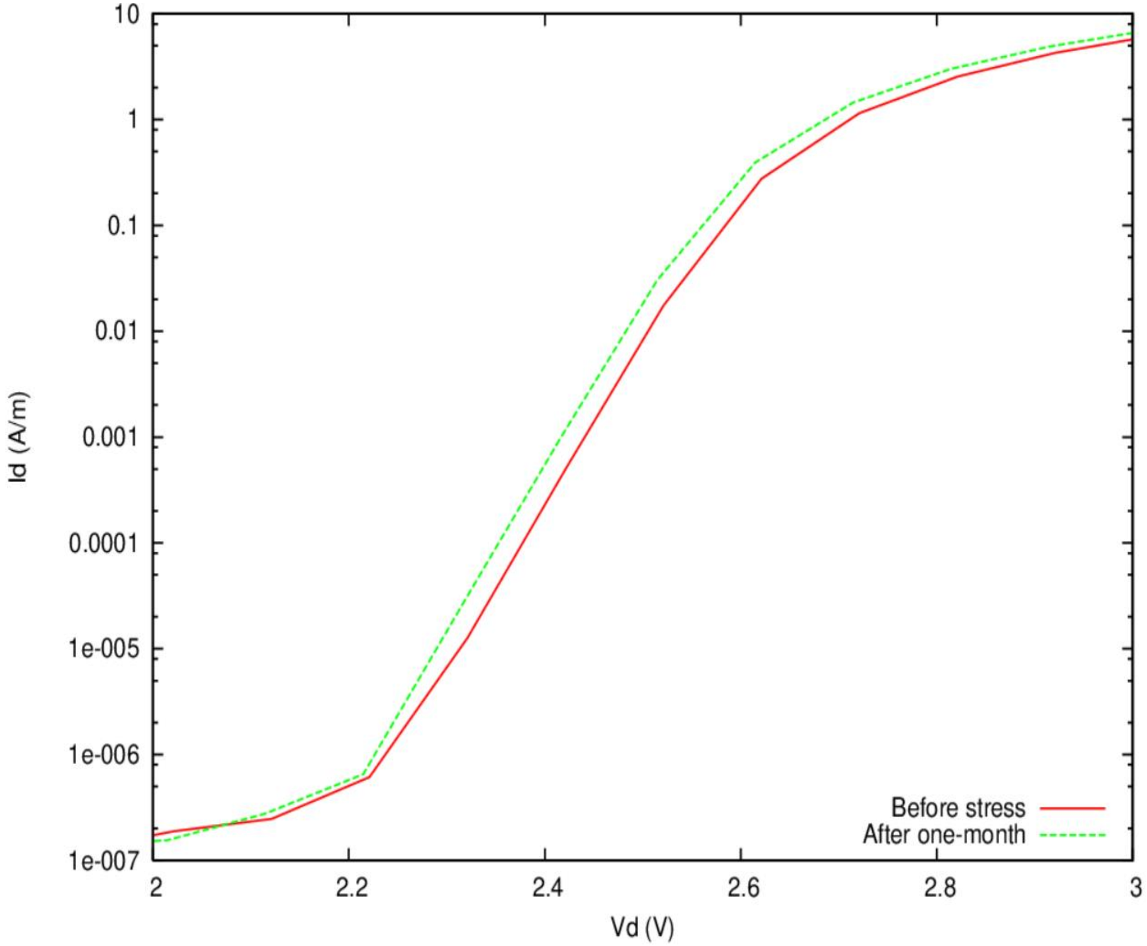
Max electron temperature experiences a large initial drop due to the screening of accelerating high field by HCI generated interface traps



Change of hot-spot carrier concentration indicating variation of electrical potential due to HCI trap generation

0.03V Vth reduction after one-month of high current stress





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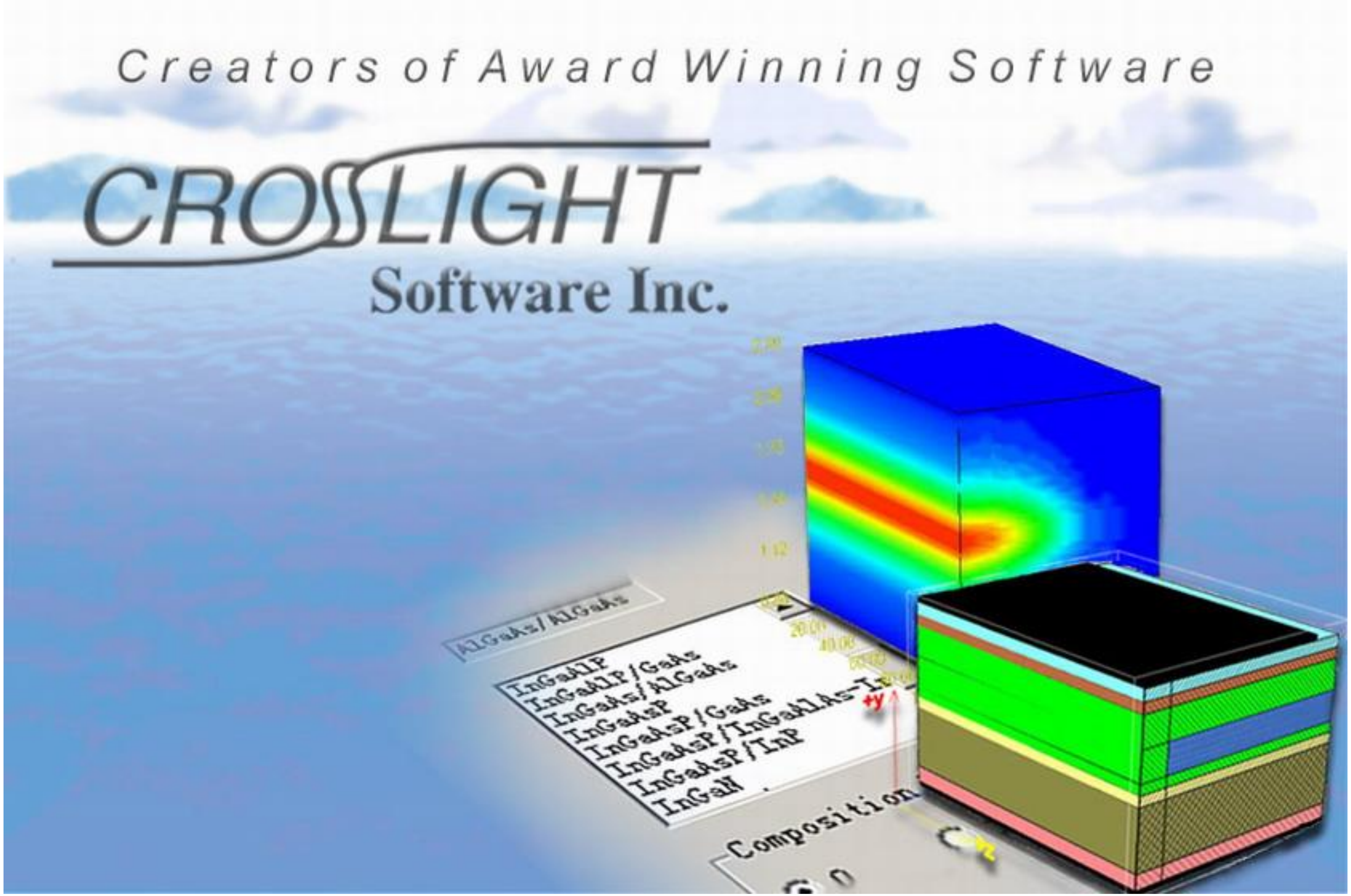
TAD hot carrier model is suitable for reliability analysis.

Interesting to note that HCI induced traps can screen the high stress field and reduce the hot carrier temperature over time.

With reasonable assumption of HCI induced interface traps, Vth degration can be quantified if proper calibration is done.

Thanks for your attention!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InGaAsP/InGaAlAs-In
InGaAsP/InP
InGaN
+y
Composition