HAPSPIDE
WP3 Simulation

27/01/2022

- WP3 Simulations – Status&Short term plans / Team

  - **Technology CAD (TCAD)** approach (**Sentaurus Synopsys TCAD**), aiming at accurate description of:

    - the charge transport within a-Si:H material;

    - the device electrical response (DC, transient simulations).

  - **Wollongong University**

    - Marco Petasecca, Matthew Large

  - **University of Perugia**

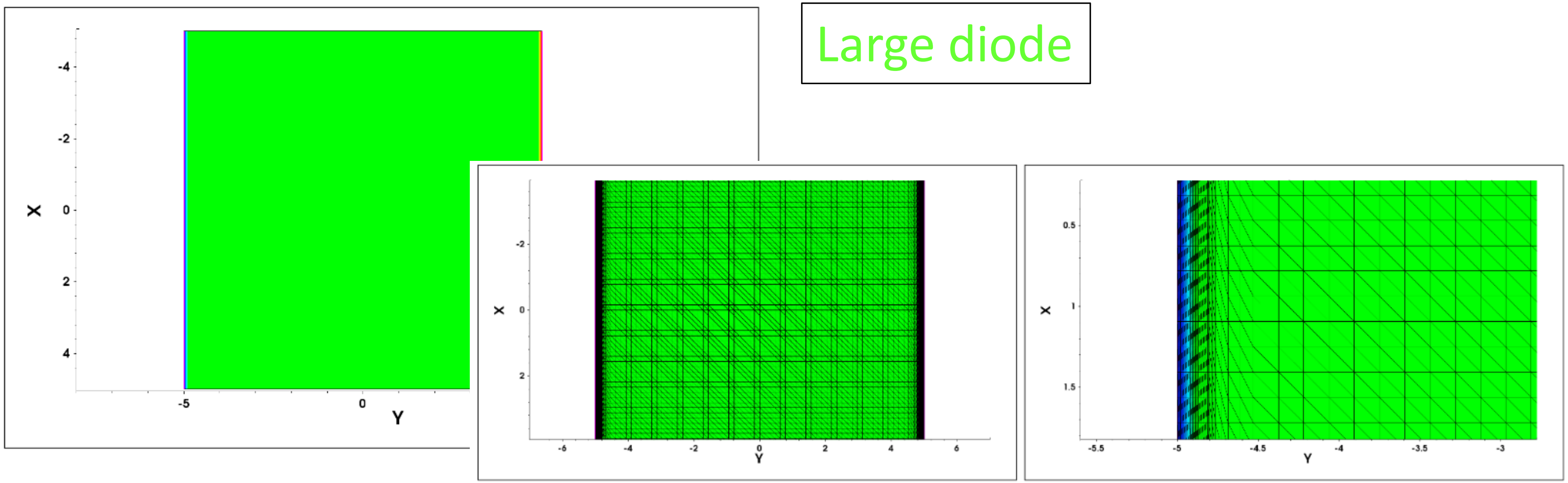
    - Daniele Passeri, Arianna Morozzi, David Polzoni, Riccardo Vinti

  - **INFN and CNR Perugia**,

    - Francesco Moscatelli, Maddalena Pedio, Mauro Menichelli, Leonello Servoli, …

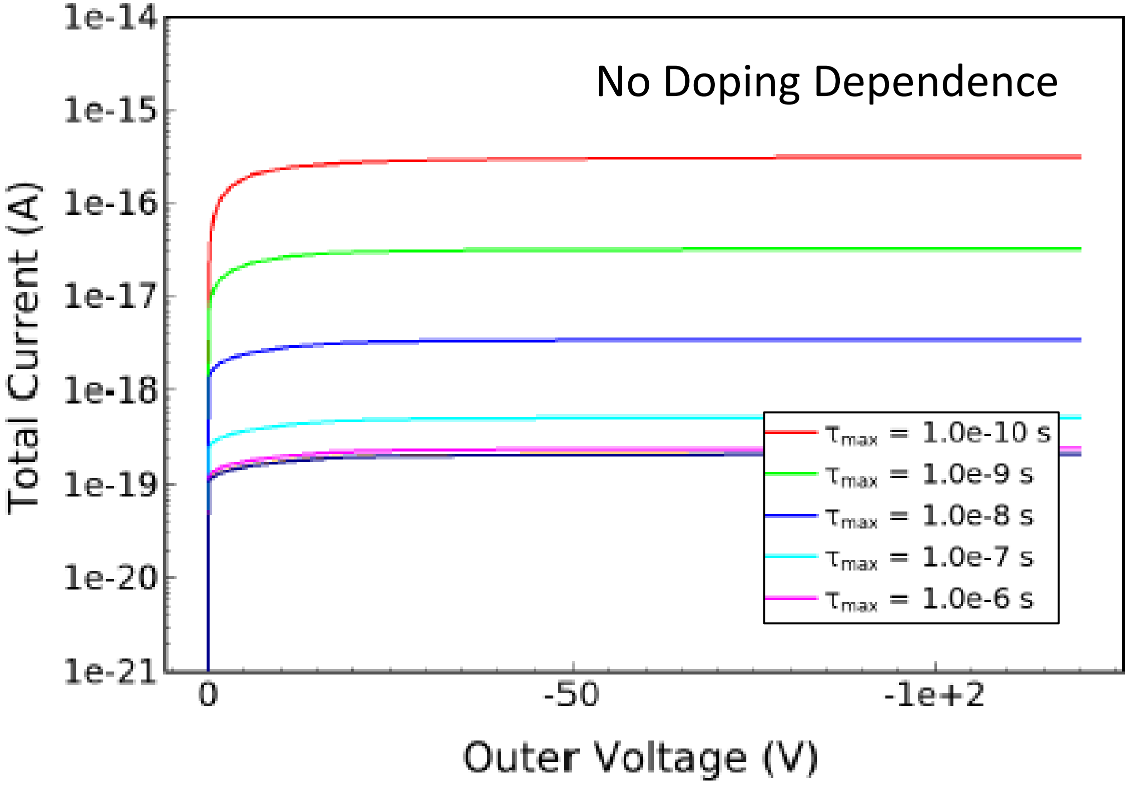
- Study of LIFETIMES and MOBILITY models
  - Interplay between carriers lifetimes and mobility models on current densities computation (e.g. simulation findings to be compared with measurements).
  - Simple 1-D structure (double-check dimensions, implants…) (10×10 μm^2
  - a-Si:H material as from Wollongong’s parametrizations (E_{g0}, traps…)

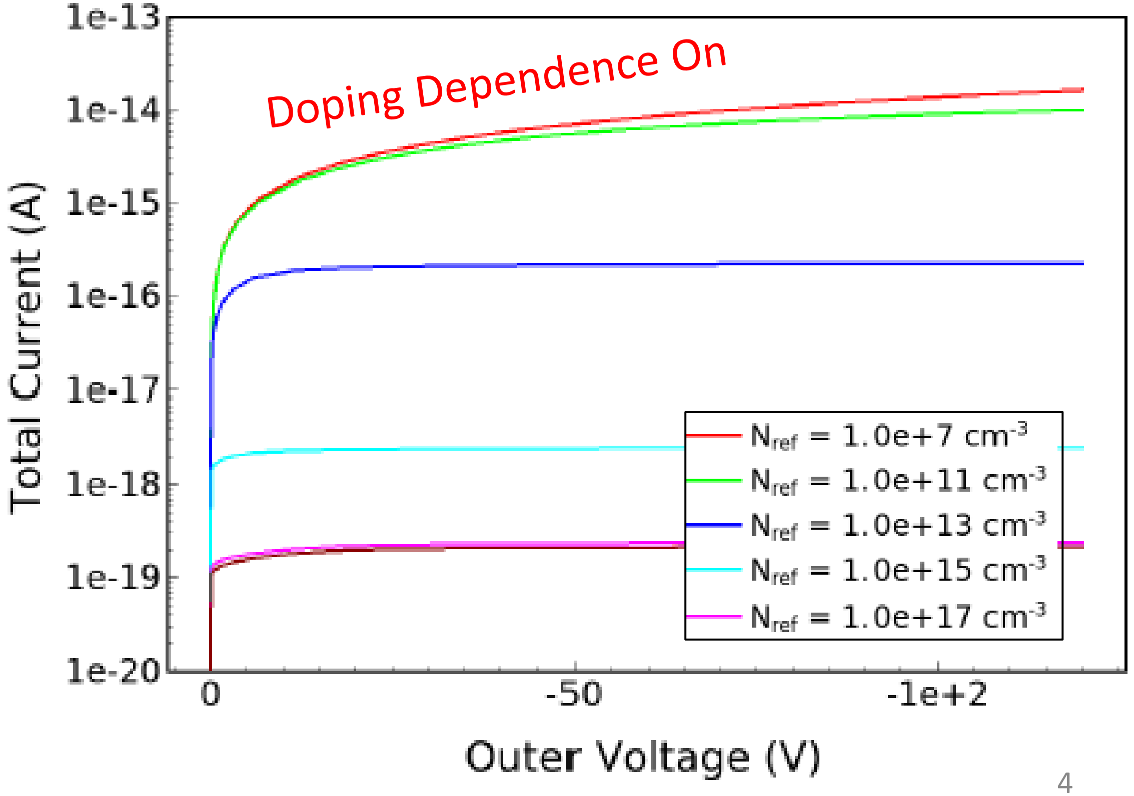
Large diode



- Study of carriers LIFETIMES models
  - Activation of the carriers lifetimes dependencies… (Scharfetter)

$$\tau_{\rm dop} = \tau_{\rm min} + \frac{\tau_{\rm max} - \tau_{\rm min}}{1 + \left(\frac{N_A + N_D}{N_{\rm ref}}\right)}$$





- Study of carriers LIFETIMES models

  - Advanced carriers lifetimes models (Nakagawa)

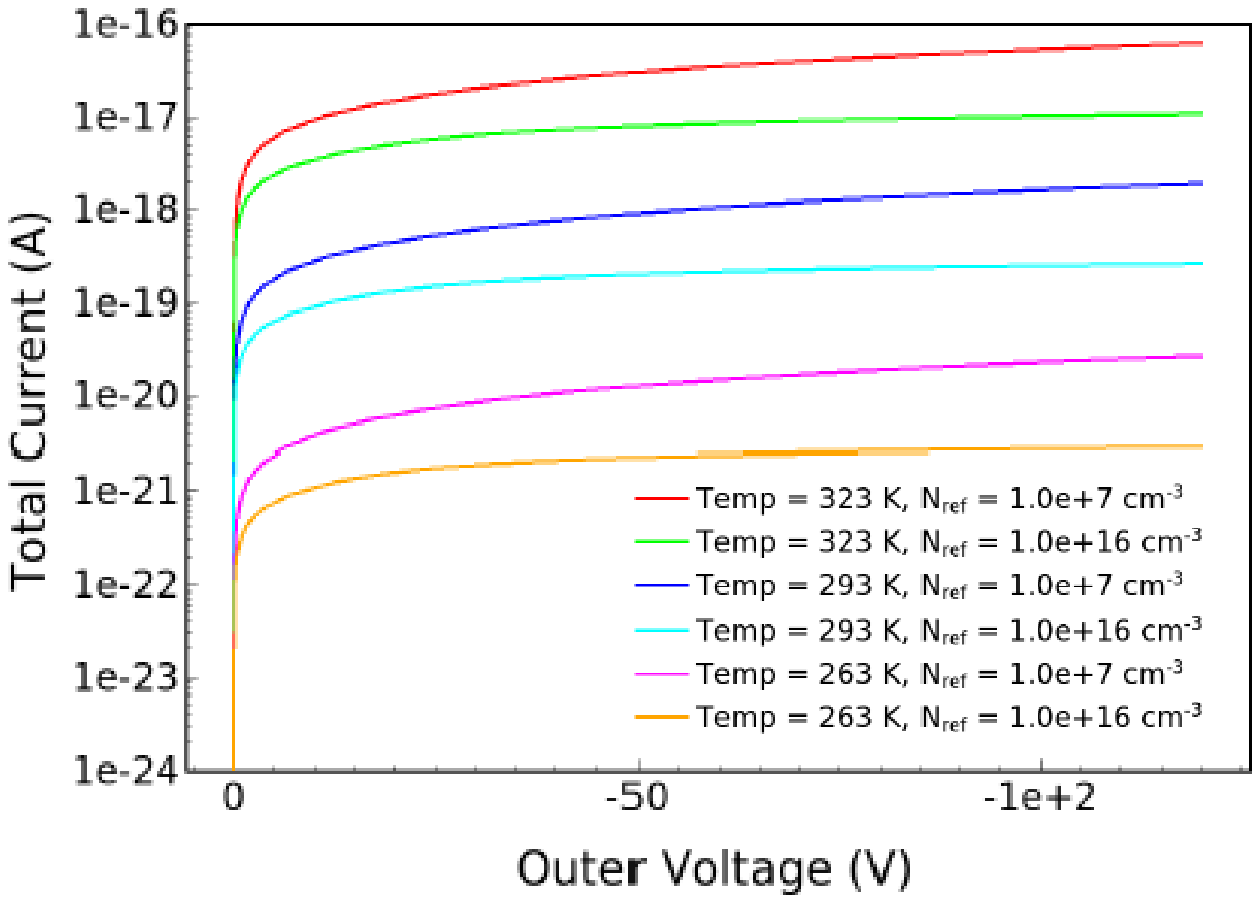
$$\tau_{\text{dop}} = \frac{\tau_{\max} + \tau_{\min}\left(\frac{N_A+N_D}{N_{\text{ref}}}\right)^{\gamma}}{1 + \frac{\tau_{\max}}{\tau_0}\left(\frac{N_A+N_D}{N_{\text{ref}}}\right)^{\gamma}}$$

  - No significant differences with respect to standard Scharfetter’s model.

- Analyses of carriers LIFETIMES + MOBILITIES (TCAD embedded) models
  - LOMBARDI's model
  - High electric field carriers -> scattering by acoustic surface phonons and surface roughness

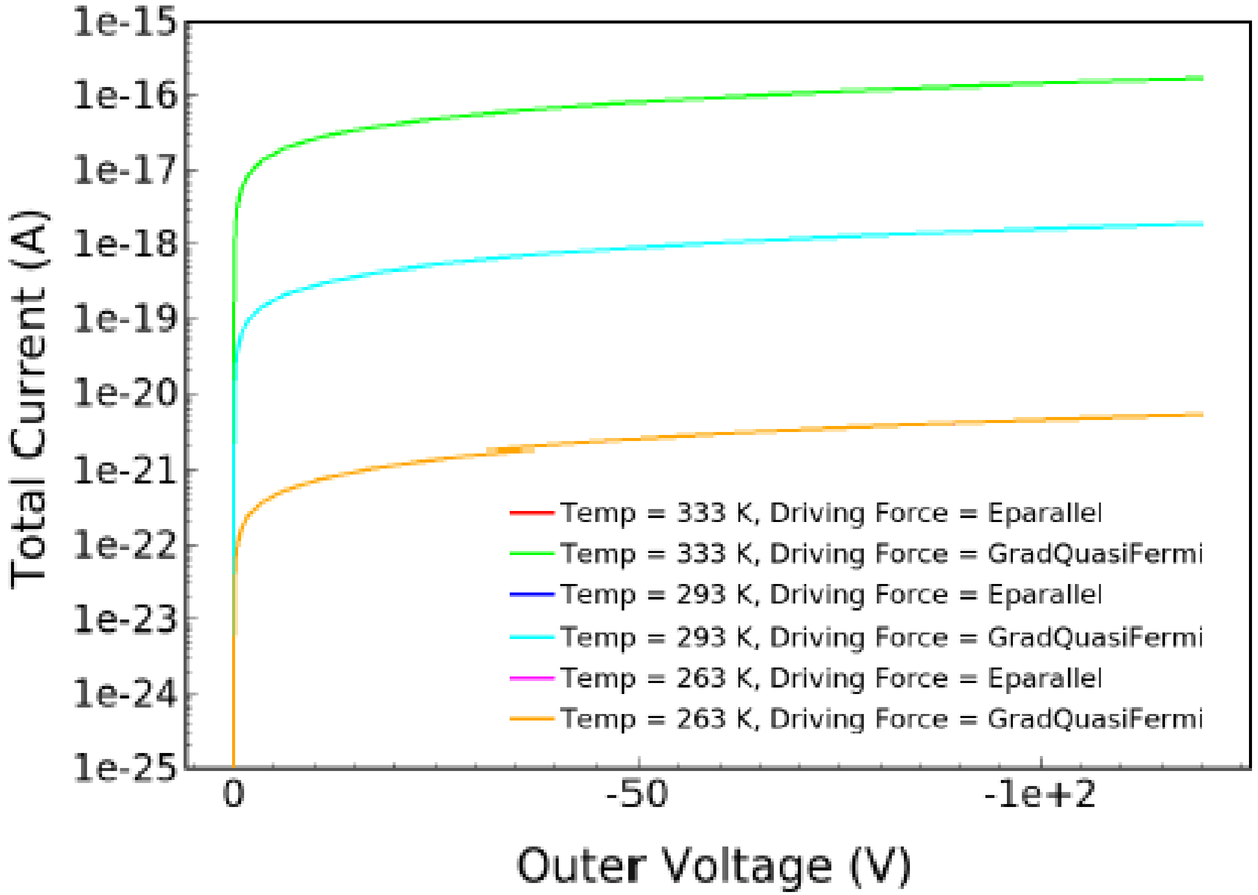
$$\mu_{ac} = \frac{B}{F_\perp} + \frac{C((N_A + N_D + N_2)/N_0)^\lambda}{{F_\perp}^{1/3}(T/300K)^k}$$

$$\mu_{sr} = \left(\frac{(F_\perp/F_{ref})^{A*}}{\delta} + \frac{F_\perp^3}{\eta}\right)^{-1}$$



- Analyses of carriers LIFETIMES + MOBILITIES (TCAD embedded) models
  - CANALI's model
  - High-Field Saturation Models

$$\mu(F) = \frac{(\alpha + 1)\mu_{\mathrm{low}}}{\alpha + \left[1 + \left(\frac{(\alpha+1)\mu_{\mathrm{low}} F_{\mathrm{hfs}}}{v_{\mathrm{sat}}}\right)^{\beta}\right]^{1/\beta}}$$



- Analyses of carriers LIFETIMES + MOBILITIES (ad hoc PMI) models

Physical Model Interface, add-on, e.g. ad hoc, external models to be compiled and embedded within the software

  - Starting from UOW's outcomes…
  - $J = AT^2\left[\exp\left(bT\sqrt{\frac{V}{d}}\right) - 1\right] \Leftrightarrow J = q\mu nE.$
  - … deriving carriers mobility models depending on electric field (F) and carriers concentrations (n, p) (and T, of course…)
  - Huge number of attempts, e.g. different dependencies on F, n, p,… V, T
  - Avoiding computational issues (e.g. NaN -> abs(F), F_{min}, …)

$$\mu = V^3 T^2\, exp(\frac{\sqrt{abs(F) + F_{min}}}{T})$$

$$\mu = A^* V^4 T^2\, exp(b\frac{\sqrt{abs(F) + F_{min}}}{T})$$

$$\mu_e = \frac{A^* V^4 T^2}{n\, q\, (abs(F) + F_{min})}\, (exp(\frac{b}{T}\sqrt{abs(F) + F_{min}}) - 1)$$

$$\mu = \frac{A^* V^4 T^2}{q\, (abs(F) + F_{min})}\, exp(b\frac{\sqrt{abs(F) + F_{min}}}{T})$$

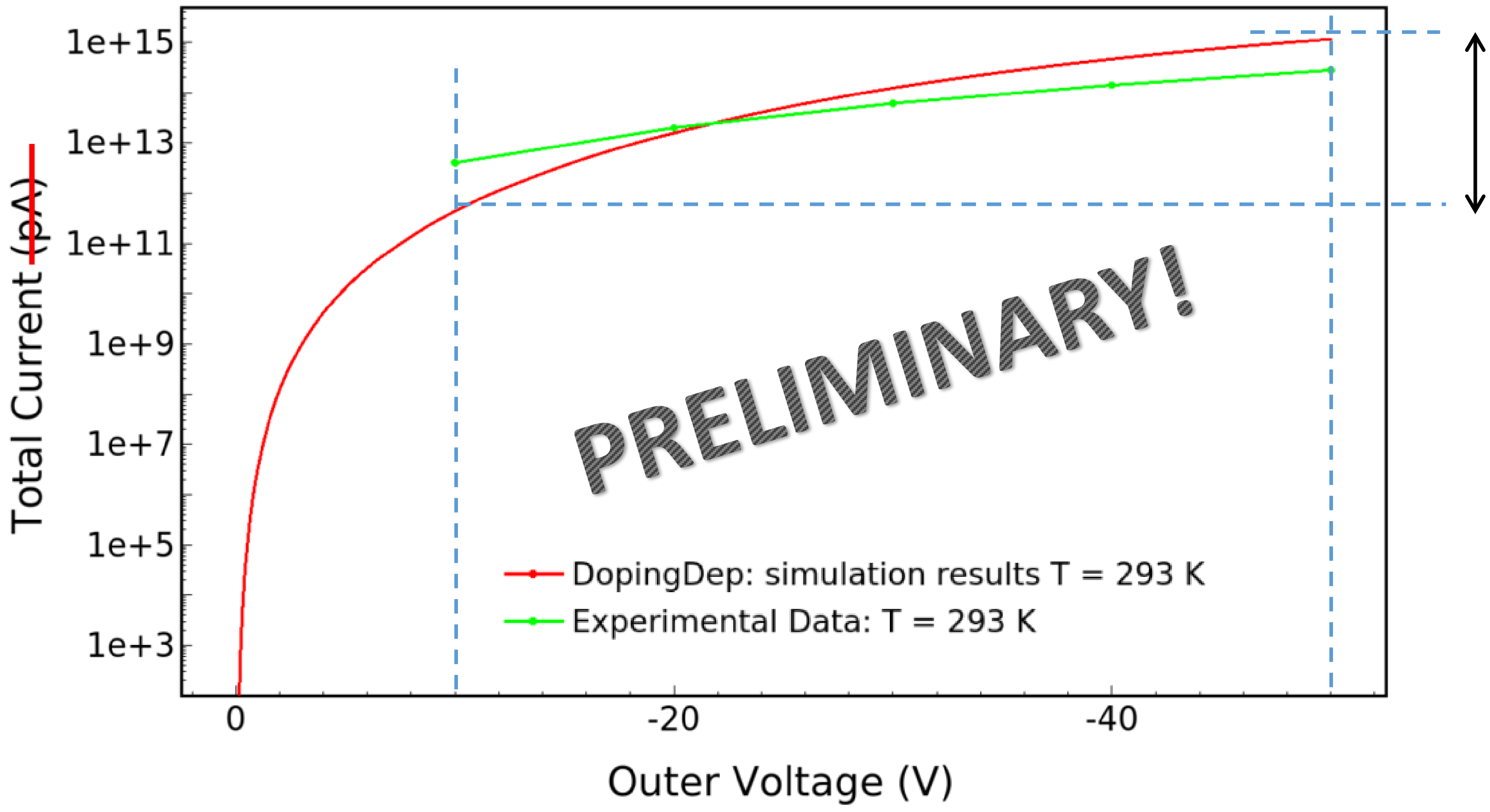
$$\mu_h = \frac{A^* V^4 T^2}{p\, q\, (abs(F) + F_{min})}\, (exp(\frac{b}{T}\sqrt{abs(F) + F_{min}}) - 1)$$

…

- Analyses of carriers LIFETIMES + MOBILITIES (PMI ad hoc) models
  - Some encouraging results

$$\mu = A^* V^4 T^2 \, exp\left(b \frac{\sqrt{|F| + F_{\min}}}{T} \right)$$

After David Polzoni's Thesis



- Analyses of carriers LIFETIMES + MOBILITIES (PMI ad hoc) models
  - Some encouraging results $$\mu = A^* V^4 T^2 \, exp\left(b \frac{\sqrt{|F| + F_{\min}}}{T} \right)$$

After Riccardo Vinti's Thesis

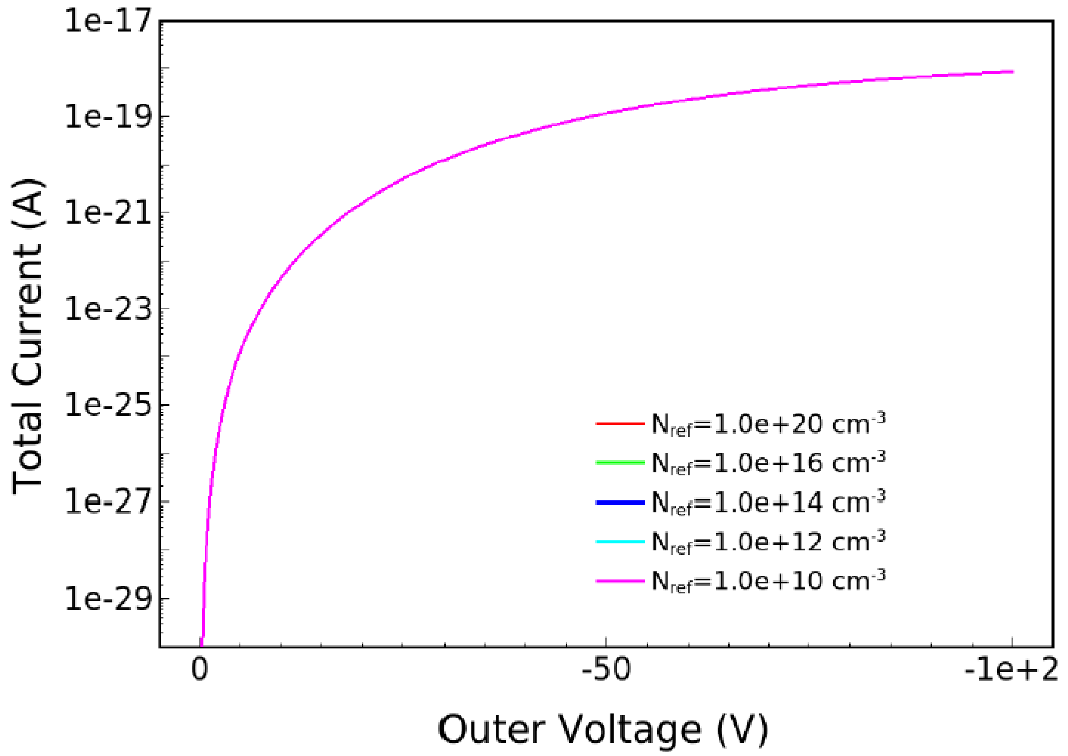


Figure 30: Mobility model based on the equation 10. DopingDependence flag active with a sweep of N_{ref} value between 1.0×10^{20} cm^{-3} and 1.0×10^{10} cm^{-3}

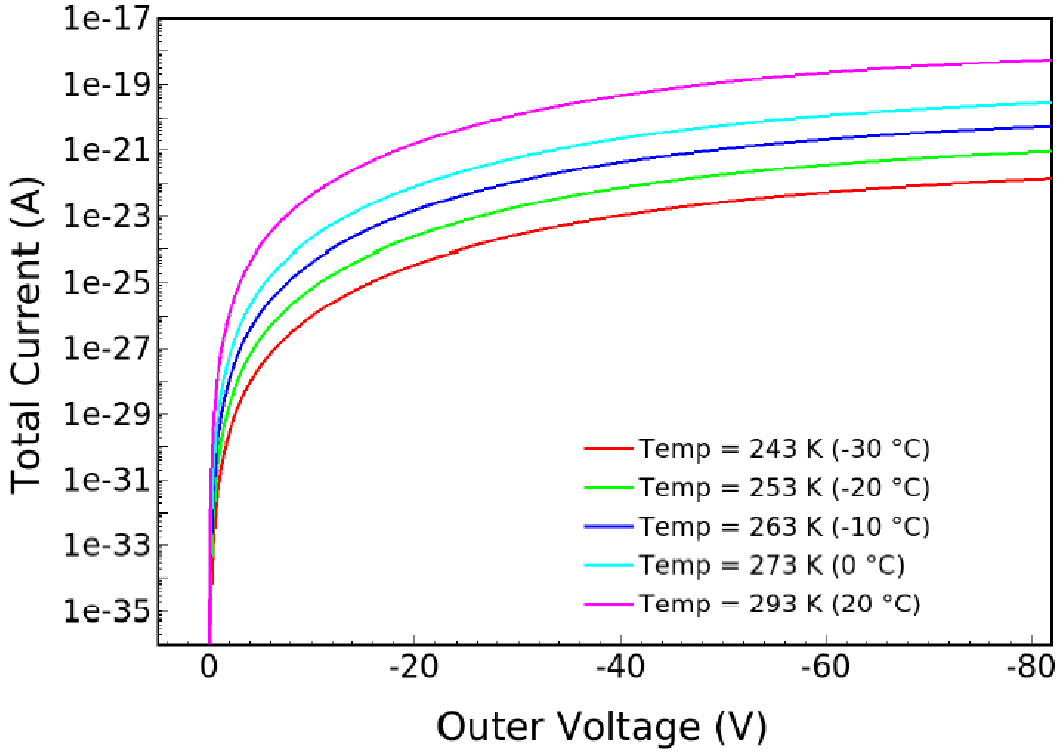
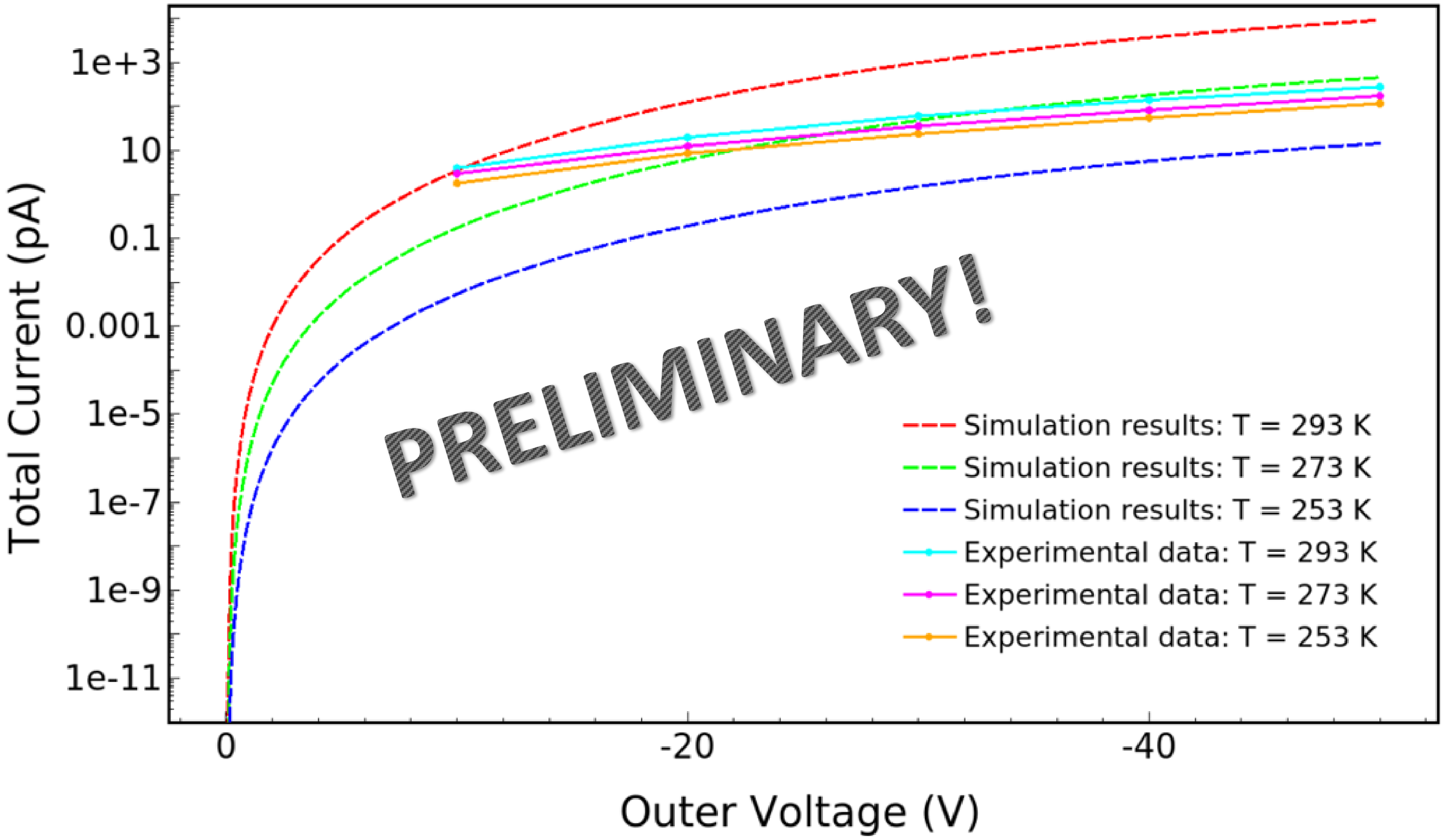


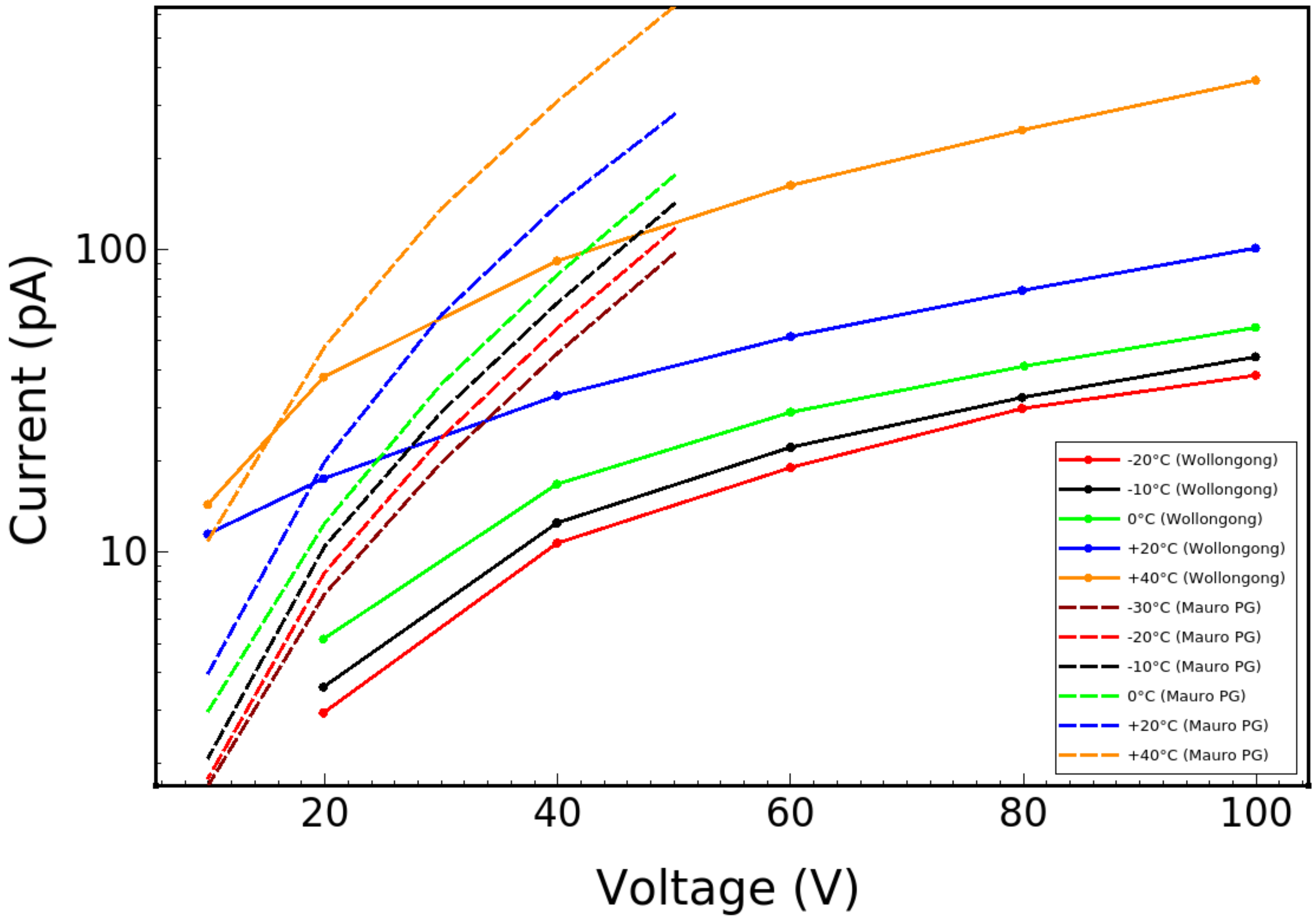
Figure 31: Mobility model based on the equation 10. DopingDependence flag active with a fixed value for N_{ref} of 1.0×10^{16} cm^{-3}

- Analyses of carriers LIFETIMES + MOBILITIES (PMI ad hoc) models
  - Dependency on T to be studied…



- Meaurements… Wollongong vs. Perugia

After Arianna's post-processing



- Study of LIFETIMES and MOBILITY models
  - Double Check of the interplay between carriers lifetimes and mobility models.
  - Effect of T.
  - Are we able to model the charge transport within a-Si:H using available or even devising new models developed for mono-crystallin Silicon?
  - Planning dedicated regular meetings within WP3

- Introduction of innovative materials (from TCAD perspective)
  - Transparent Contact Oxides (TCO) -> transport modeling within oxides.
  - Electrons/Holes selective Contacts -> selective mobility for e, h.