Design and Demonstration of Ultra-thin Glass Panel Embedding Packages for RADAR Applications

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Acknowledgements

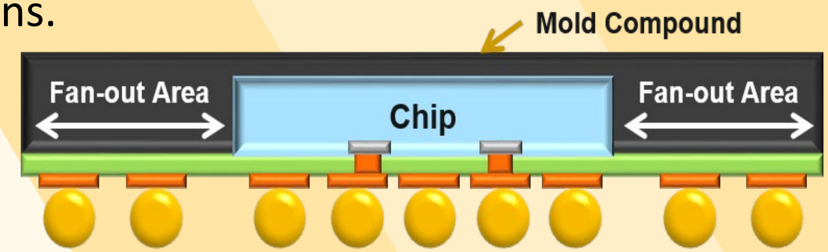
Research Centers: Package Research Center

Liaisons: Nagase, Schott, Ajinomoto

1. Research Objectives

- Design and demonstration of ultra-thin, high Performance Glass Panel Embedding(GPE) Packages for RADAR Applications.

Radar module with GPE package

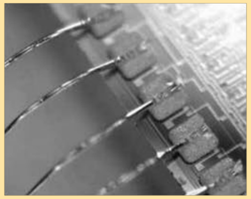


Infineon's eWLB

Parameter		Objectives	Prior Art	Challenges	Tasks
Miniaturization		<200 um thickness	>500 um	Miniaturized package architecture for lowest system loss	Design and demonstrate package architecture with minimum package thickness
Performance	T-line loss	< 0.2 dB/mm	0.30 dB/mm		
	System Insertion loss	0.3-0.5 dB	0.65 dB	Electrical discontinuities in die-to-package interconnection	Modeling and design of embedded chip interconnections with minimum loss
	System return Loss	< -20 dB	-16 dB		
	TPV loss	>0.8 dB	0.2-0.5 dB		
Demonstration		< 100 um warpage on 2 inch panel	>500 um warpage on 6 inch wafer	Package warpage after thermal debonding due to CTE mismatch	Demonstrate low warpage ultra-thin GPE packages

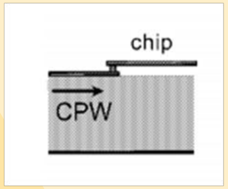
2. Strategic Need

RADAR Applications



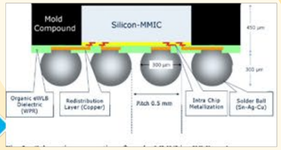
Wire Bonding

Tolerance of bond wire parasitic up to ± 15%



Flip-chip

Lower loss than wire bonding

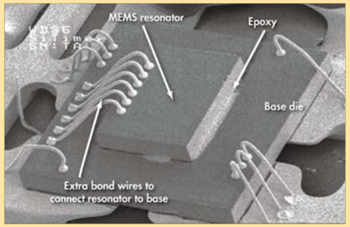


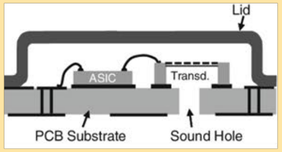
eWLB

Better electrical performance than flip-chip. Flexible for antenna integration.

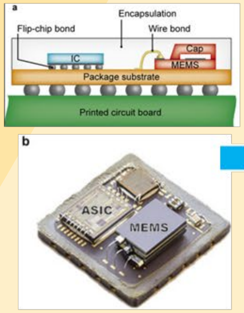
Frequency for automotive radar module: 24GHz → 77GHz

Frequency for 5G MEMS cell applications: 3.3GHz → 40GHz

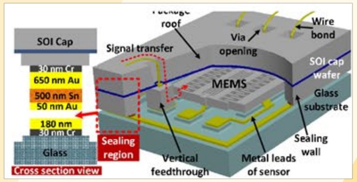




Wire Bonding



Flip-chip & wire-bonding

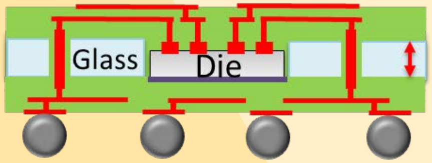


Wafer-level package

MEMS Applications

Also, emerging applications: RF GaN…

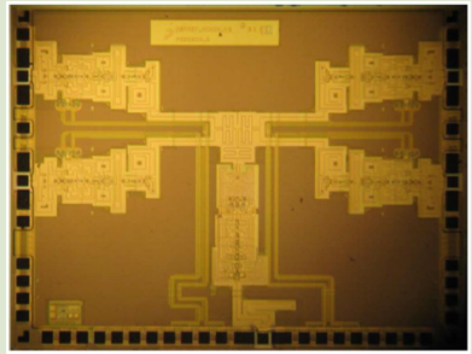
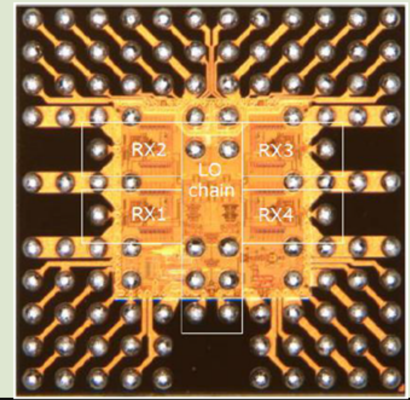
Ultra-thin GPE



- Small z-height
- Possible direct chip cooling
- Ease of TPV formation
- Low loss enabled by ultra-short signal path
- Lower warpage than EMC
- Low cost from large panel process

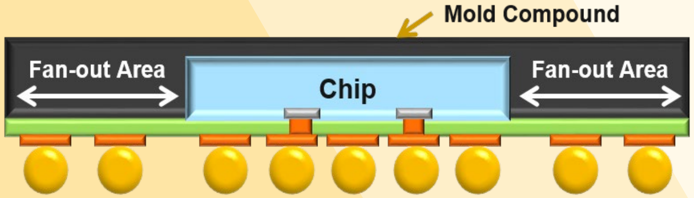
Need for low loss ultra-thin packages

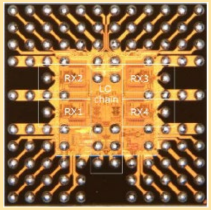
3. Prior Art

Radar Module		Freescale TMTT 2012	Infineon RFIC 2012
			
Package		RCP	eWLB
Miniaturization	Size	6mm x 6mm	6mm x 6mm
	Thickness	N/A	> 500 um
Performance	Package inductances	<50% of wirebond solutions	<50% of flip-chip solutions
	Package loss	< 1 dB	0.65 dB
Demonstration	Warpage	> 500 um	> 500 um
	Die-shift	N/A	>10 um

4. Technical Approach Beyond Prior Art

Infineon's eWLB for 77GHz Radar Module



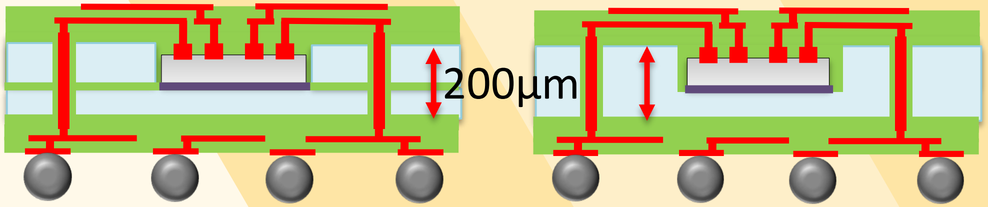


Size: 6mm x 6mm
Thickness: >500 µm
Die shift: ~10µm

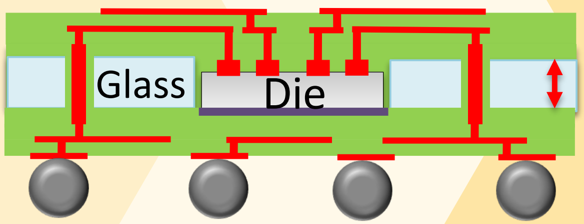
Generation 1

Laminated GPE

Blind cavity GPE



Ultra-thin GPE



100µm

Generation 2

Ultra-thin GPE vs. eWLB

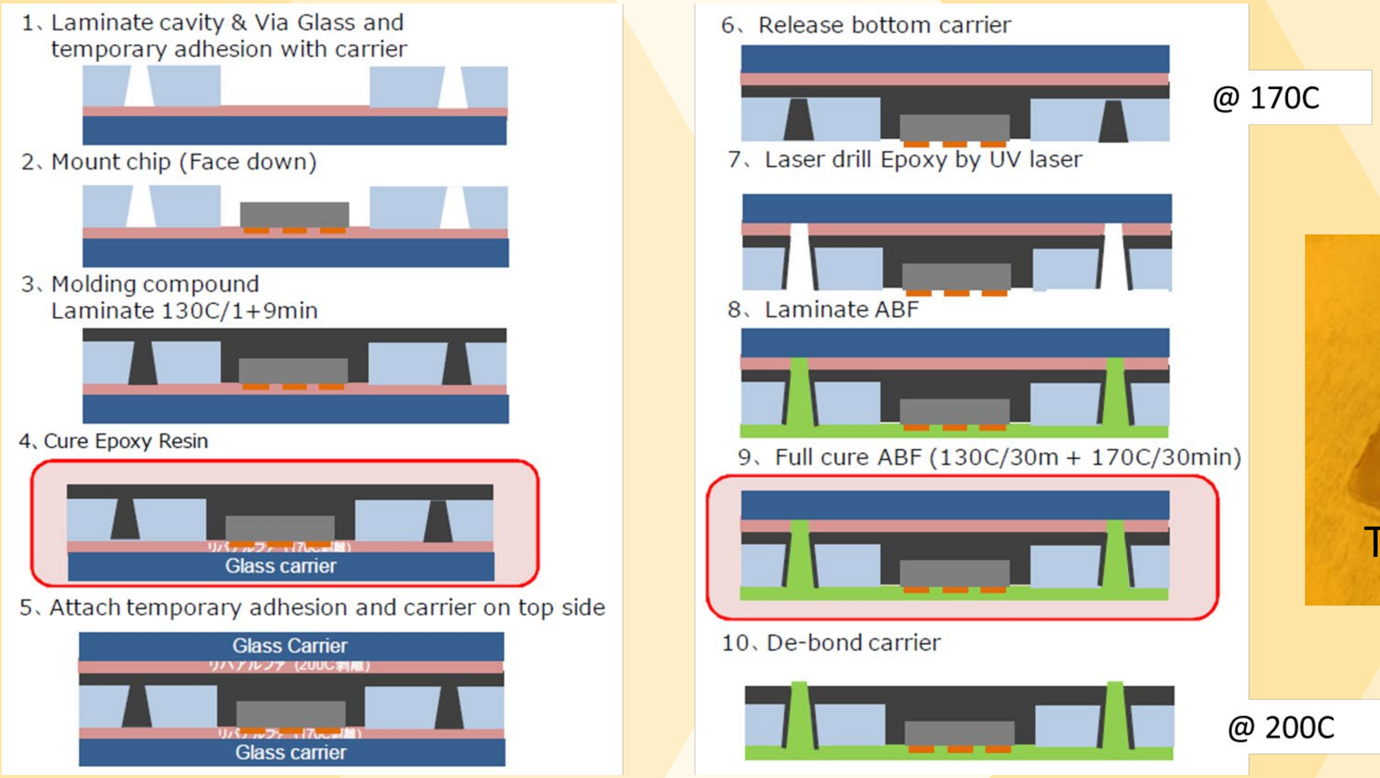
- 1~2µm die-shift
- Low loss enabled by via in line interconnect
- Lower warpage than EMC
- Low cost from large panel process

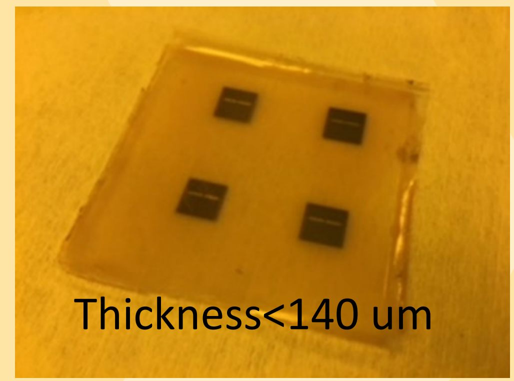
Ultra-thin GPE vs. Laminated & Blind cavity GPE

- Smallest z-height
- Easier TPV formation
- Lower loss enabled by shorter signal path
- Possible direct chip cooling

5. Results

5.1 Design and demonstrate package architecture with minimum package thickness



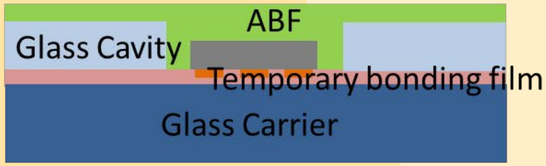


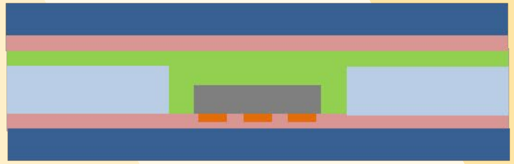
Process flow for ultra-thin GPE packages

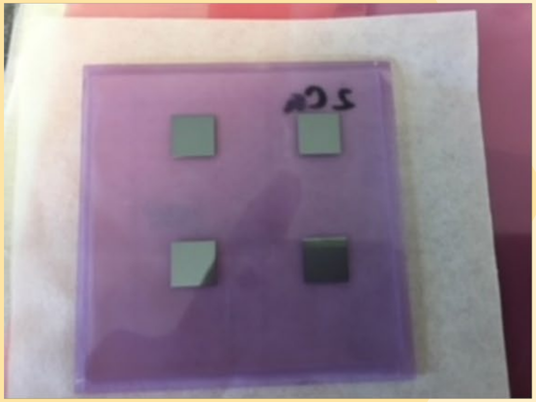
5. Results

5.1 Design and demonstrate package architecture with minimum package thickness

Demonstration: Ultra-thin GPE with ABF

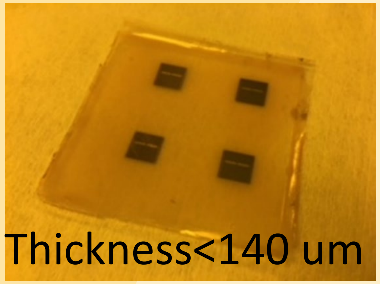






GPE with carrier A

GPE with both carriers



GPE after carrier removal

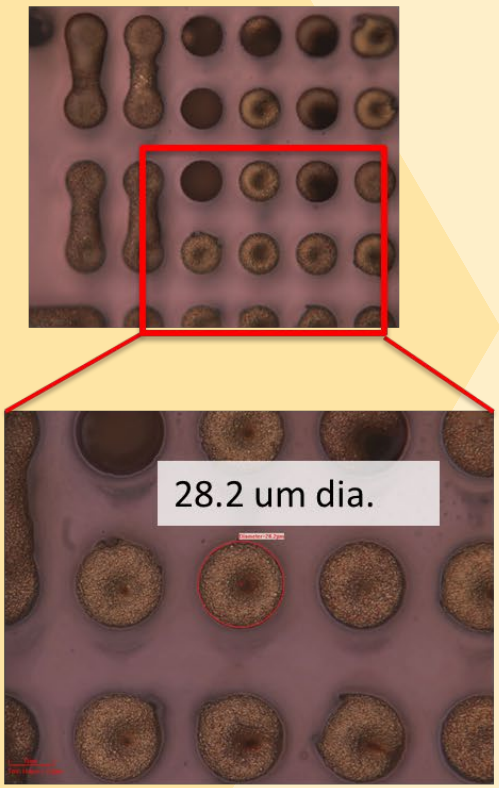
Parameter	Value
Glass cavity thickness	100 um
Glass carrier thickness	1 mm
ABF thickness	30 um
Die thickness	100 um
Die size	7.2 mm x 7.2 mm
Temporary bonding film thickness	10 um
Temporary bonding film A release temp.	170 C
Temporary bonding film B release temp.	200 C

Specification

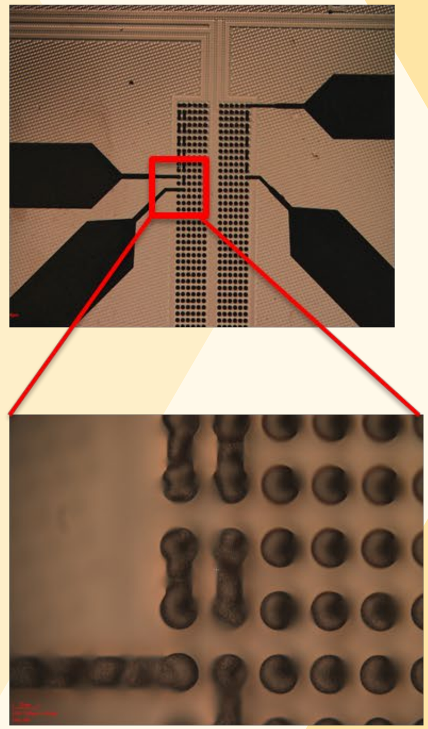
5. Results

5.1 Design and demonstrate package architecture with minimum package thickness

RDL - Plating, P.R. Strip & Seed layer etching



Plating

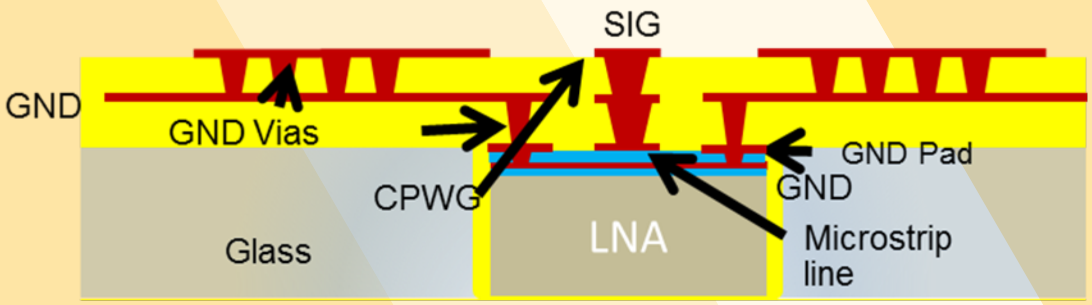


P.R. strip

Seed layer etching

5. Results

5.2 Modeling and design of embedded chip interconnections with minimum loss



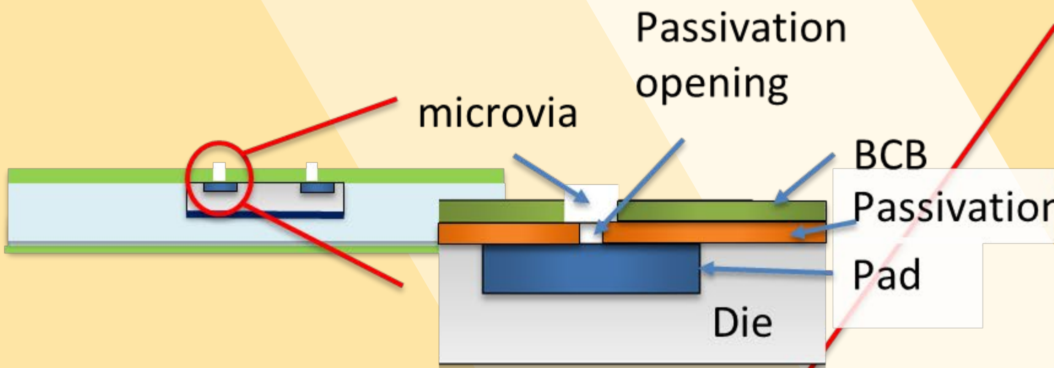
Pad dia. 30 um Via dia. 20 um 	Pad dia. 60 um Via dia. 20 um 
0.12 dB	0.16 dB

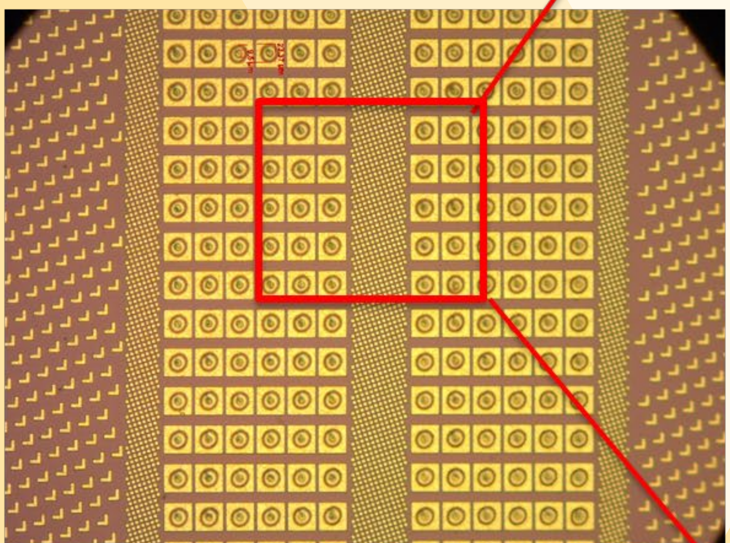
Simulation of the interconnection loss @ 77 GHz

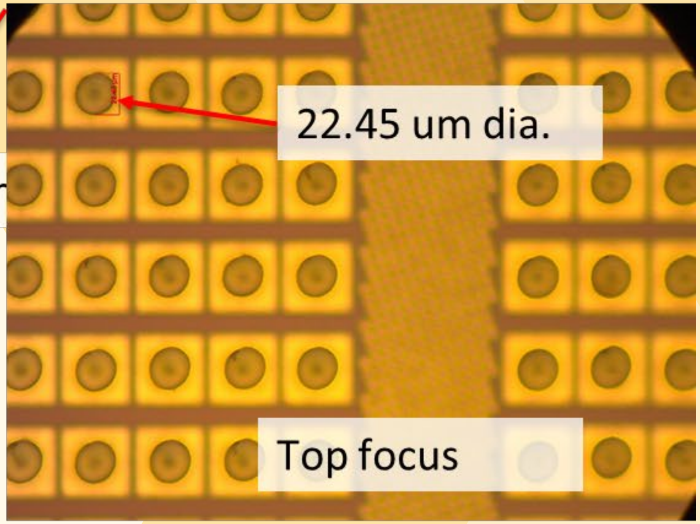
- Smaller Cu pads → lower parasitic effect → lower loss
- Lower interconnection loss can be achieved by high precision processing with minimal variations in line and via geometries on glass substrates

5. Results

5.2 Modeling and design of embedded chip interconnections with minimum loss







- Demonstration of precise microvia laser drilling on dies w/o bumps for GPE structure

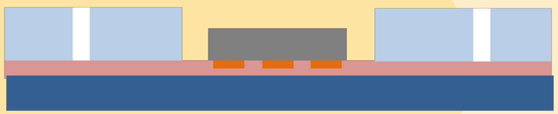
5. Results

5.3 Demonstrate low warpage ultra-thin GPE packages

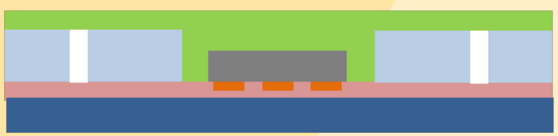
Challenge: Package warpage after thermal debonding due to CTE mismatch

1.Glass cavity lamination on glass carrier

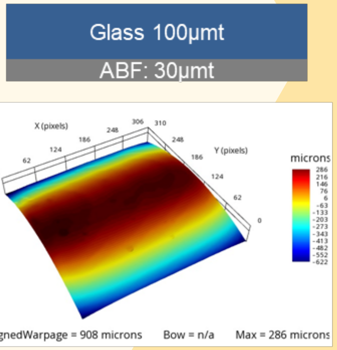
2.Chip assembly



3.Dielectric encapsulate and curing



4. Release carrier and temporary adhesion (and flip)



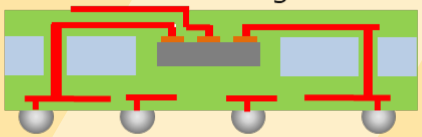
-758µmt

>750 µm warpage observed for 100 µm thick glass cavity

5. Dielectric lamination

6. Via Laser drilling

7. RDL and BGA balling

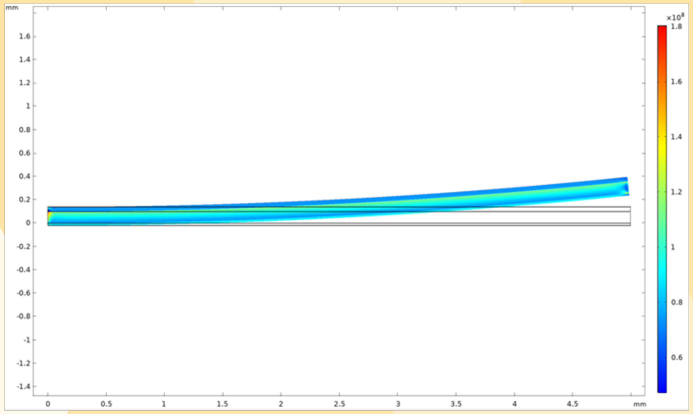


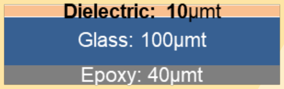
5. Results

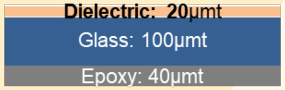
5.3 Demonstrate low warpage ultra-thin GPE packages

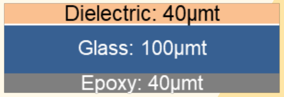
Mechanical Modeling for Warpage Optimization

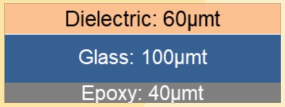
		Sheet type EMC	Glass	Dielectric material
CTE	ppm	15	3.8	30
Modules	GPa	15	77	7.5
Thickness	µm	40	100	20 x n











Modeling	-189µm	+68 µm	+480µm	+887µm
Measured	-287µm	+137µm	+884µm	+1693µm

- ABF with certain thickness can be applied to compensate epoxy for a symmetric structure to reduce warpage

6. Project Summary and Plan

- ❑ Demonstration of ultra-thin GPE packages below 140 um thick
- ❑ Demonstration of precise microvia drilling for low-loss interconnects
- ❑ Modeling and process optimization for warpage reduction
- ❑ Next step: Design, demonstration and characterization of ultra-thin GPE packages with functional dies for RADAR applications

Tasks	Sub-Tasks	2019		2020		
		Sep-Oct	Nov-Dec	Jan-Feb	Mar-Apr	May-Jun
Modeling	Optimization of modeling				→	→
Design	Design optimization of RADAR module with ultra-thin GPE package	→				
Demonstration	Fabrication of RADAR module with functional die		→			
Characterization	High frequency characterization of RADAR module			→	→	