Finite Element Simulation of Wafer Laser Heating

Using COMSOL Multiphysics

Project Report

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Introduction

Laser heating of silicon wafers is widely used in **semiconductor fabrication, annealing, and surface treatments**. A key challenge is capturing the **transient thermal response** under moving, localized heat sources.

In this project, I replicated and extended the official *COMSOL Application Library* model. My personal aim was to understand **temperature evolution, hotspot formation, and smoothing due to wafer rotation**, while also studying the effects of varying emissivity and laser power.

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Model Definition

Model Setup

- **Geometry:** 2-inch diameter, 275 µm thick silicon wafer.
- **Laser:** 10 W Gaussian beam, 2 mm spot radius.
- **Motion:** Wafer rotation at 10 RPM, laser scans radially with a 20 s period.
- **Physics:** Heat Transfer in Solids with Gaussian heat flux.
- **Boundary Conditions:** Surface radiation ($\epsilon = 0.8$), ambient $T = 293$ K.
- **Mesh:** Swept triangular mesh, single element in thickness.
- **Solver:** FEM, time-dependent transient solver.

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Results and Discussion

Temperature Evolution

The wafer's **maximum, minimum, and average** temperatures were tracked over time. Results showed that localized heating quickly creates hotspots, while wafer rotation helps distribute heat.

Hotspot Distribution

Surface plots confirmed **Gaussian-shaped hotspots** under the laser. Rotation smoothed the overall profile, yet **thermal gradients remained** at the beam focus.

Thermal Gradients and Stresses

The difference ($T_{max} - T_{min}$) indicated sharp **thermal stresses**, important for predicting crack initiation in semiconductor wafers.

My Personal Extensions

Beyond the COMSOL example, I performed additional studies:

- Varied emissivity ($\epsilon = 0.6$ to 0.9) to analyze radiation effects.
- Increased laser power from 10 W $\rightarrow$ 20 W, showing steeper heating and faster hotspot growth.
- Compared cases **with vs without wafer rotation**, highlighting the importance of mechanical motion for thermal uniformity.

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Conclusion

This project demonstrated how the **Finite Element Method (FEM)** in COMSOL Multiphysics can simulate laser heating of wafers.

Key takeaways:

- Gaussian laser flux produces strong **localized heating**.
- Wafer rotation reduces but does not fully remove hotspots.
- Emissivity and laser power significantly alter wafer thermal behavior.

Such studies are vital for **semiconductor process design, defect minimization, and laser-based material processing**.

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