In [1]:
```
#%%capture
!pip freeze > requirements.txt
!pip freeze | grep -v -f requirements.txt - | grep -v '^#' | grep -v '^-e ' | xargs pip uninstall -y
```

Abstract

This 3D heat flow simulation work pertains to a Silicon-on-Insulator (SOI) wafer, using COMSOL's 'Heat Transfer in Solids (ht)' interface of **Multiphysics®** tool which uses FEM with Quadratic Lagrange shape functions (as referred in **[1] COMSOL Documentation**). The SOI heat flow modelling parameters include -

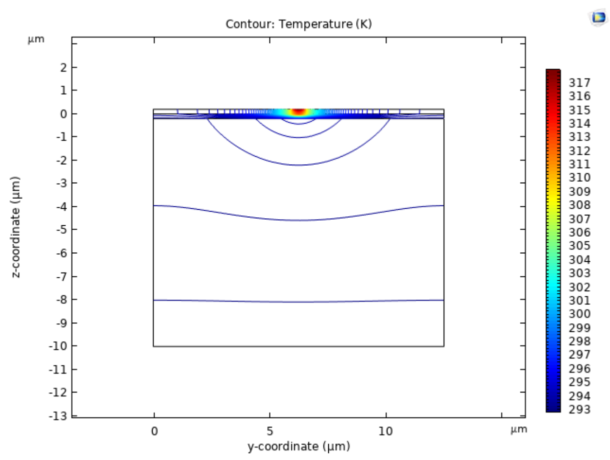
1. Initial width, depth of 12.5μm.
2. Top Si thickness of 0.2μm.
3. Buried oxide thickness of 0.2μm.
4. Si wafer thickness (beneath the buried oxide) of 9.8μm.
5. Finer Mesh across the SOI geometry.
6. A circular heat source at the center of the top boundary of top Si, with heating power of depthx100W = 1.25E-3 W.

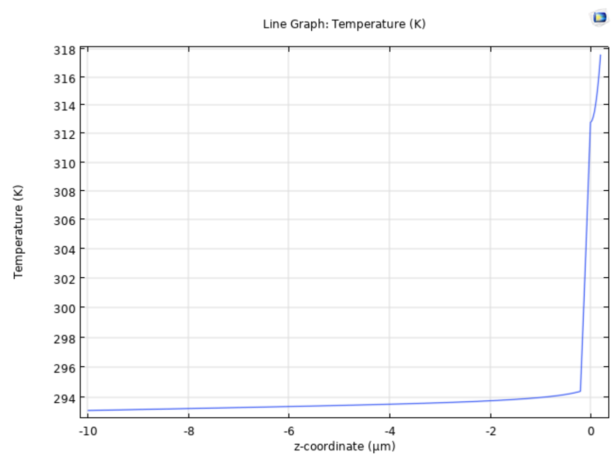
All ensuing simulation plots are defined with appropriate 3D-cutplanes and 2D-cutlines in the SOI geometry.

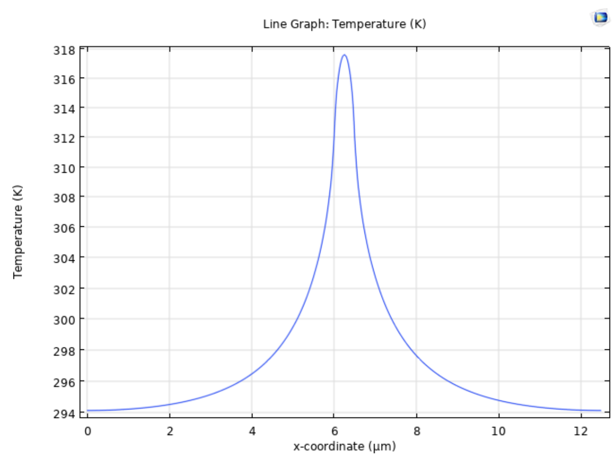
Table of Contents

Part I: Heat Flow with Temperature Boundary Condition (T)

Simulations at $T = 293.15K$







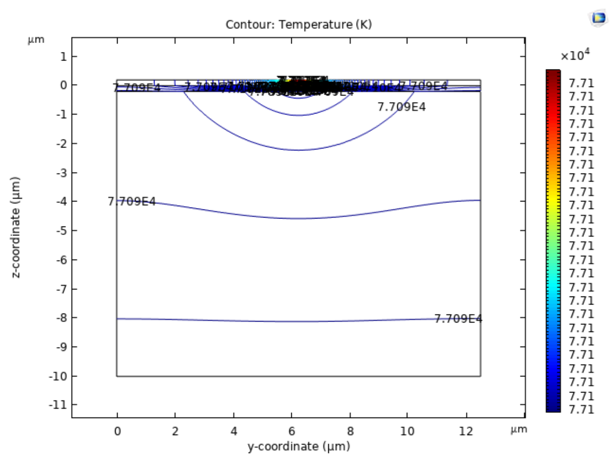
Summary

1. This simulation was performed by setting temperature boundary condition (T) at the bottom of Si wafer to 293.15K, along with stated SOI modelling parameters.
2. The resulting temperature contour plot and line graphs across z \& x axes indicate a gaussian-profile for temperature into and across the Si wafer, with a maximum at the heat source.

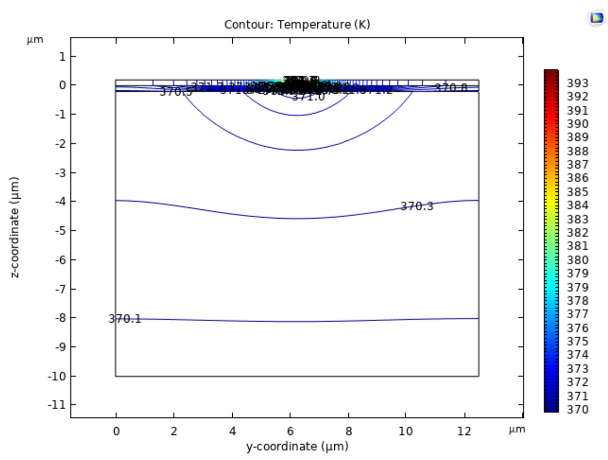
Part II: Heat Flow with Heat Flux Boundary Condition (h)

Simulations at $h = 10^2 W/m^2.K, 10^5 W/m^2.K, 10^9 W/m^2.K$

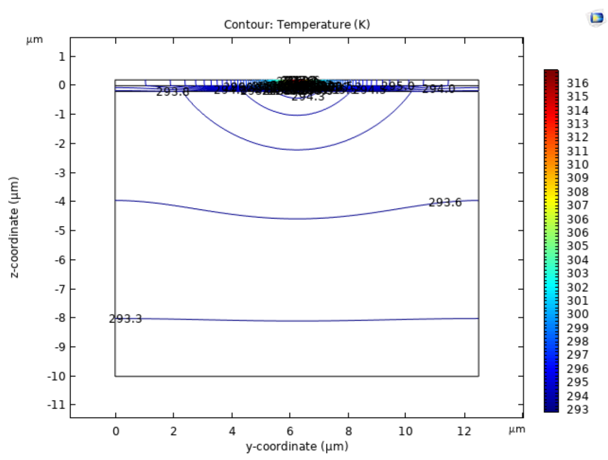
$h = 10^2$



$h = 10^5$



$h = 10^9$

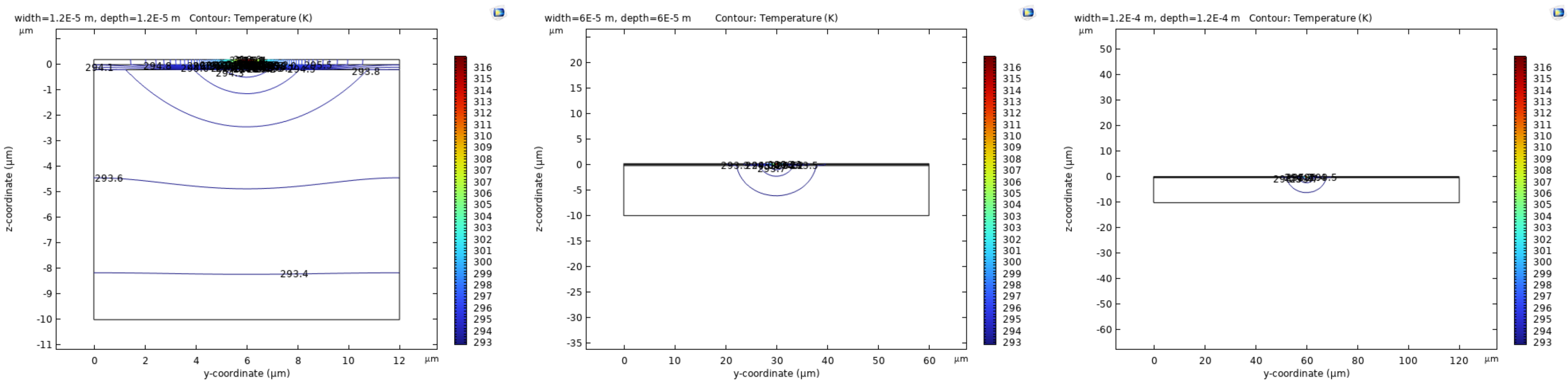


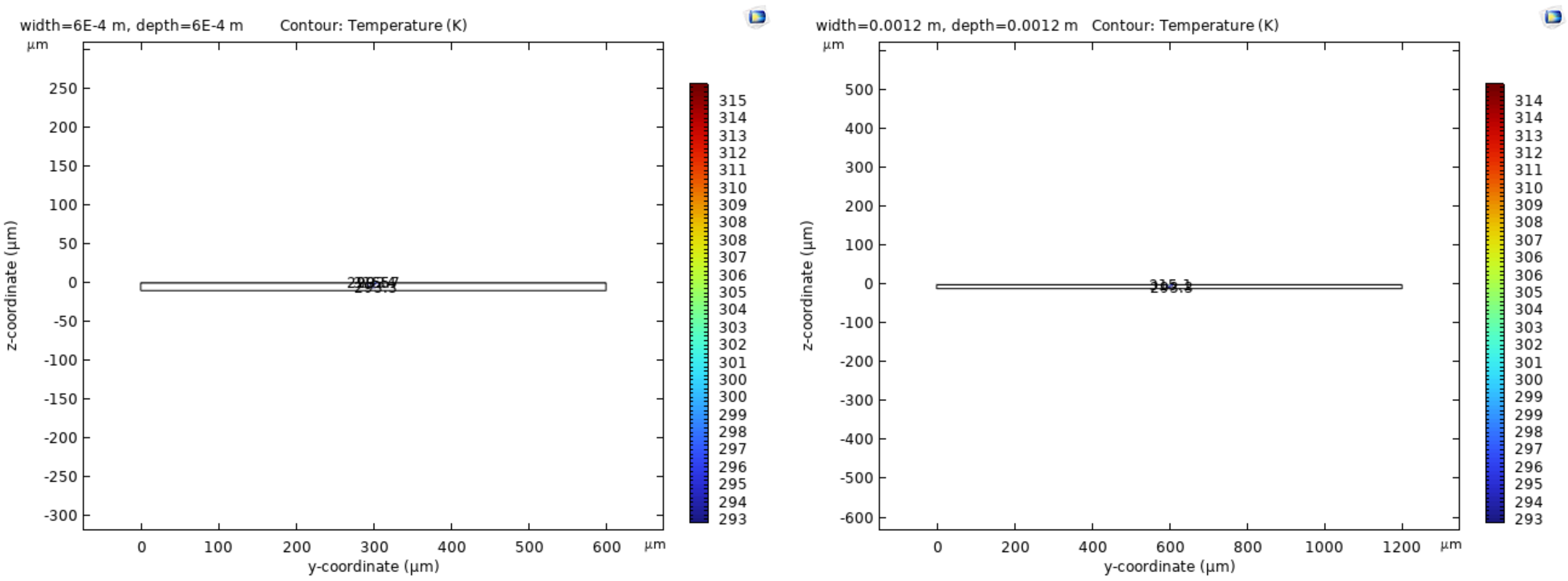
Summary

1. This simulation was performed by disabling the temperature boundary condition (T) at the bottom of Si wafer, and replacing it with Convective Heat Flux and varying the heat transfer coefficient h until the temperature profile in the Si wafer matches that of the temperature boundary condition $(T = 293.15K)$.
2. The resulting temperature contour plot for $h = 10^9 W/m^2.K$, matches that of the temperature boundary condition $(T = 293.15K)$ in Part I. Henceforth this Convective Heat Flux boundary condition is used.

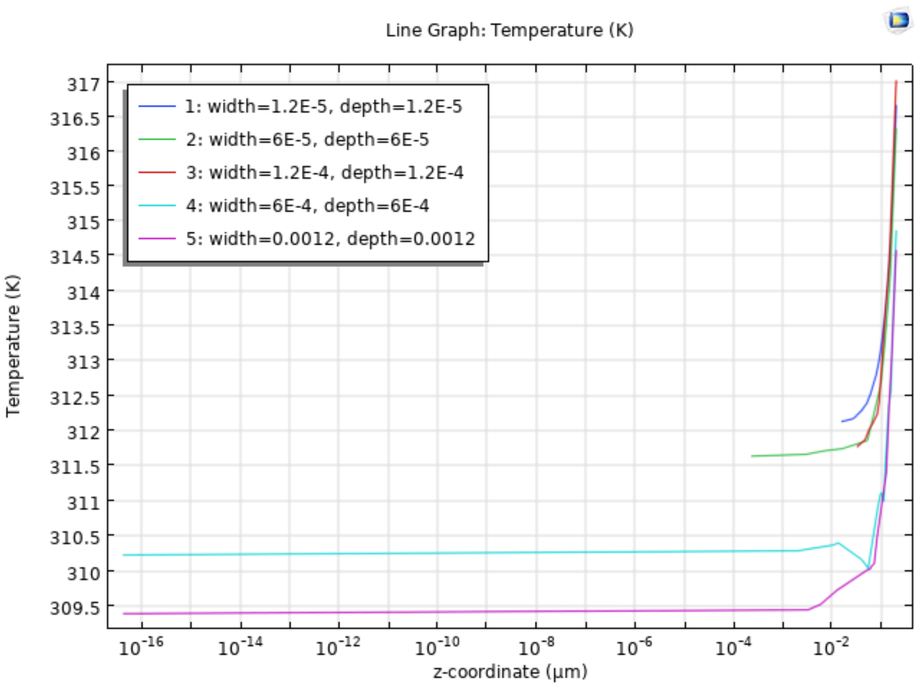
Part III: Effect of Dimensional parameteric sweep (equal width, depth) on Heat Flow with Heat Flux Boundary Condition $(h = 10^9\ W/m^2.K)$

Simulations with width (and depth) = 1.2E-5m, 6E-5m, 1.2E-4m, 6E-4m, 0.0012 m

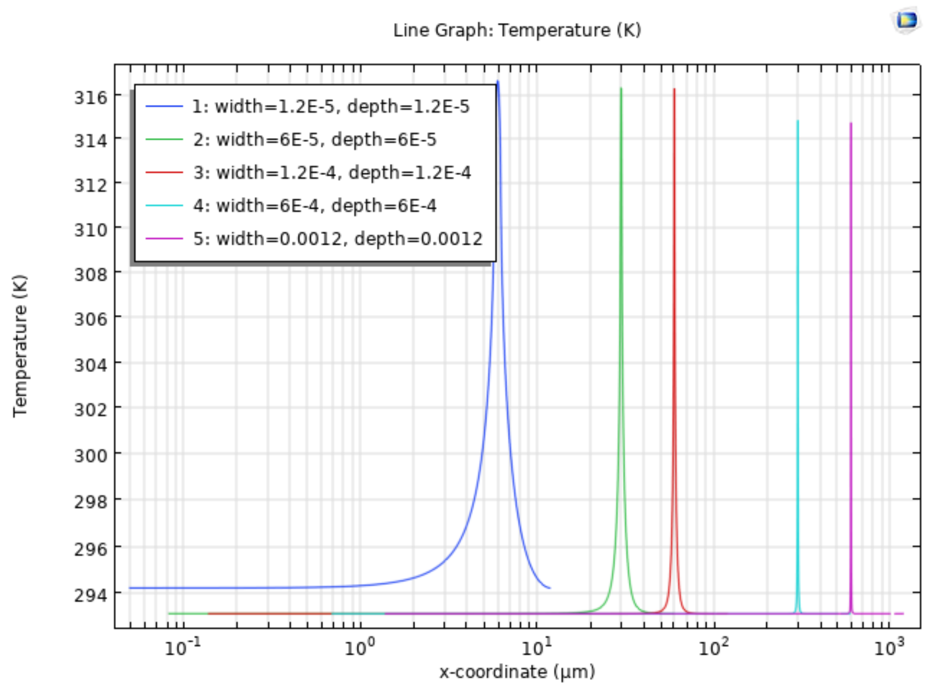




semi-log z



semi-log x

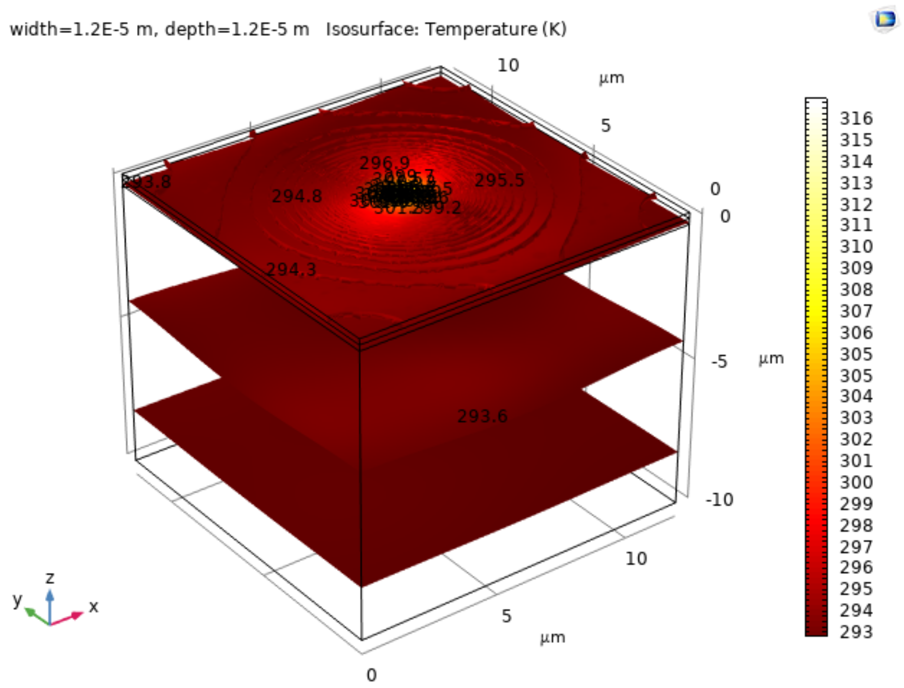
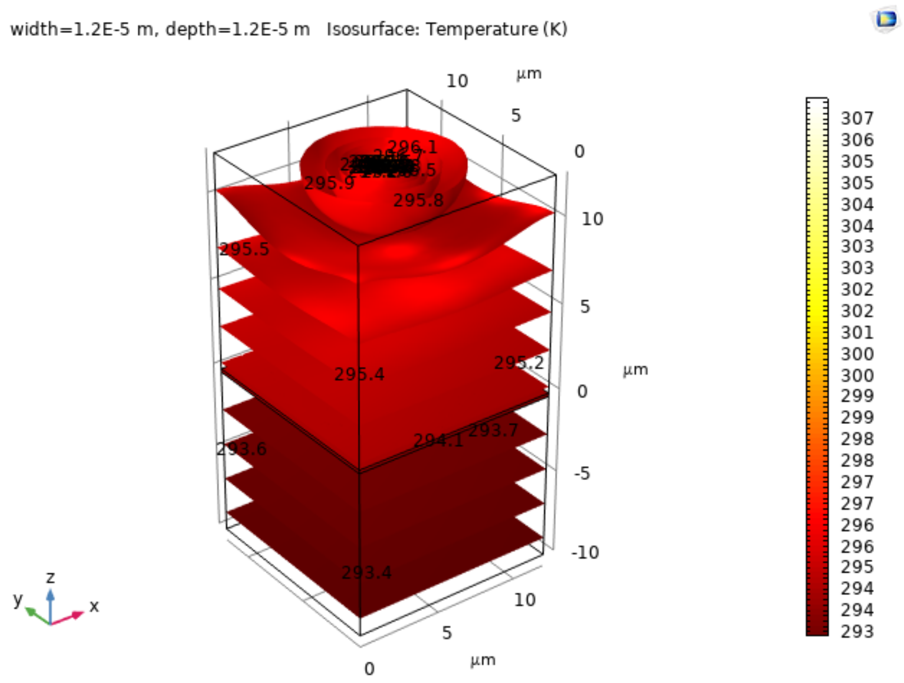


Summary

1. This simulation was performed by parametrically increasing the width (along with depth) of SOI geometry until the peak and edge temperatures saturate, i.e. the gaussian temperature profile across the SOI wafer converges to a delta profile.
2. The resulting temperature contour plot and line graphs across z \& x axes for width (\& depth) of 0.0012m (when compared to those of 1.2E-5m) show a sharp peak (concentrated delta profile) at the heat source, indicating a large enough simulation domain so that any effect of boundary conditions on heat flow is negligible.

Part IV: Effect of top Si thickness on Heat Flow with Heat Flux Boundary Condition $(h = 10^9 \; W/m^2.K)$

Simulations with top Si thickness = 0.2μm, 12.5μm

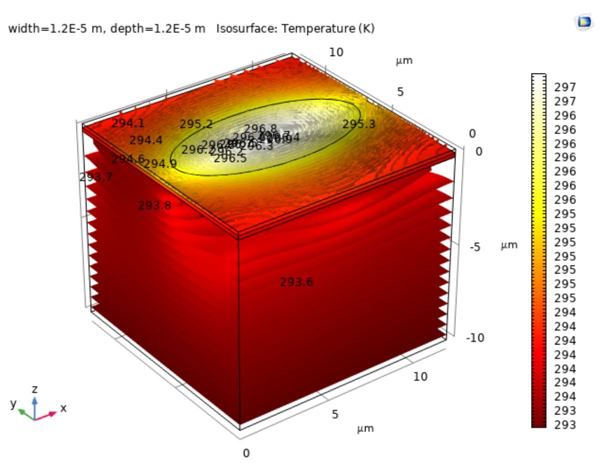
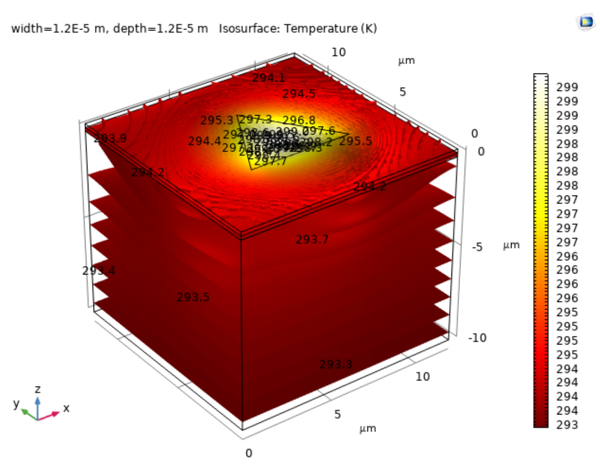
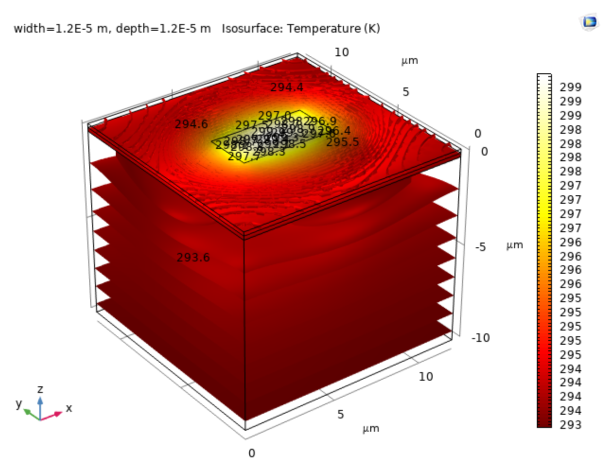
top Si thickness = 0.2um	top Si thickness = 12.5um
	

Summary

1. This simulation was performed by parametrically increasing the top Si thickness, to reach a predominantly lateral heat flow across the SOI wafer.
2. The resulting temperature isosurface plot for top Si thickness of 12.5μm (when compared to that of 0.2μm), indicates a laterally varying temperature profile into the Si wafer.

Part V: Effect of top boundary heat source profile on Heat Flow with Heat Flux Boundary Condition $(h = 10^9\ W/m^2.K)$

Simulations with top boundary heat source profile of - ellipse, triangle, rectangle

Ellipse with minor axis=5um, major axis=10um	Equilateral triangle of side=5um	Rectangle with smaller side=2.5um, larger side = 5um
		

Summary

1. This simulation was performed by modifying the heat source profile through the 'Plane Geometry' node, from an initial circular profile in all prior simulations to that of a wide ellipse (minor axis = $5\mu m$, major axis = $10\mu m$), an equilateral triangle (side = $5\mu m$) and a rectangle (smaller side = $2.5\mu m$, larger side = $5\mu m$).
2. The ellipse heat source profile owing to its wide top boundary coverage replicates a 2D simulation case, and the resultant heat flow is more uniformly and laterally varying than the other heat source profiles.

References

- [1] COMSOL Documentation - The Heat Transfer in Solids Interface

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Additional information

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IH2653 Examiner: Dr. Gunnar Malm, Professor KTH

Data and config file at: Github