Modeling of Solar Cell with Laser-fired Contact by using CSuprem and APSYS

CROSSLIGHT Software Inc.

www.crosslight.com

Crosslight CSuprem & APSYS

Crosslight CSuprem:

- Extension of Stanford code to 3D.
- Non-uniform temperature annealing.
- Data interface to Crosslight/Apsys simulator.
- Local heating profile imported from Apsys.
- Interface to Monte-Carlo implant simulator.

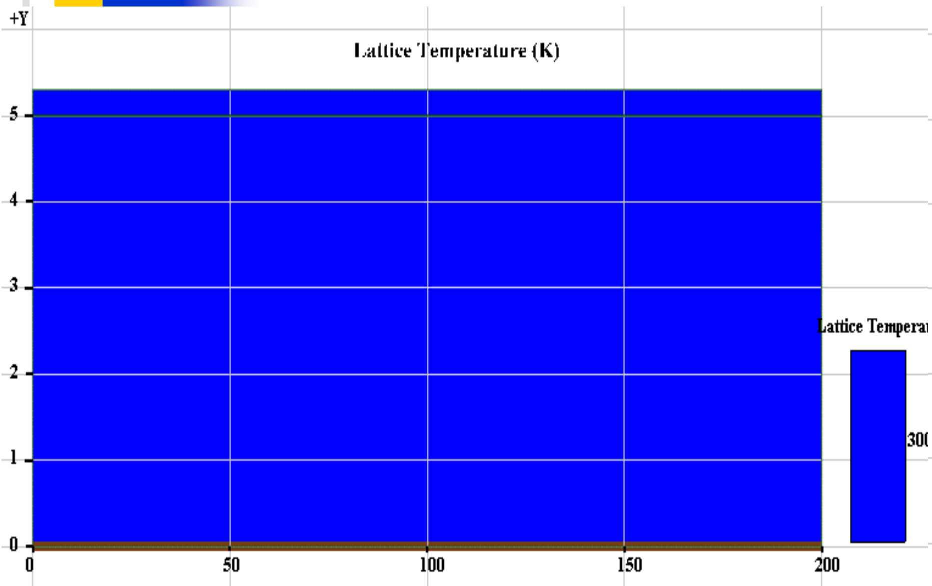
Crosslight APSYS:

- 2D/3D drift-diffusion & Poisson device simulator
- Multi-layer optical coating model
- Full-spectrum illumination & wavelength effects
- 3D ray tracing
- Bandgap, mobility & lifetime models for many specific materials.
- Thermal effects

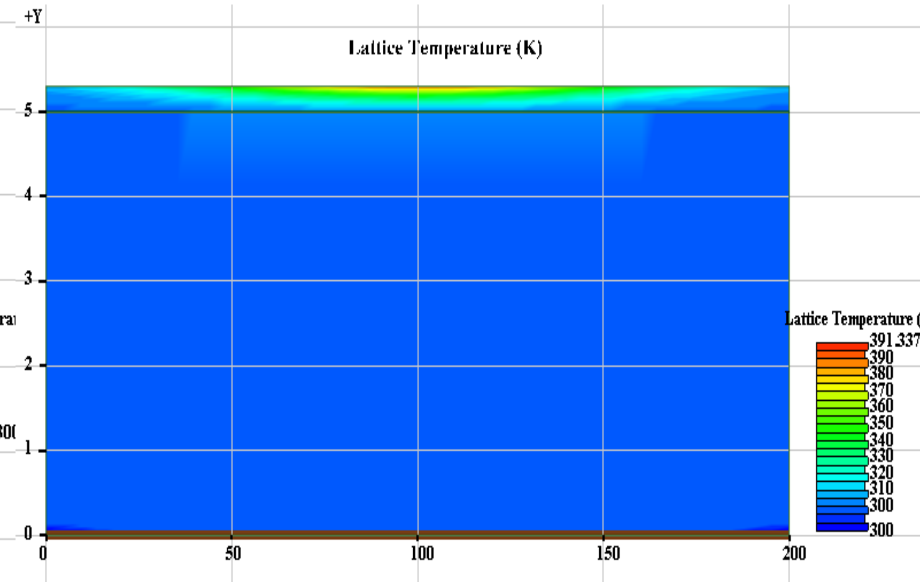
Modeling LFC solar cell with CSuprem & APSYS

- Use CSuprem (2D/3D) to set up mesh structure of silicon wafer or thin film layers.
- Transfer mesh data from CSuprem to APSYS to simulate local heating temperature profile based on laser parameter (pulse power, spot size, laser firing time etc).
- Transfer local heating temperature profile data from APSYS to CSuprem to simulate diffusion of aluminum impurity into silicon wafer or thin film layers.
- Transfer mesh + doping profile data from CSuprem to APSYS to simulate solar cell performance (I-V curves) under solar spectrum (e.g., AM1.5).

Simulation of laser scribing/LFC

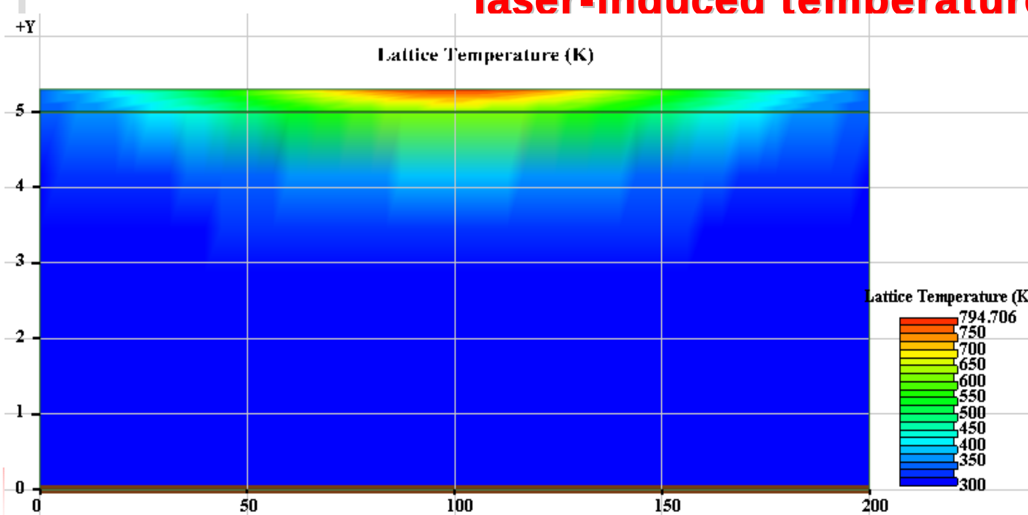


1 300k

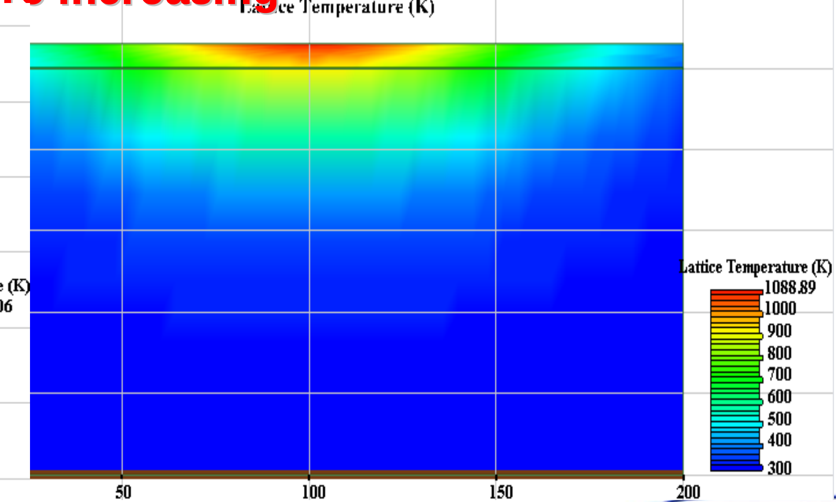


2 391k

laser-induced temperature increasing

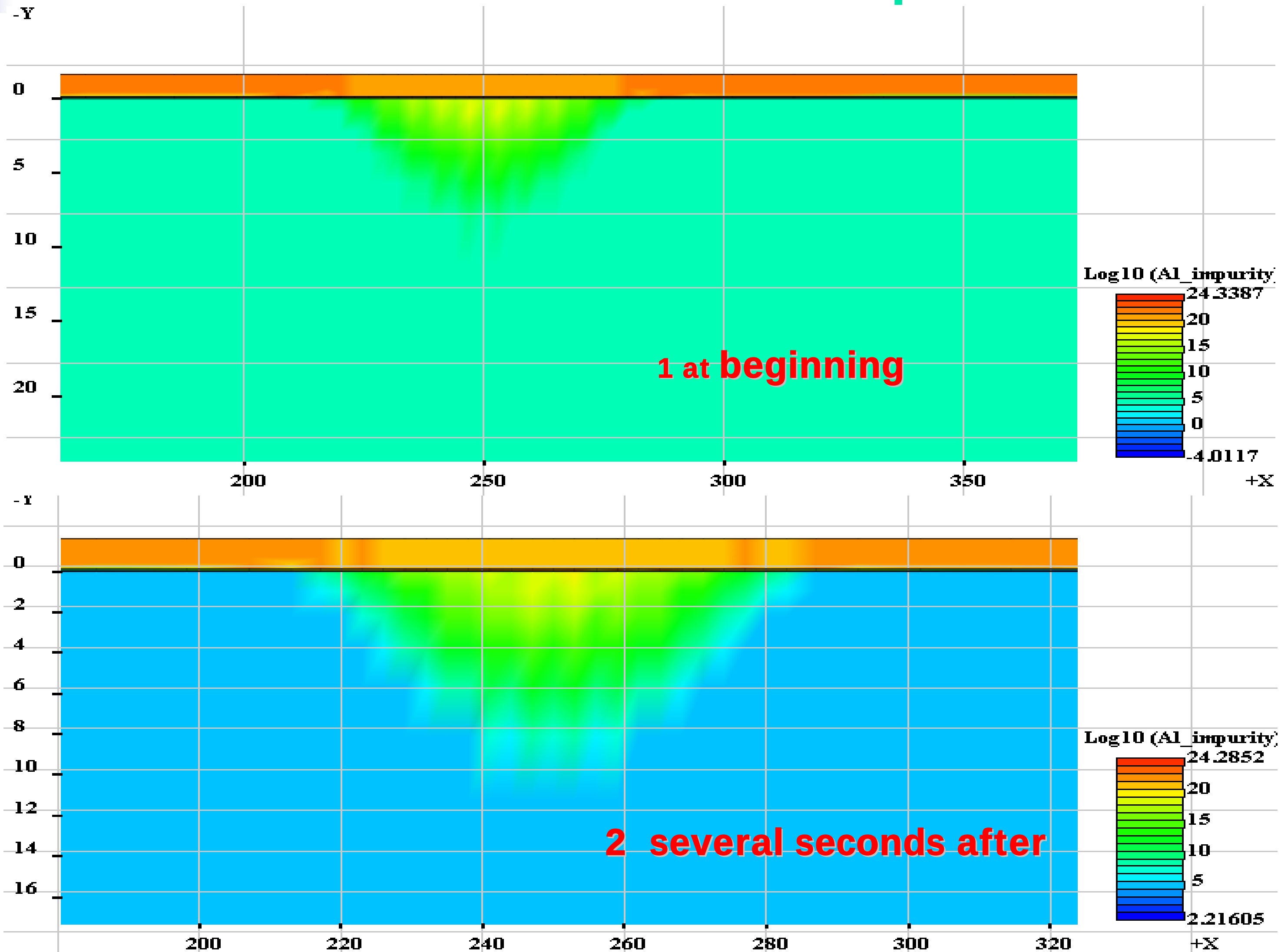


3 794k



4 1089k

Simulation of LFC with CSuprem



diffusion of aluminum impurity in silicon substrate

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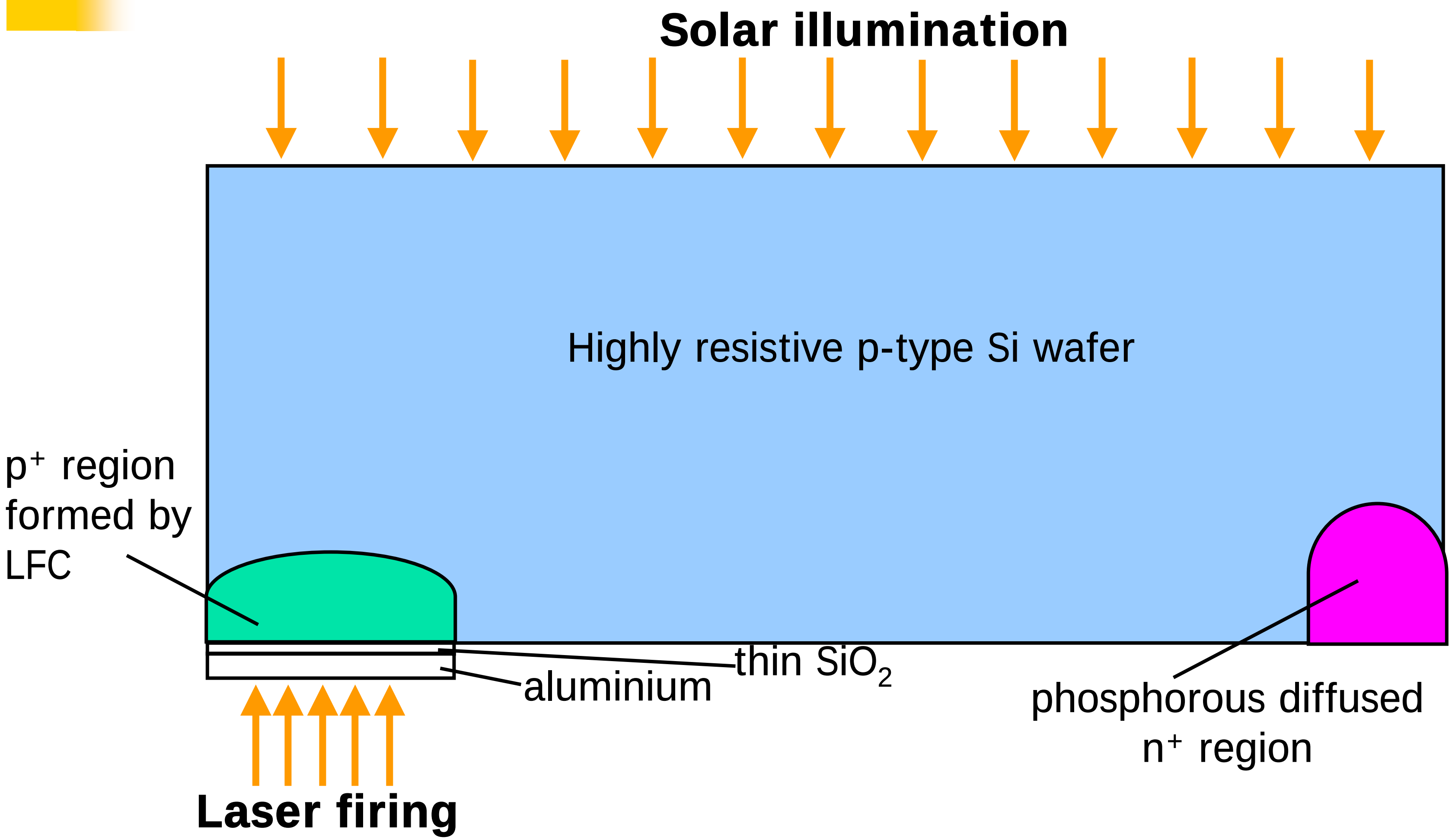
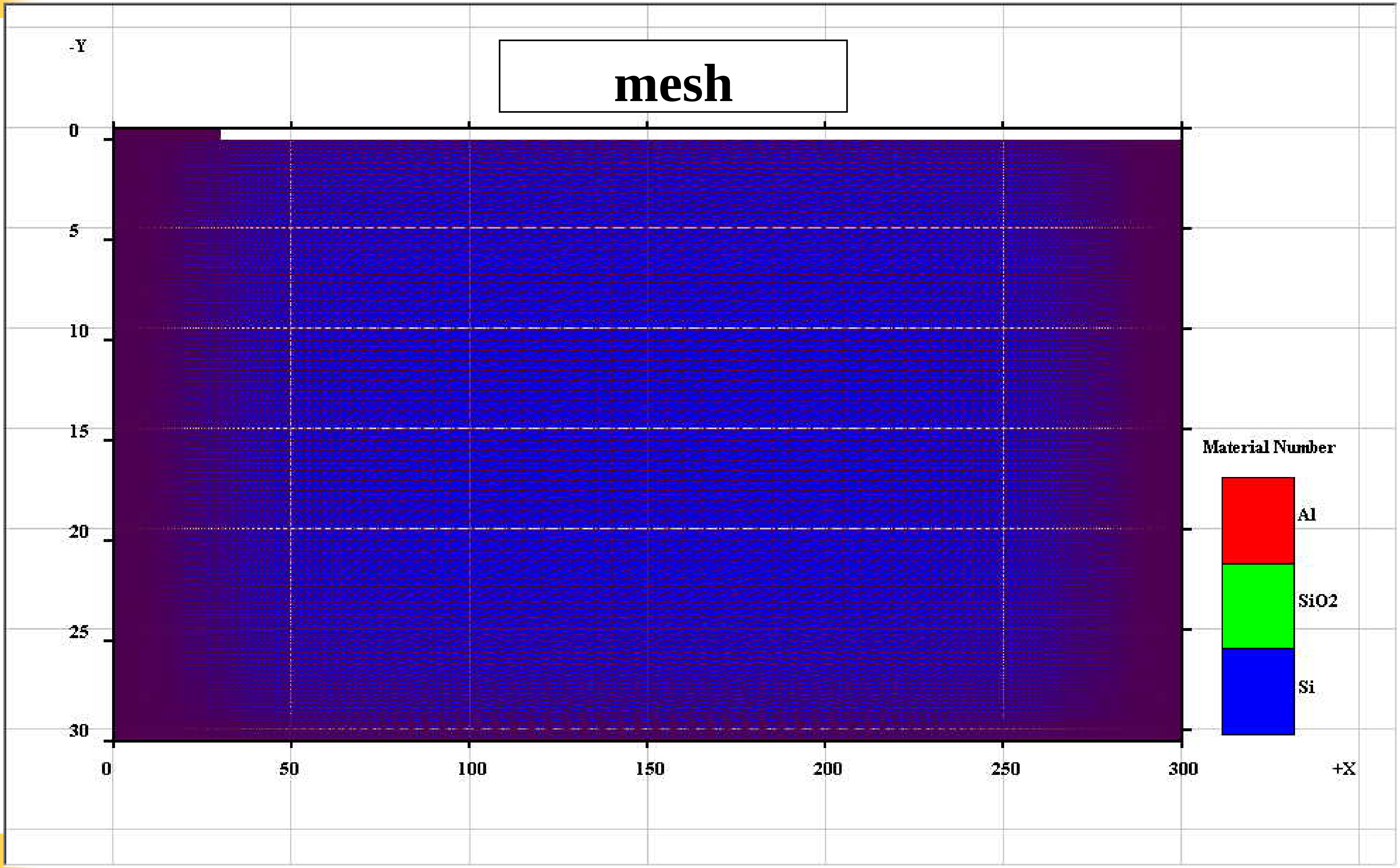
Application to rear-contacted cell (RCC)



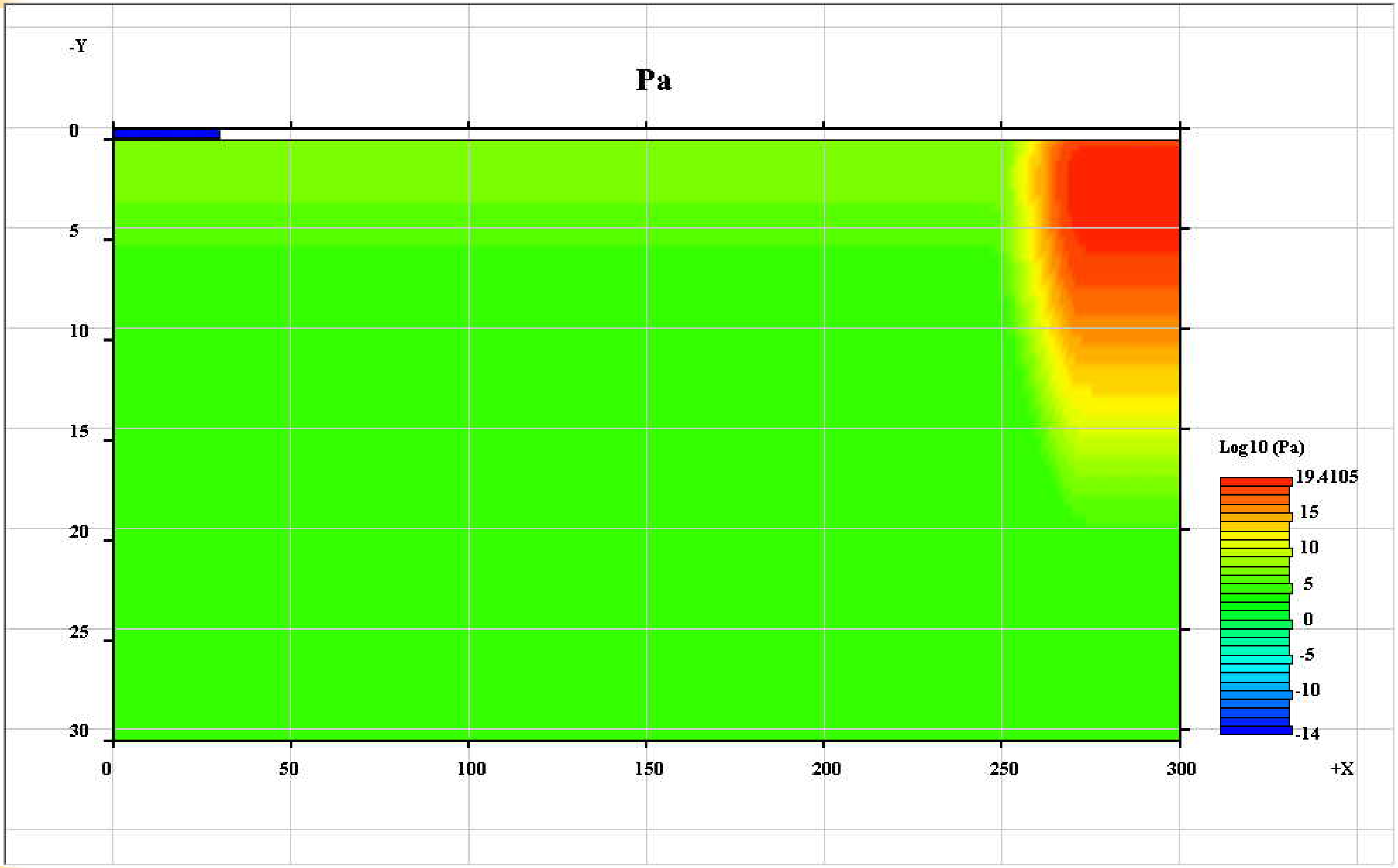
Schematic RCC unit (no texture & coating)

Structure mesh setting by CSuprem

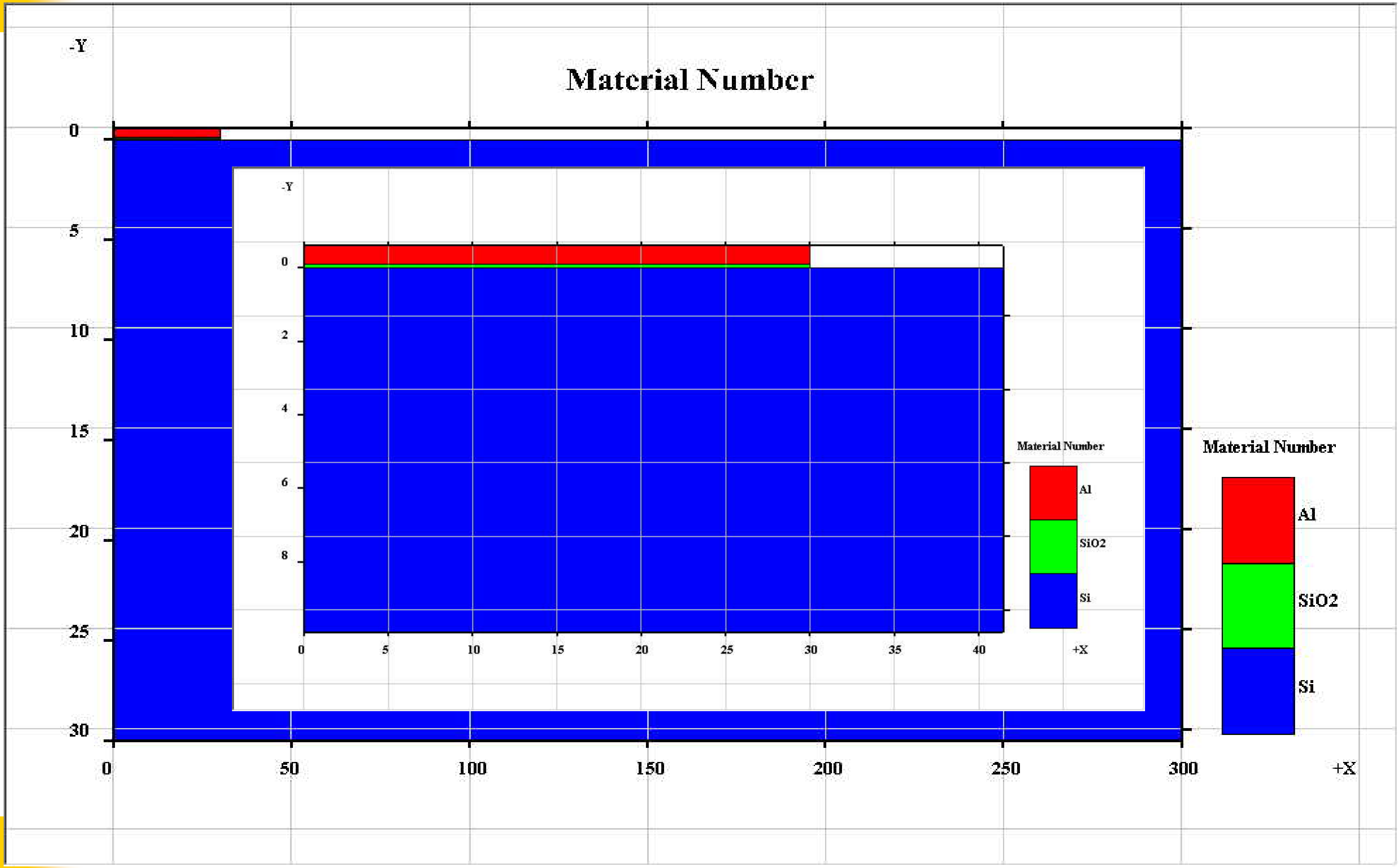


For simplicity, wafer thickness reduced to 30 μm.

Phosphorous diffusion by CSuprem



Preparation of laser firing region by CSuprem



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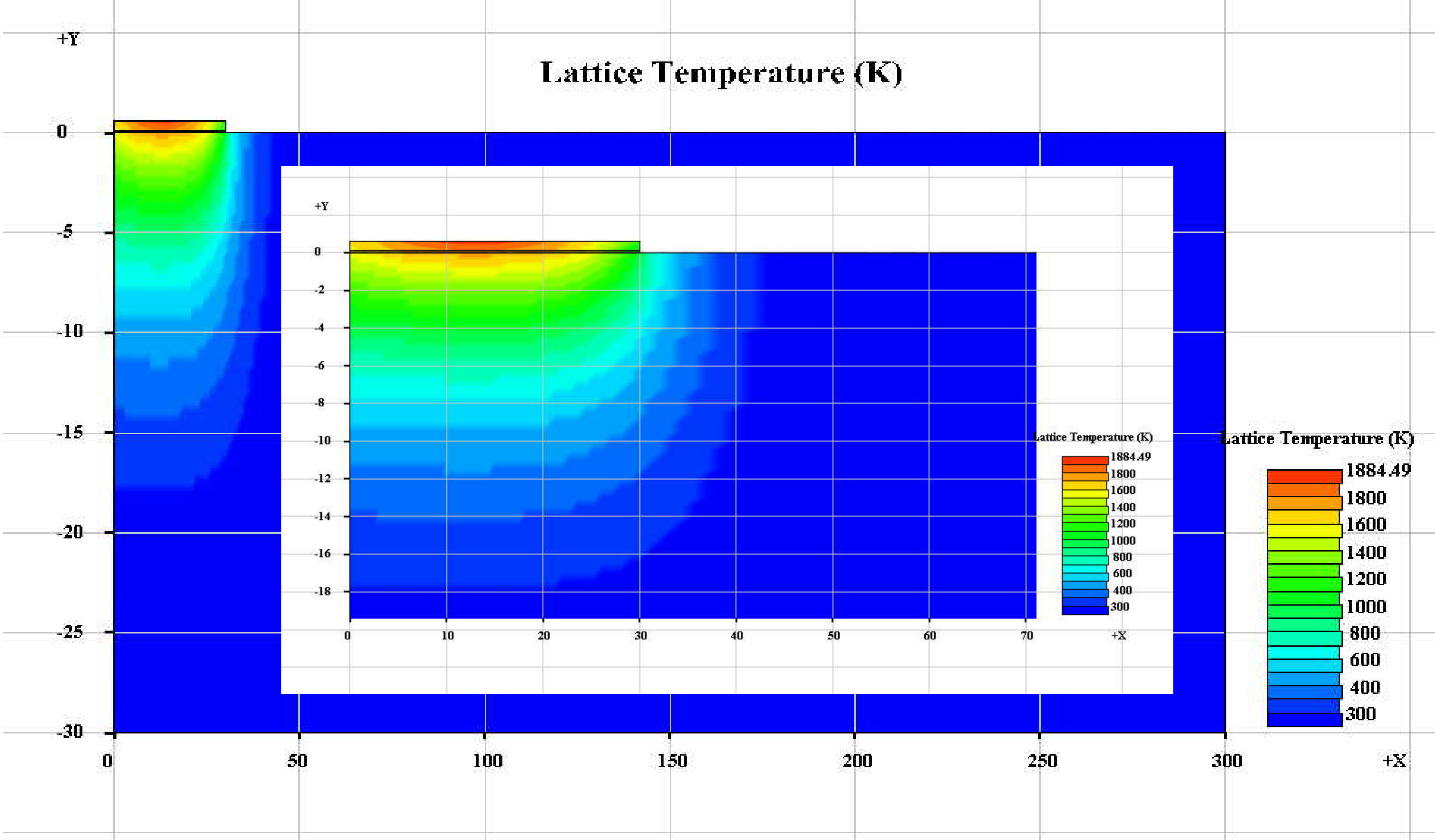
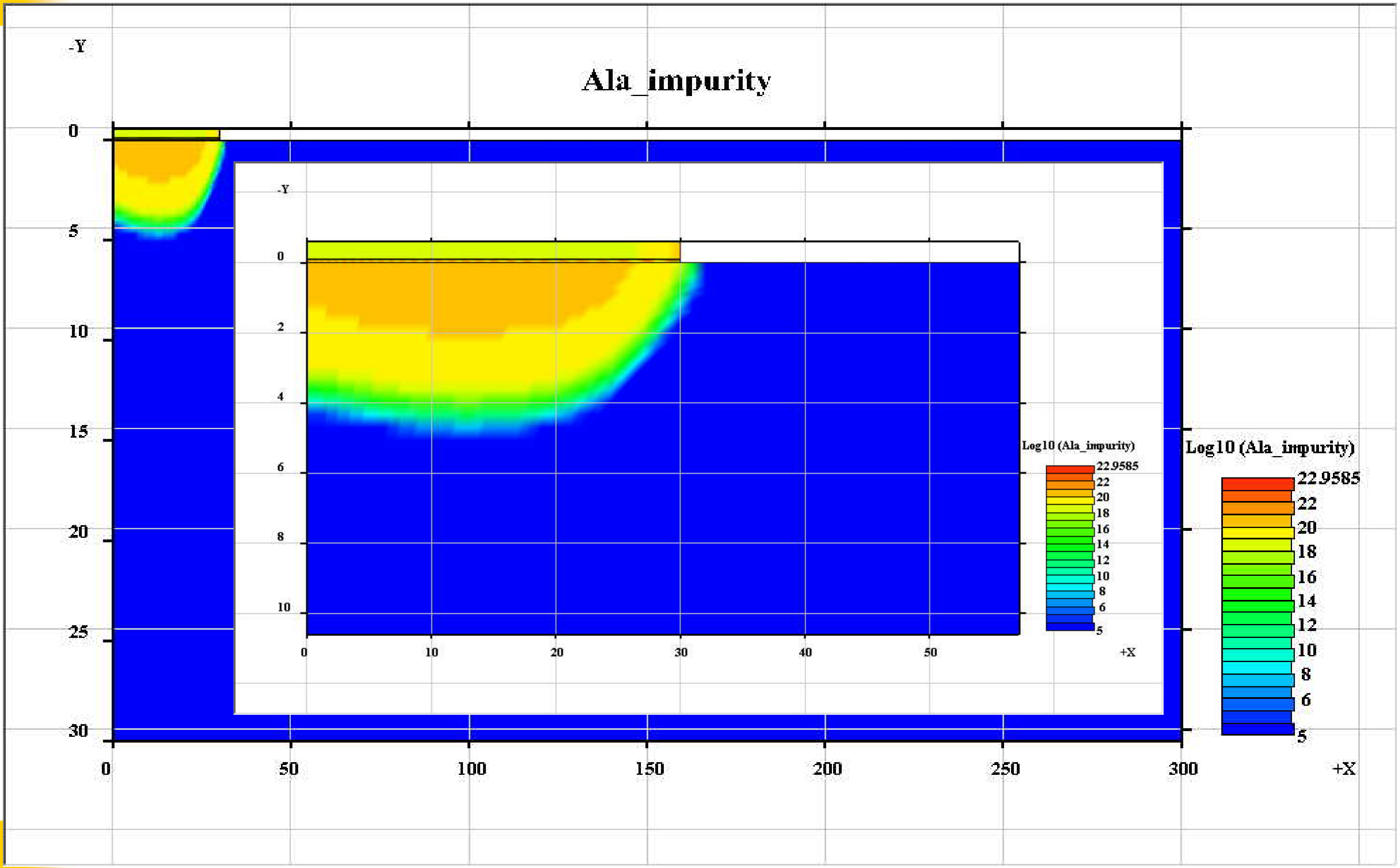
Lattice temperature change by laser firing



Firing wavelength 1064 nm; laser power 2.25×10^{11} W/m^2; firing time 480 ns

Local heating & Al diffusion by CSuprem



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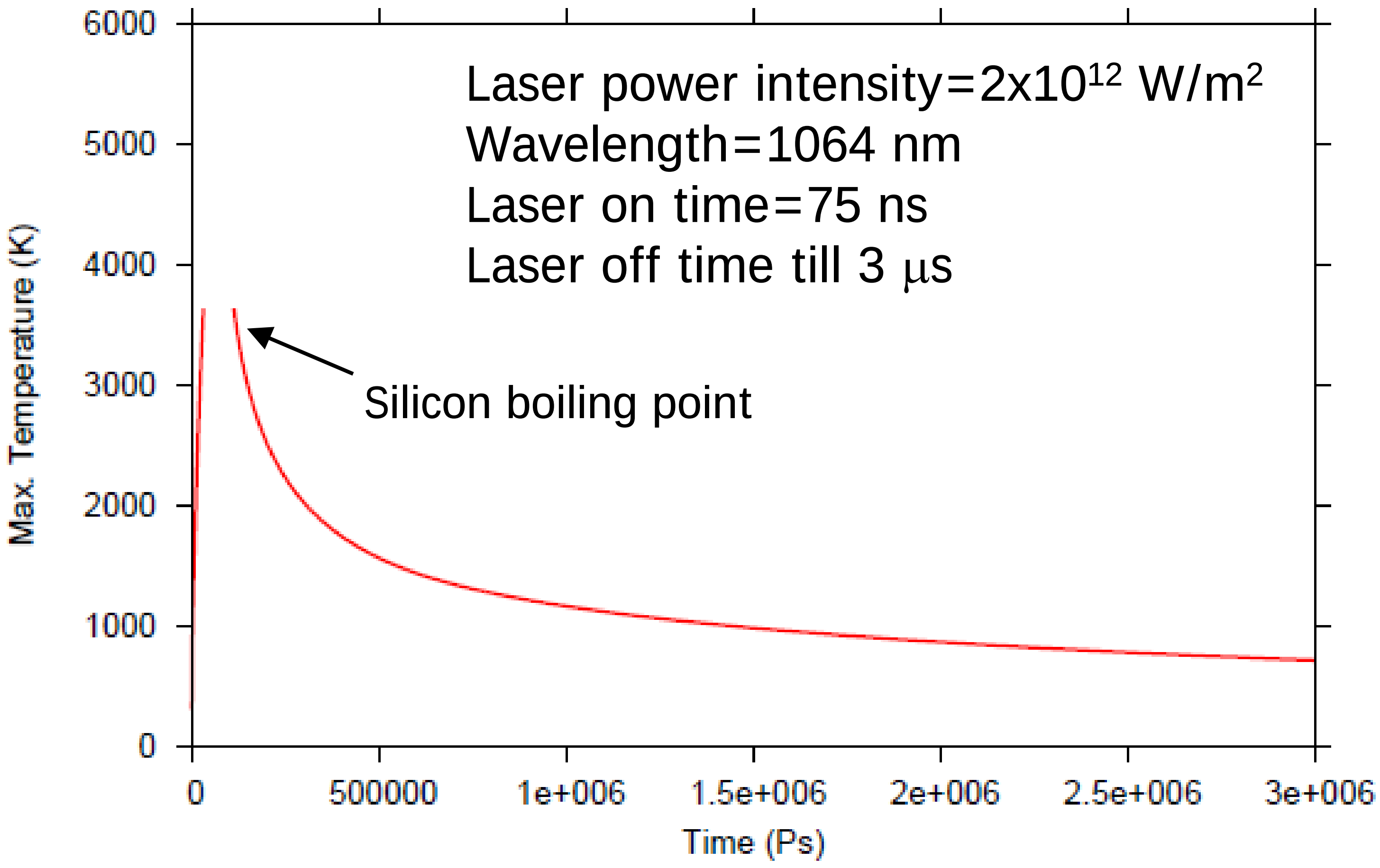
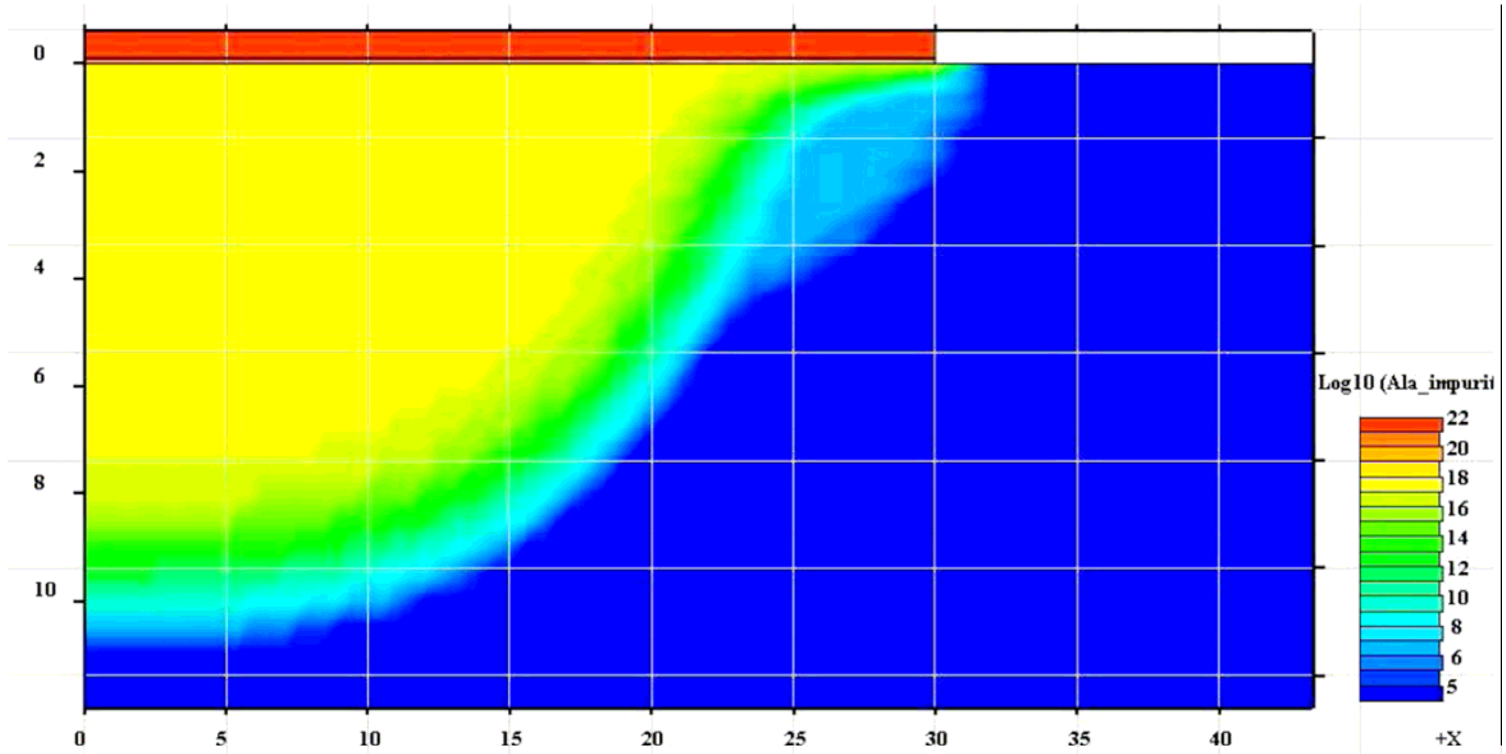
Max. temperature vs time with laser pulse

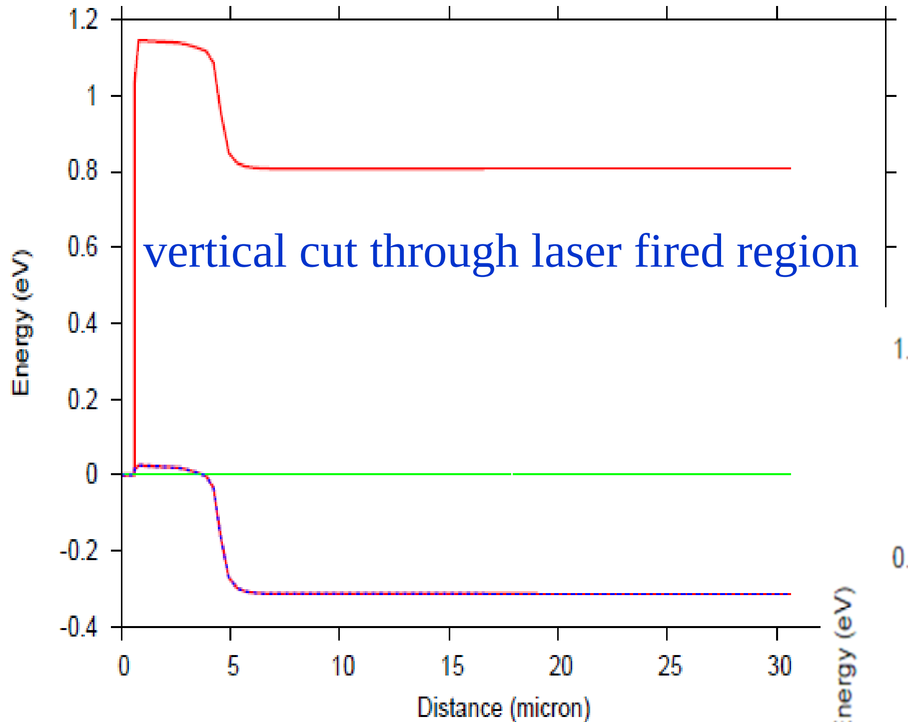


Al diffusion profile – melted state



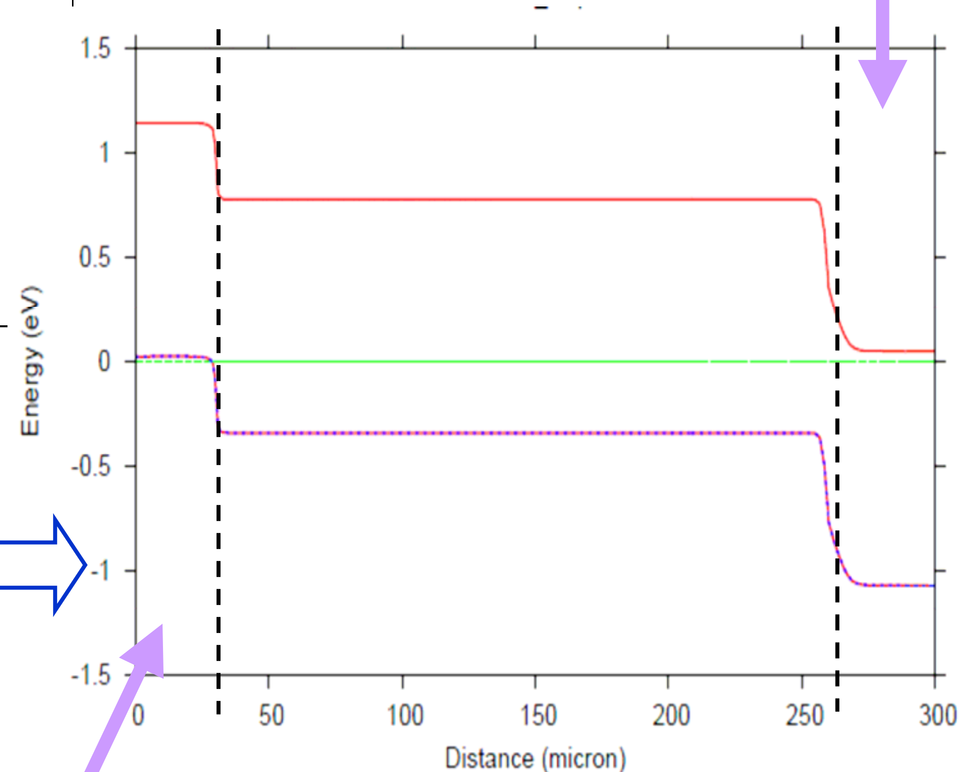
Assuming that, when both Al and Si melted, melted Al atom has 10^9 times of the diffusion coefficient of Al atoms diffusing into solid Si. After 1 pulse of laser firing (laser-on 75 ns, laser-off to 3 μs), further annealing for 3 seconds with average temperature profile at 1 μs with the Temperature vs Time profile shown on last slide. Less annealing diffusion time expected for quasi-liquid melted state diffusion

Band diagrams: simulation of RCC with LFC by APSYS



vertical cut through laser fired region

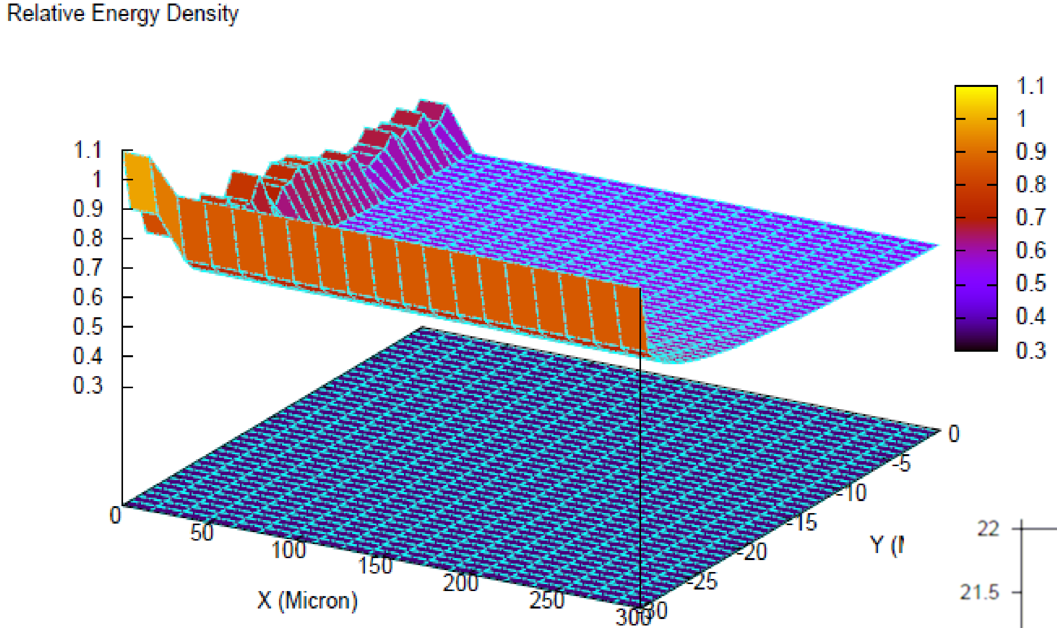
phos diffused region

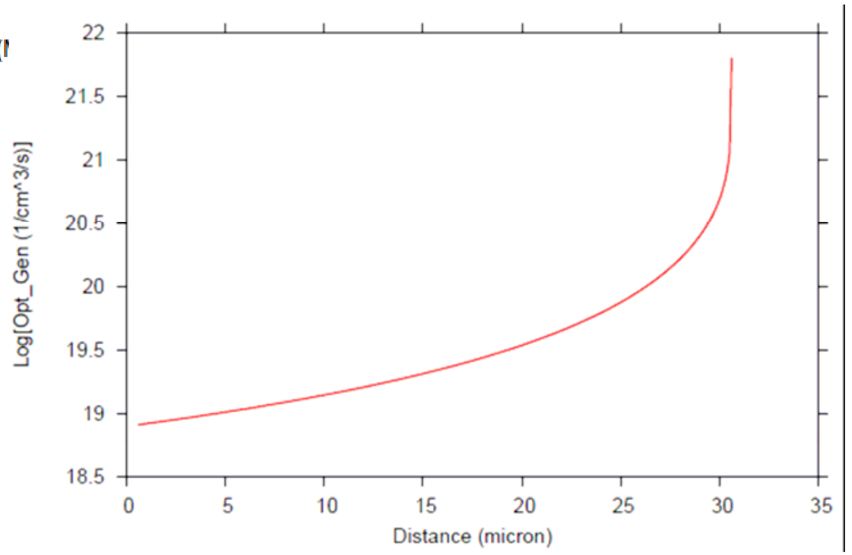


horizontal cut through laser fired region

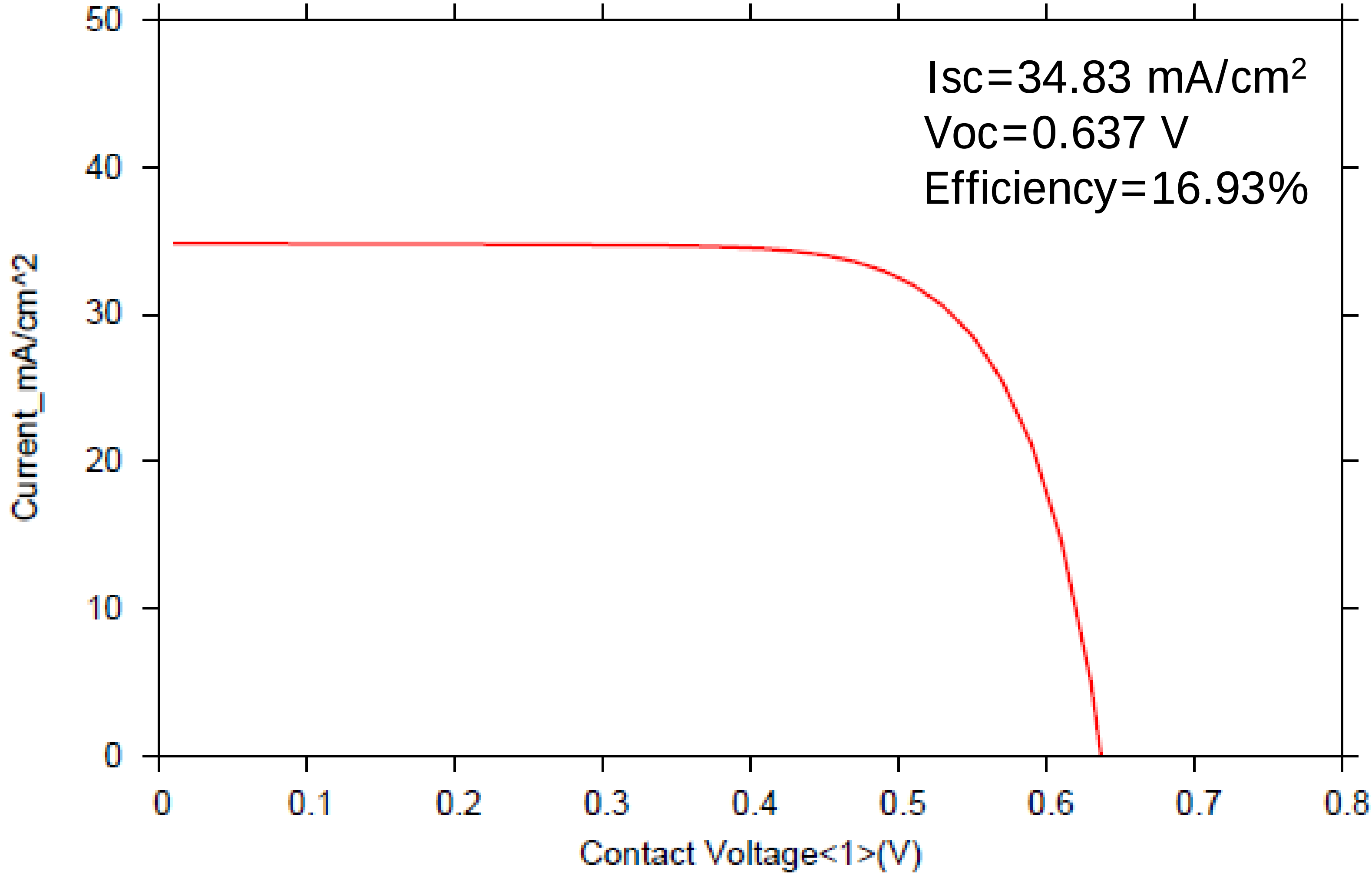
LFC region

Relative power density & optical generation





I-V curve: simulation of RCC with LFC by APSYS



Summary

- Laser fired contact processing demonstrated by combining Crosslight CSuprem & APSYS.
- Finally-processed RCC device with LFC imported successfully to APSYS for modeling solar cell performance.
- Reasonable cell performance demonstrated for RCC with LFC.
- Results also discussed with actual laser pulse firing & possible diffusion of melted Al atom into melted silicon.
- Crosslight CSuprem & APSYS capable for modeling 2D/3D solar cell with LFC.