Modeling of pulsed Laser Thermal Annealing for junction formation optimization

**Introduction**

Laser Thermal Annealing (LTA) is a technique for junction formation in process fabrication of semiconductor devices:

- Low thermal budget
- Melt and recrystallization of c-Si
- Box-like dopants profiles with high activation (>90%)
- Ultrafast (~μs)

Gas laser technology challenge is the time stability.

- Parameters to adapt and control the laser process:
  - Electrical discharge
  - Gas mix (others are constructive, not subject of this study)

- Levers impact can be translated in ED shift and PD change.

**Thermal problem: Phase-Field model**

- Heat equation:
  \[ \frac{\partial \theta}{\partial t} = \frac{\rho C_f}{\rho} - \nabla^2 (\kappa T) \]

- Phase-Field equation:
  \[ \frac{\partial \phi}{\partial t} = W^2 \nabla \phi - \phi (\phi^2 - 1) - \frac{C_p}{L_{fus}} (T - T_m)(\phi^2 - 1)^2 \]

- Boundary at solid-liquid interface:
  \[ S(x, t) = E_lwp(t)(1 - R)ae^{-\frac{1}{\lambda_x}t} \]

**Diffusion and segregation problem: Adsorption model**

- Diffusion + adsorption equation:
  \[ \frac{\partial C}{\partial t} = \nabla (D_C \nabla C) - \nabla \left( \frac{D_{B_C}}{C_{eq}} \nabla C \right) \]

**Thermal simulation**

- Temperature evolution
- Melting stage (1417°C)
- Tents of ns to reach melting temperature

**Boron segregation and diffusion modeling**

- Model validity with implant conditions:
  - Model reproduces measured SIMS for:
    - Different implant conditions
    - LTA ED range
  - Good simulation of pile-up phenomenon
  - Model is reliable for PD change between 135ns and 155ns

- Boron simulated profiles accuracy is >90%

**Conclusions**

- Presented model was developed for EXCICO LTA process for bulk c-Si:
  - Follow the process variability inherent for gas lasers
  - Thermal and adsorption models provide results with over 90% accuracy
  - Adsorption model reproduces the experimental scenario for Boron diffusion and segregation

- Was analyzed the feasibility to furnish a process monitoring software for optimization and control of non-measurable parameters such as melt depth.