

3D Electro-Thermal Study for Reliability of Automotive Power Vertical MOSFET Using COMSOL Multiphysics

T. Azoui^{*1}, S. Verde^{1,2}, J. B. Sauveplane¹ and P. Tounsi¹

¹LAAS/CNRS, 7 avenue du Colonel Roche - 31077 Toulouse, France.

²Departement of Electronics and Telecommunications Engineering,
University of Naples “Federico II”; Naples, Italy

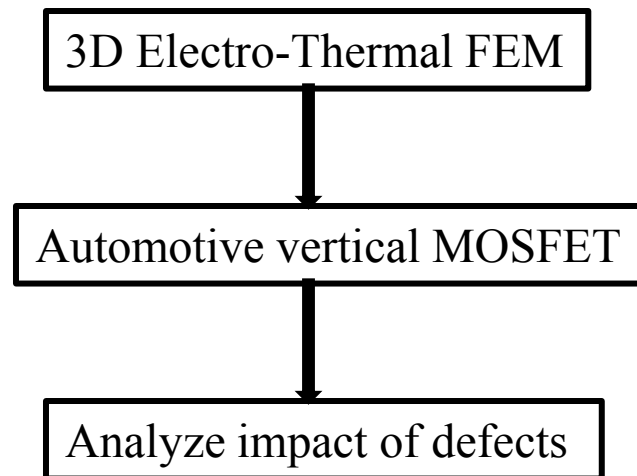
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Introduction

What ?



Hypothesis: MOSFET is ON state

Introduction

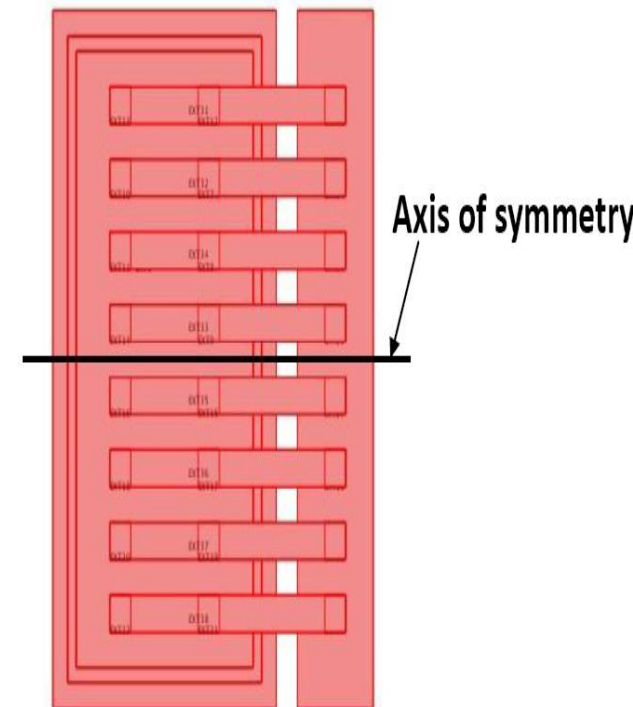
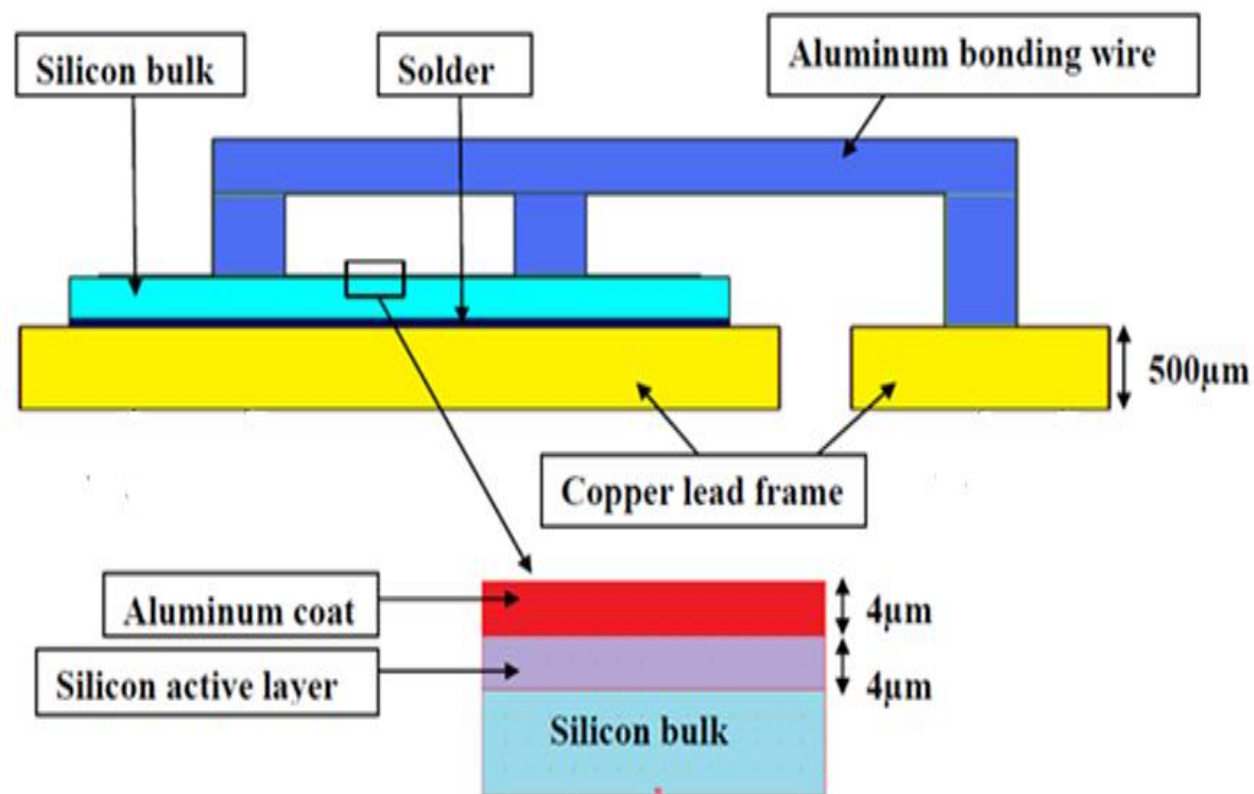
Why ?

- Electro-thermal simulations are required to improve the design of components and ensure longer lifespan.
- Temperature could creates defects in the structure which affect the electrical functions.
- The sequence of the events after emergence of defects occur the breakdown of the power device.
- These events are related to electro-thermal coupling phenomena.
- simulate the “fully ON” behavior of the transistor which is the dominating heat loses during a short circuit mode.

Device description

- Power vertical MOSFET
- Used in the automotive industry
- sustain current up to 150 A on a 2 m Ω on-state resistance device

Device description



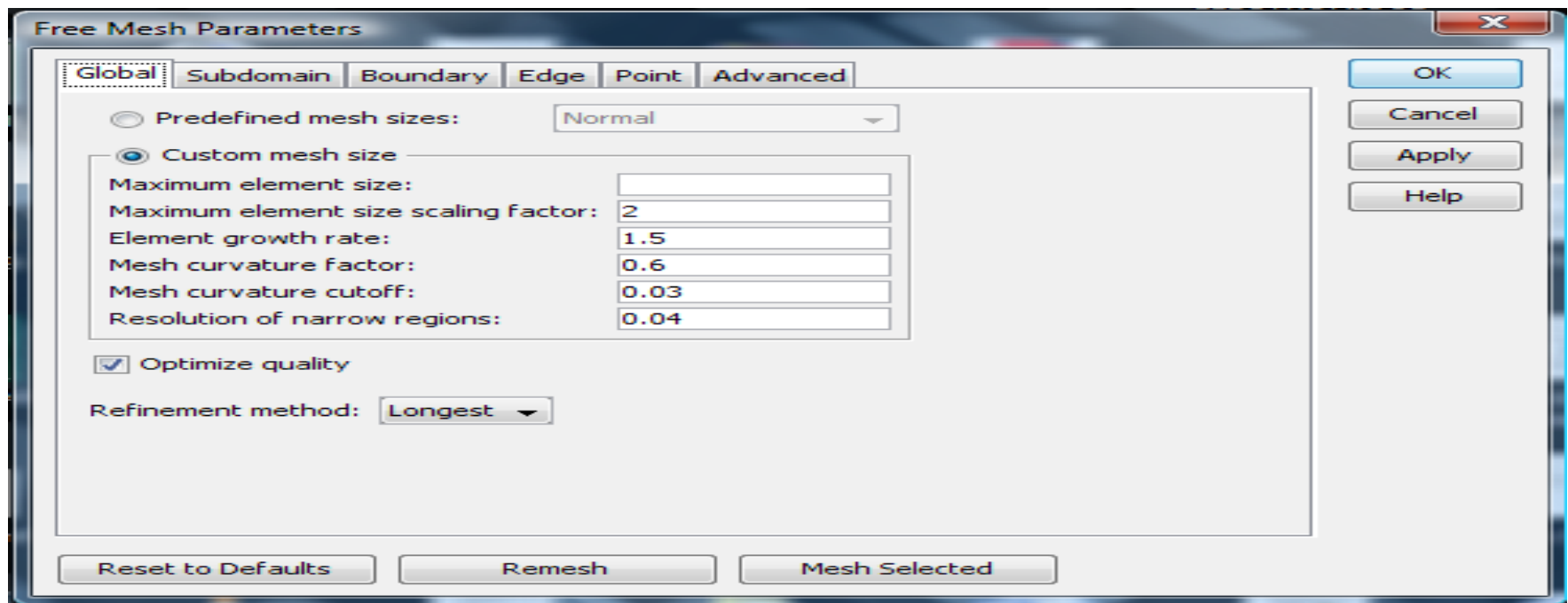
F.E. Model of power device

- Power device model is achieved with COMSOL Multiphysics software.
- 3D electro-thermal element type that has two dependent variables, voltage and temperature.

F.E. Model of power device

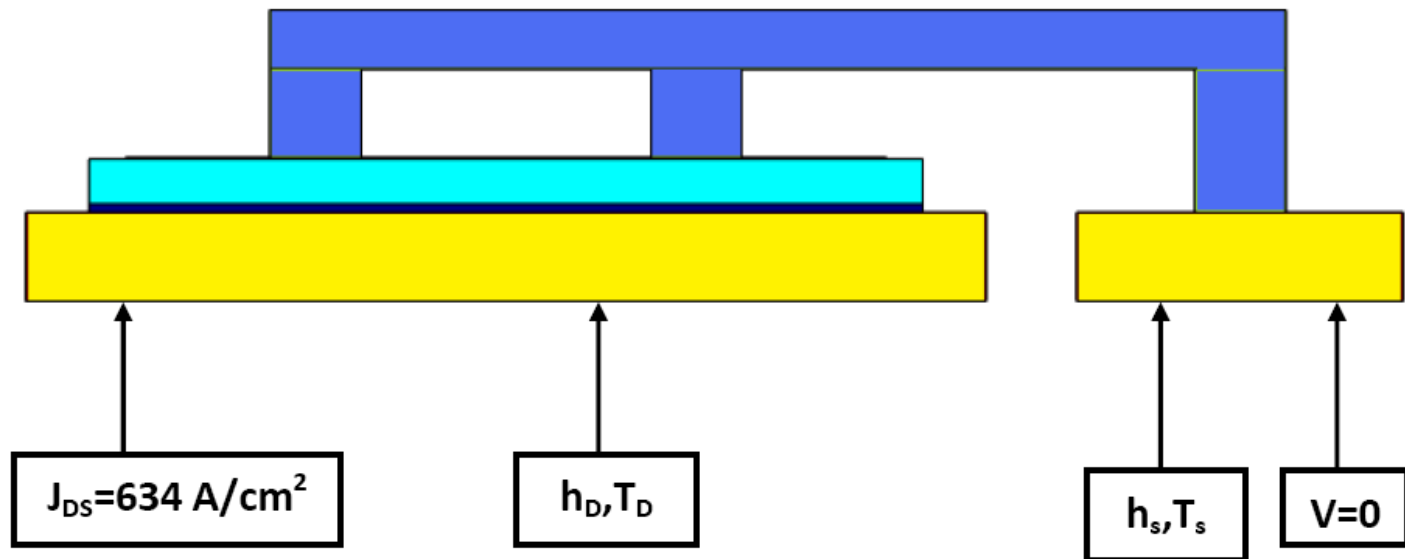
Mesh

- Large scale difference issue
- using the free mesh parameters box
- Number of elements: 36560



F.E. Model of power device

Boundary conditions



Electrical boundary conditions

$$J_{DS} = 634 \text{ A/cm}^2$$

$$V = 0 \text{ V}$$

Thermal boundary conditions

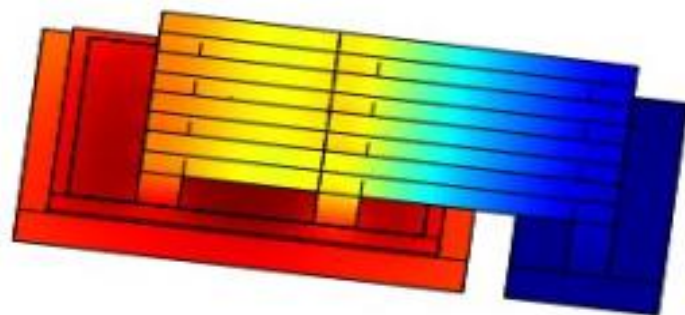
$$h = 2000 \text{ W m}^{-2} \text{ K}^{-1}$$

$$(T_D, T_S) = 20^\circ\text{C}$$

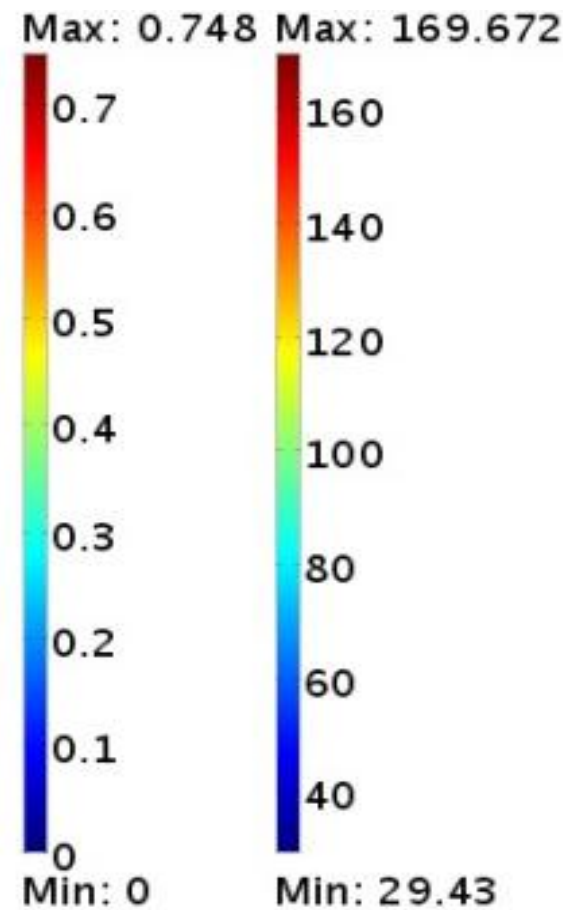
F.E. Model of power device

Results

Time=0.05 Slice: Electric potential [V]
Subdomain: Temperature [°C]

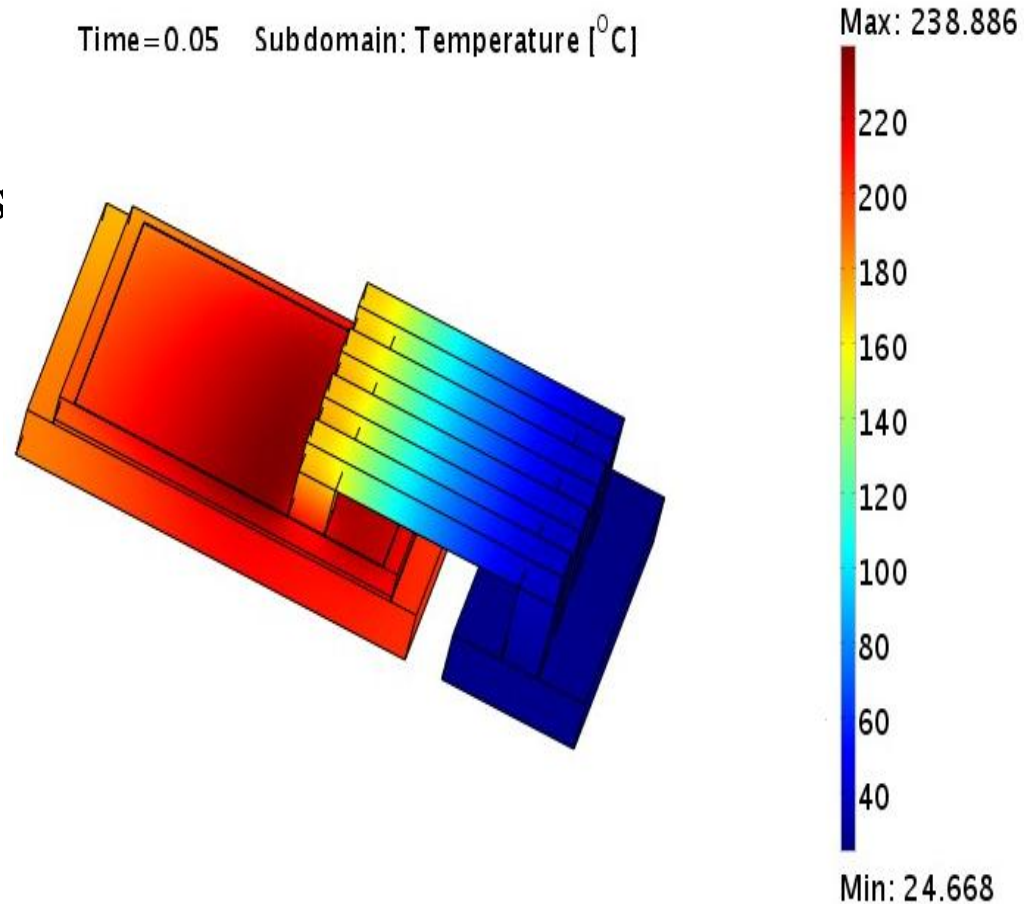


Temperature distribution after 50 ms
 $T_{\text{Max}} = 169^{\circ}\text{C}$



Electro-thermal simulation of power device damages

- Damage: Bonding wire lift off
- Same boundary conditions
- Increase in temperature by 69°C



Electro-thermal simulation of power device damages

Impact of the number of bonding wire

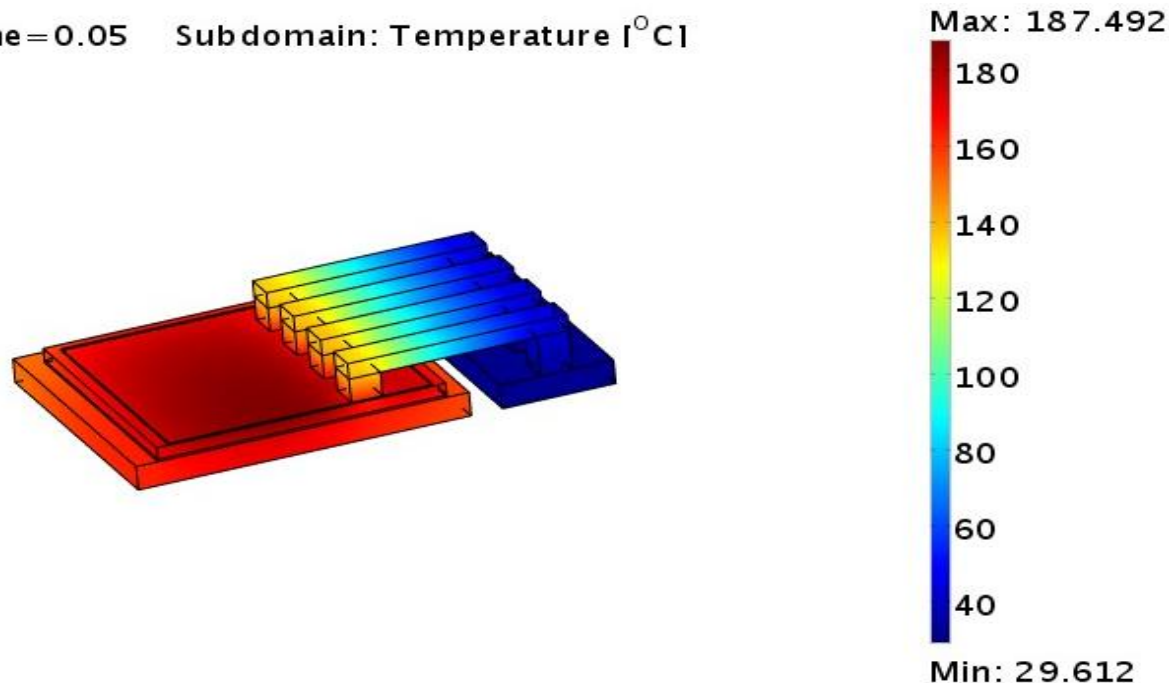
Number of failed wires	Maximum temperature (°C)
0	170
1	178
2	190
3	402
4	239

The maximum temperature increases with the number of failed wires.

Electro-thermal simulation of metallization thickness

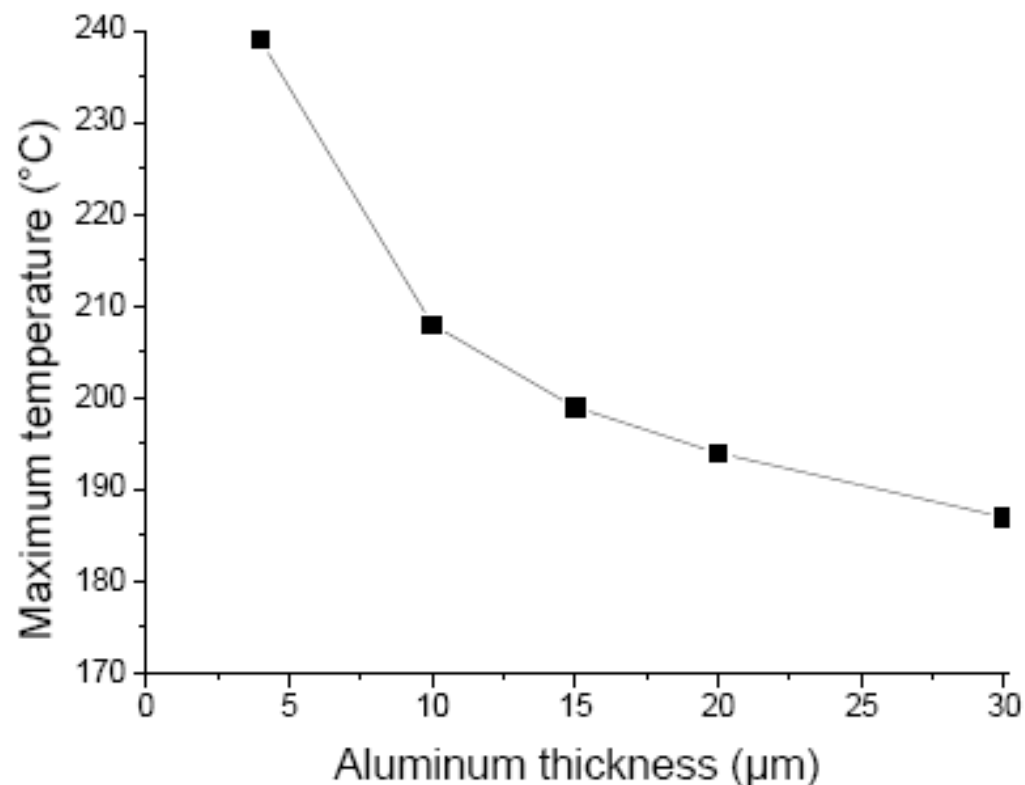
Solution: Increasing top metallization thickness

Time = 0.05 Subdomain: Temperature [$^{\circ}\text{C}$]



Metallization thickness of 30 μm $\rightarrow$ decrease of 52 $^{\circ}\text{C}$ compared to the device with 4 μm

Electro-thermal simulation of metallization thickness



Conclusion

- The F.E. model studied is used to investigate 3D electro-thermal coupling effects during a short circuit mode.
- The effects of bonding wire lift off and number of wires on the device transient electro-thermal behavior are investigated.
- Increasing metallization thickness is a solution given to limit temperature increases due to bonding wire lift off.
- Electro-thermal simulation are useful for optimization of structure design to guarantee a longer lifespan.

Thank you for your attention