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

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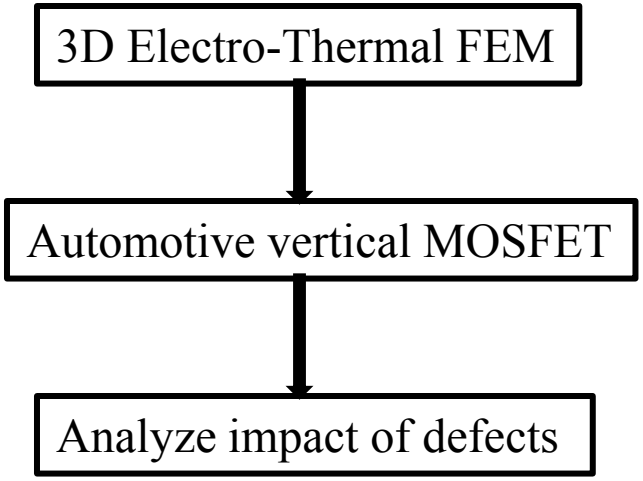
Introduction

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.

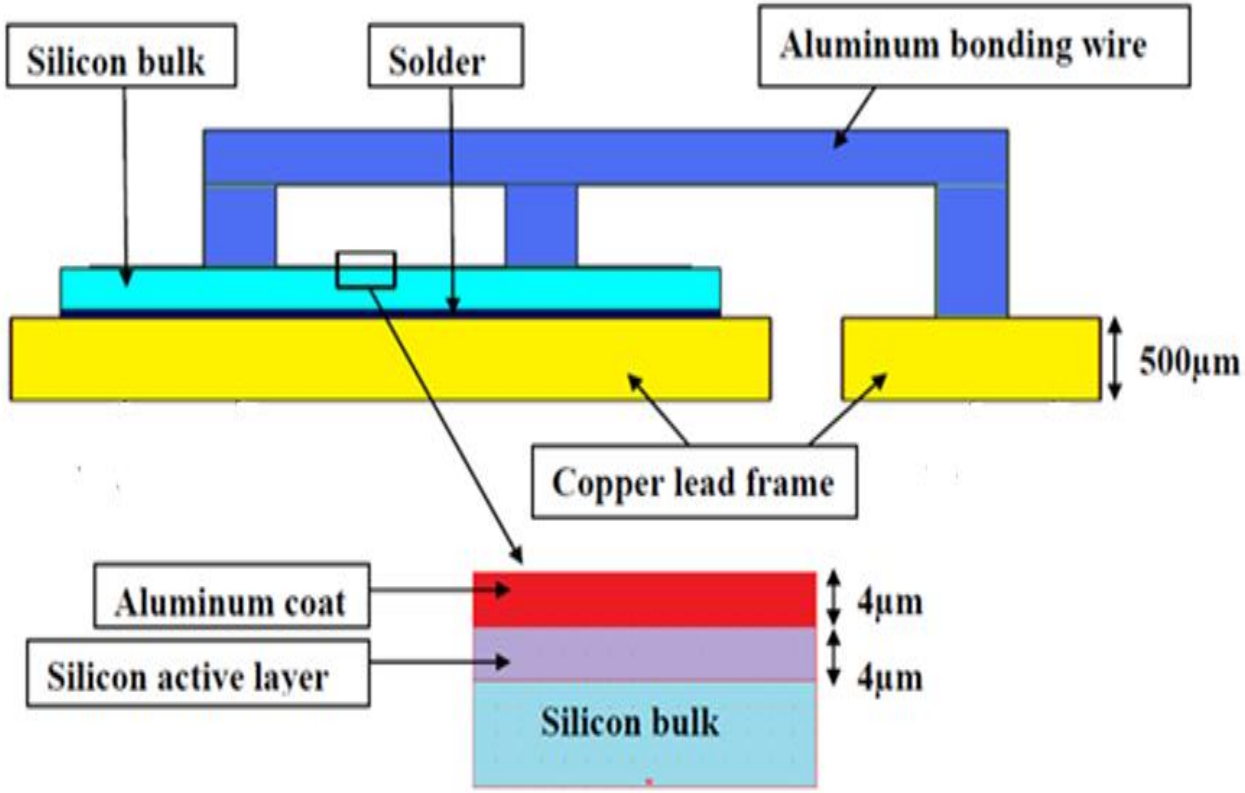
•These events are related to electro-thermal coupling phenomena.

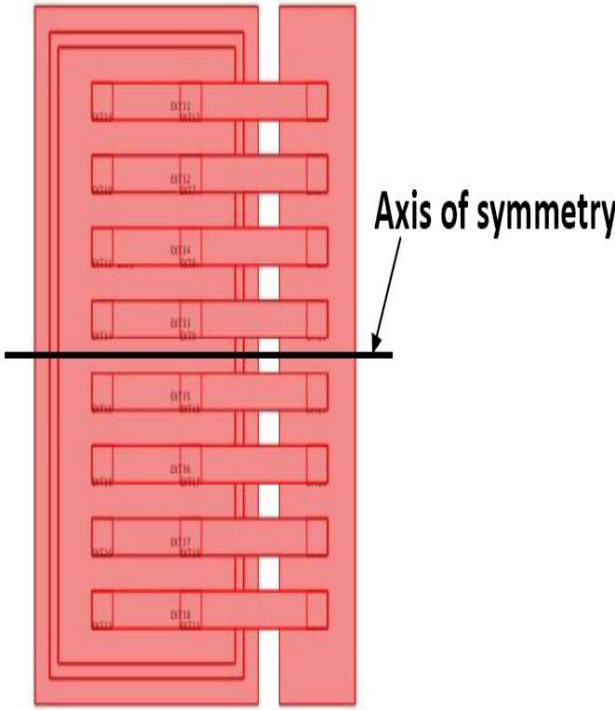
• simulate the “fully ON” behavior of the transistor which is the dominating heat loses during a short circuit mode.

Device description

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

Device description





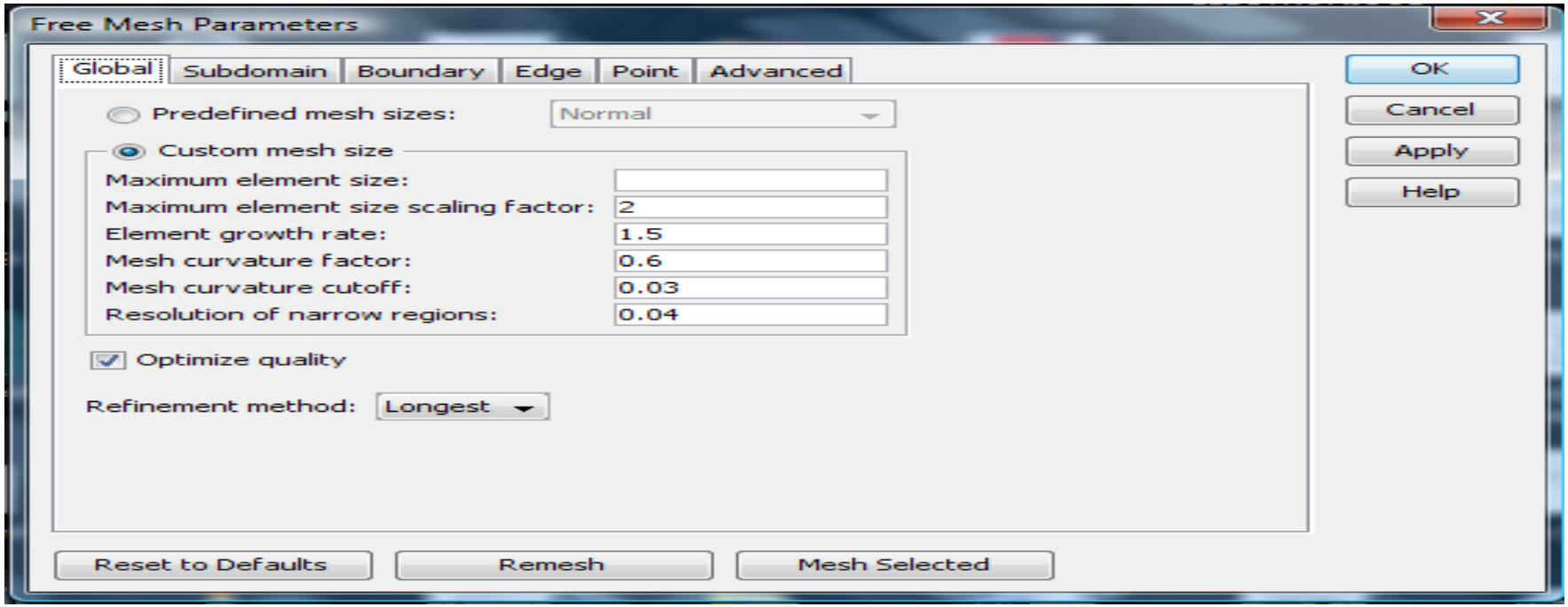
F.E. Model of power device

- 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

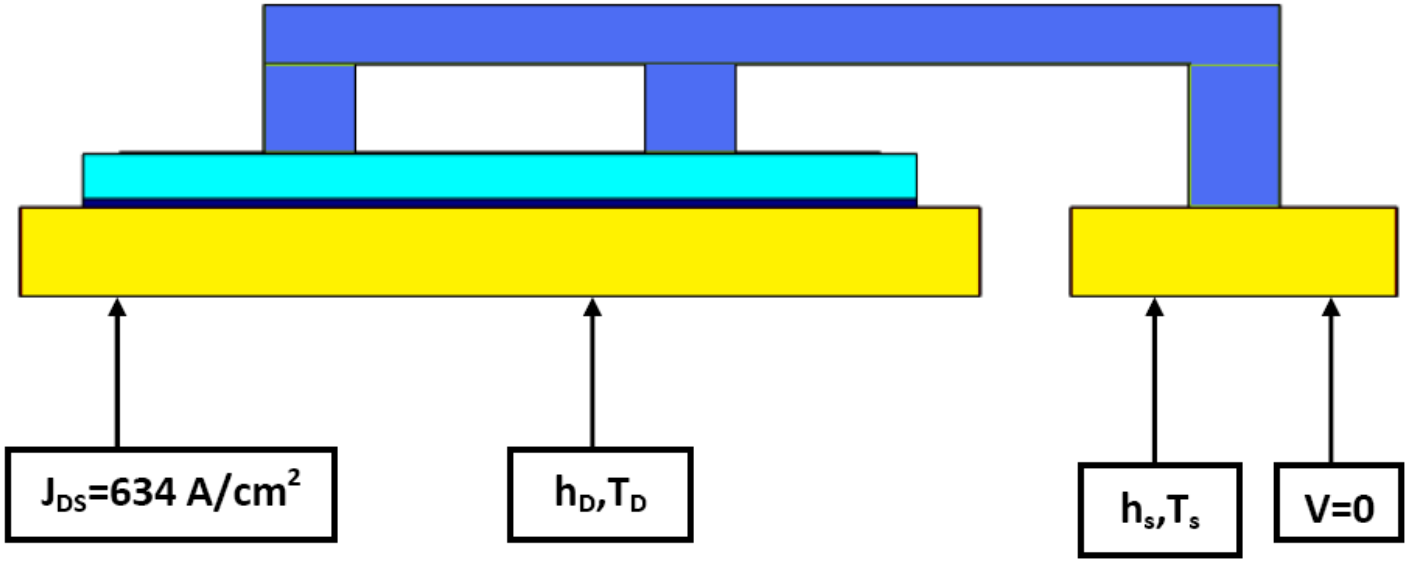
Mesh

- 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 A/cm²

V=0 V

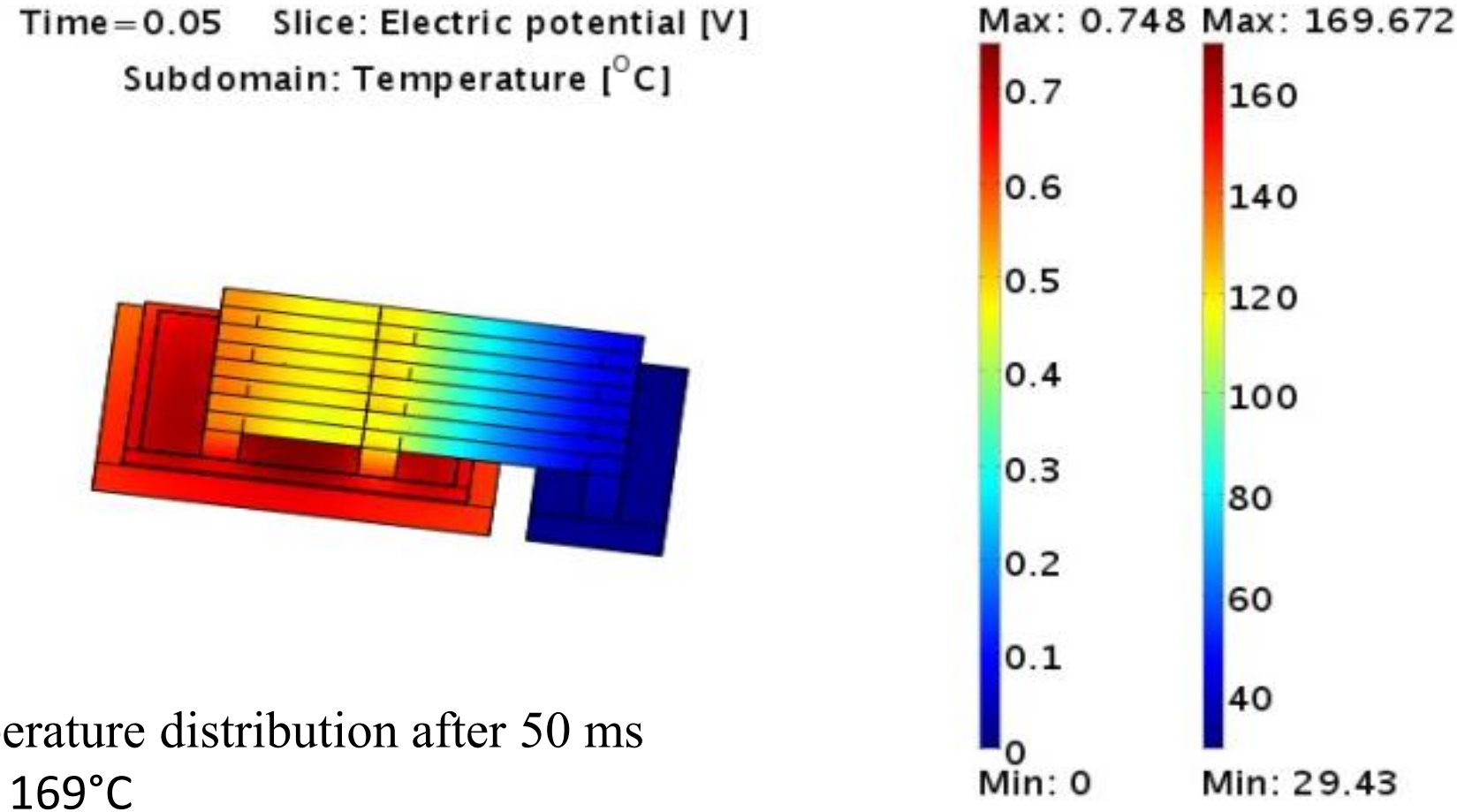
Thermal boundary conditions

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

(T_D,T_S)= 20°C

F.E. Model of power device

Results

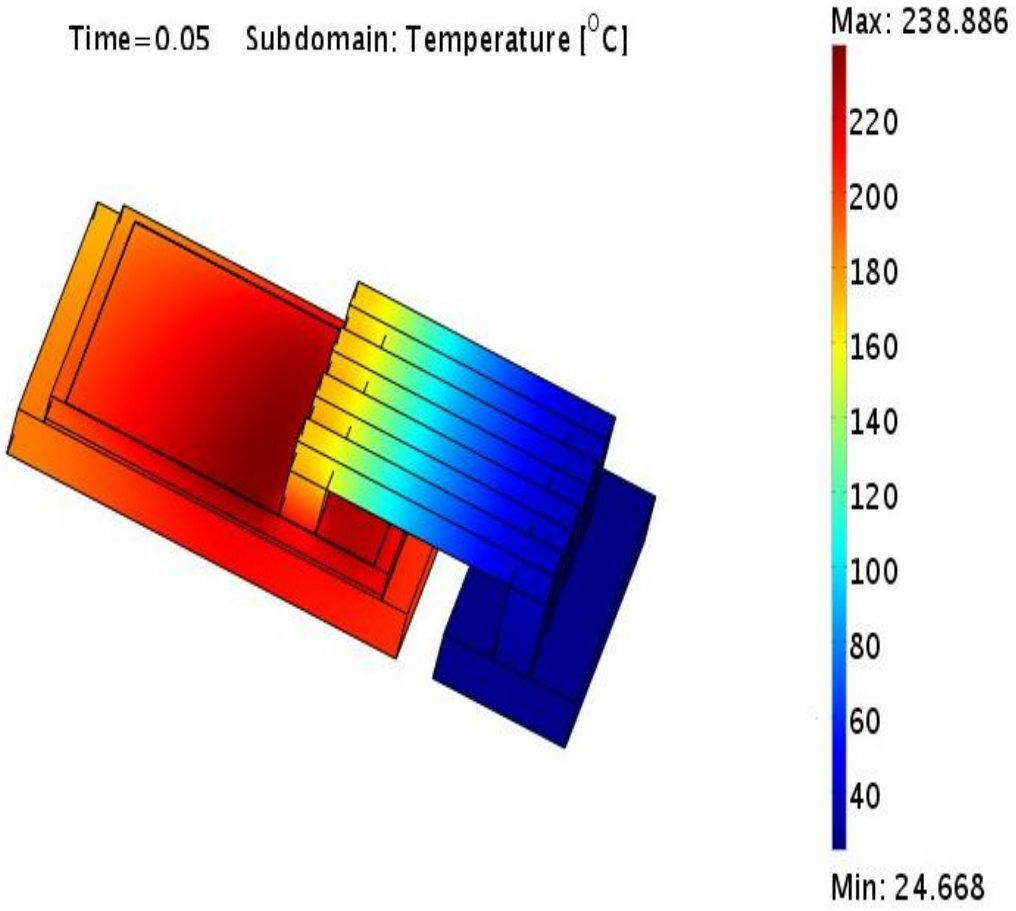


Temperature distribution after 50 ms

T_{Max}= 169°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

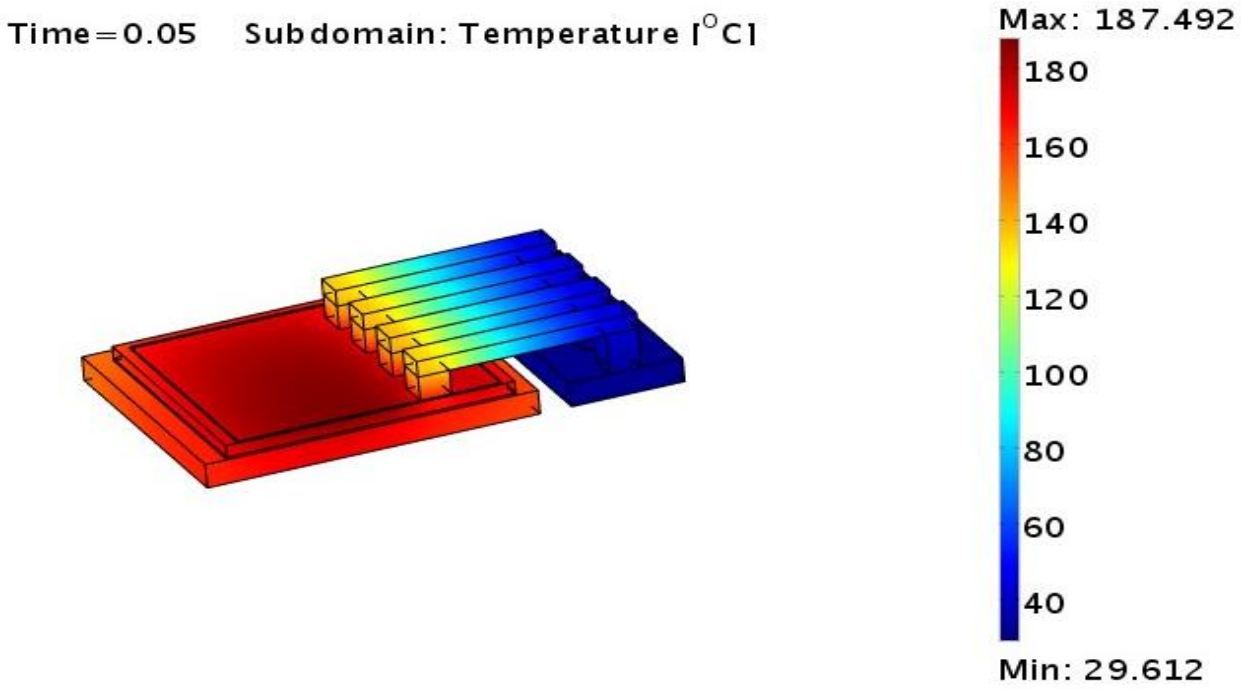
Impact of the number of bonding wire

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.

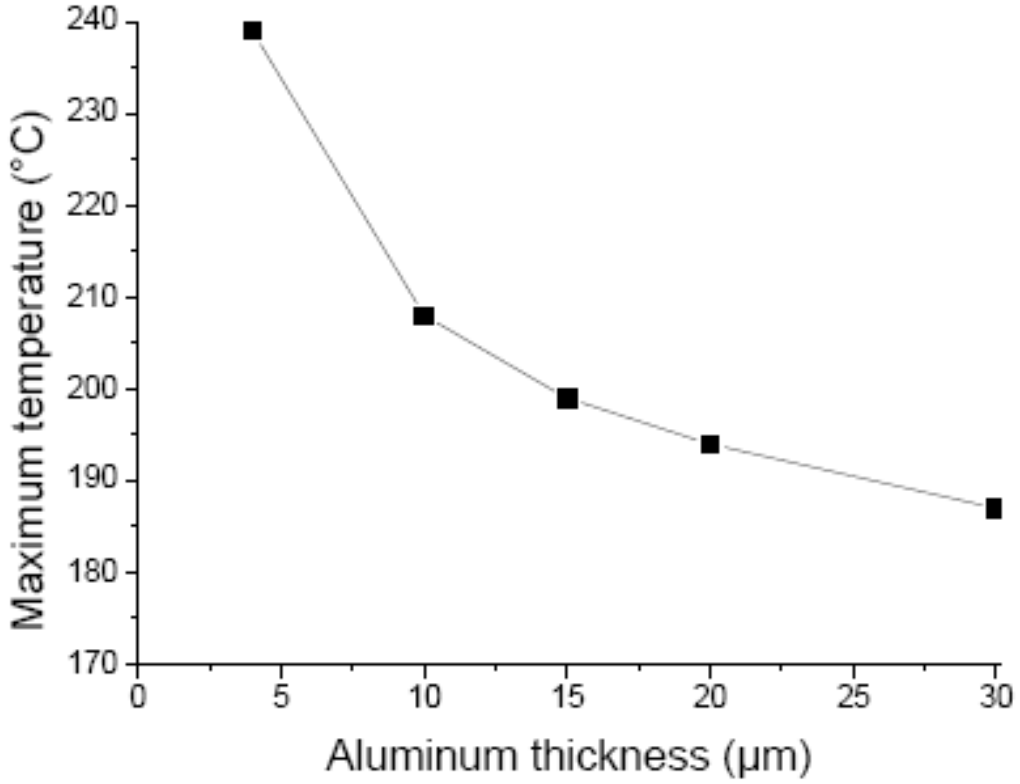
Electro-thermal simulation of metallization thickness

Solution: Increasing top metallization thickness



Metallization thickness of 30 µm→ decrease of 52°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