COOLING TECHNOLOGIES RESEARCH CENTER

Thermal Design of Multilayer/Stacked Structure

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PURDUE
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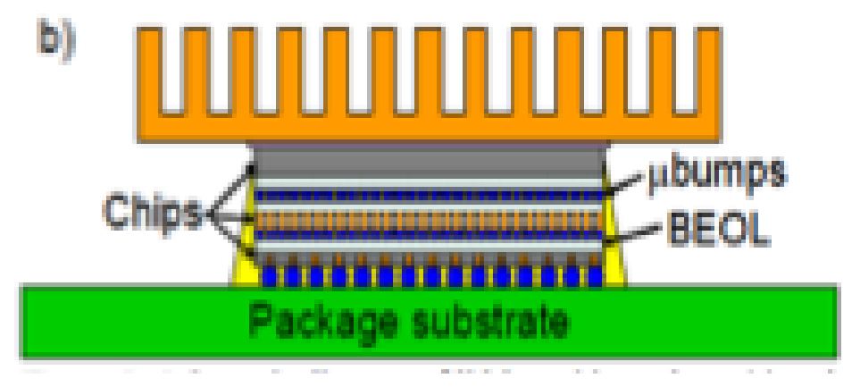
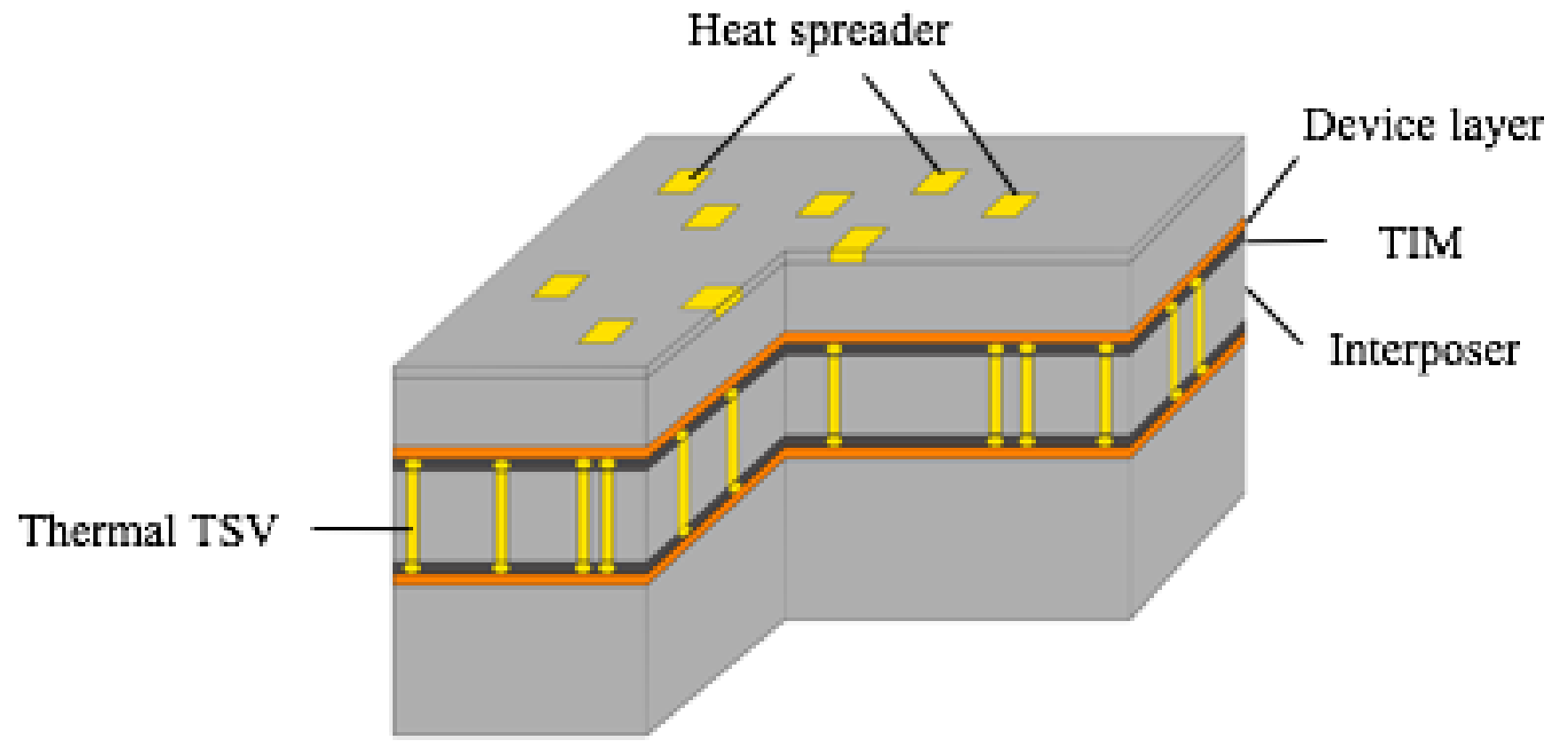
Objectives

To develop and demonstrate thermal design tools for optimal arrangement of multilayered/stacked structures





Methods

Topology optimization carried out by coupling finite element analysis (FEA) with sequential quadratic programming (SQP) algorithm.

SIMP Method: $k_i = \rho_i^p k_{i_1} + (1-\rho_i^p) k_{i_0}, p \geq 3$

Objective Functions

Minimize Peak Temperature: $\min\limits_{\rho_i} \frac{T_{max}}{T_{max,0}}$

Minimize Stored Energy: $\min\limits_{\rho_i} \frac{\{f\}^T\{T\}}{\{f\}^T\{T_0\}}$

Sensitivity Analysis

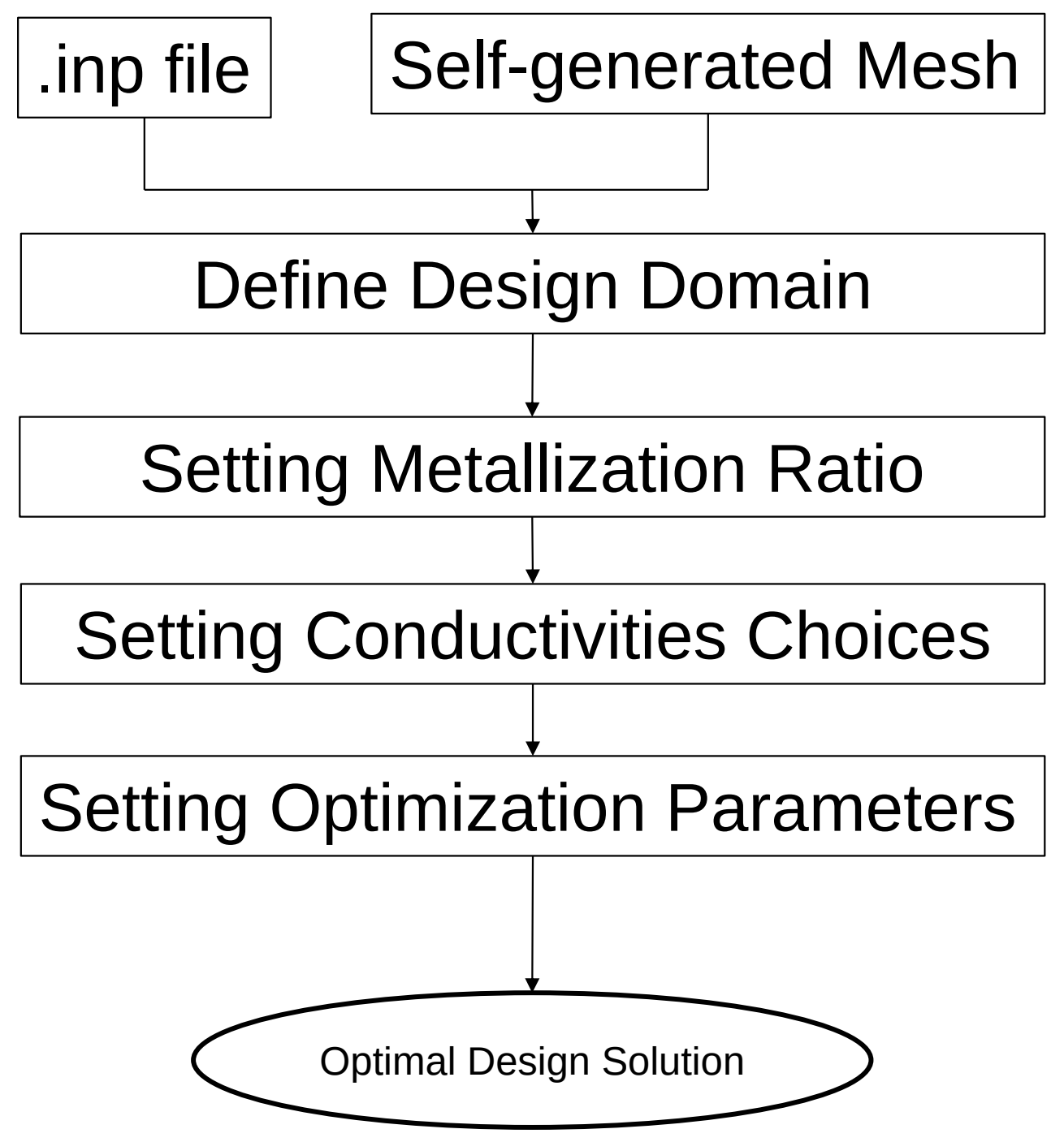
➢Sensitivity to Temperature:

$$\frac{\partial\{T\}}{\partial\rho_i} = -p\rho_i^{p-1}(k_{i_1} - k_{i_0})[K]^{-1}\frac{\partial[K]}{\partial k_i}\{T\}$$

➢Sensitivity to Stored Energy:

$$\frac{\partial\{f\}^T\{T\}}{\partial\rho_i} = -p\rho_i^{p-1}(k_{i_1} - k_{i_0})\{T\}^T\frac{\partial[K]}{\partial k_i}\{T\}$$

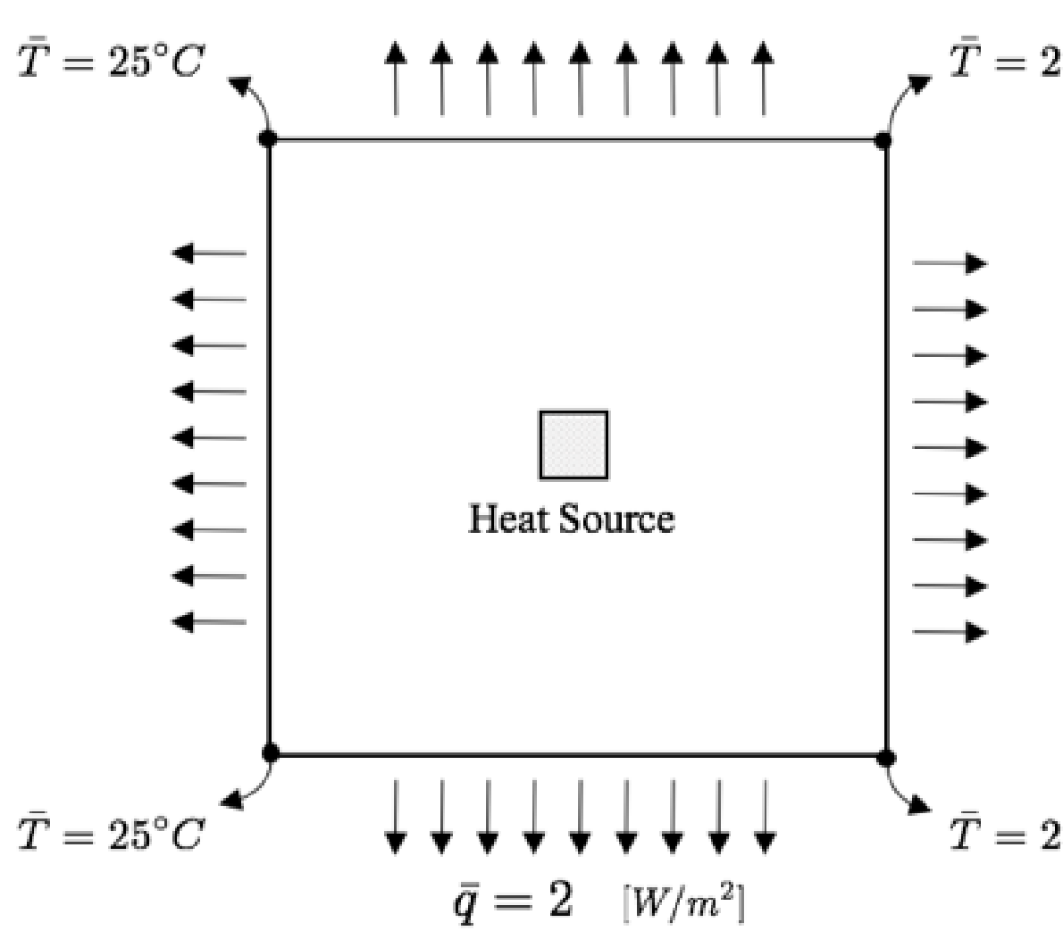
Procedures



.inp file
Self-generated Mesh
Define Design Domain
Setting Metallization Ratio
Setting Conductivities Choices
Setting Optimization Parameters
Optimal Design Solution

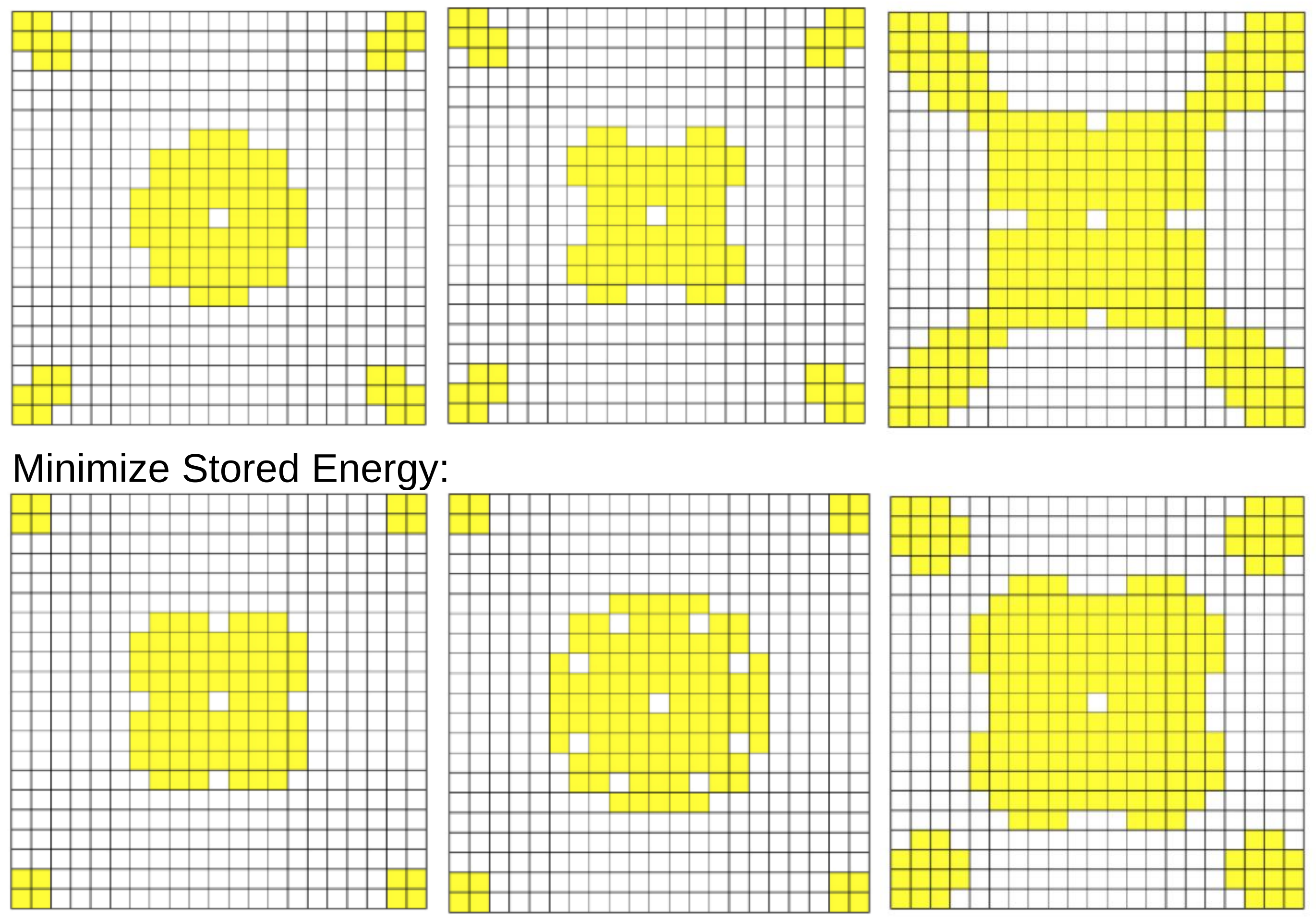
Results

➢Heat Spreader Design:



☐ Substrate
🟨 Heat Spreader

Minimize Peak Temperature:

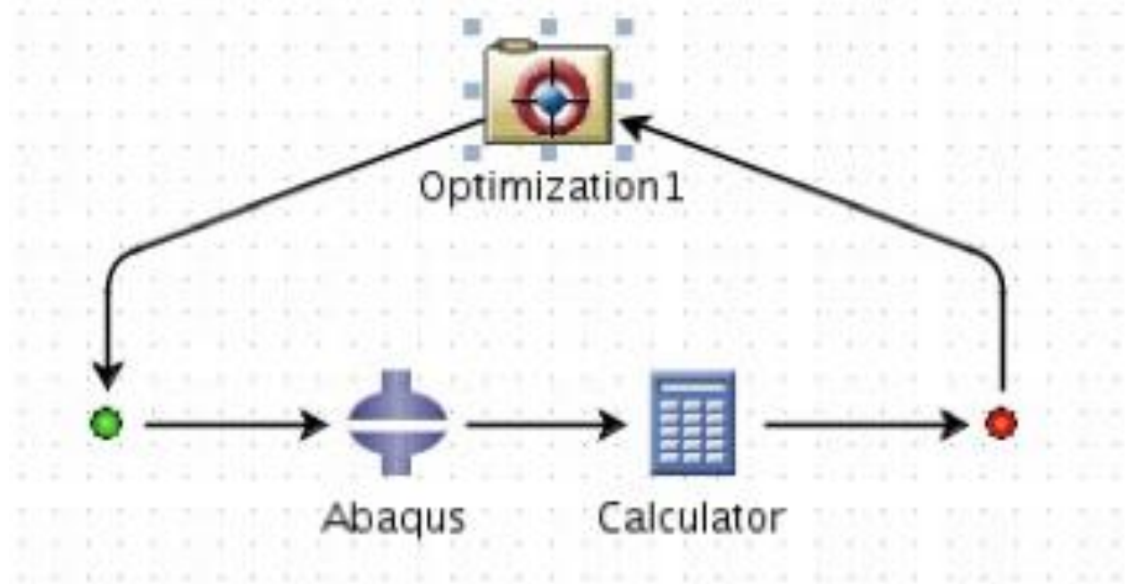


Minimize Stored Energy:

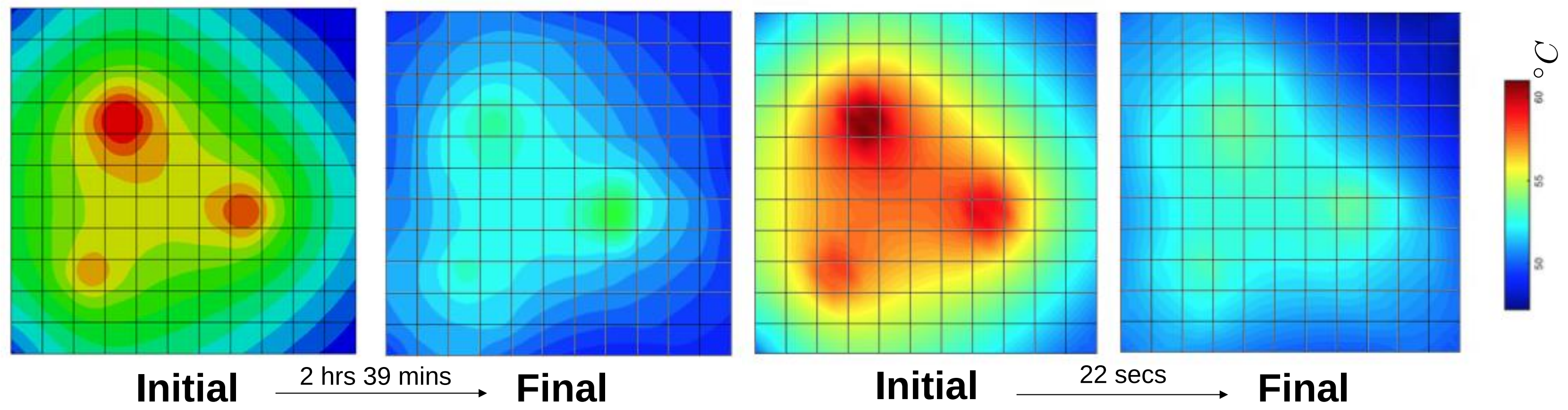
Metallization Ratio	20%	25%	45%

➢Validation and Comparison:

Simulia Isight Flow of Control

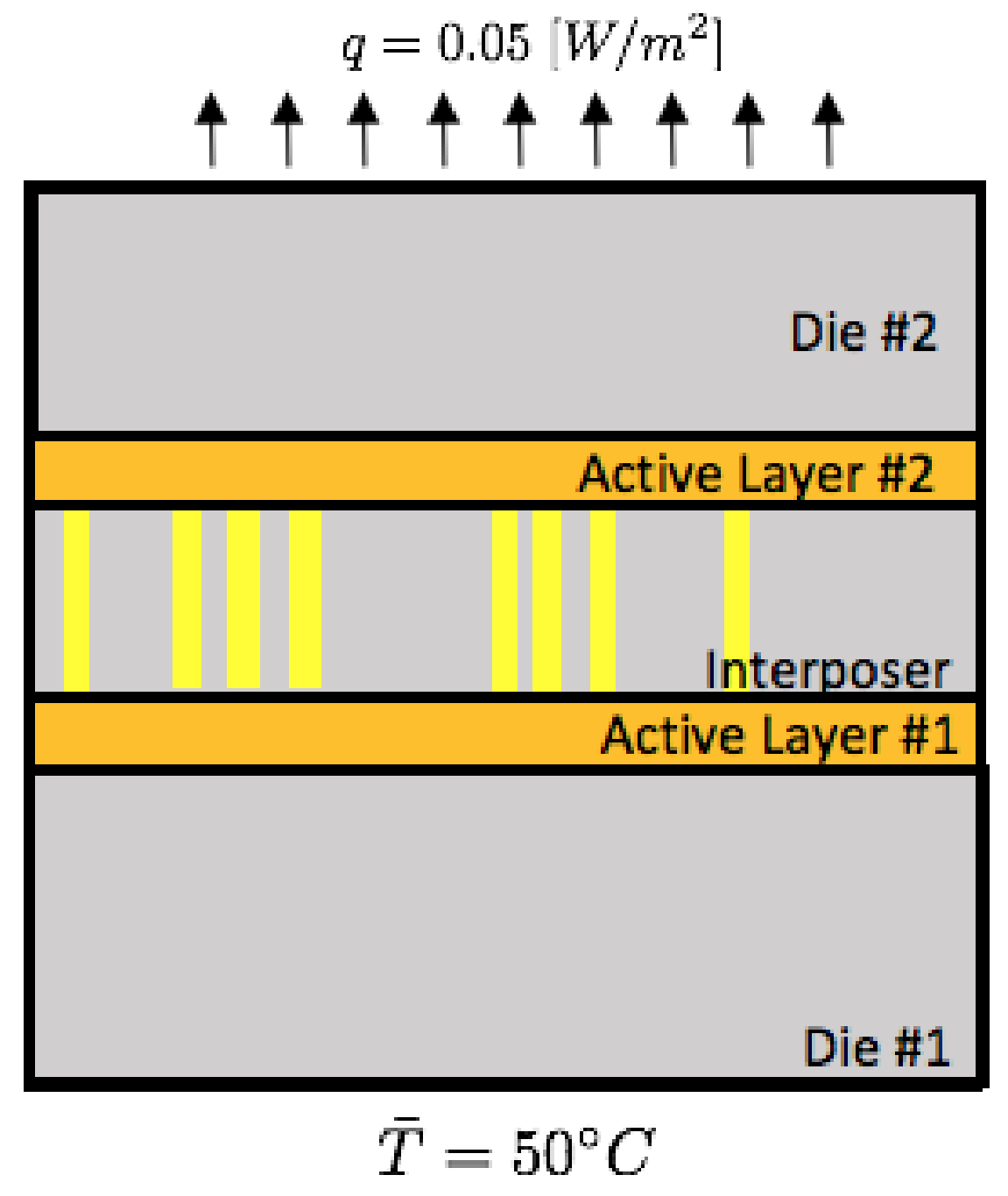


Abaqus Results **Matlab Results**



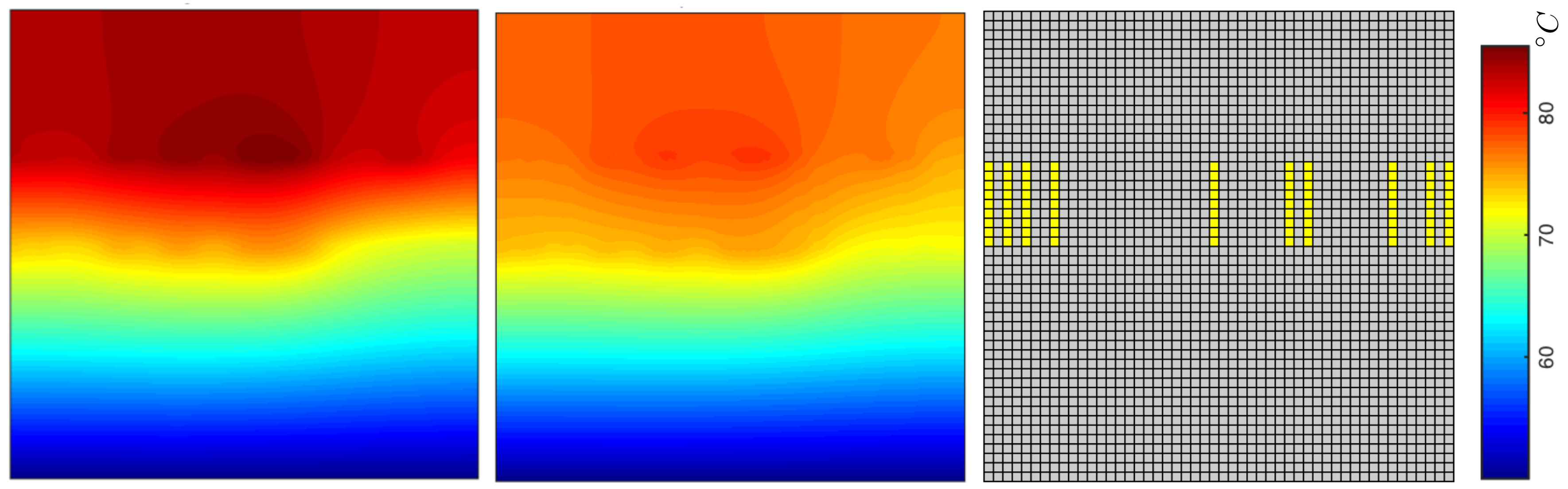
Initial 2 hrs 39 mins → **Final**   **Initial** 22 secs → **Final**

➢Thermal TSV Design:



Minimum Peak Temperature
(Area Constraint: 20 %)

🟨 TSV
☐ Substrate



Initial **Final** **TSV Design Solution**

Summary

- The developed standalone tool requires two orders of magnitude lower time for design as compared to a popular commercial tool.
- The developed tool will enable thermal design of 3D packages by identifying efficient heat removal paths through optimal placement of TSVs and optimizing heat spreader as well TIM material.

Acknowledgement

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References

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