Agenda

Investigation of Interface Delamination of EMC-Copper Interfaces in Molded Electronic packages

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- Introduction of team competencies
- Motivation
- Description of Problem
- Experimental investigation
- Numerical Analysis, structural simulation
- Debonding simulation/CZM
- FE Simulation and Parameter Identification
- MultiPlas material modeling
- Conclusion & Summary

Introduction to competency

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- **Introduction**
- Motivation
- Problem description
- Experimental investigation
- Experimental results
- Numerical Analysis
- Structural Simulation
- Debonding simulation
- CZM
- FE Simulation
- MultiPlas material
- Sensitivity analysis
- conclusion

Reliability Lab:

Location			
	NhP	Karnataka	350 km
	Cob	Tamil Nadu	

Associates

Associates	NhP	Cob
Reliability Engineers	13	
Technician	4	4
Lab Quality Engineer	1	

Major Equipments

Equipments	NhP	Cob
Climatic chambers	6	14
Th. shock chambers	3	
Vibration shakers	1+ 1	
Visual inspection	3	
Salt spay chambers	1	
Milling machine	1	
Inspection sample machine	1	

Validation

- Design Validation -DV
- Product validation - PV
- Qz - PV
- Failure analysis
- Application assessment
- Vehicle measurement

Competencies

- Validating ECUs, sub-systems and modules
- Scientific knowledge about function, reliability, error and failure mechanisms ECU/subassembly/components/devices;
- Application assessment
- Failure/service life and reliability prognosis
- Formation of field load spectrum
- loading capacity of design elements (El.component)

CCS-Tester/Climatic chambers

PPTFOOTCOL.png

Vibration shaker

Polishing machine

Salt spray chamber

Milling machine

ECU Tightness tester

Digital microscope

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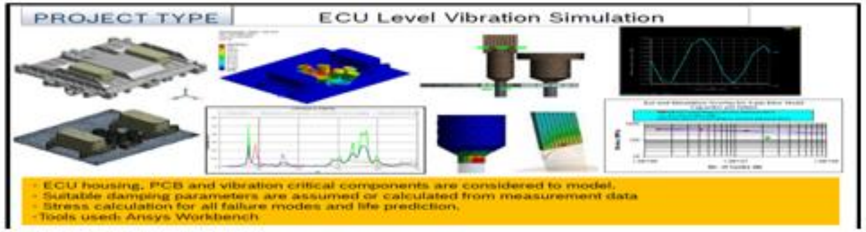
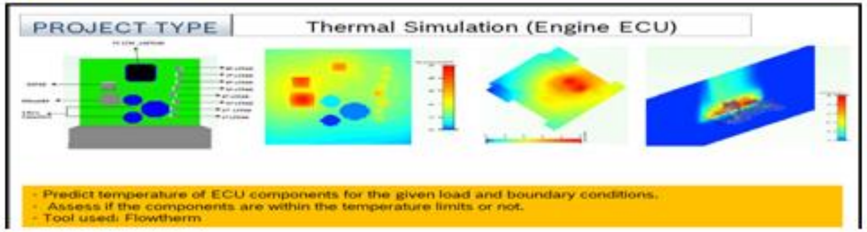
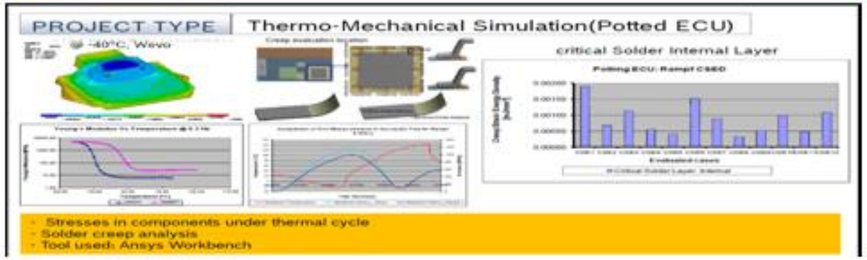
Introduction to competency

Simulation Team:

Associates	19 Fulltime, 2 contract employees, 2 Intern Students
Competencies	Thermo-Mechanical simulations
	Thermal simulations
	Reliability modeling and system optimization (N-Layer, DOE, Material characterization)
	Mechanism (Static – ICT, Connector Insertion and Dynamic- Drop simulation, Vibration simulation)

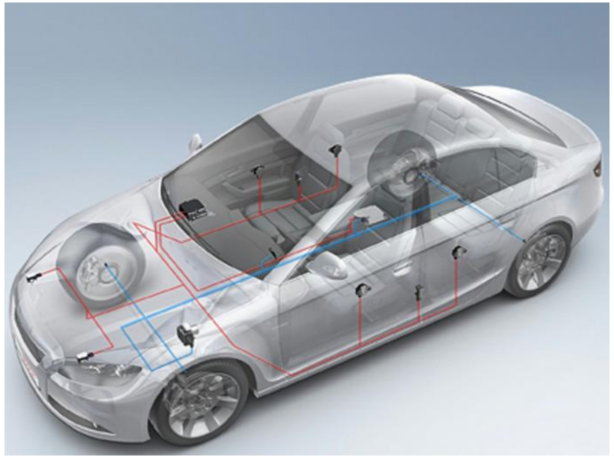


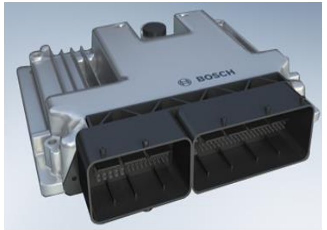


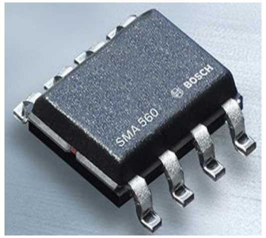


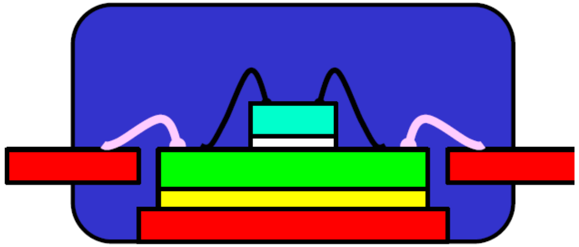
Motivation

- New generation of vehicle uses a lot of electronics.
- These Electronic packages in automotive industry are prone to harsh environmental conditions.
- Plastic encapsulation is introduced to protect the electronic part by molding a compound material around it.
- This has been proven as a powerful solution to these challenges.









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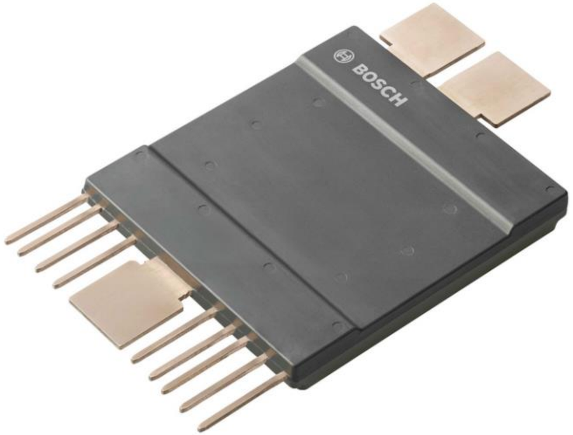
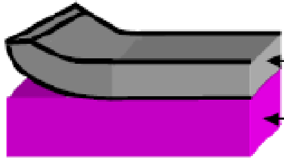
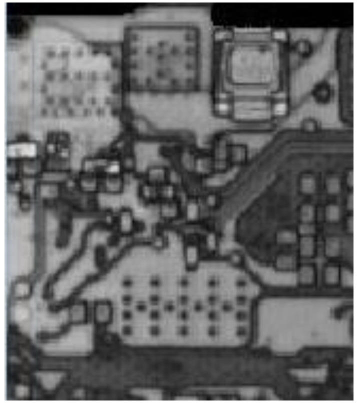
Problem description

- Interfacial delamination is one of the major concerns in reliability issues of electronic packages.
- The interface between EMC and copper-based lead frame is often a weak link.
- Button shear test is used in this study to characterize the adhesion strength of EMC/Cu interface.







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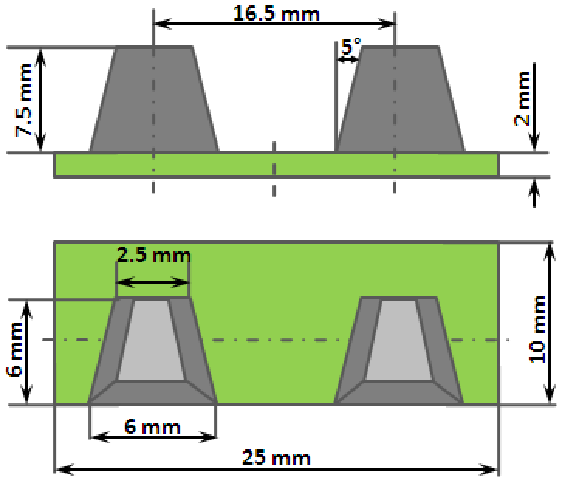
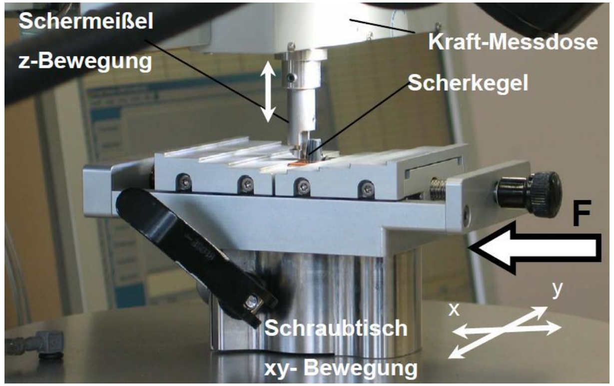
Experimental investigation

- Button shear test is used in this study to characterize the adhesion strength of EMC/Cu interface.
- The effect of temperature (between -20°C to 165°C) and shear height (mode mixity between 100 µm to 4000 µm) is also investigated.
- The sample used in this study is a triangular shaped button shear test sample, as illustrated in Fig. 1

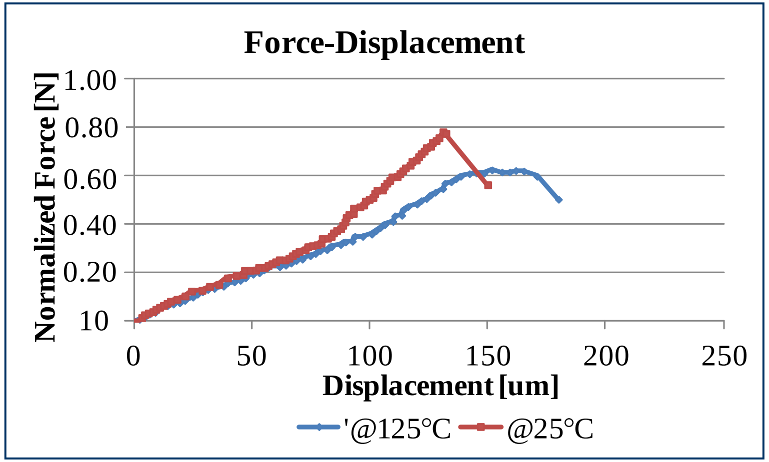




Experimental results

Force-Displacement graph

- Graph shows example of a typical force-displacement graph obtained from the experiment.
- The peak point in the force-displacement of the test represents the required load for the propagation of crack across the interface. This force leads to the interfacial delamination and is used to characterize the strength of adhesion at EMC/Cu interface.



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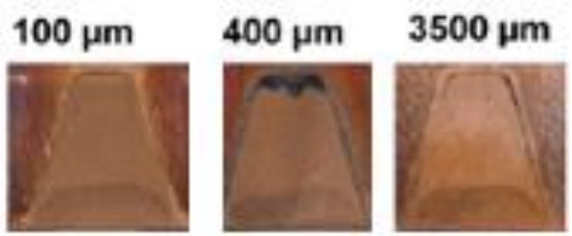
Experimental results

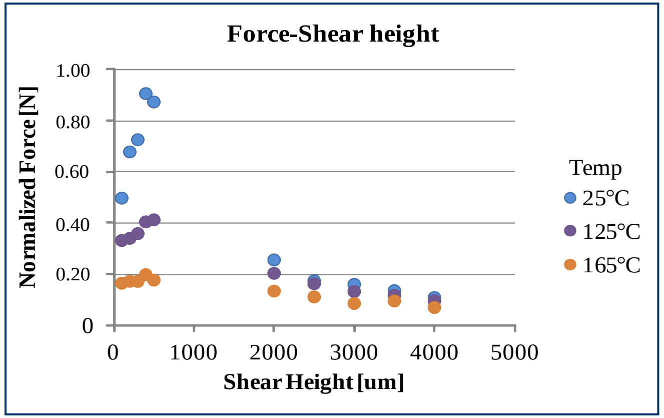
Effect of Shear Height

➢ In general, two trends are observed in the graph. At low shear height (from 100µm to 500µm), the shear force is increasing with an increase of shear height.

➢ This effect is caused by the shear tool presses the EMC button to the copper substrate. The compressive normal stress is induced and contributes to the closure of the crack and could induce fracture in the bulk

➢ It is also seen from the Fracture images that the samples sheared at 400/500µm display a different fracture type compared to the other samples.

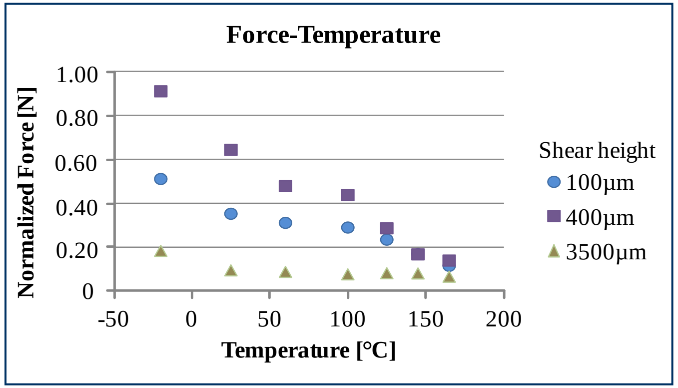




Experimental results

Effect of Temperature

- The interfacial adhesion strength is seen to decrease with the test temperature. The sample, which is tested at room temperature, exhibits higher interfacial strength than the sample tested at higher temperature.
- The influence of shear height may become negligible when the test temperature is higher than 165°C.
- At lower shear height, the adhesion strength decreases rapidly when the test temperature rises. The second trend, which corresponds to the shear height between 2000µm and 4000µm, indicates a small drop in maximum shear force as the test temperature increases.



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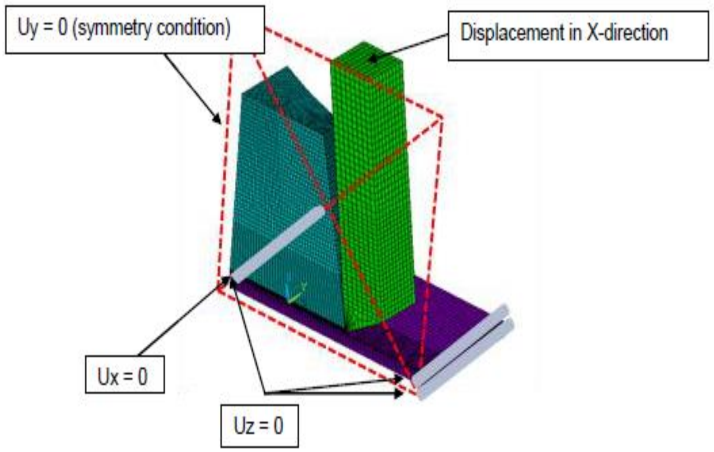
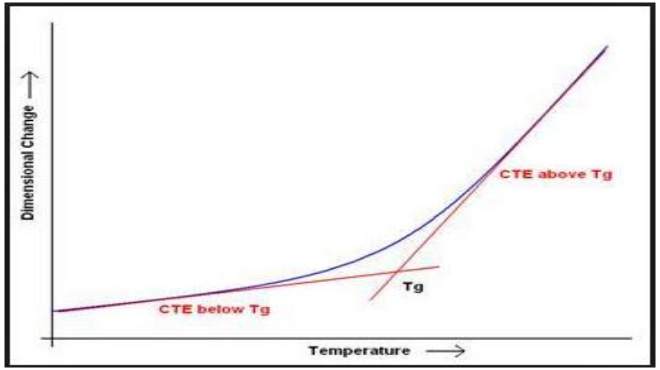
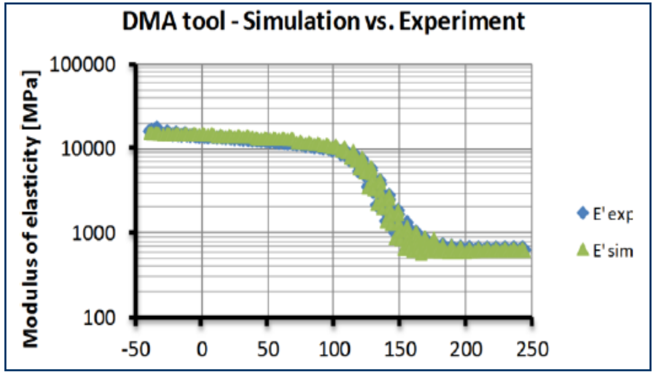
Numerical Analysis

- The preparation phase of the simulation begins with the modeling of the button shear test sample and the shear tool.
- Molding compound is modeled with viscoelastic properties, which exhibit both viscous and elastic characteristics when undergoing deformation.

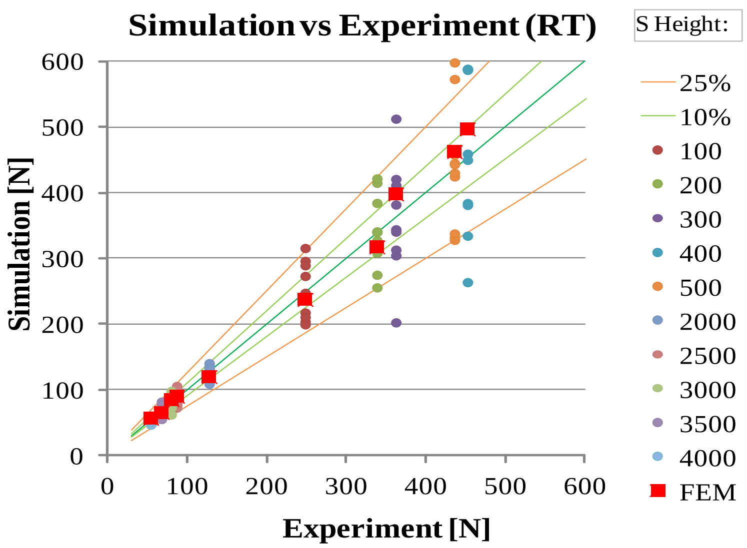


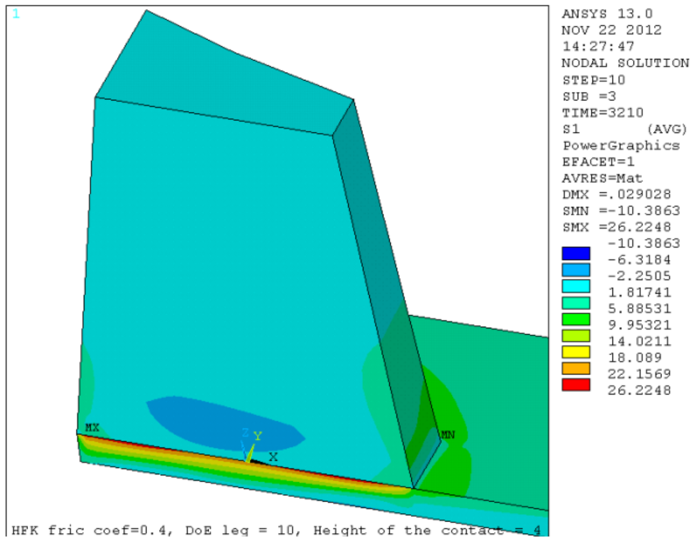




Structural Simulation

- ➢ In order to validate the model, a structural simulation is carried out. In this case, the nodes at the EMC/Cu interface are merged.
- ➢ Load conditions, cooling down and shear process, are taken into account for the load steps.





Debonding simulation

➢ The primary objective of numerical analysis is to investigate the capability of cohesive zone model (CZM) to study the debonding mechanism.

G_{II}= Tangential critical fracture energy
G_{I}= Normal critical fracture energy

	T=25°C	. . .	T=100°C	. . .	T=165°C
500 µm	$Gc_{25}=GII_{25}$	$Gc_{25..100}=GII_{25..100}$	$Gc_{100}=GII_{100}$	$Gc_{100..165}=GII_{100..165}$	$Gc_{165}=GII_{165}$
. . . .	$Gc_{25}=GI+GII$	$Gc_{25..100}=GI+GII$	Gc100=GI+GII	$Gc_{100..165}=GI+GII$	$Gc_{165}=GI+GII$
4000 µm	$Gc_{25}=GI_{25}$	$Gc_{25..100}=GI_{25..100}$	$Gc_{100}=GI_{100}$	$Gc_{100..165}=GI_{100..165}$	$Gc_{165}=GI_{165}$

➢The cohesive parameters, viz. cohesive strength and cohesive energy, are determined by fitting the simulation result with the experiment result.

$$\tau_{ct} = \frac{F_{exp} \cdot 2}{A_{surface}}$$

$$U_{ct} = d_{test} \cdot 2$$

$$G_{ct} = \frac{1}{2}\tau_{ct}\,U_{ct}$$

τ_{ct}: Cohesive strength in shear direction
U_{ct}: Critical sliding distance
G_{ct}: Tangential critical cohesive energy
F_{exp}: Maximum shear force of experiment
$A_{surface}$: Area of contact surface (at the interface)
d_{test} : Maximum displacement of experiment

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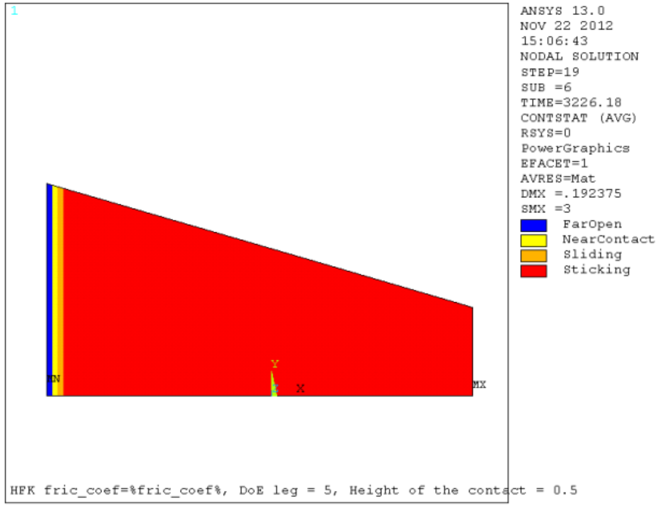
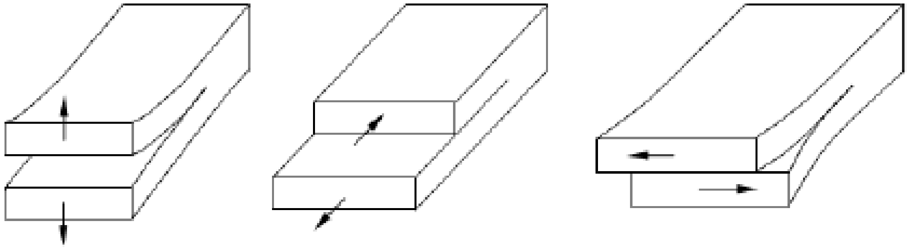
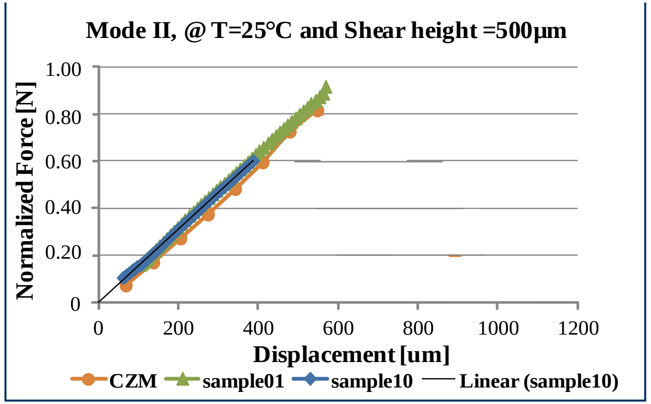
CZM

Mode II Fracture

- Tangential critical fracture energy (G_{II}) at room temperature is summarized.
- This case corresponds to 500µm shear height, where the total critical fracture energy is assumed equal to tangential critical fracture energy.
- Cohesive parameters in this case are determined by an inverse method, correlation of the numerical and experimental of force-displacement graph







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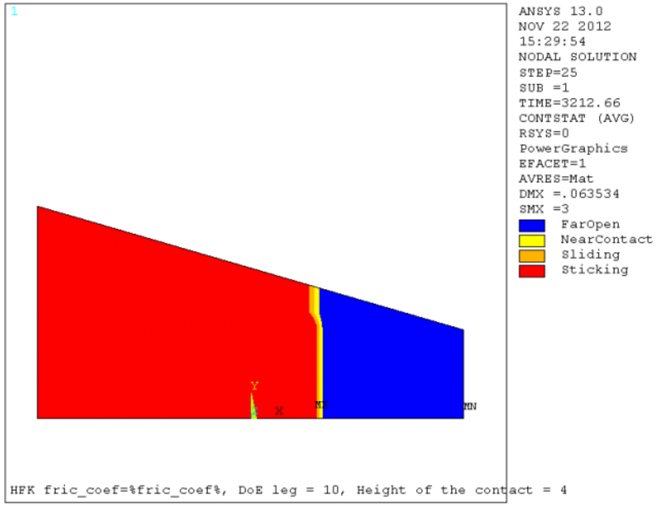
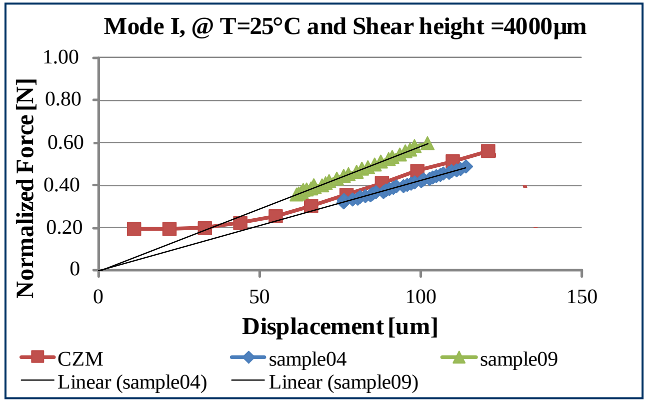
CZM

Mode I Fracture

- normal critical fracture energy (G_I) at room temperature is summarized.
- shear height in this case is 4000µm. The same correlation procedure as implemented for pure mode II fracture is done to obtain normal critical fracture energy (G_I).





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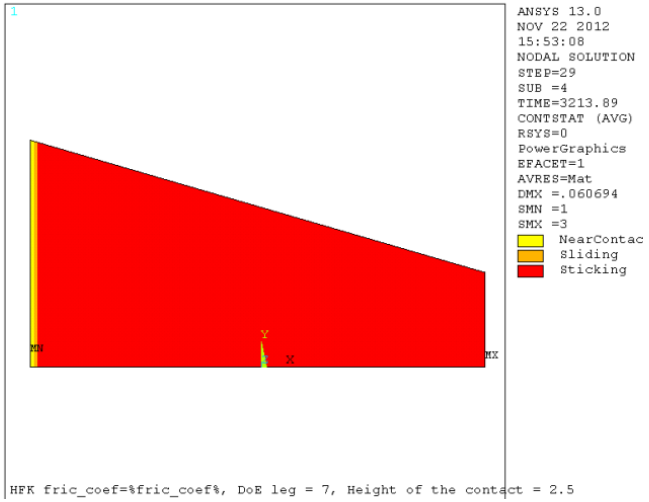
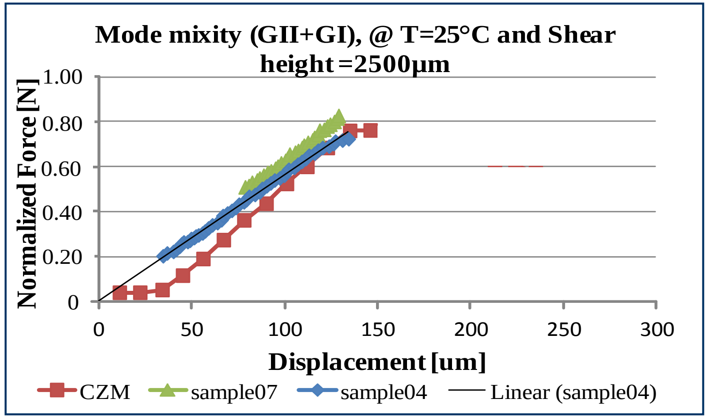
CZM

Mixed-Mode Fracture

- ➢ The loading condition for shear height between 500µm and 4000µm is assumed mixed-mode.
- ➢ Here the result is presented for simulation case of 2500µm shear height and 25°C test temperature.
- ➢ The first principal stress and contact status of FE-Model are shown. The result shows that the crack tends to slide (mode II) rather than open (mode I) at the beginning of delamination process.





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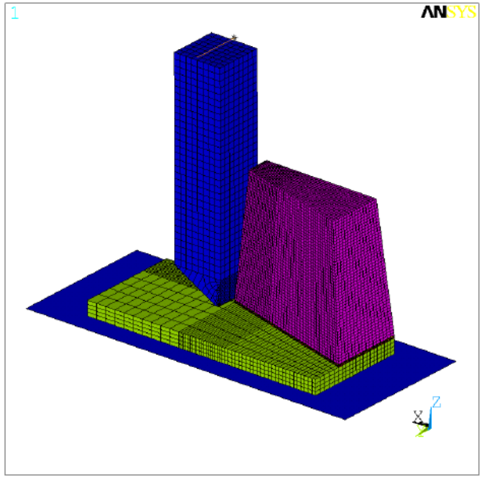
FE Simulation

➢ The goal of the analysis is the buildup of an appropriate mechanical model and the parameter identification for the shear button test carried out.

➢ To simulate the crack behavior of the interface and the mold compound the material library multiPlas is applied that uses multi-surface plasticity models at continuum element level.

Parameter	Description	Unit
C	cohesion	[MPa]
f_t	tensile strength	[MPa]
f_i	friction angle	[°]
G_I	mode I fracture energy	[mJ/mm²]
G_{II}	mode II fracture energy	[mJ/mm²]



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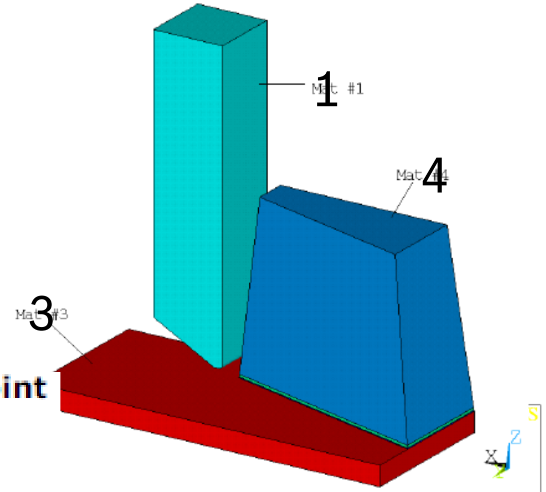
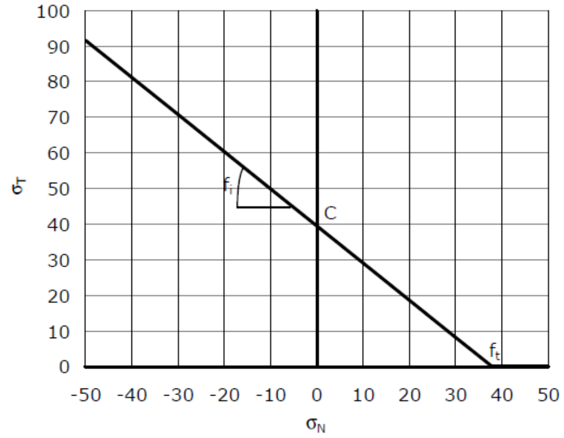
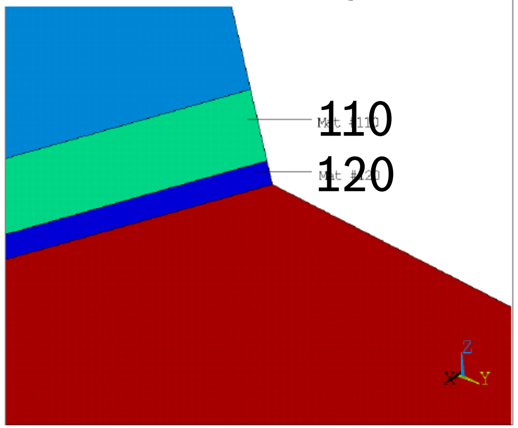
MultiPlas material

Mat #1: Steel (linear elastic)
Mat #3: Copper SE-Cu58 (linear elastic)
Mat #4: Mold Compound CEL400ZHF16 / Bulk material (Drucker-Prager, multiPlas LAW=2, ideal plastic)
Mat #110: Mold Compound CEL400ZHF16 / Multi-layer joint (Mohr-Coulomb, multiPlas LAW=120, ideal plastic)
Mat #120: Interface Mold Compound-Substrate / Single layer joint (Mohr-Coulomb, multiPlas LAW=120, with softening)



Mohr-Coulomb anisotropic yield criterion





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Numerical Analysis

Structural Simulation

Debonding simulation

CZM

FE Simulation

MultiPlas material

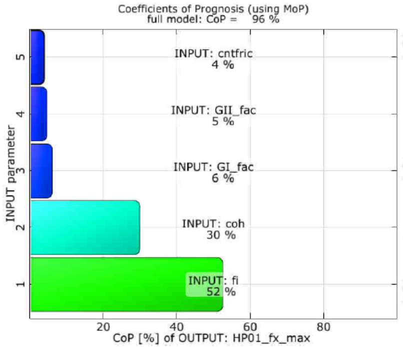
Sensitivity analysis

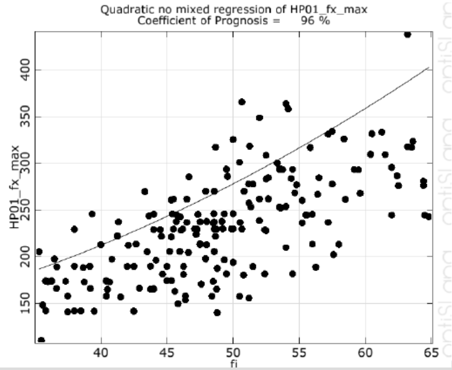
conclusion

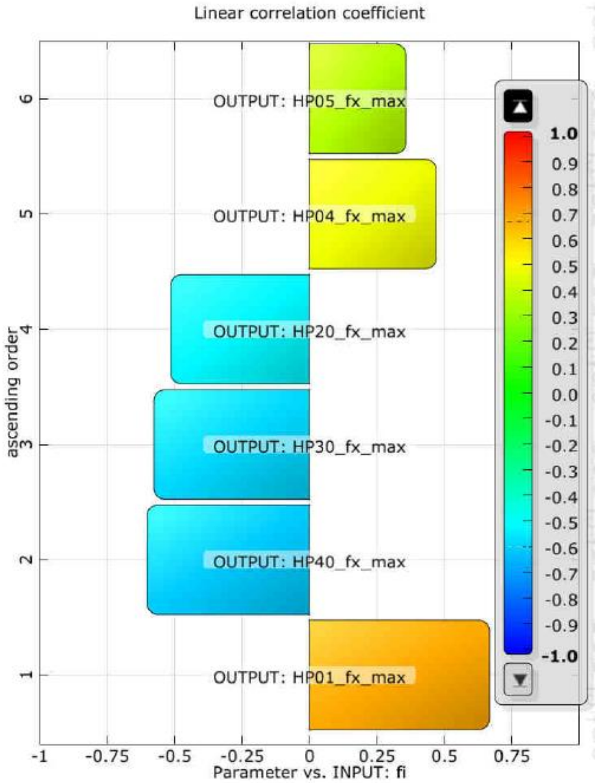
Sensitivity analysis

#	Parameter	Description	Unit
1	coh	cohesion	[MPa]
2	fi	friction angle	[°]
3	GI_fac	mode I fracture energy scale factor	[-]
4	GII_fac	mode II fracture energy scale factor	[-]
5	cntfric	contact friction angle hammer-mold cap	[°]
6	cnttmax	contact shear limit hammer-mold cap	[MPa]

#	Parameter	Description	Unit
1	HP01_fx_max	maximum shear force for 0.1 mm HP	[N]
2	HP04_fx_max	maximum shear force for 0.4 mm HP	[N]
3	HP05_fx_max	maximum shear force for 0.5 mm HP	[N]
4	HP20_fx_max	maximum shear force for 2.0 mm HP	[N]
5	HP30_fx_max	maximum shear force for 3.0 mm HP	[N]
6	HP40_fx_max	maximum shear force for 4.0 mm HP	[N]







conclusion

- Based on the experimental results, the following conclusions can be made:

•At low shear height the interface strength increases with increase of shear height due to the compressive normal stress

• At high shear height maximum shear force decreases with increase of shear height due to mixed-mode ratio.

- The simulation results can be summarized in the following statements:

•CZM offers the possibility to distinguish between tensile fracture toughness and shear fracture toughness.

• CZM is able to describe the entire fracture process including crack initiation and propagation.

THANK YOU

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