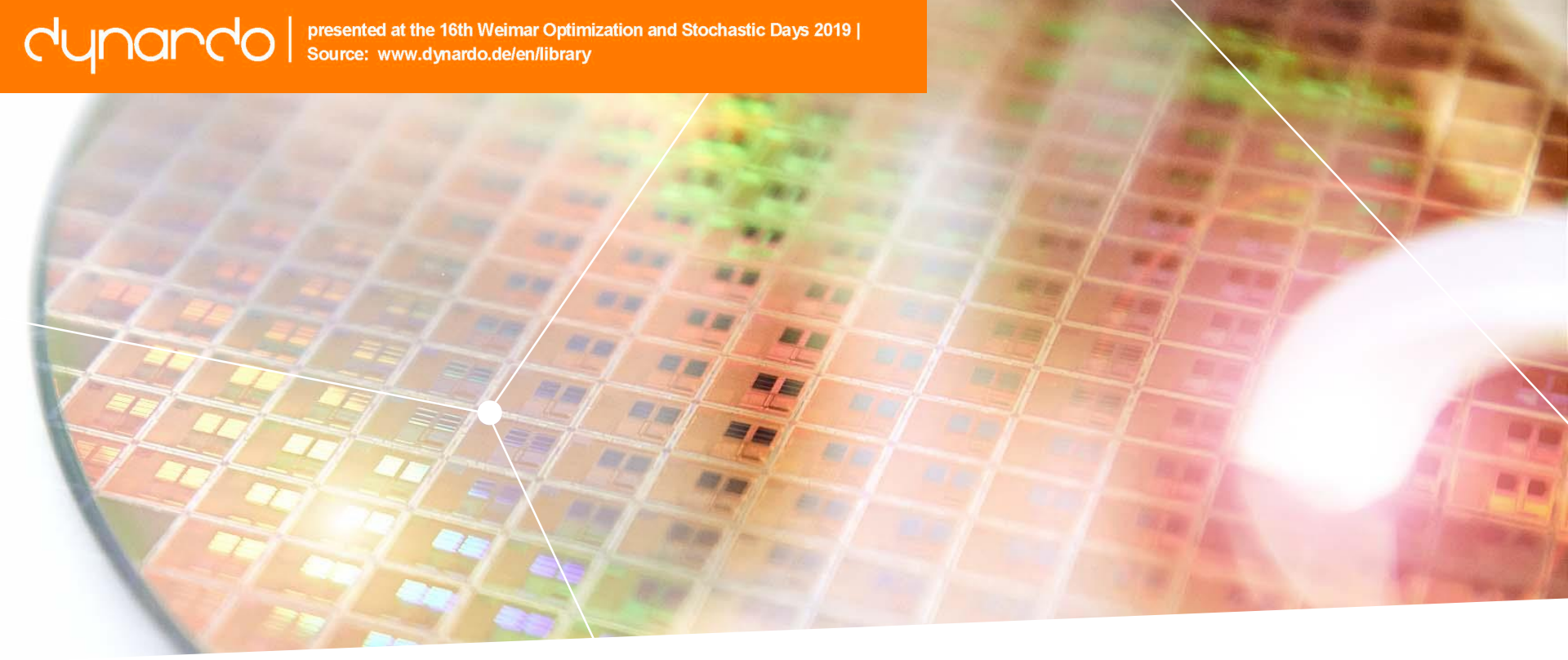

Controlling the Solder Joint Reliability of eWLB Packages in Automotive Radar Applications Using a Design for Reliability Approach

M. Niessner, G. Haubner, W. Hartner, S. Pahlke
June 6th 2019

16. Weimarer Optimierungs- und Stochastiktage (WOST)
6.-7. Juni 2019

infineon

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1. Background, Motivation and Objectives
2. Approach
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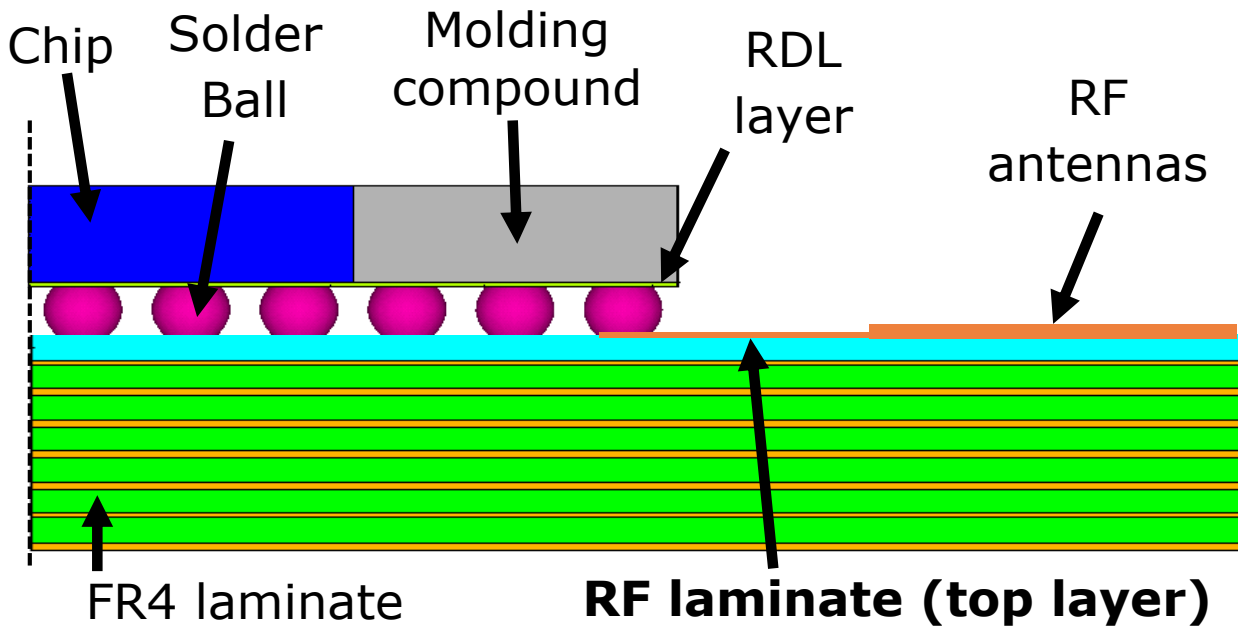
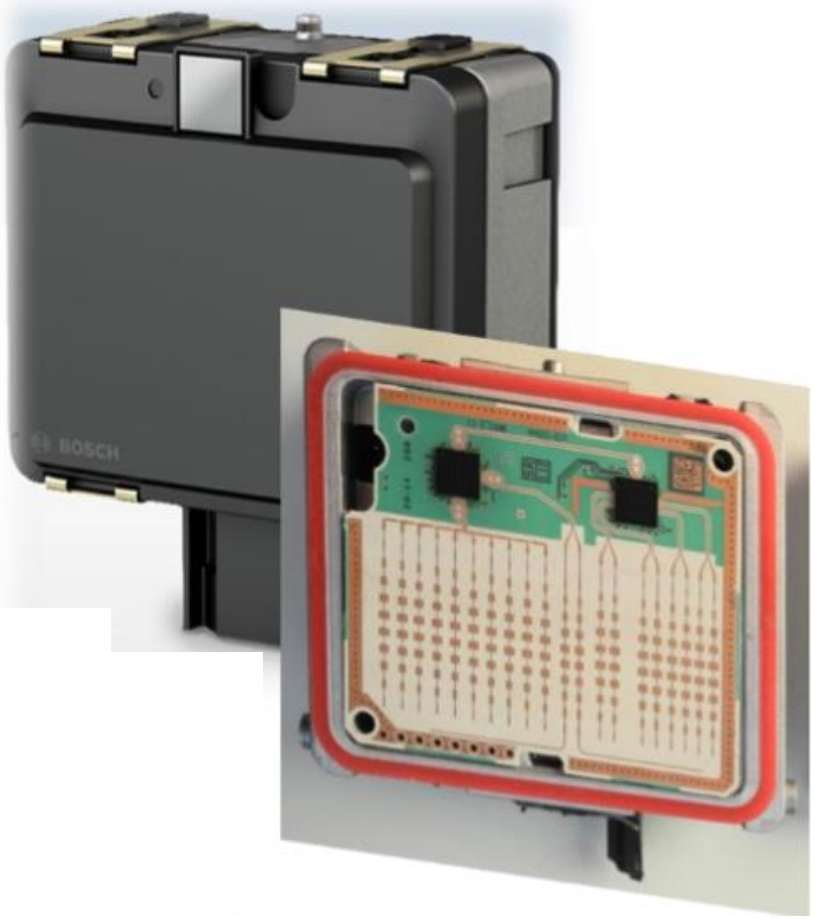
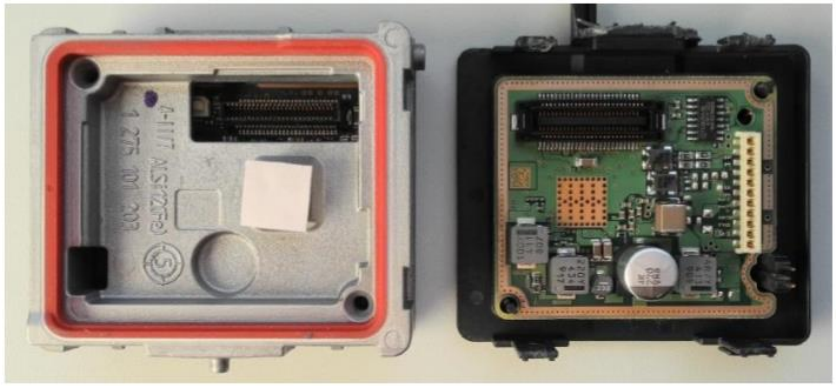
Background: Automotive RADAR



› The **solder joint reliability** of an assembly characteristic to automotive RADAR applications is analyzed

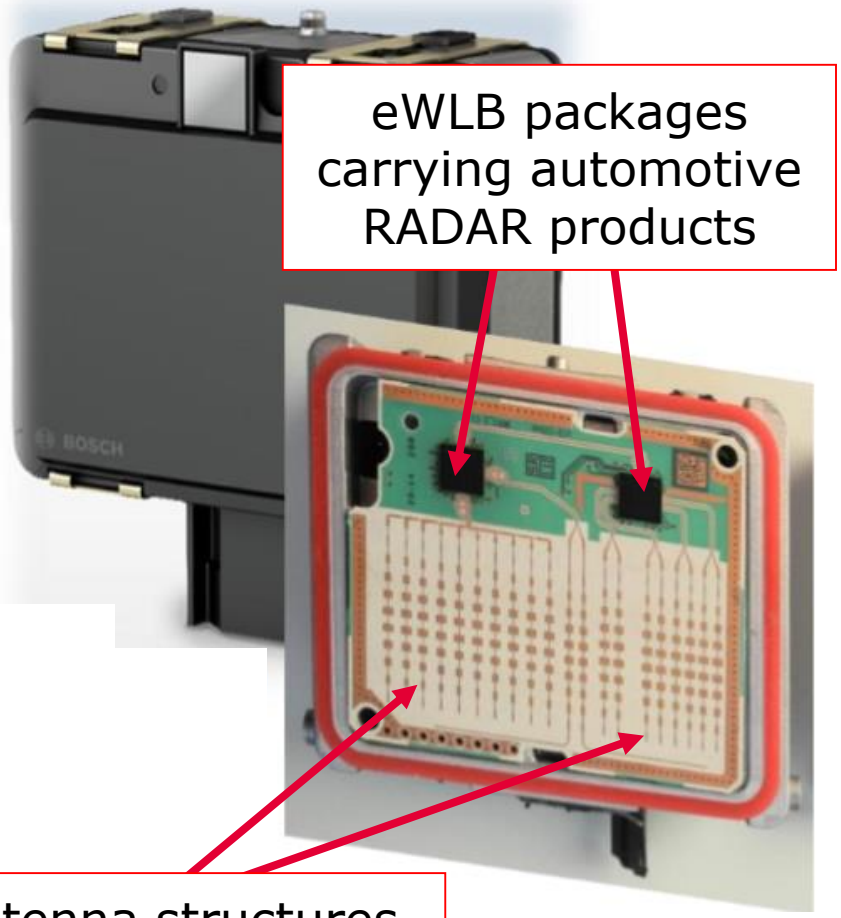
Background: Automotive RADAR

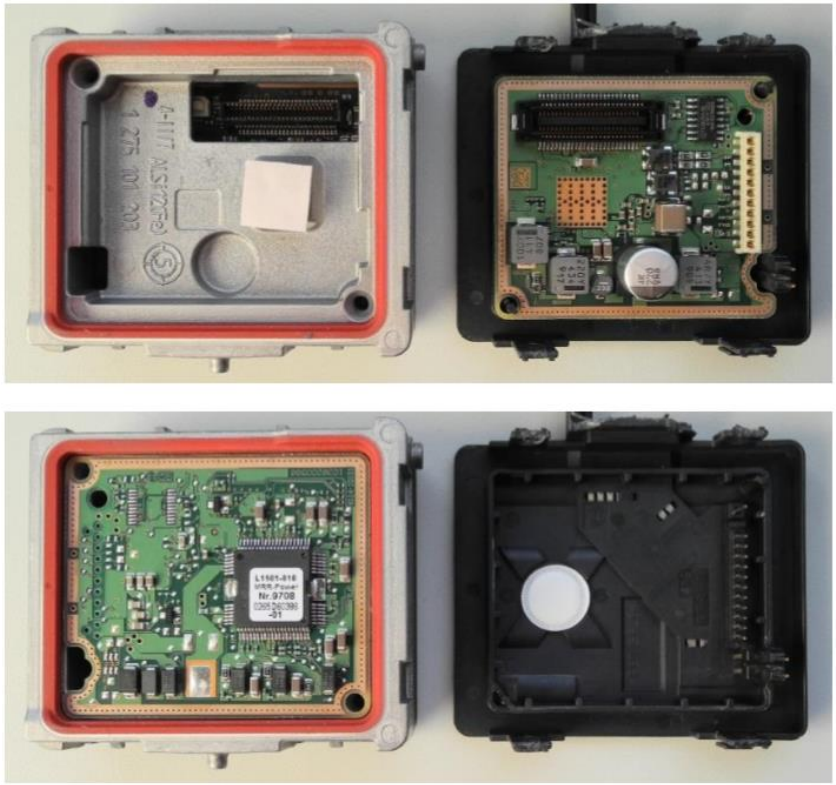




Source: M. Eichhorst *et al.*, VII. SGW-Forum, 2019

Background: Automotive RADAR

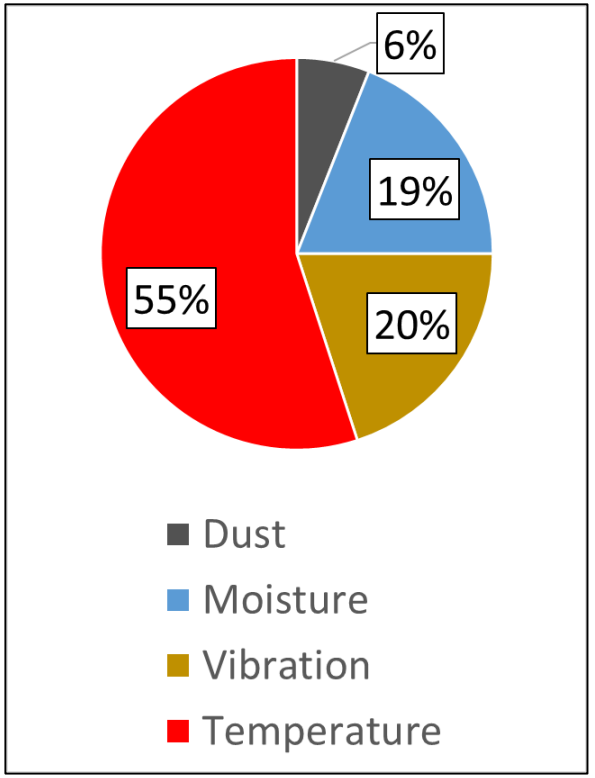




Source: M. Eichhorst *et al.*, VII. SGW-Forum, 2019

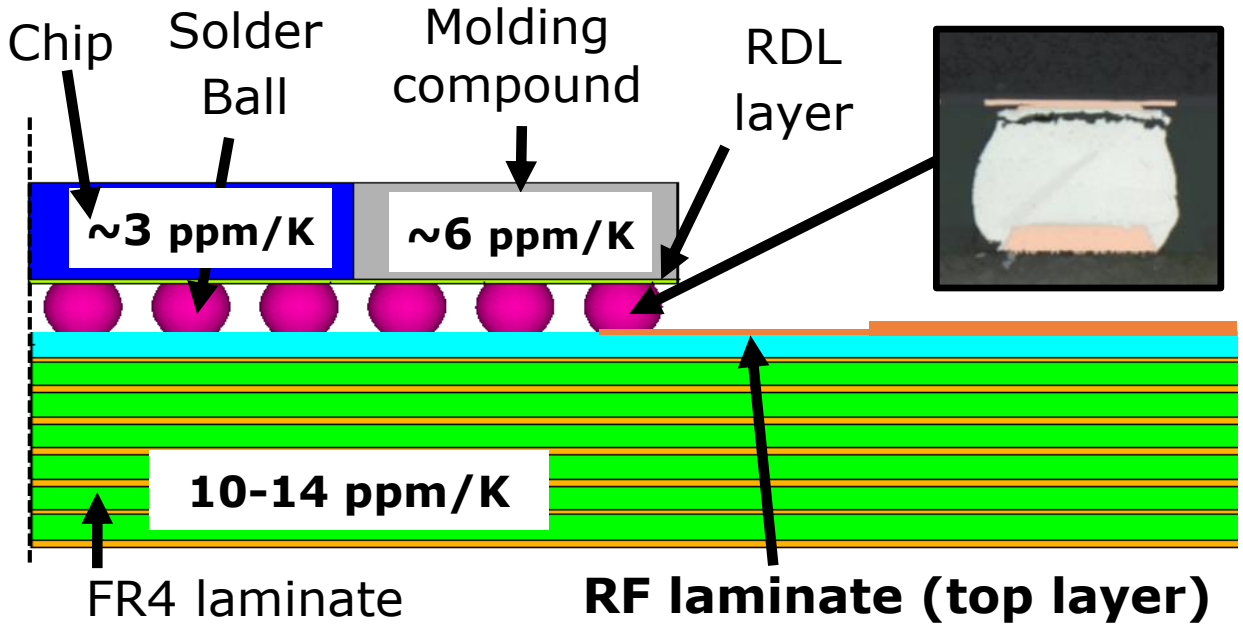
Motivation: Solder joint reliability

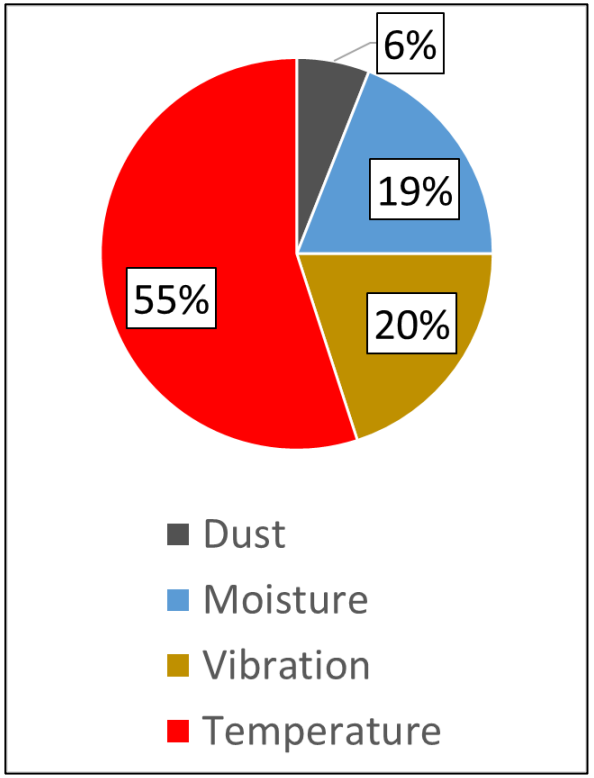
- The major part of fails in the considered class of products/assemblies is related to deltas/changes in **temperature**



Source: M. Eichhorst *et al.*, VII. SGW-Forum, 2019

Motivation: Solder joint reliability

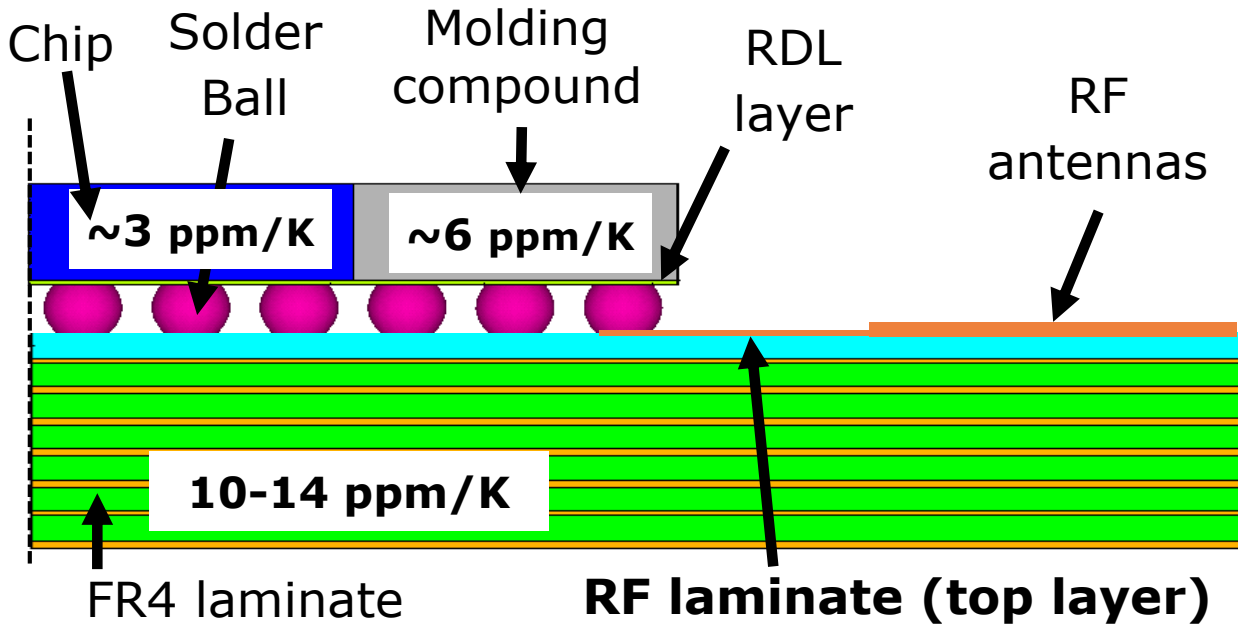


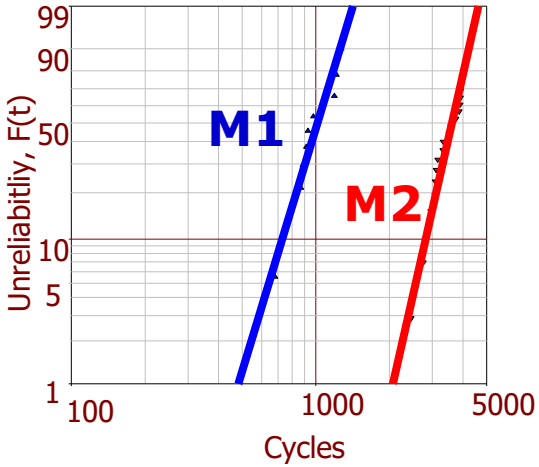


Source: M. Eichhorst *et al.*, VII. SGW-Forum, 2019

- **CTE mismatch** between package and PCB induces stress
- There is no layer at package side which could absorb stress

Motivation: Previous findings



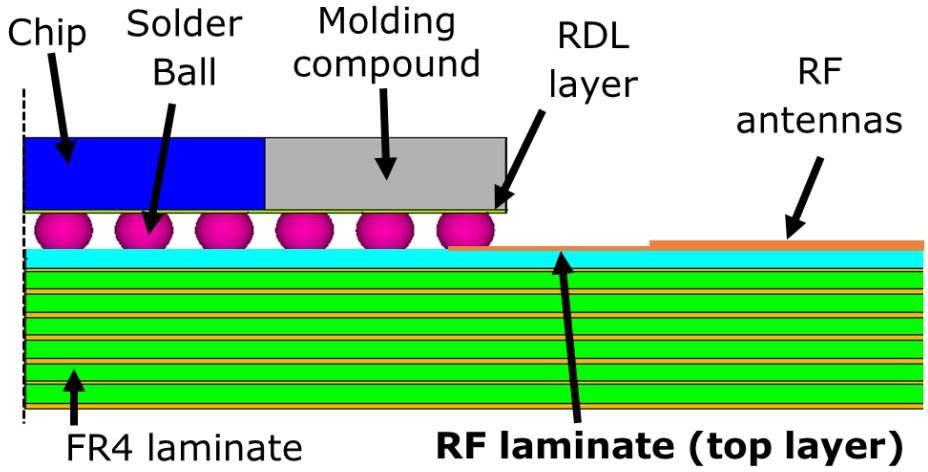


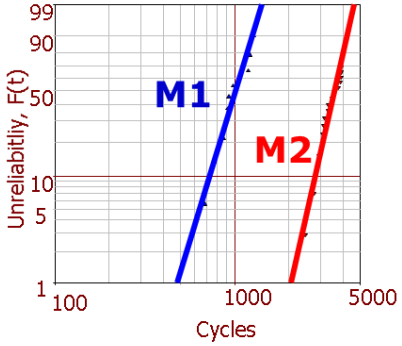
Solder joint reliability for 2 top layer materials

› The solder joint reliability (**SJR**) of eWLB packages for automotive radar is sensitive to the RF laminate

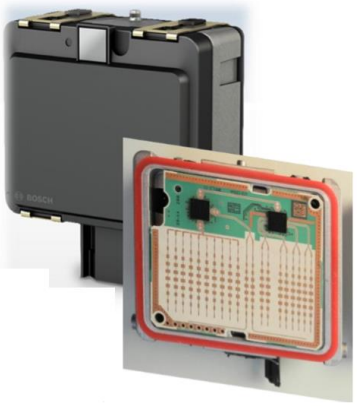
(see Haubner et al., Microelectronics Reliability 2016)

Objectives





Solder joint reliability for 2 top layer materials



- SJR of eWLB for automotive radar is sensitive to the RF laminate
- **Objectives of this work regarding solder joint reliability:**
  - **Analyze the sensitivity to the RF laminate**
  - **Enable Design for Reliabilty (DfR) approach**
  - **Enable Product to System (P2S) design approach**

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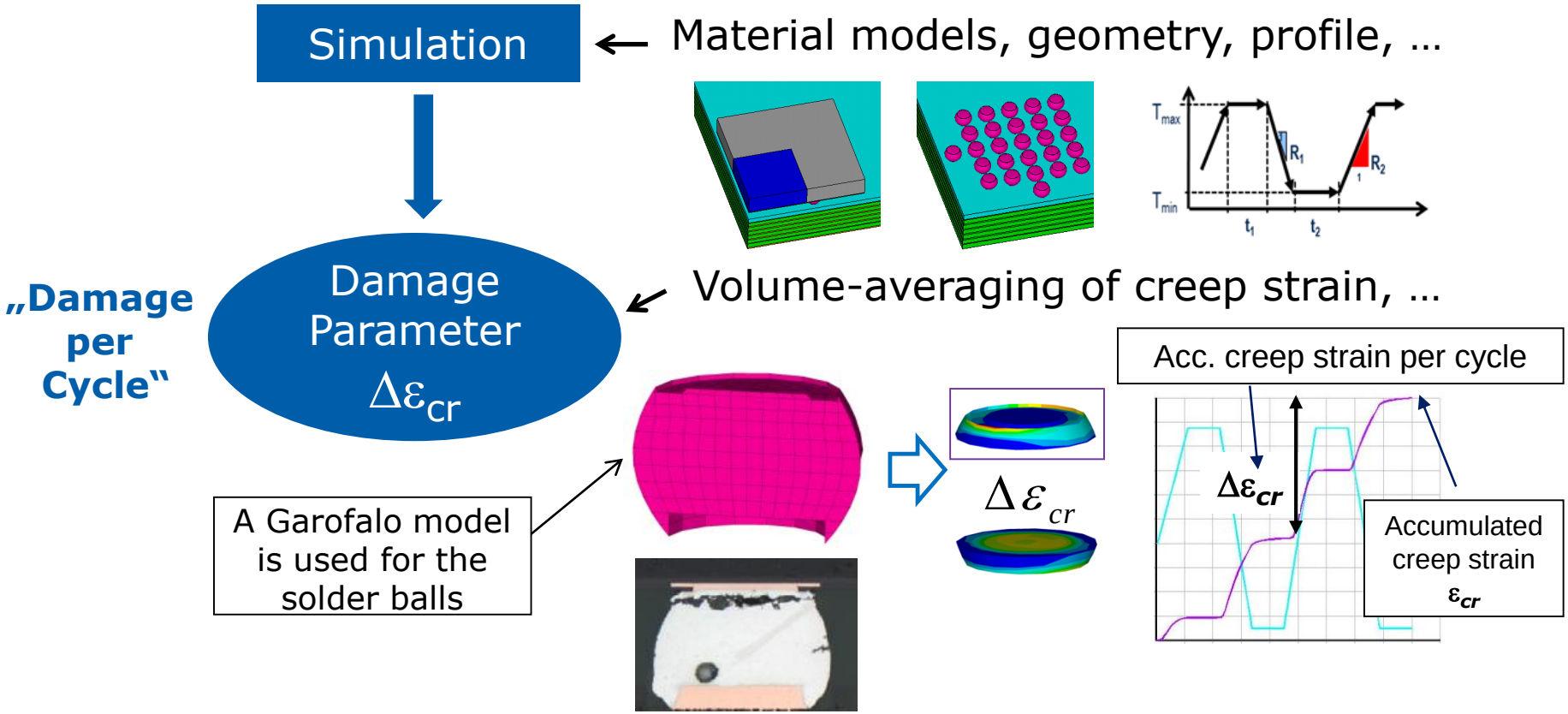
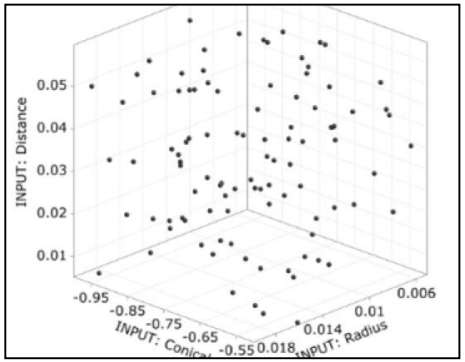
Predicting Solder Joint Fatigue



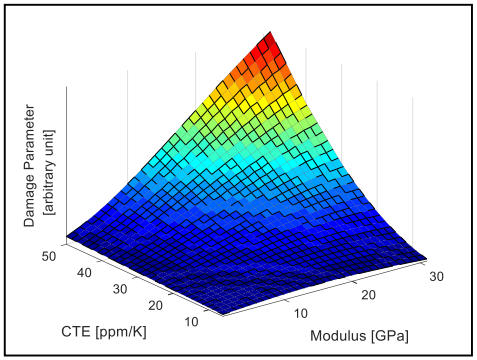
- A simulation framework from literature (Darveaux 1997, Syed 1997) is used to assess solder joint fatigue in a qualitative way
- Different materials and conditions can be compared relatively

Analyzing Sensitivities: MOP and CoP

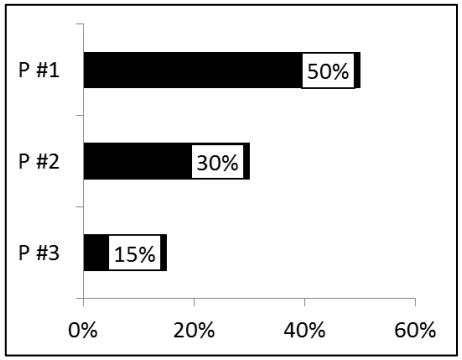
Design Space Sampling

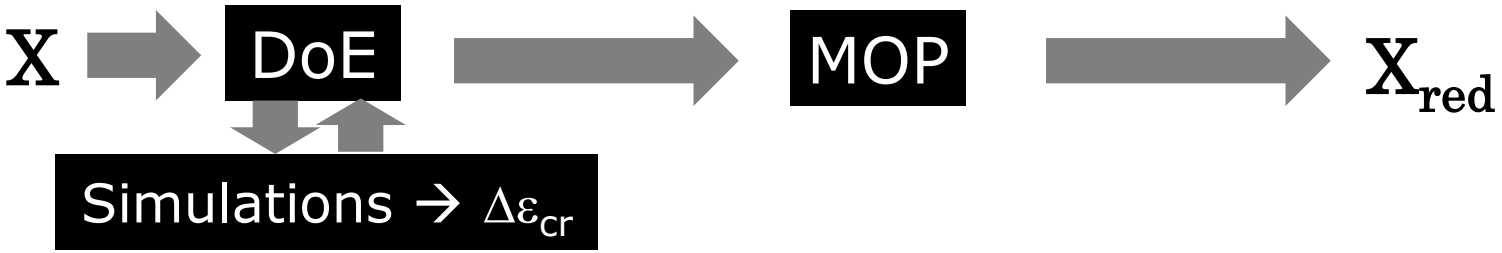


MOP: Metamodel of Optimal Prognosis



CoP: Coefficient of Prognosis





- The software optiSLang© is used to systematically explore the multi-parameter design spaces with a minimum of samples
- Metamodeling is used to analyze and rank the sensitivity w.r.t. the investigated parameters

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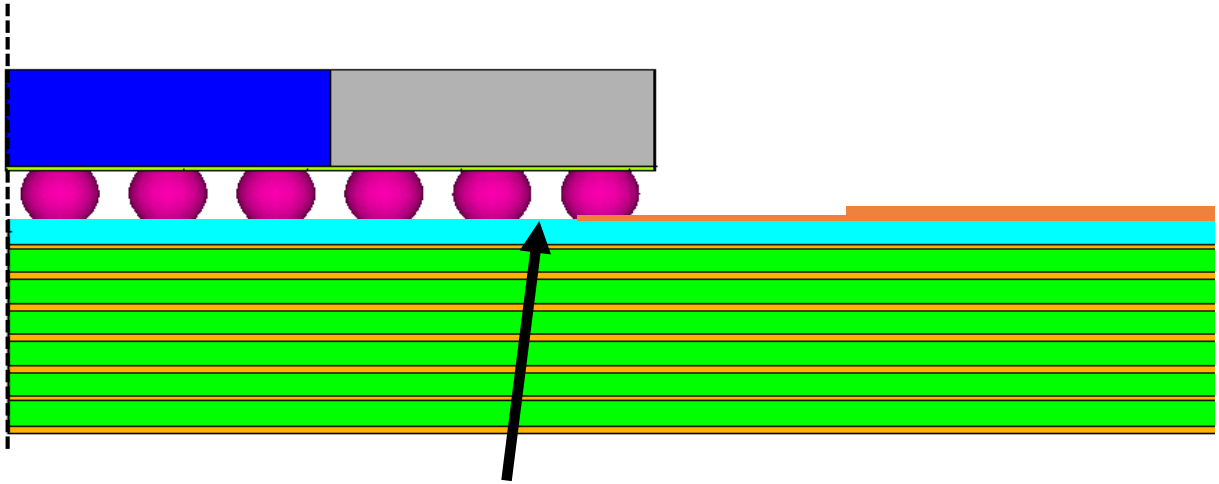
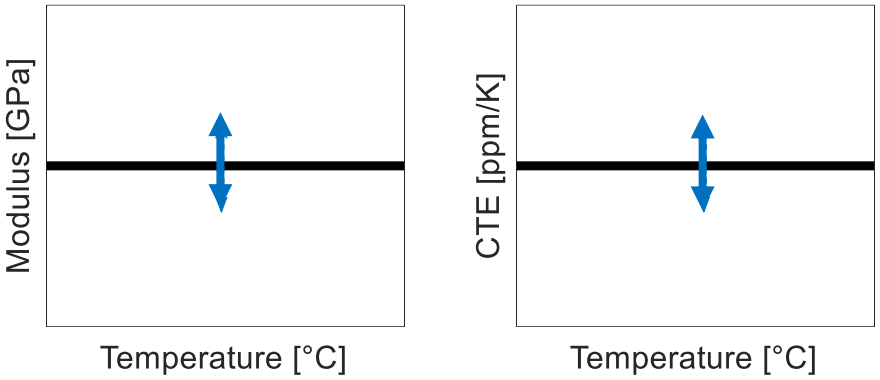
Studies #A,#B,#C
Setup

- The studies #A,#B and #C presented in the next slides have the following setup:
  - **All geometry and material properties are constant**
  - The variables are:
    - **Study #A & #B: Mechanical properties of RF laminate**
    - **Study #C: Same as #A, but with PCB constraints added**

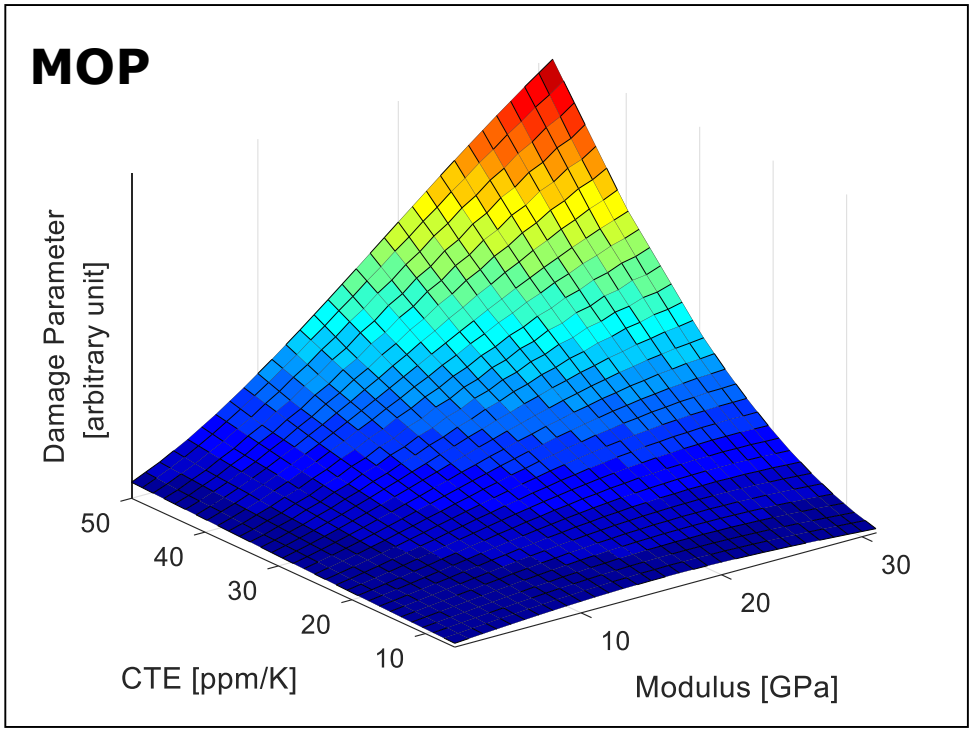


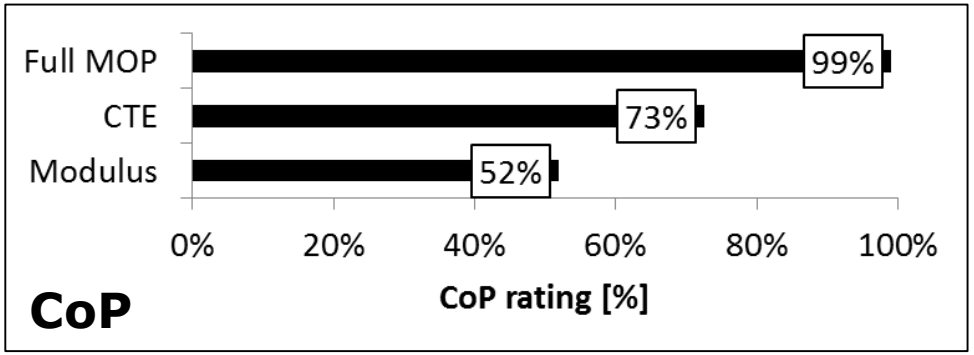
Please note:
Datasheets of RF laminates focus on electrical, especially RF properties. Very often, little information about the mechanical properties is given in those datasheets.

Study #A: Linear-elastic (1/2)
Constant E and CTE

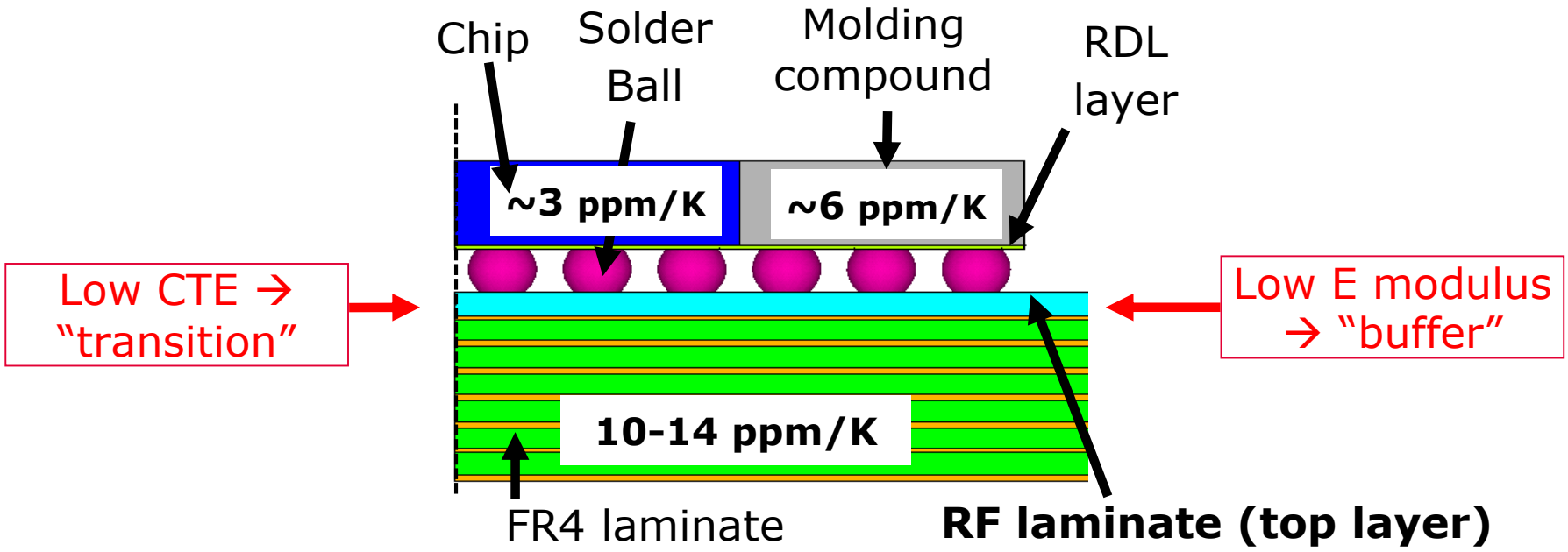


- **Low damage to solder joints (=high reliability) when RF laminate has:**
  - **Low E modulus**
  - **and/or low CTE**



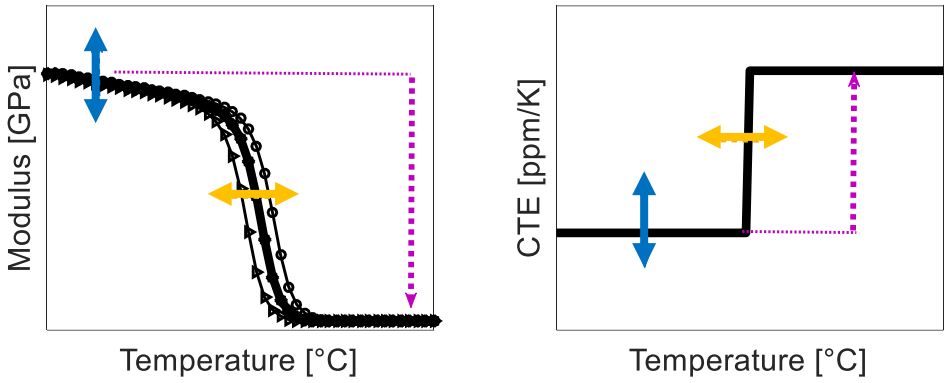


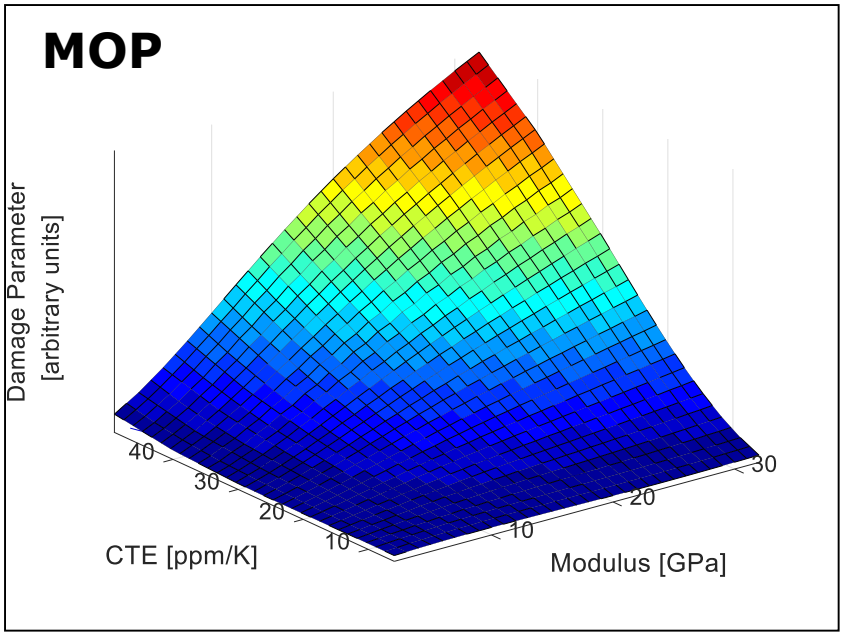
Study #A: Linear-elastic (2/2)
Constant E and CTE



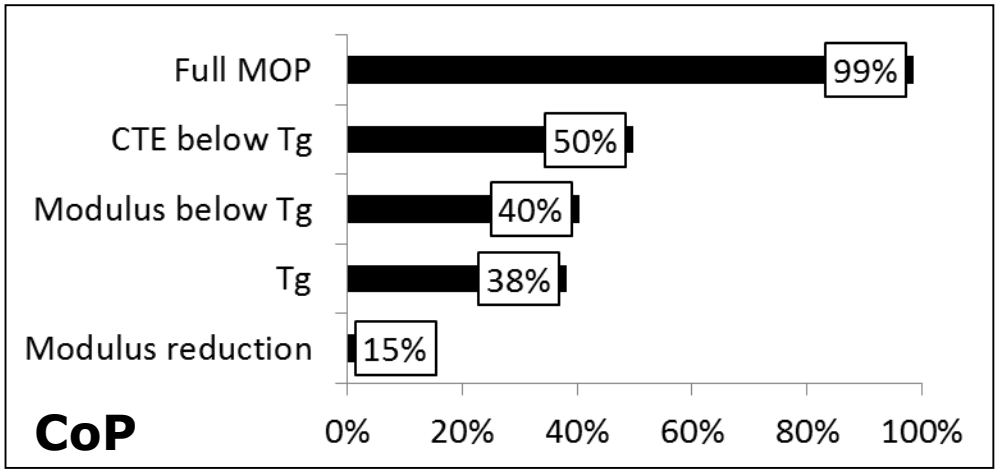
- **Interpretation of findings:**
  - For low CTE, the RF laminate generates a "CTE transition" between the PCB and the package
  - For low E modulus, the RF laminate becomes a "buffer layer"

Study #B: Linear-visco-elastic (1/2)
Coupled E and CTE

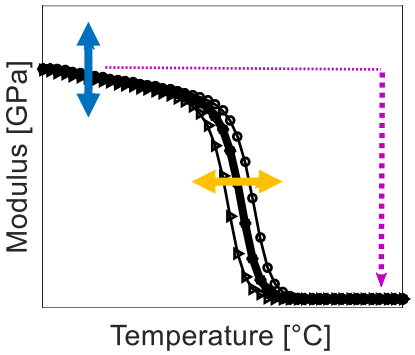


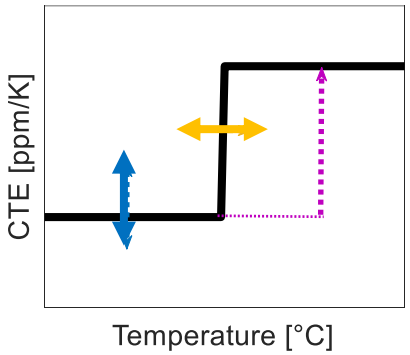


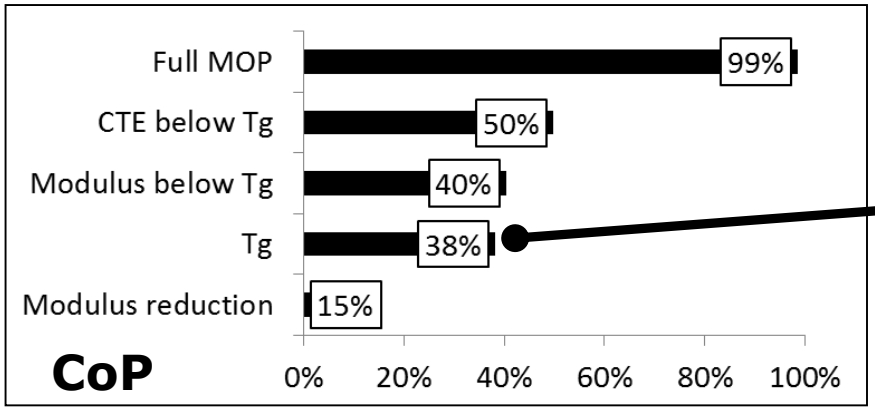
- **Low damage when RF laminate has:**
  - **Low modulus E (below Tg)**
  - **and/or low CTE (below Tg)**
- **Modulus reduction has only impact of 2nd order**

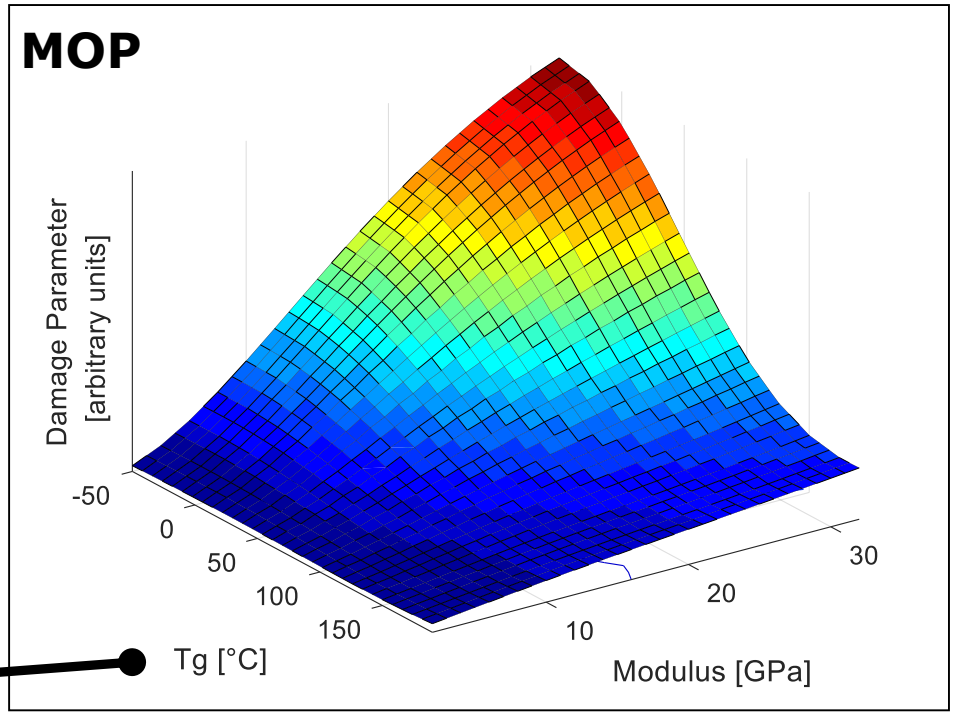


Study #B: Linear-visco-elastic (2/2)
Coupled E and CTE





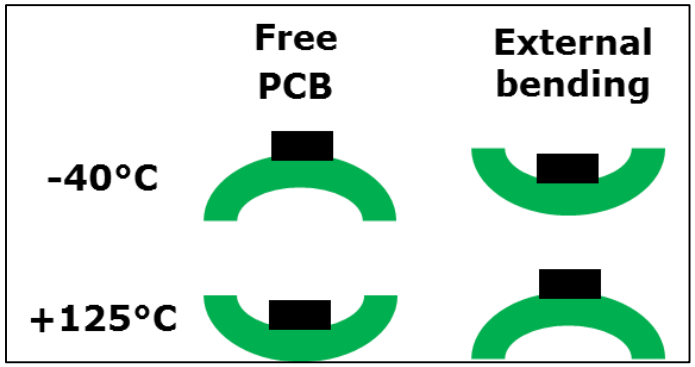


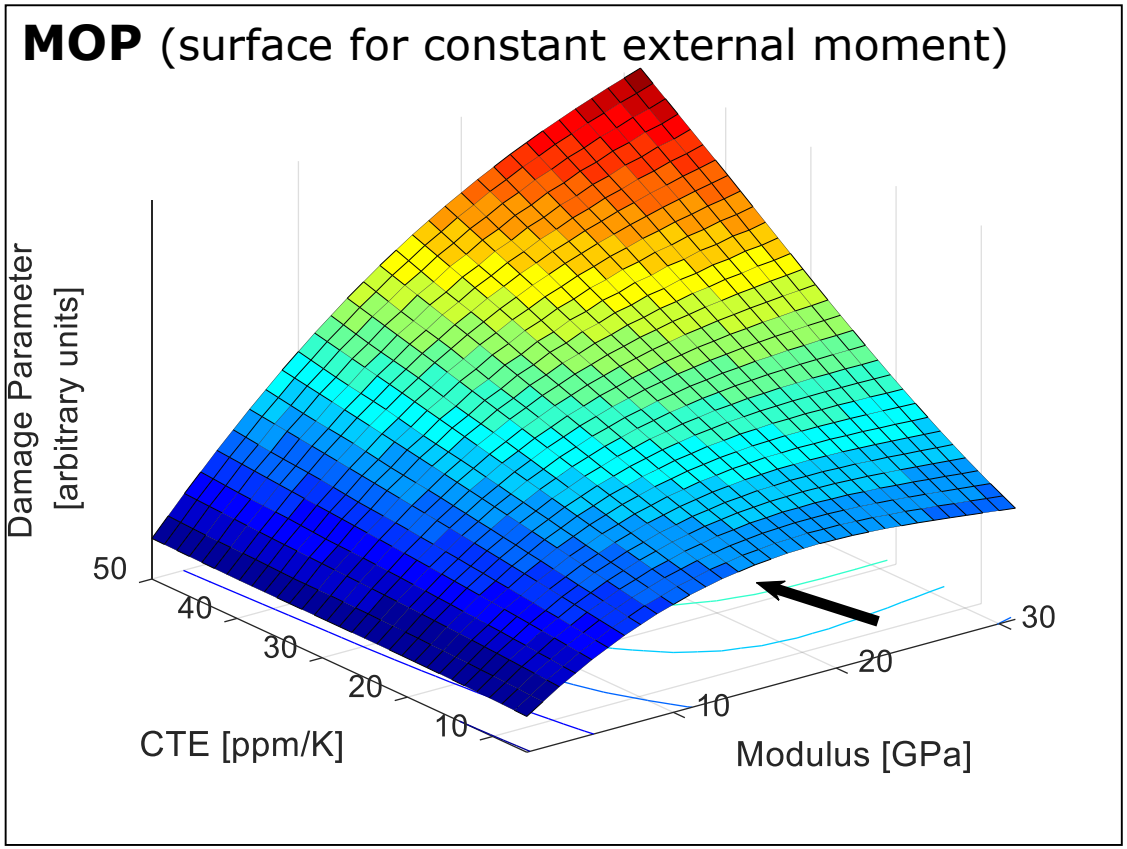


› **Tg has only an impact when E modulus below Tg is high**

Study #C: Linear-elastic (1/1)
External moments @ constant E and CTE

In order to model stresses coming from fixing the PCB in the module, external bending was applied in simulation forcing PCB in direction opposite to deformation resulting from thermal mismatch of package and PCB





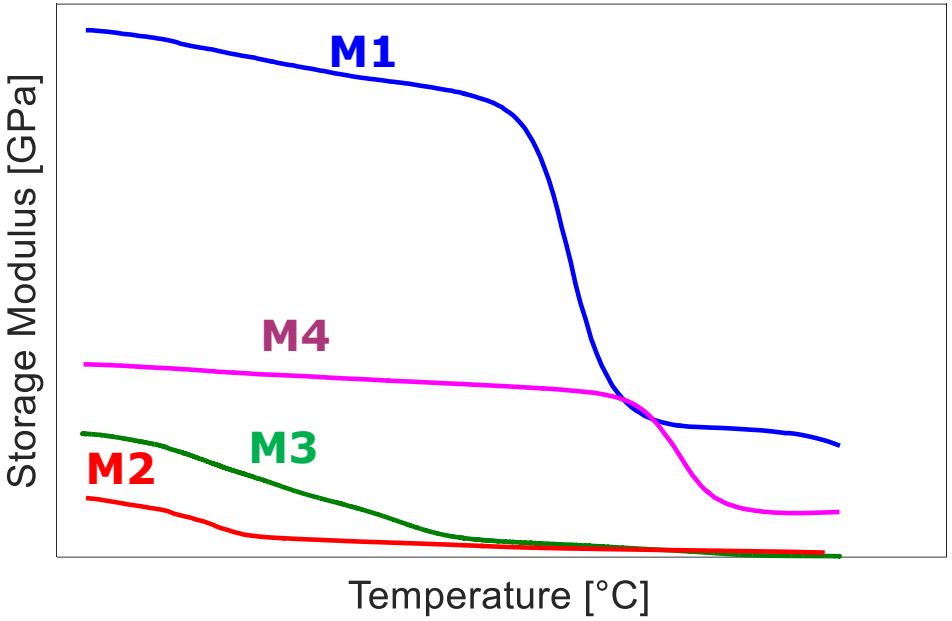
› **RF laminates with low Young's modulus further reduce sensitivity w.r.t. external bending of PCB**

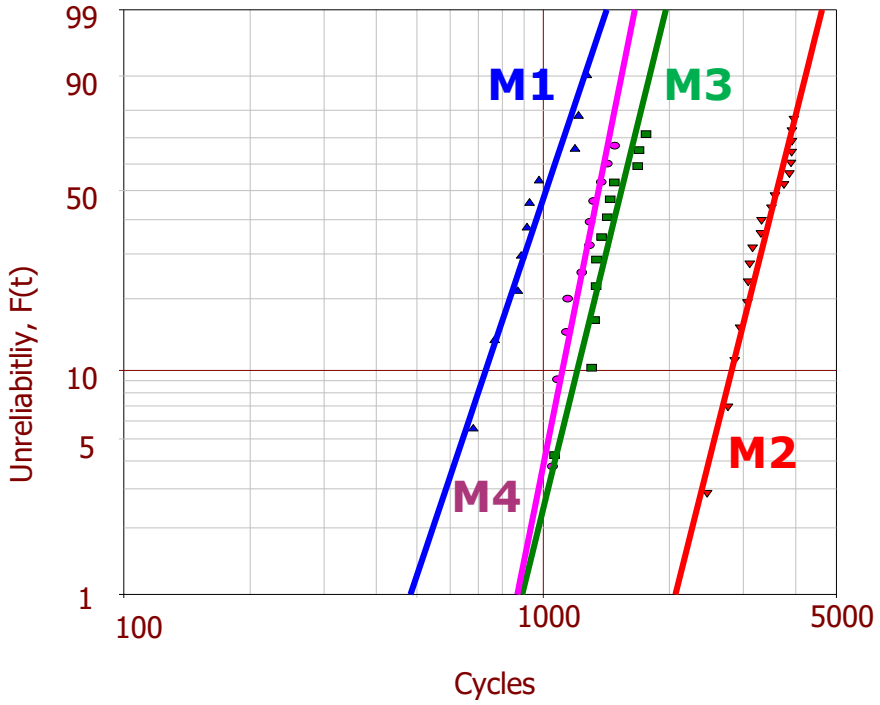
Further findings from sensitivity studies

- **Only little impact of RF laminate layer thicknesses** when it varies between 60 µm and 120 µm
  - Consequently, E and CTE of RF laminates are more important
- RF laminates with **low E modulus** allow better for buffering:
  - Stresses coming from increasing the PCB thickness

For more see: M. Niessner *et al. "Controlling the solder joint reliability of eWLB packages in Automotive RADAR Applications Using a Design for Reliability Approach", ASME InterPACK 2018, 2018*

Experimental verification:
Sensitivity to E and CTE

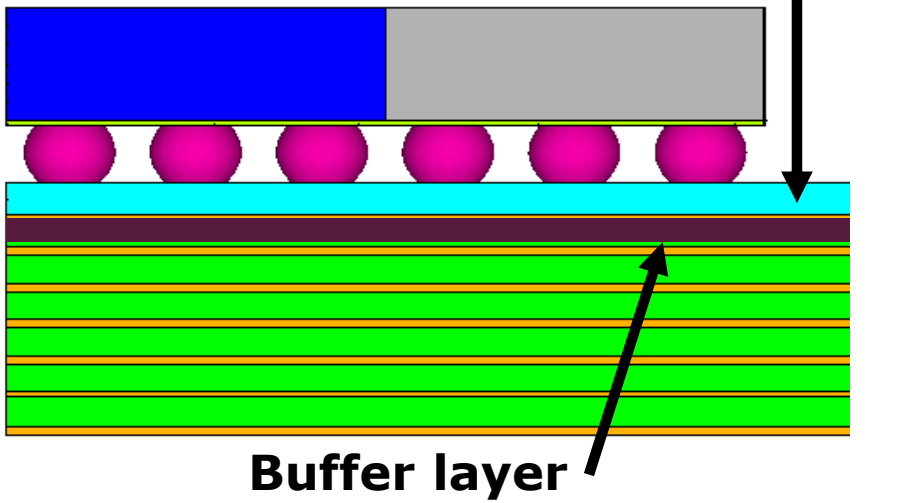


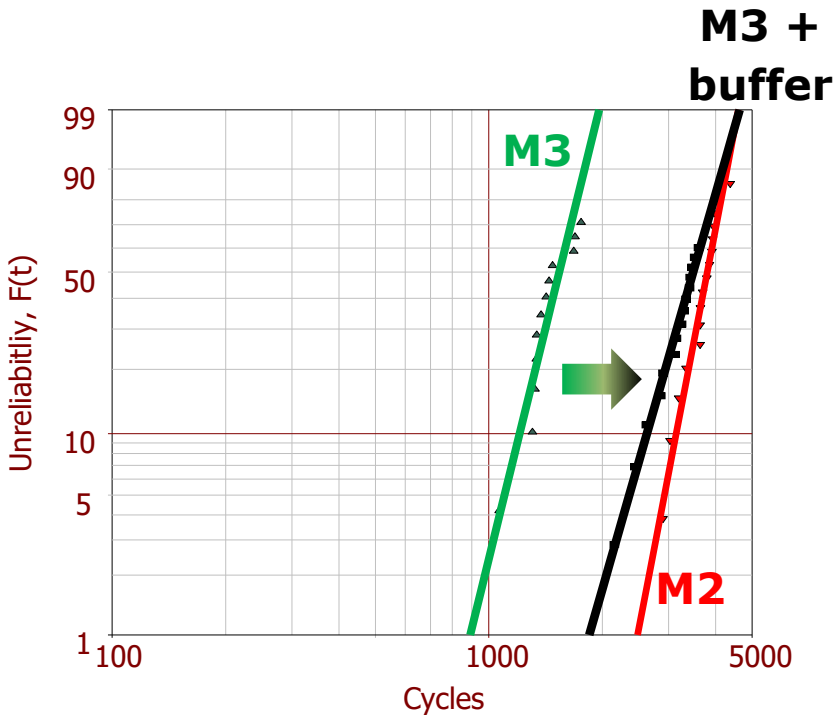


- Experiments with the same PCB stack, but different top layer laminates confirm:
  - Lower E modulus allows for longer solder joint life
  - Level of E modulus towards lower temperatures is essential

Experimental verification:
Additional buffer layer

- The framework was successfully enabled for quantitative prediction by calibrating a Coffin-Manson-type lifetime model
- Using the calibrated framework, a PCB stack was designed, which allows for improved solder joint reliability even in the presence of a non-optimal RF laminate





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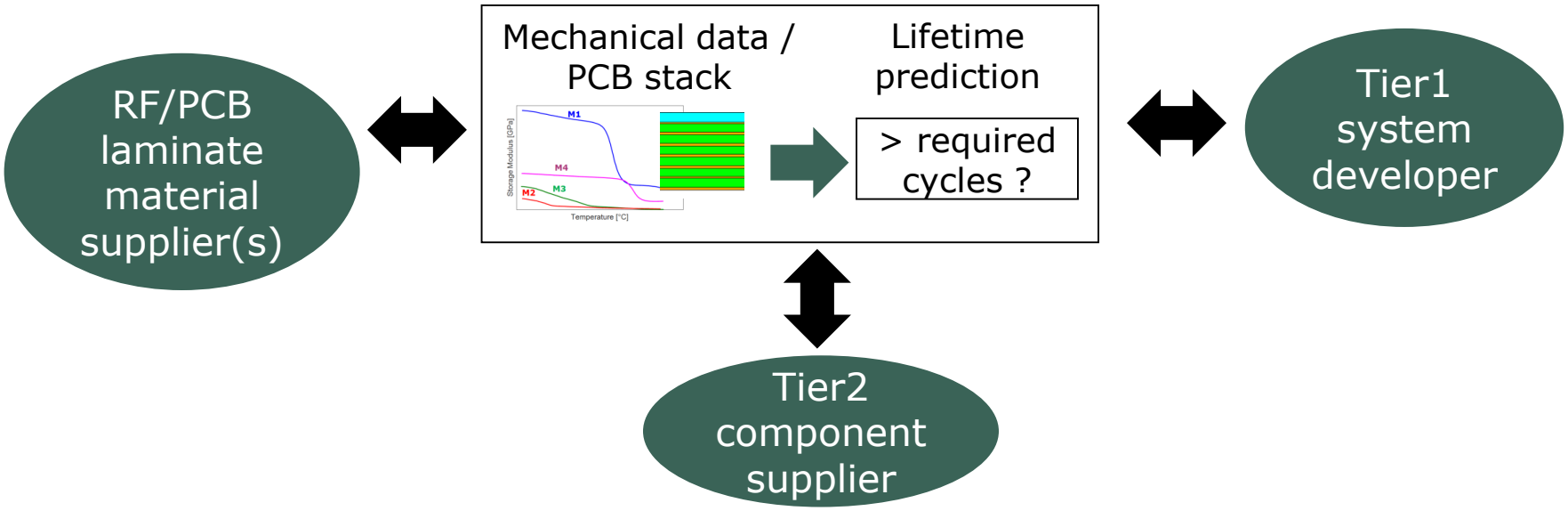
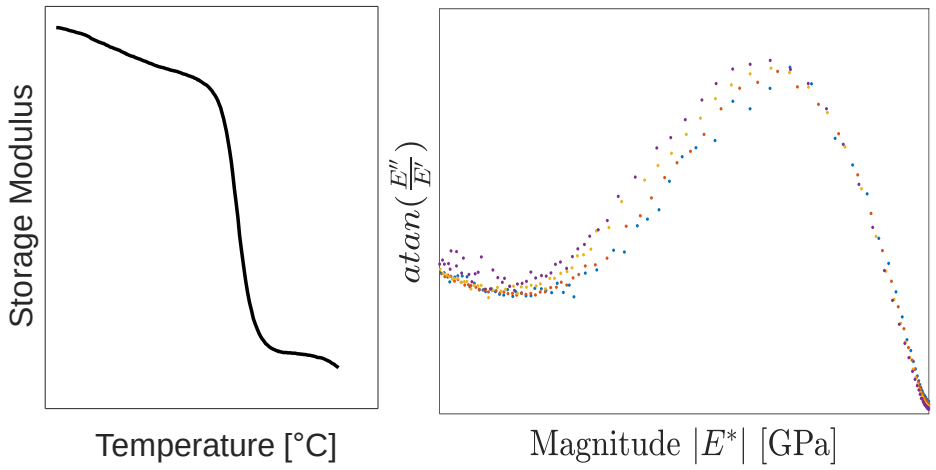
Summary

- RF laminates with **low Young's modulus** allow for the highest solder joint reliability on unconstrained and constrained PCBs
- A simulation framework allows for **early and predictive Product to System (P2S)** assessment of hybrid PCB stacks used with automotive RADAR applications and, thus, **Design for Reliability (DfR)** in order to ensure that **automotive reliability requirements** can be met



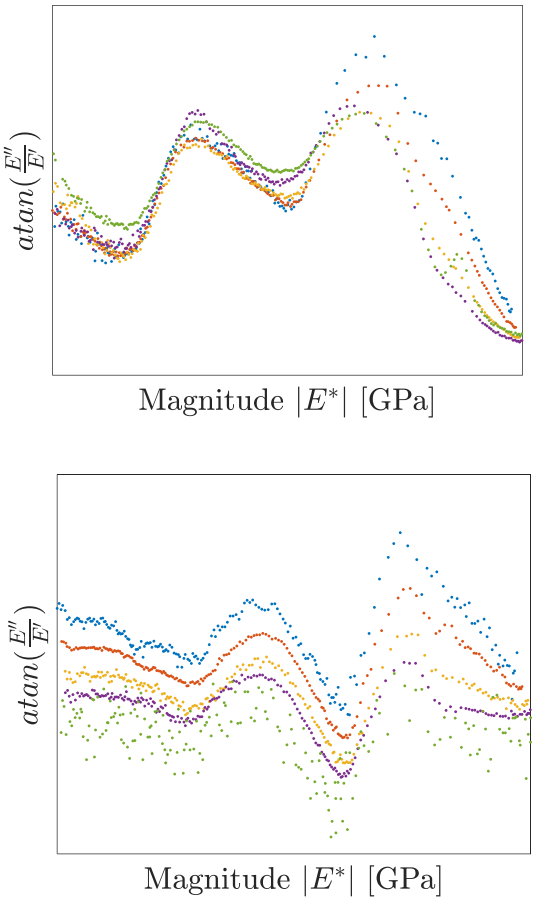
Outlook

- Linear-elastic and linear-visco-elastic material modeling of RF laminates may not be sufficient



Characteristic linear-visco-elastic behavior

- **Future work will focus on advanced material modeling**



Two examples of behaviors measured with RF laminates

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