HICUM Workshop 2010

Thermal Modeling of Power Devices

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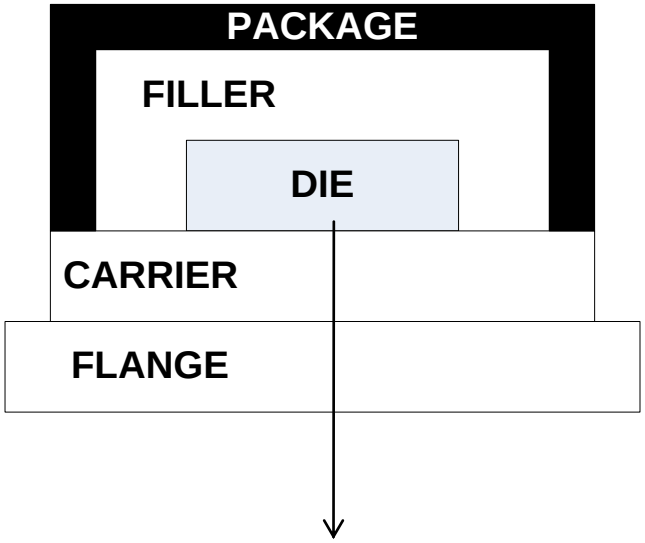
Outline

- Device Structure
- Boundary Conditions (BC)
- Green‘s Function Approach
- TRADICA Input
- Example
- Conclusion

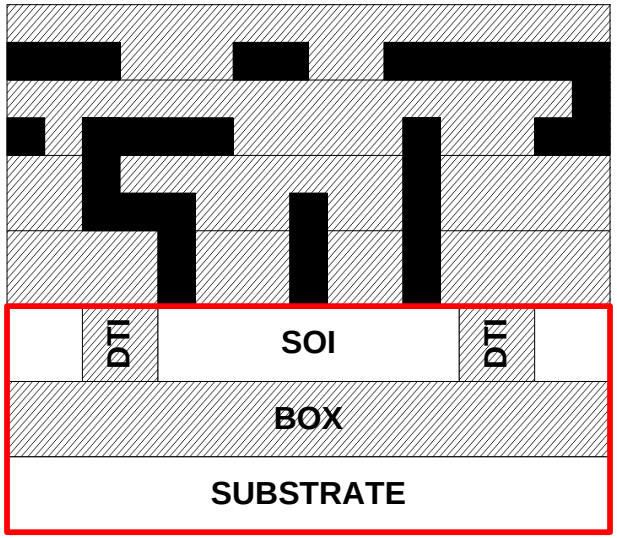
Device Structure

- electrical Compact Model (CM)
  - small dimensions
  - properties known (doping, dimensions, …)
- thermal CM
  - large dimensions
  - properties unknown (process and layout dependent)



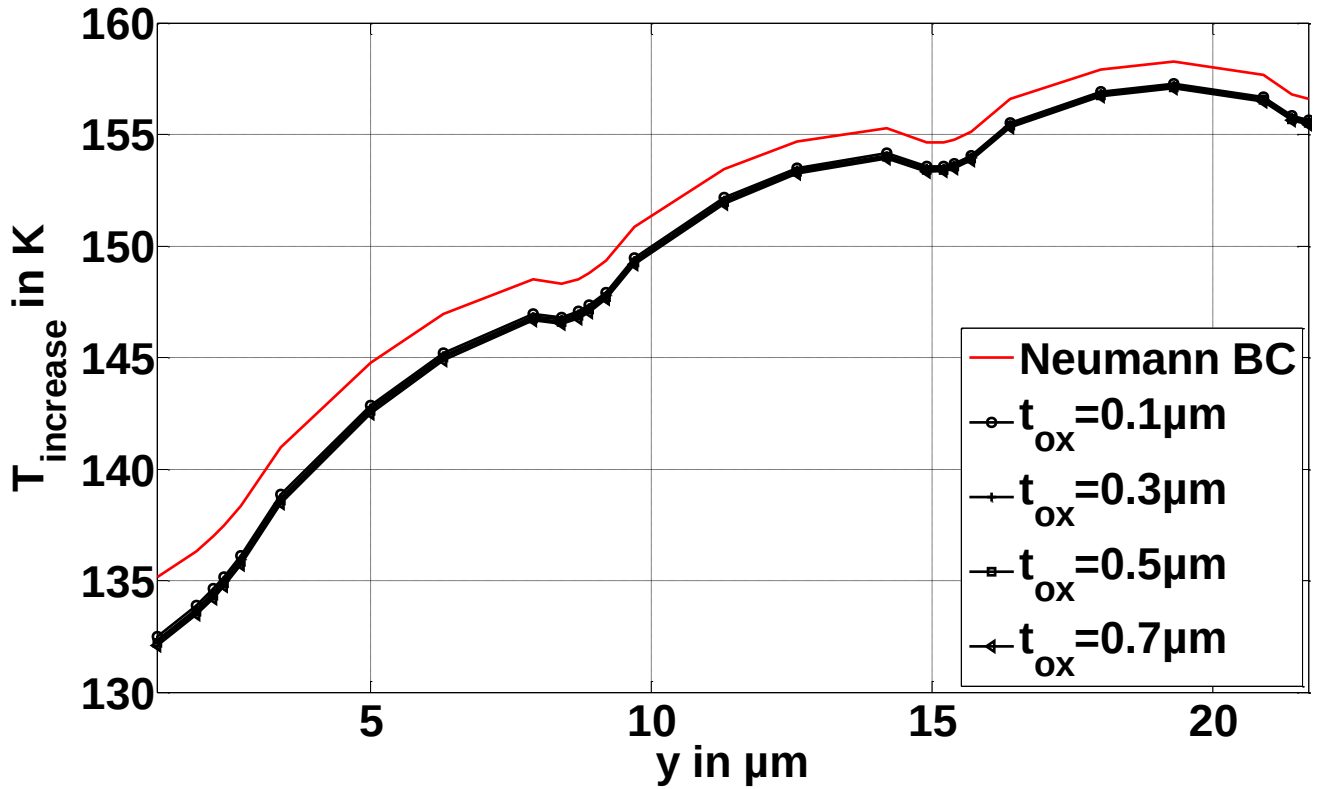
What should a thermal CM include?

- CM accounts for the transistor
  - geometry dependent
- separate CM for
  - metallization
  - package
  - ambient temperature



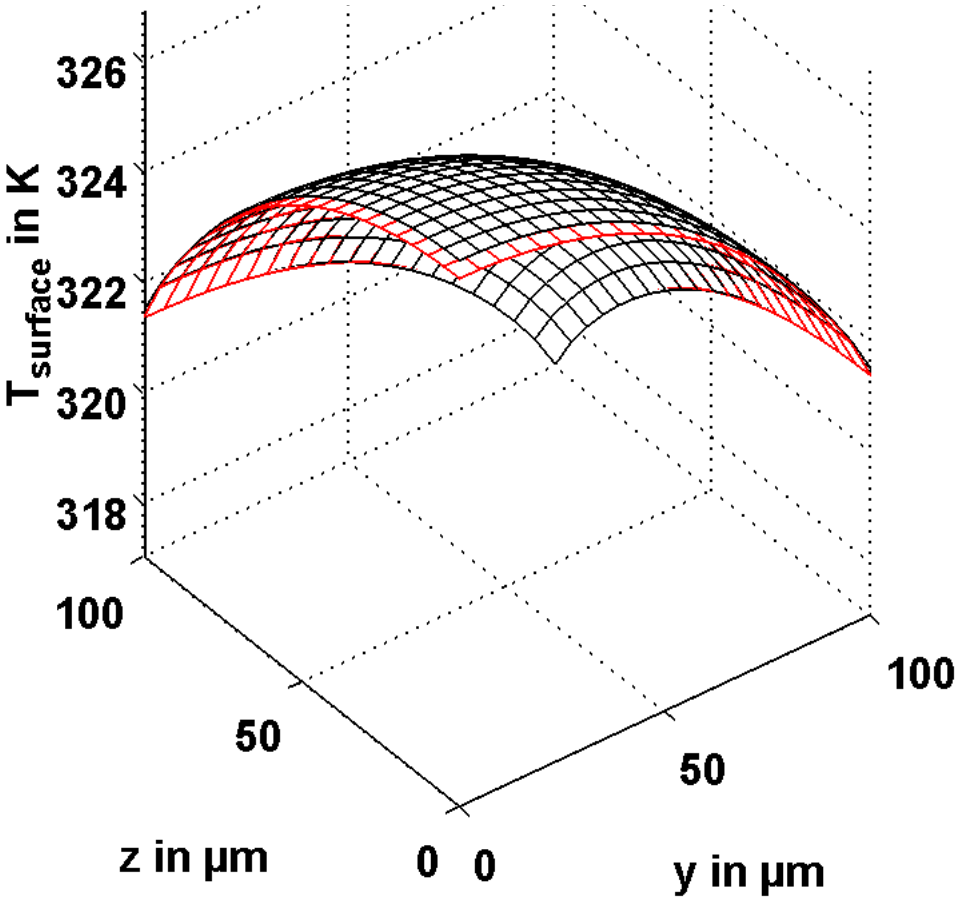
Boundary Conditions

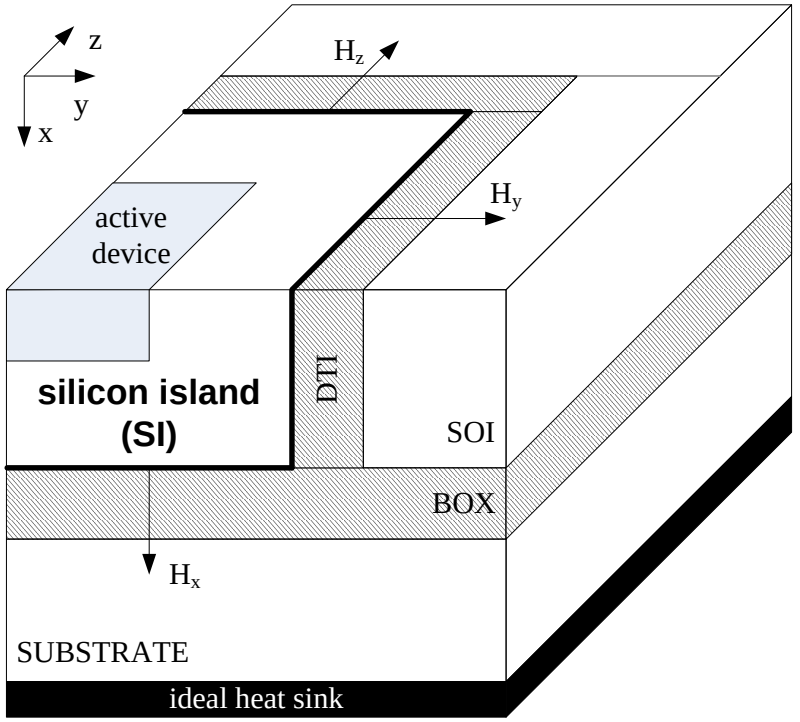
- default structure
  - highly conductive carrier ≈ ideal heat sink
  - unknown surface structure => Neumann BC
- worst case is to pessimistic
- thin SiO_2 surface layer yields more realistic results



Green‘s Function Approach

- limited to:
  - rectangular structure
  - one material





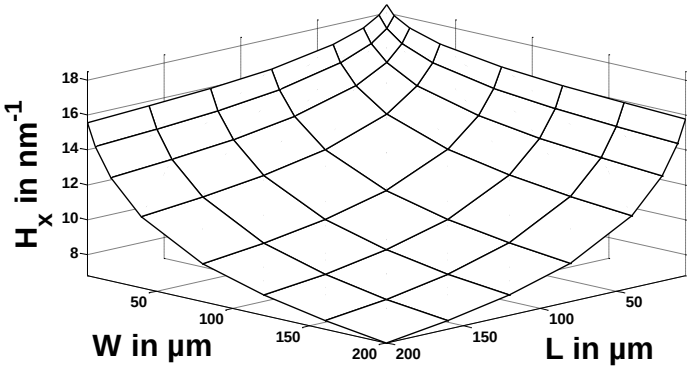
? DTI BOX ?

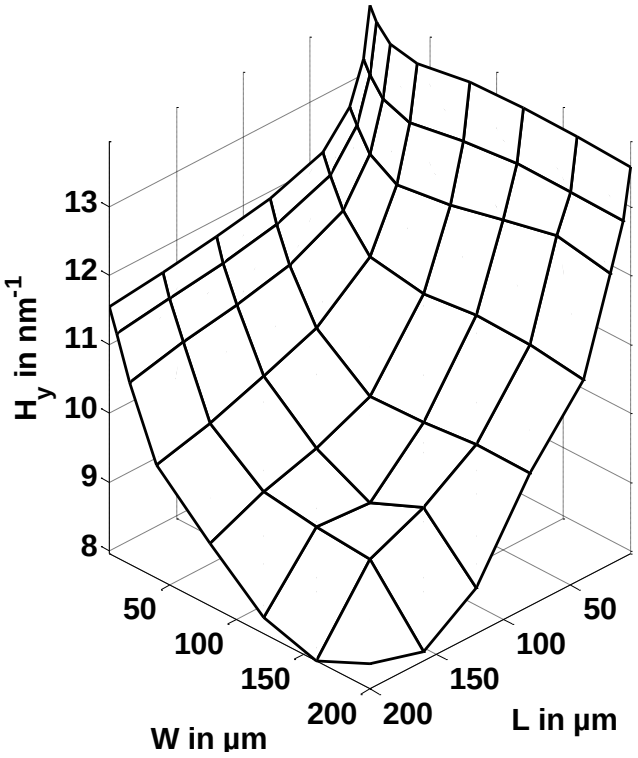
=> conductive BC

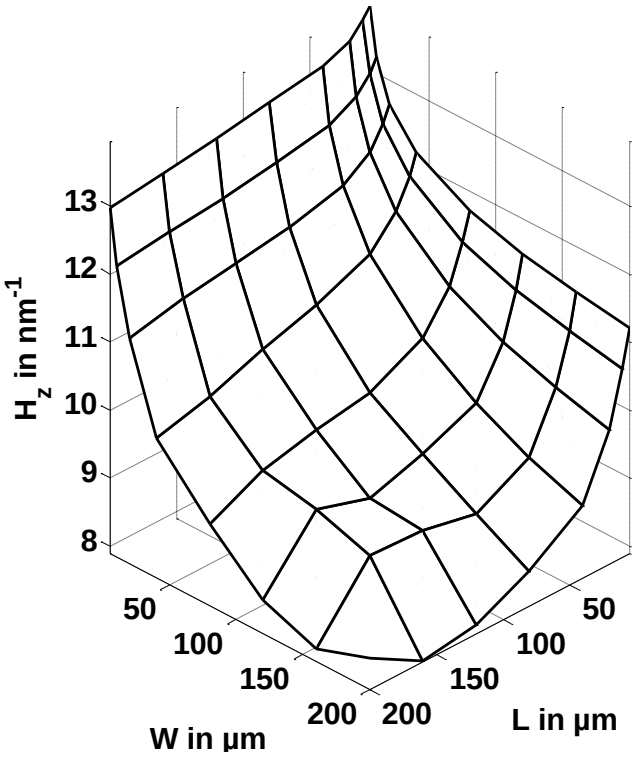
$$dT/dx\text{-}HT=0$$

Green‘s Function Approach

- H coefficients are geometry dependent
  - t_{BOX}, t_{SOI}, t_{SUB}, l_{DTI}
  - L and W of silicon island
- two equations for H_x and H_{yz}
- H coefficient‘s symmetry is exploited



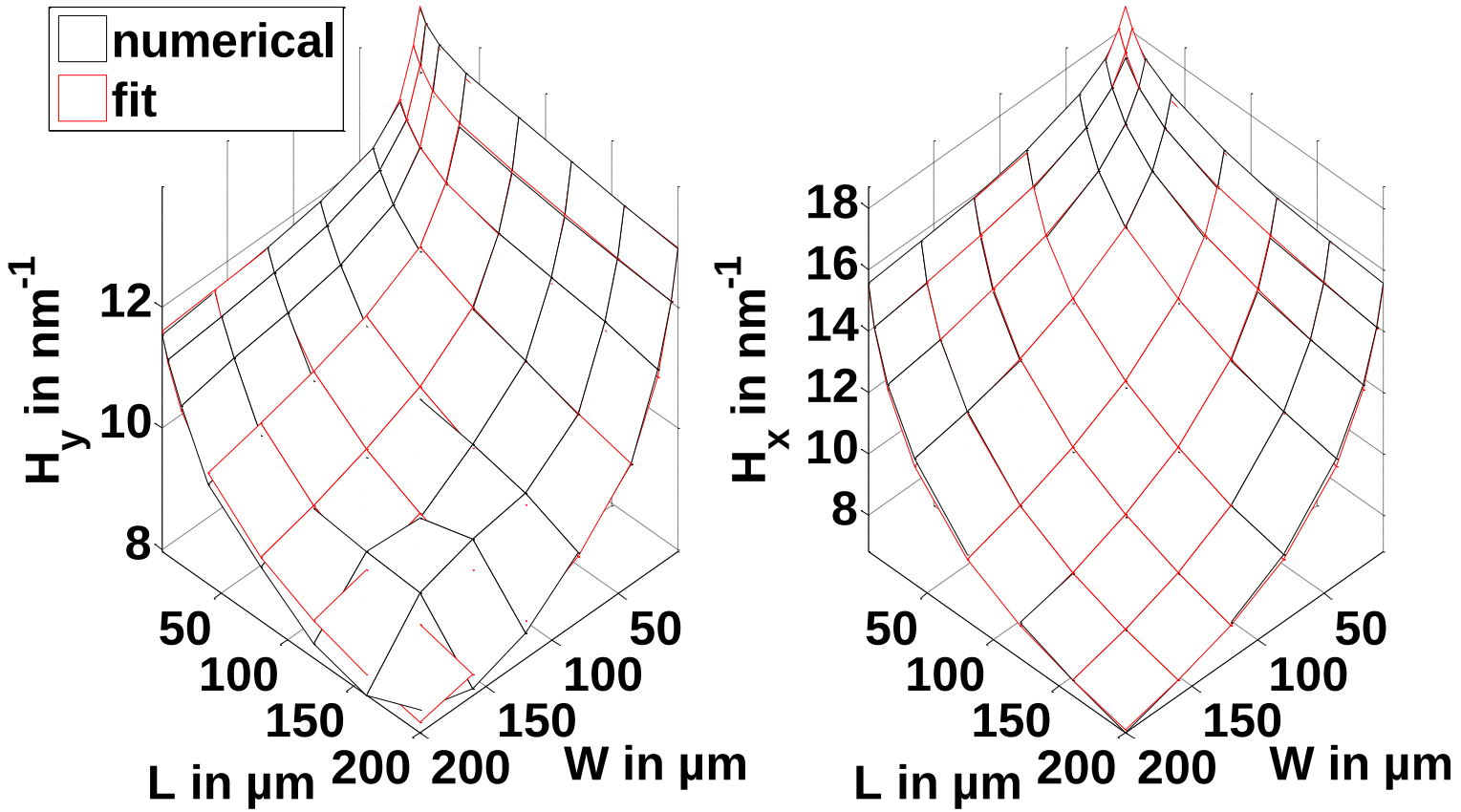




Green‘s Function Approach

$$H_x = \left[x_1 e^{-x_2 L} + x_1 e^{-x_2 W} + x_3 e^{-x_4 (LW)^{x_5}} + x_6 e^{-x_7 t_{BOX}}\right] \cdot t_{BOX}^{-x_8} \cdot l_{DTI}^{-x_9}$$

$$H_y = \left[x_1 e^{-x_2 L} + x_3 e^{-x_4 W} + x_5 e^{-x_6 (LW)^{x_7}} + x_8 e^{-x_9 t_{SOI}}\right] \cdot l_{DTI}^{-x_{10}}$$



TRADICA Input

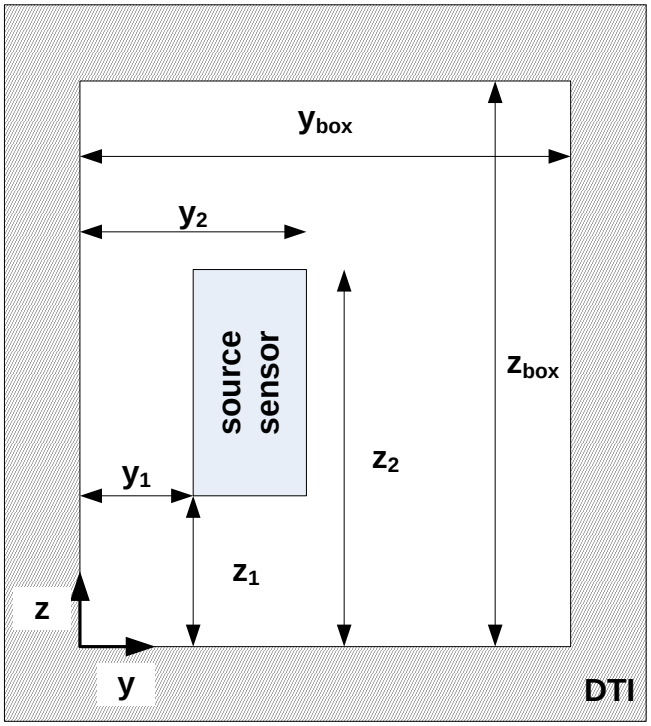
&THERMAL kappa_semi = κ_{Si} diff_semi = d_{Si} alpha_semi = α_{Si}

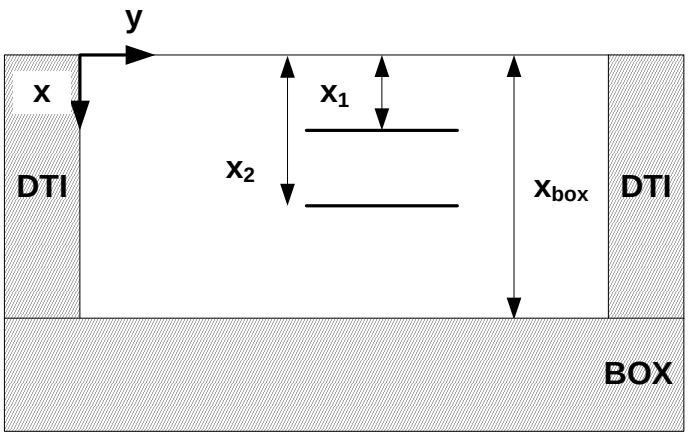
htc_xyz = H_x H_y H_z

htc_verpar = x_{v1} x_{v2} x_{v3} x_{v4} x_{v5} x_{v6} x_{v7} x_{v8}

htc_latpar = x_{l1} x_{l2} x_{l3} x_{l4} x_{l5} x_{l6} x_{l7} x_{l8} /

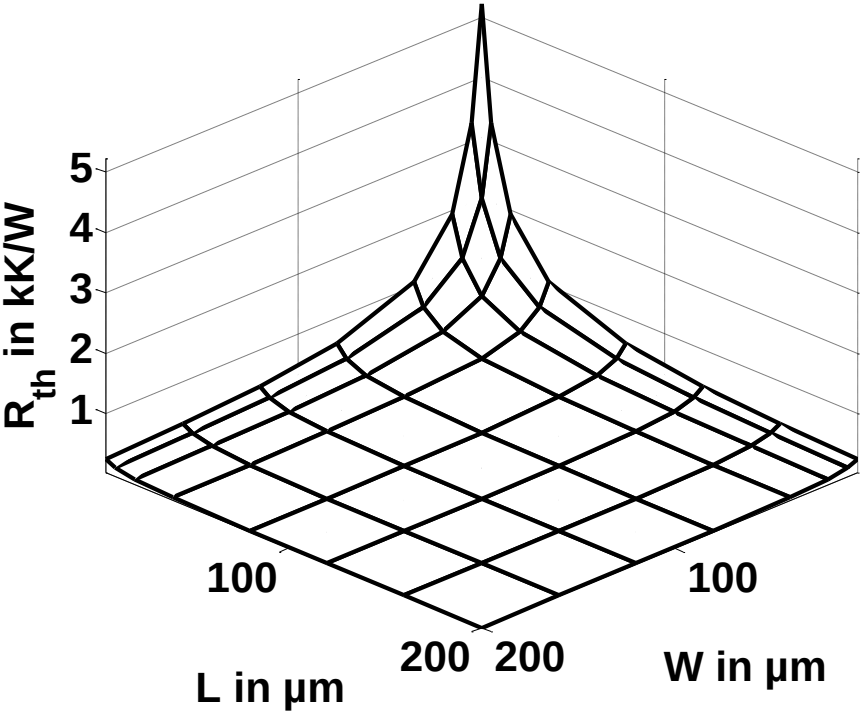
- no dimension input required => determined from &GEOM_DATA



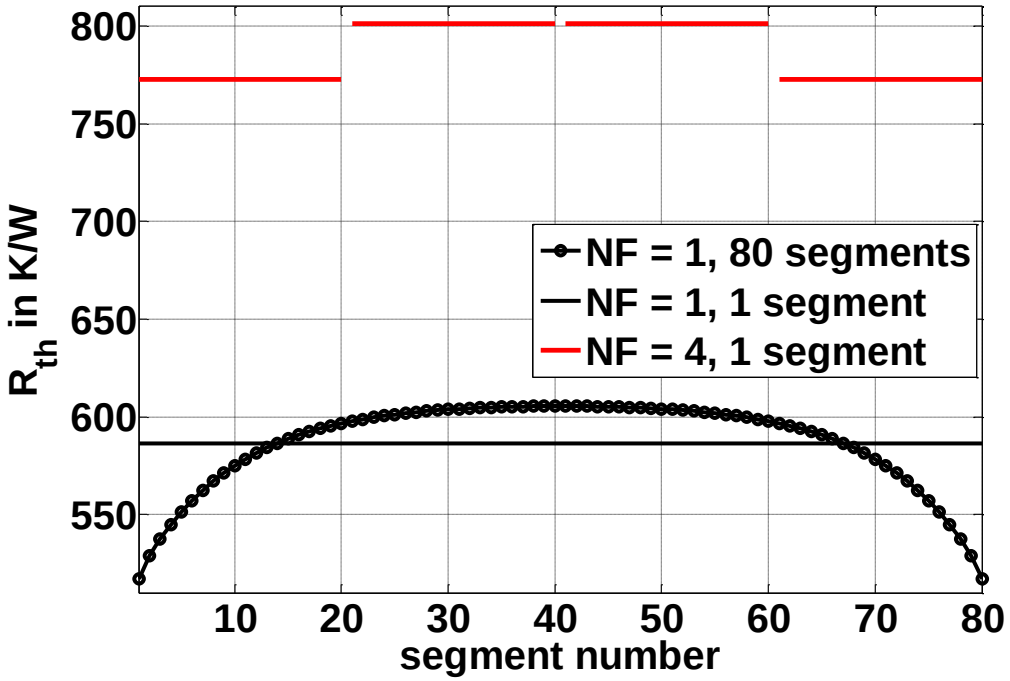


Example

- different SI dimensions



- layout optimization,
  e.g. constant A_E



Conclusion

- fast and accurate generation of SH networks
- thermal coupling and finger segmentation
- enables predictive and concurrent engineering
- geometry dependent via analytical H equations
- low computation times (milliseconds)
- simplifies PDK development