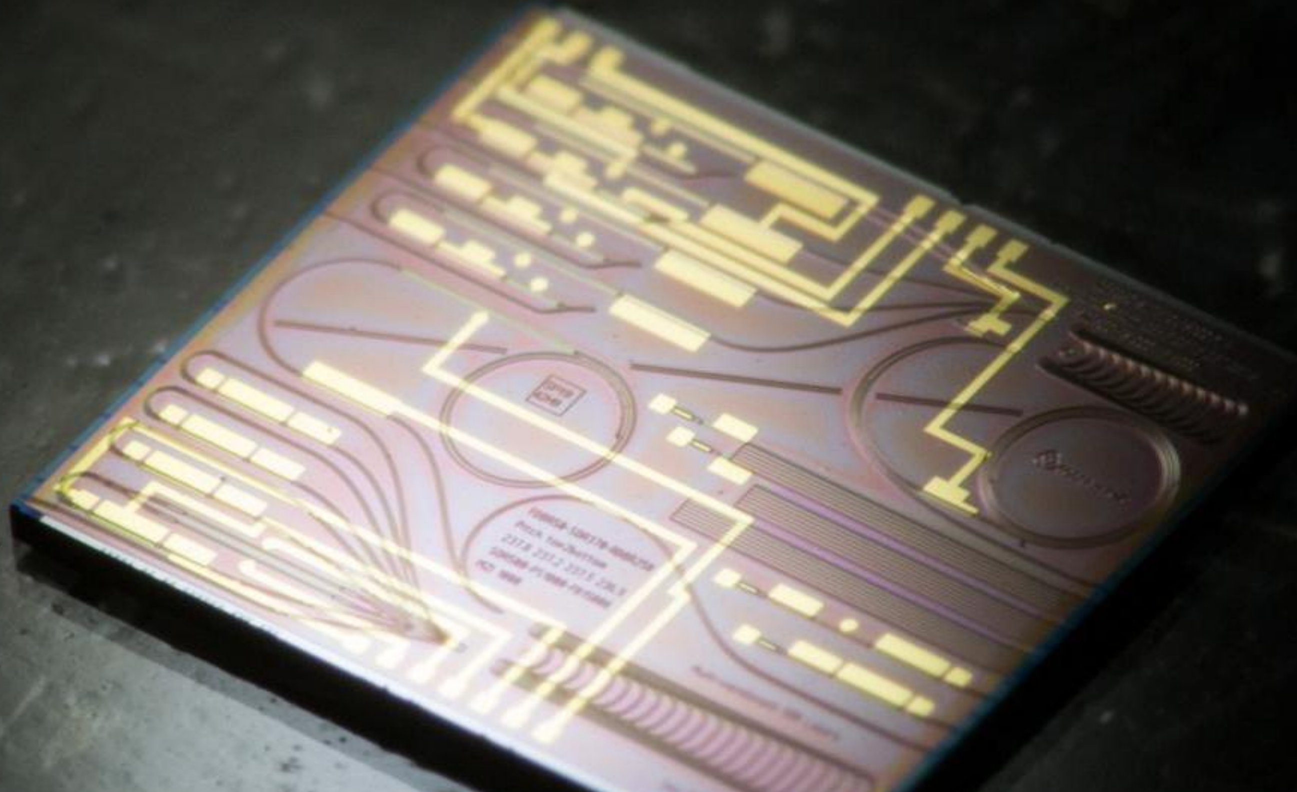
DELO



source: www.eurekalert.org

ADHESIVES PROPERTIES FOR SUCCESSFUL PHOTONIC PACKAGING

Garian Lim – Strategic Business Development Manager

P R RESTRICTED C I S

Outline

DELO

- DELO introduction
- Silicon photonics bonding task and adhesive applications
- Optical coupling evaluation
- Wafer level photonics coupling solution
- Summary

HQ near Munich, Germany

€ 229 M. Revenues in 2024

1,000 employees

2nd production in Malaysia under construction

15 offices across 11 countries

DELO

Outline

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PIC Packaging - Bonding Tasks

Edge Coupling

Cladding

V-Groove Bonding

Optical Coupling

Strain Relief

PIC / EIC / Optical Element Attach

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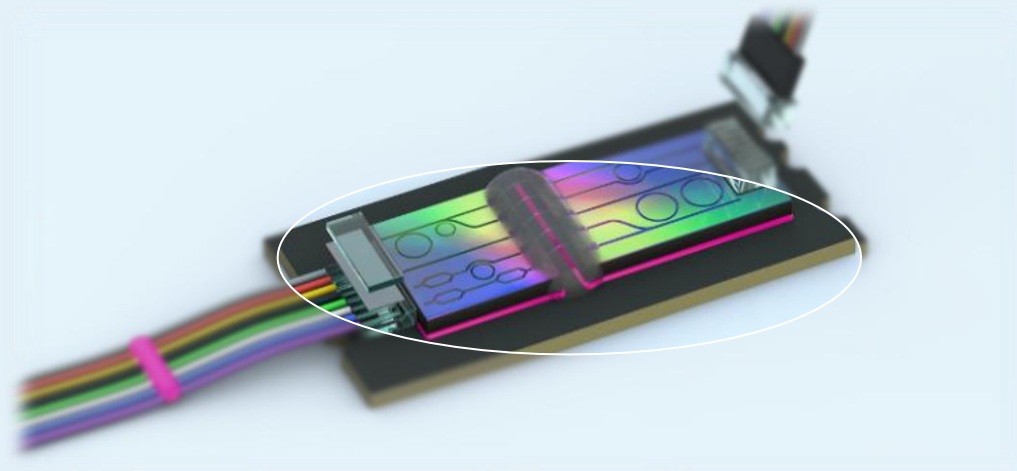
PIC/EIC/Optical Element Attach



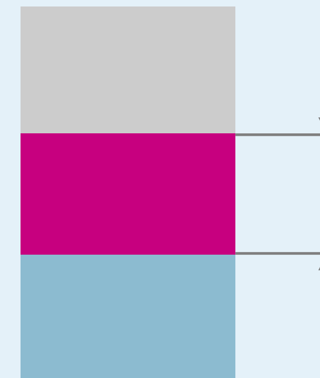
Challenges

- CTE mismatching
- Small bondline thickness (keep R_{th} low)
- Lateral die dimensions mm to cm

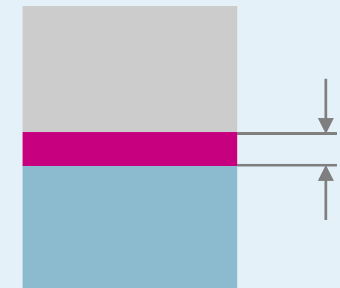
Adhesive key properties

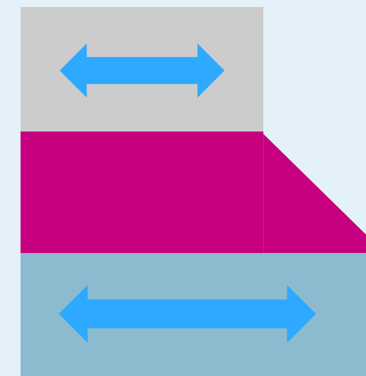
- Flexibility (Young‘s modulus and elongation at tear)
- Adhesion strength
- Thermal conductivity

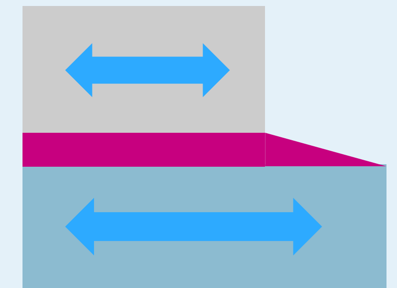
High BLT



Low BLT







Elongation

Low deformation @ adhesive

Elongation

High deformation @ adhesive

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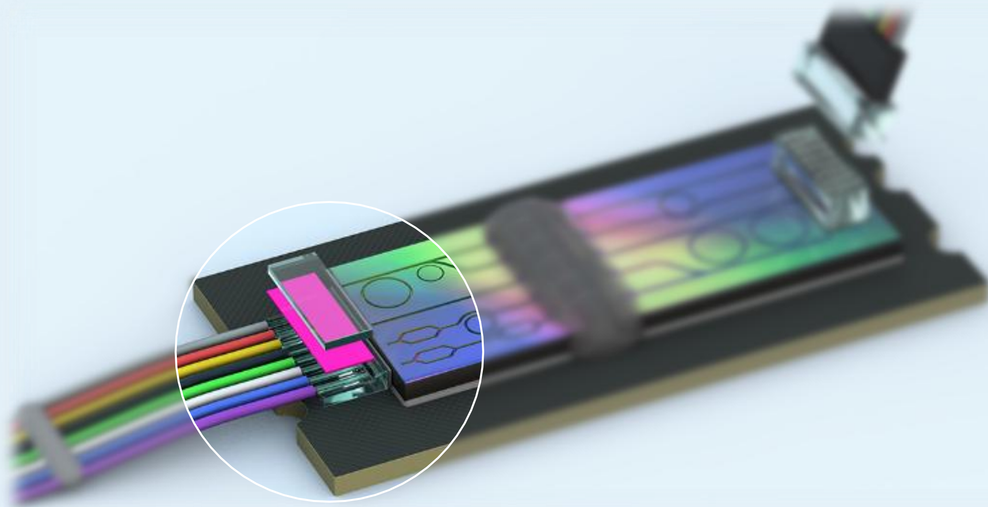
01078

V-Groove Bonding

DELO



Lidless FA

Challenges

- Wetting and flowing
- (Thermo)mechanical stress

Adhesive key properties

- Viscosity
- CTE
- Shrinkage
- Young‘s Modulus
- Water absorption

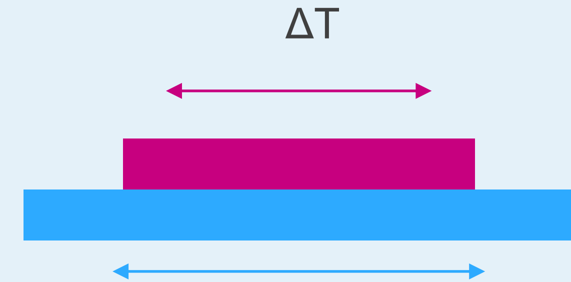
Regular FA

Challenges

- Wetting and flowing
- Delamination

Adhesive key properties

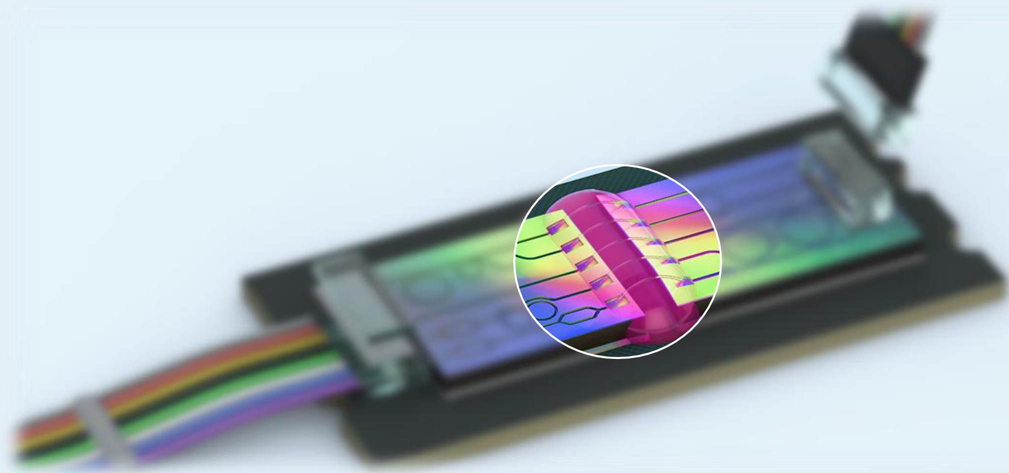
- Viscosity
- Adhesion
- Water absorption

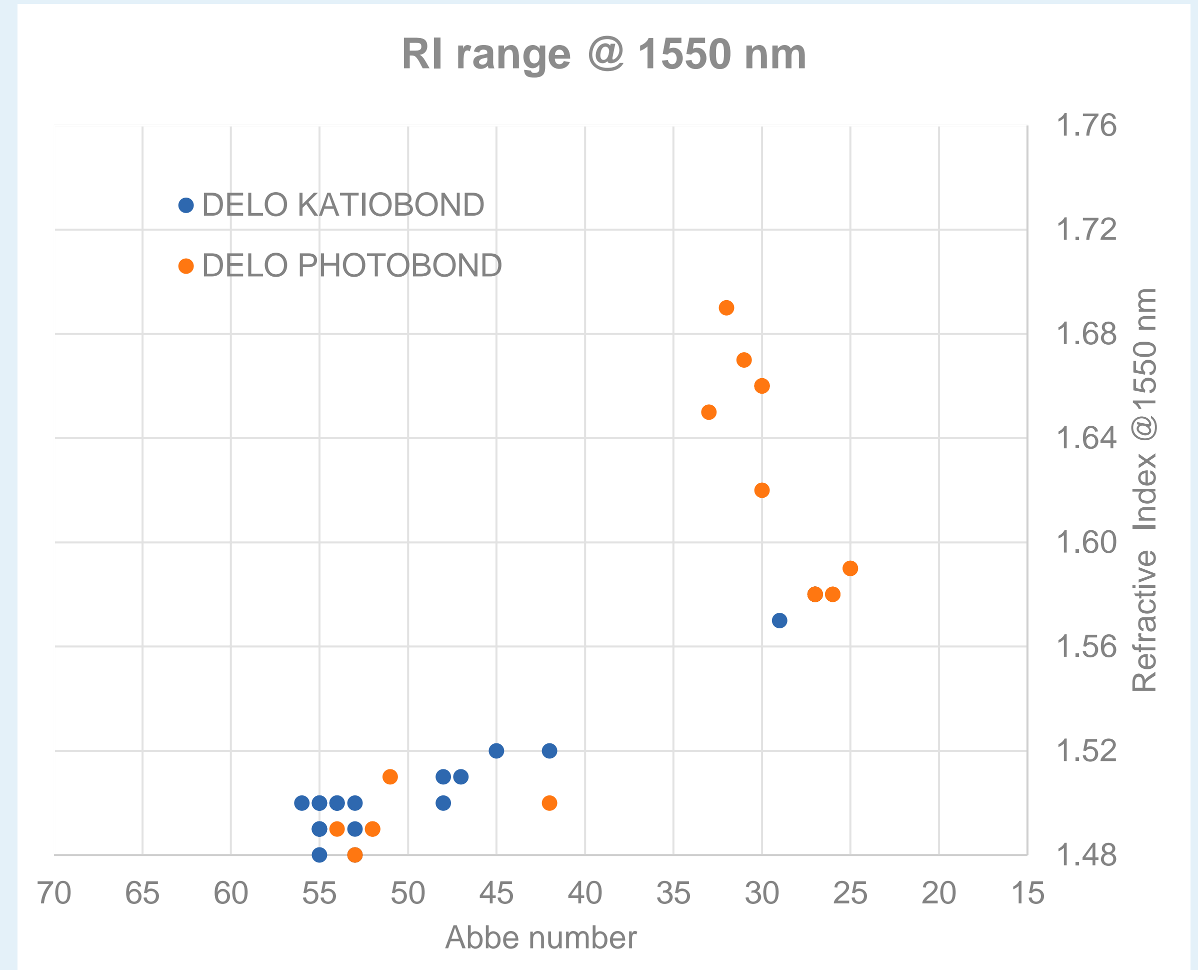


$$\sigma_T = (\alpha_{adhesive} - \alpha_{substrate})*E_{adhesive} * \Delta T$$

- Stress on bonding interface
  → CTE, YM, Tg (because CTE 2 > CTE 1), shrinkage
  low modulus → less stress
  low shrinkage → less stress
  Adjusted (low) CTE → less stress

Cladding





Challenges

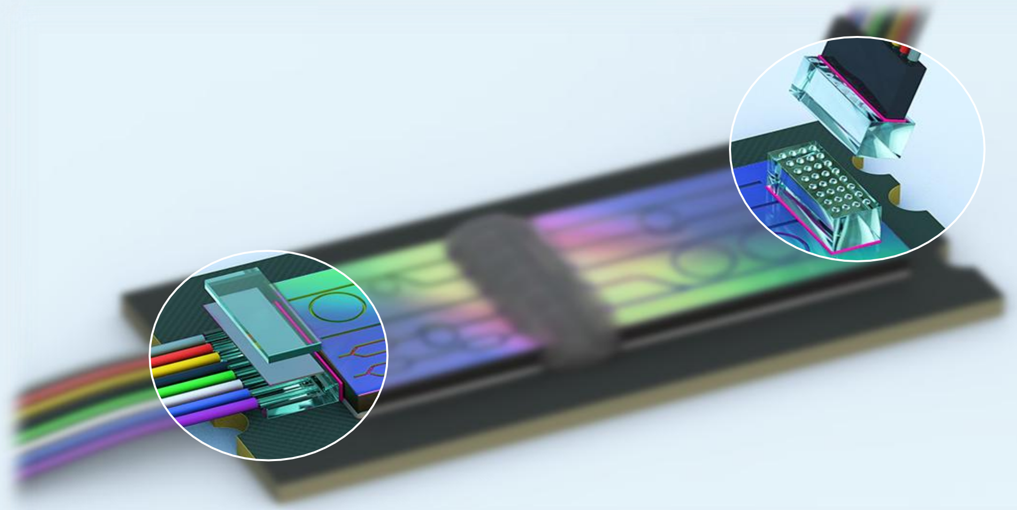
- (Thermo) mechanical stress
- Reliable optical properties

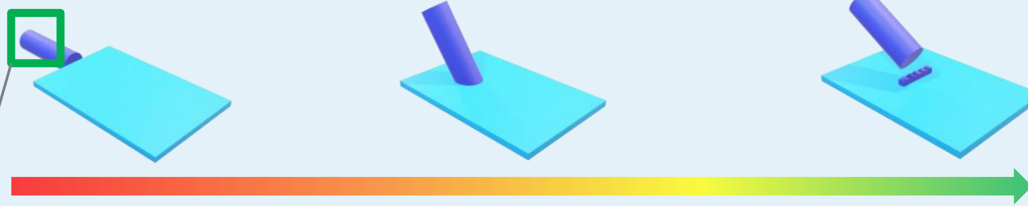
Adhesive key properties

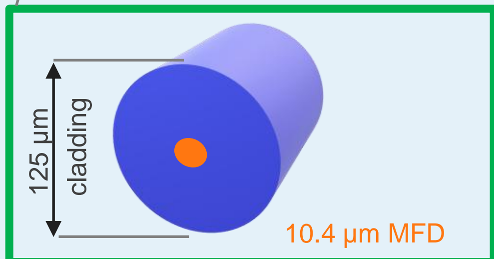
- Shrinkage
- CTE
- Young‘s modulus
- Refractive index
- Water absorption

Optical Coupling

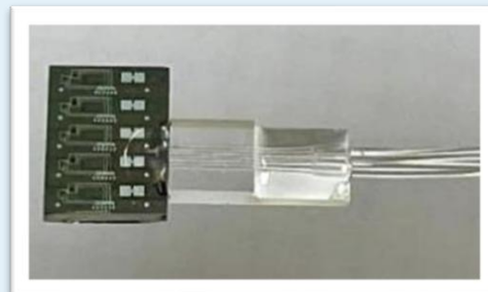
DELO







cross section of a SM fiber



Edge coupling FAU to PIC

Active Alignment Process

- Highly precise alignment → low & even shrinkage, homogenous fillet (shrinkage, viscosity)
- High Processing speed → fast curing, low thermal drift, low post curing (curing speed, enthalpy, fast build up of adhesion, max. curable layer thickness)

Performance & Reliability

- High Coupling efficiency → low signal attenuation (transmission, refractive index)
- Reflow compatibility → no movement or degradation after reflow (T-resistance (optical properties), Tg, CTE)
- TC → no delamination (CTE, bonding strength, Young's Modulus)
- THT → no delamination, no swelling (bonding strength, water absorption)

Photonic Packaging Material Challenge

Mechanical properties

Thermal expansion
Young's modulus
Glass transition temperature

Optical properties

Index of refraction
Transmission
Optical stability

Processing

Shrinkage control
UV curing
Active Alignment

Reliability

Reflow stability
Dimensional stability
Adhesion to substrate

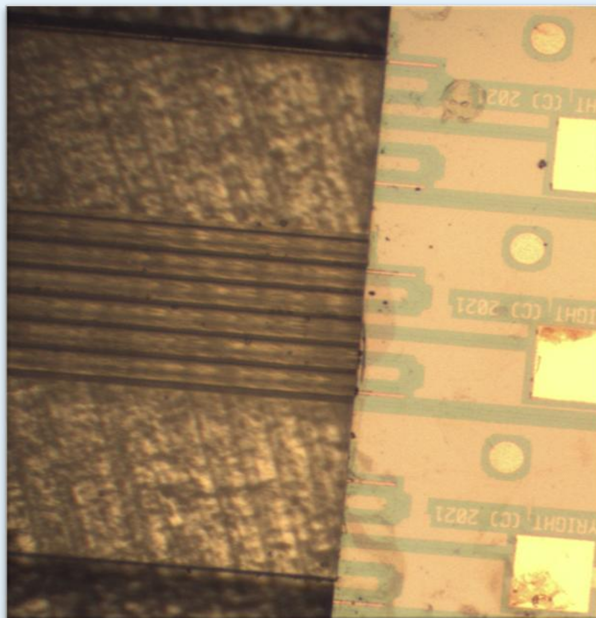
Photonic assembly different from classical packaging assembly

01082

Assembling the parts: Working with a fillet

Without fillet

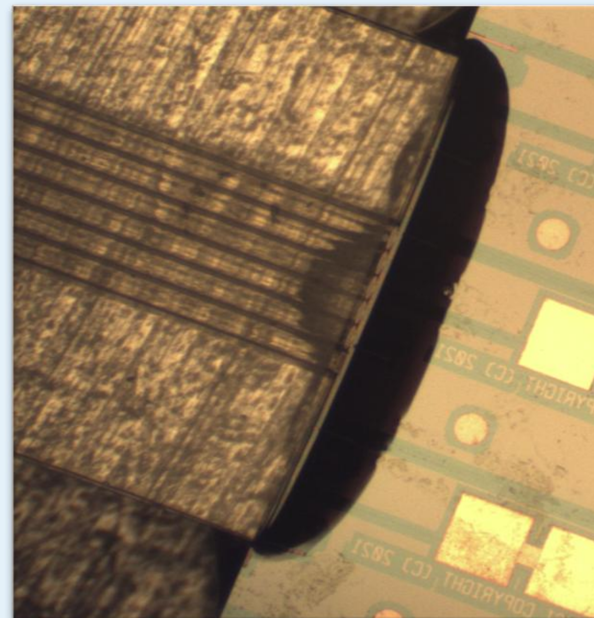
- ✓ Low effect by shrinkage
- x Low bonding area → low bonding strength
- x Hard to realize



Edge coupling without fillet

With fillet

- x Significant effect of shrinkage
- ✓ Supporting bonding strength



Edge coupling with fillet

01083

General Targets

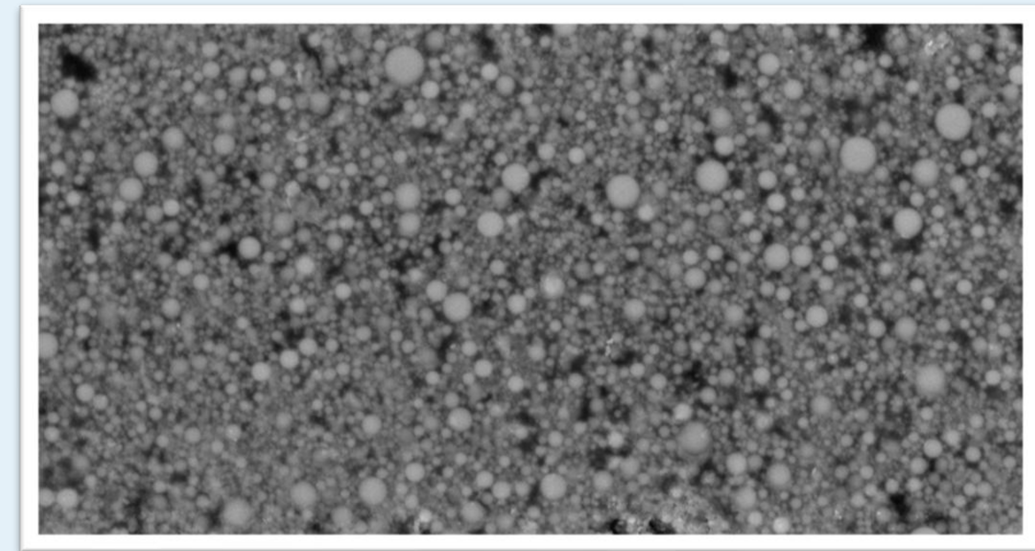
- Low shrinkage
- Low CTE
- High Tg
- **High transmission**
- **RI matching**
- **Reliable bonding strength**
- **Fast curing**

Fillers

DELO

Adding fillers to resin influences mechanical, optical and rheological properties:

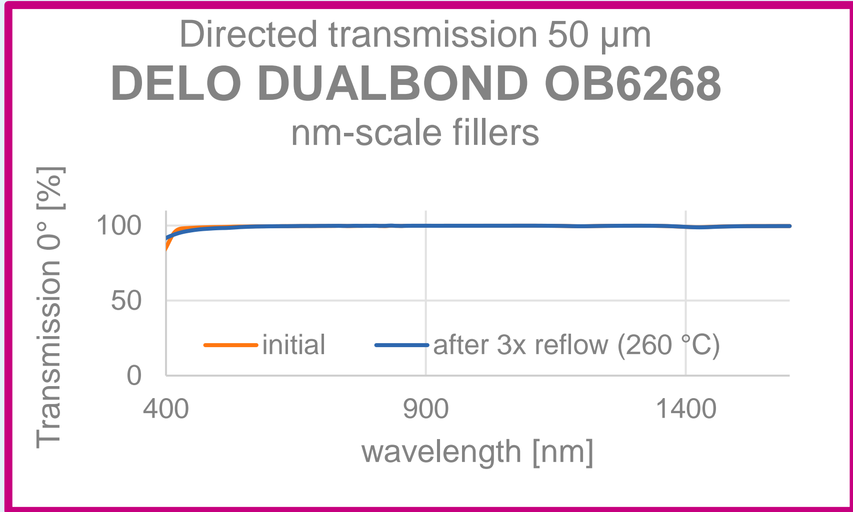
- Shrinkage → Reducing polymer content ($V_{total} = V_{polymer} + V_{fillers}$)
- CTE
- Enthalpy (less exothermic energy)
- Refractive Index
- Transmission
- Young‘s Modulus & hardness
- Viscosity
- Adhesion

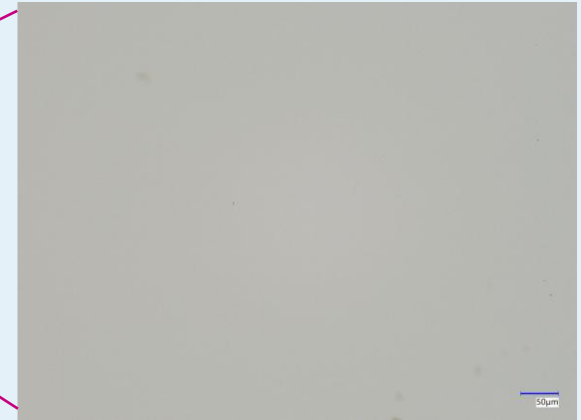


µm-sized SiO_2 fillers in epoxy-based adhesive

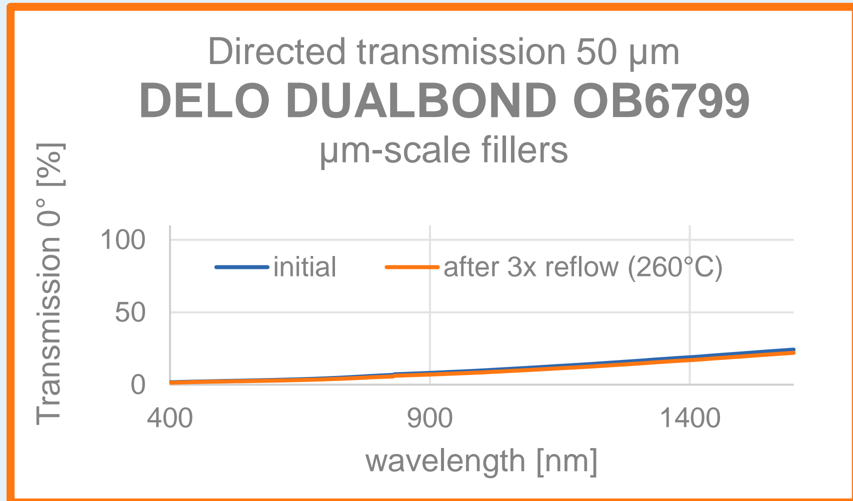
- Typical fillers: SiO_2, TiO_2, ZrO, Ag, Ni, polymer

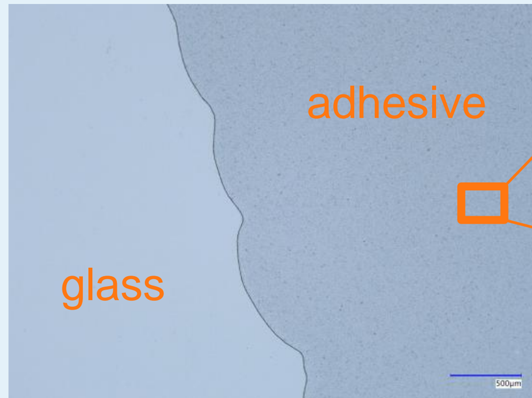
Nano scale vs. micro scale





OB6268 nano-sized fillers





01085

OB6799 micro-sized fillers

Temperature Impact

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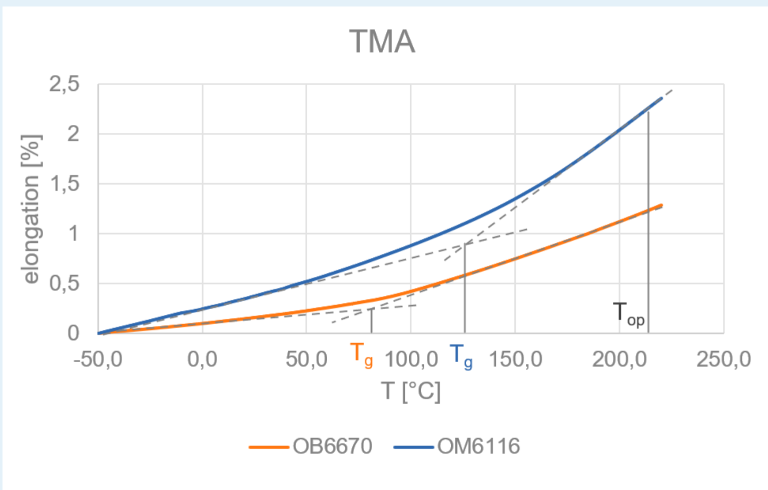
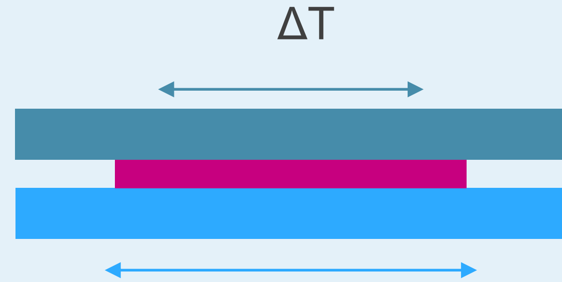
Misalignment

Why high T_g?

- In general: α2 > α1
- More essential:
  CTE @ T_{op} as low as possible



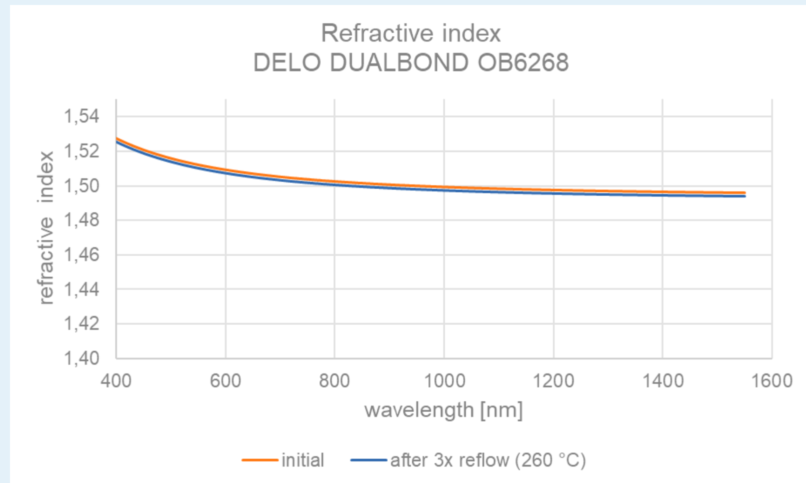
Delamination

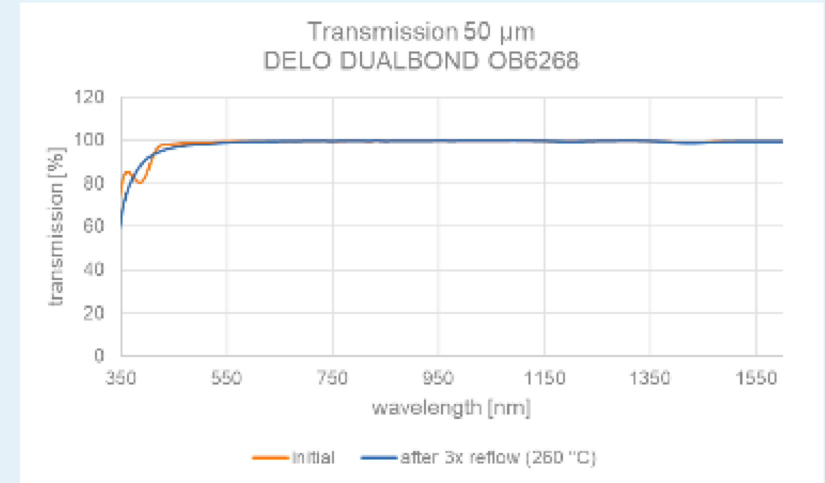


- CTE mismatch: stress on adhesive
- Young‘s Modulus
- Adhesion strength

Optical reliability

- Refractive Index
- Transmission





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01086

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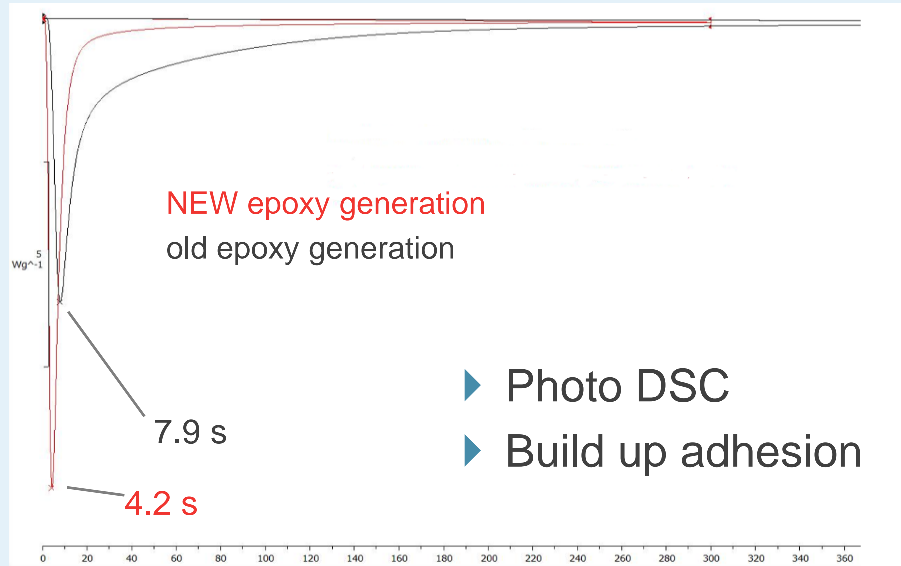
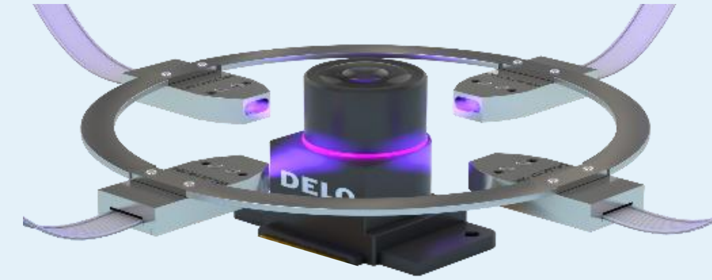
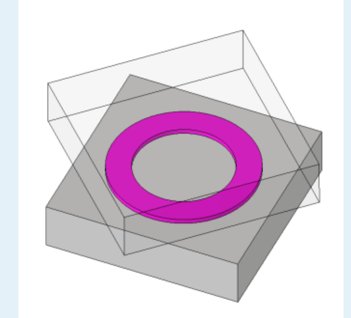
Curing speed



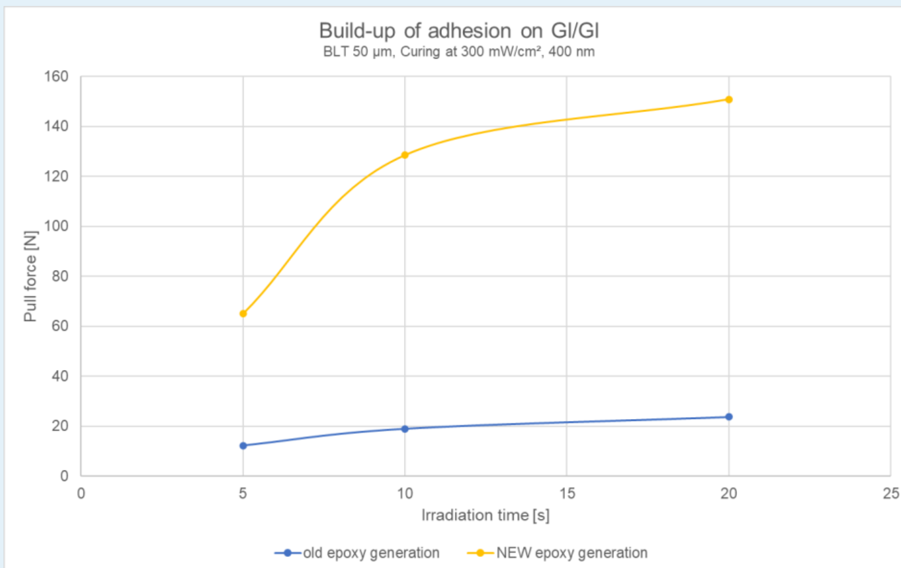
- Photo DSC
- Build up adhesion



4-sided curing with DELOLUX504 (365 or 400 nm)



Crossed lap joints for pull-off test



Why does it matter?

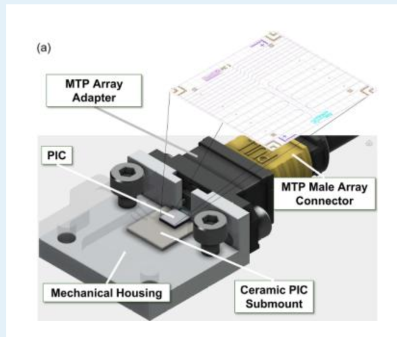
- UPH
- More important: Post shrinkage

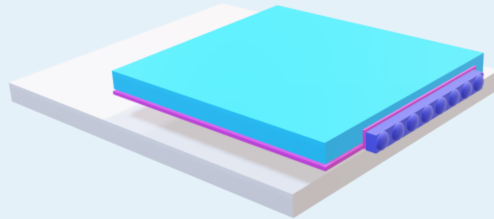
DELO µlens to PIC Assembly

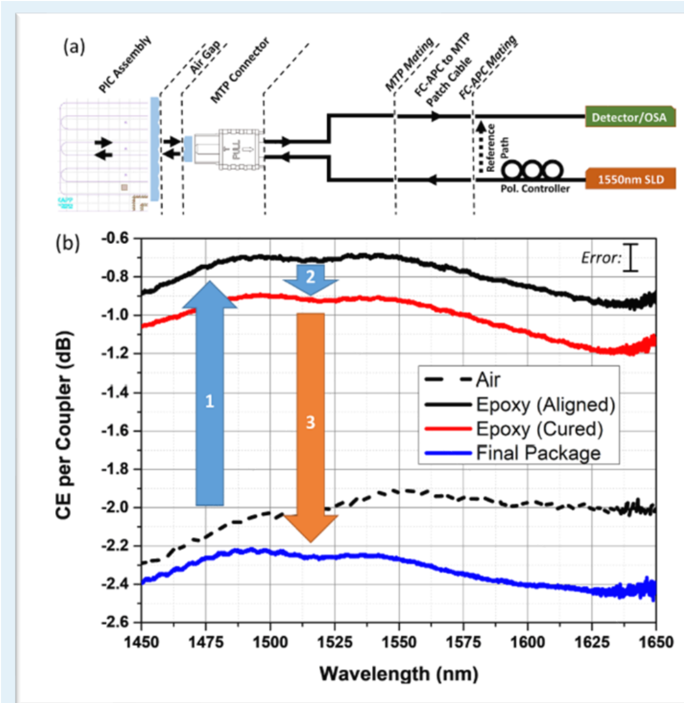
- iNEMI program: Module with Separable Single-Mode Expanded-Beam Optical Interface for Edge-Coupled PIC Optics

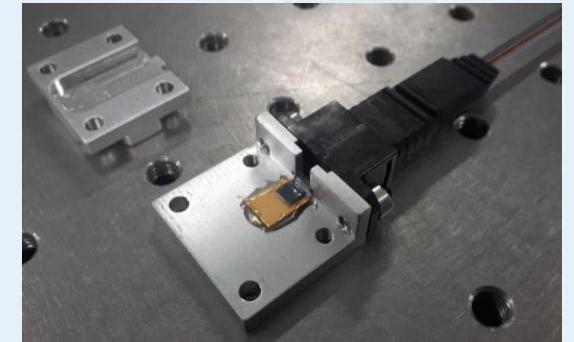
DELO DUALBOND OB6268

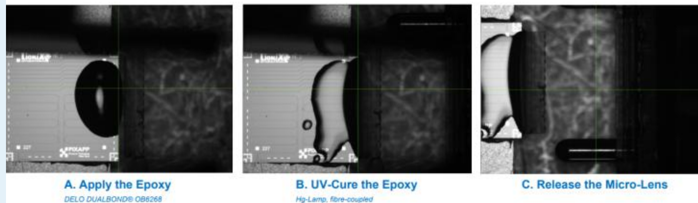
1) µ-lens to PIC (AA)
2) Submount to housing (AA)











- Only **0.2 dB loss** by shrinkage (2)
- 1.3 dB loss by final packaging (3) → not optimized

Demonstration of a Single-Mode Expanded-Beam Connectorized Module for Photonic Integrated Circuits

K. Gradkowski et al. Journal of Lightwave Technology Vol. 41, No. 11 (2023)

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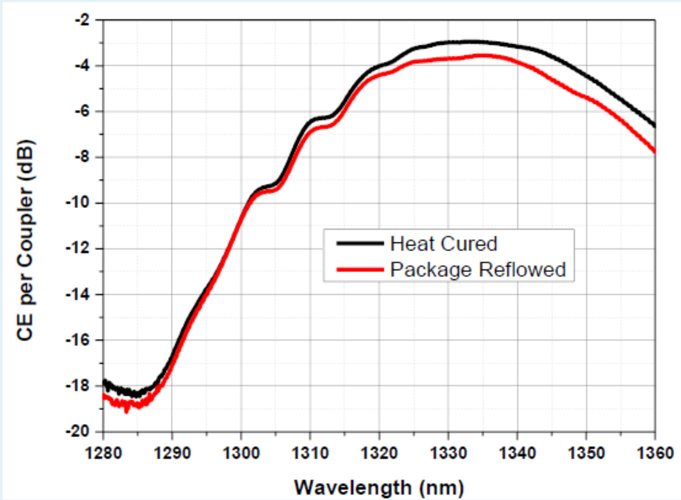
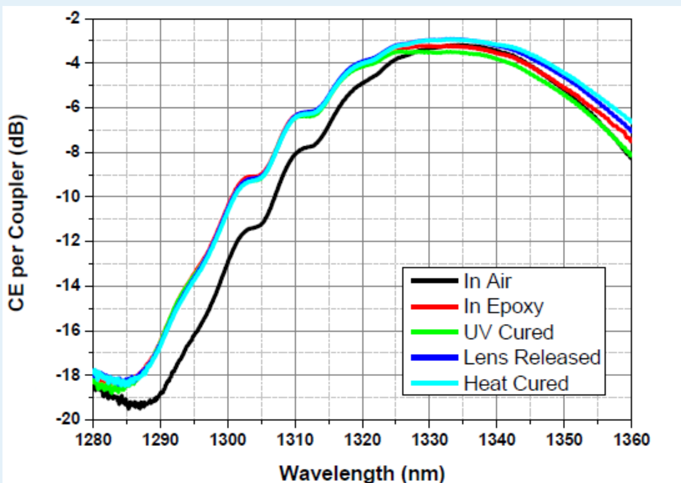
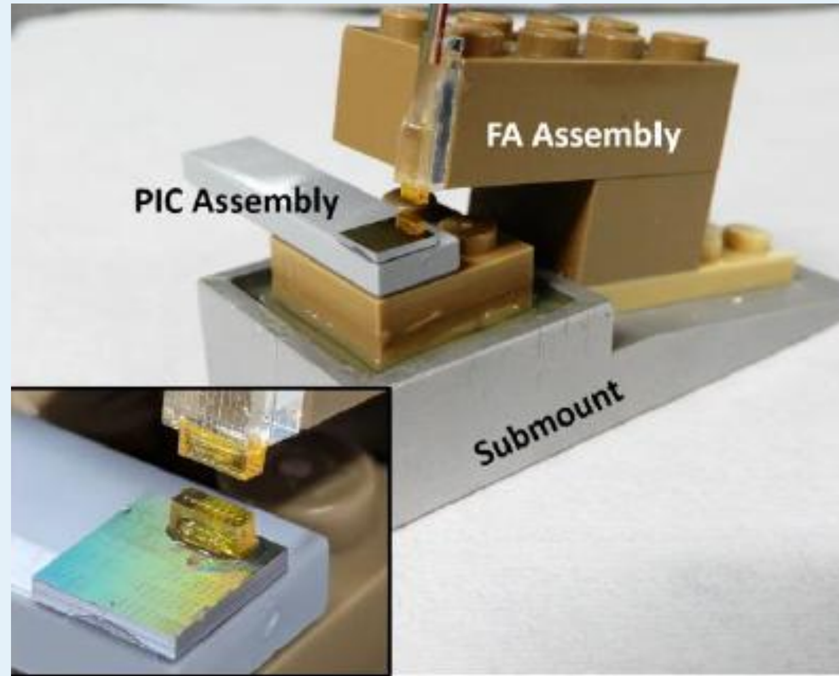
DELO μlens to PIC Assembly

DELO

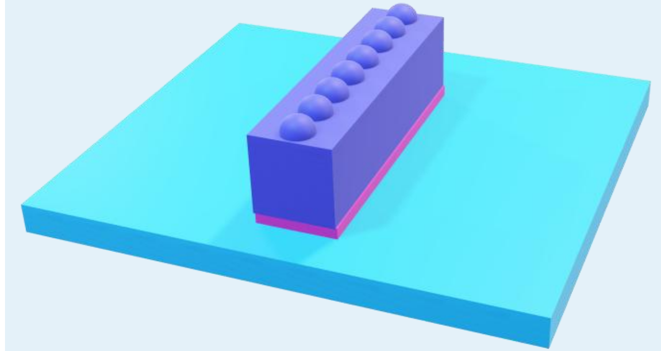






DELO DUALBOND OB6235

1) μ-lens to PIC (AA)
2) μ-lens to FAU (AA)



- **0.3 dB loss** by shrinkage
- **0.7 dB** CE decrease per coupler after reflowing the whole package

Solder Reflow Resistant Thermoplastic for Optical Coupling
K. Gradkowski et al. IEEE Transactions on Components, Packaging and Manufacturing Technology (2024)

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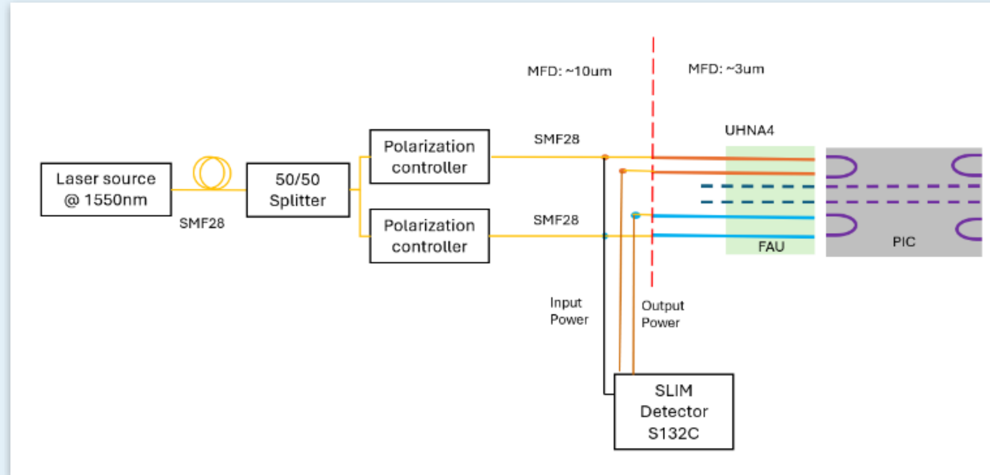
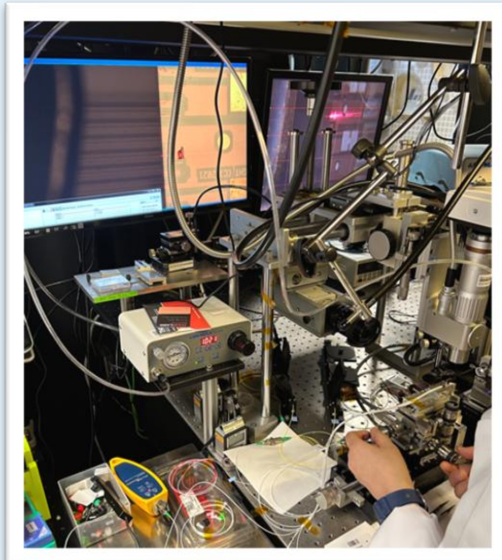
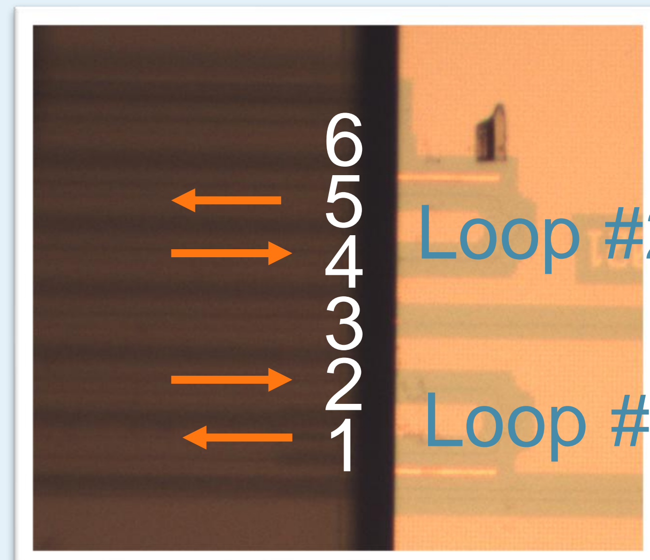
Edge coupling – Fast curing epoxy

DELO





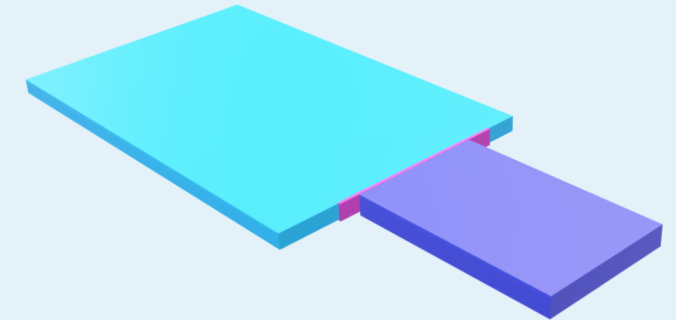


FAU to PIC edge-coupling

01091

DELO DUALBOND D2

1) FAU to PIC



- Highly filled (nm)
- High T_g (172 °C)
- Very fast curing
  (Photo-DSC Peak 4.5 s)

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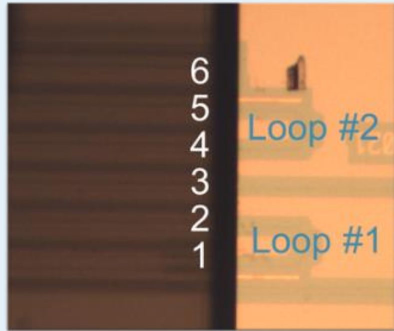
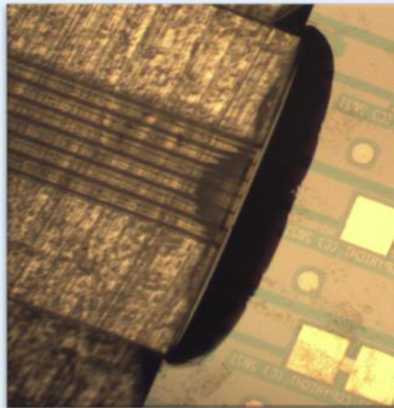
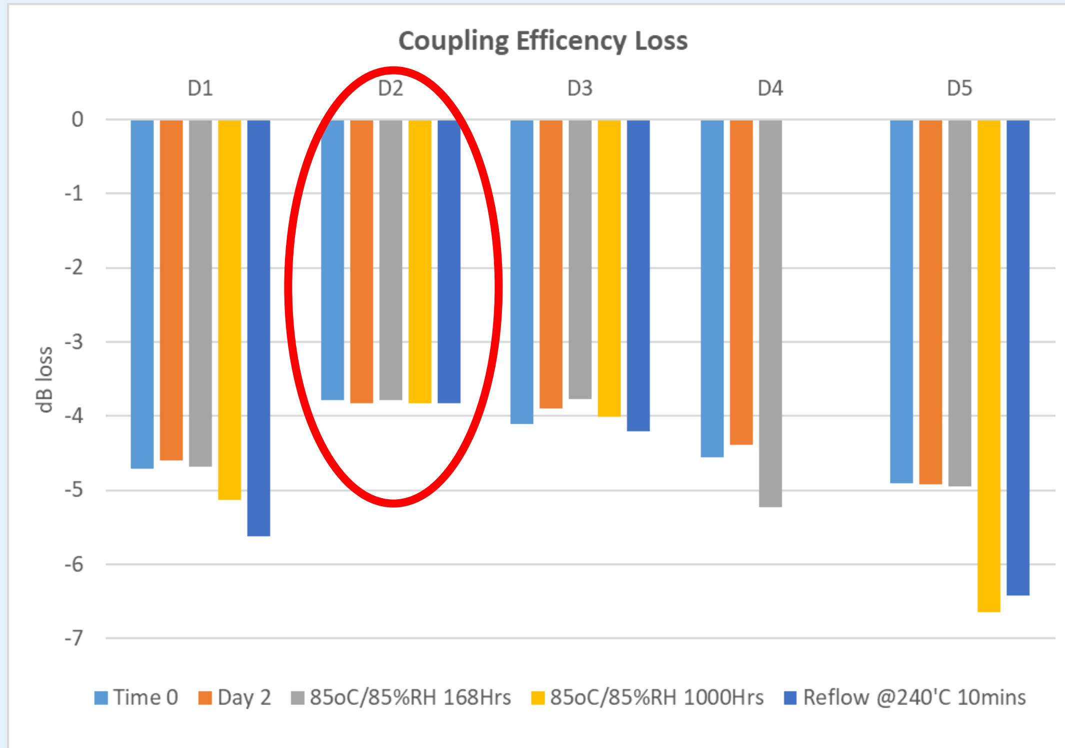
Edge coupling – fast curing epoxy

DELO

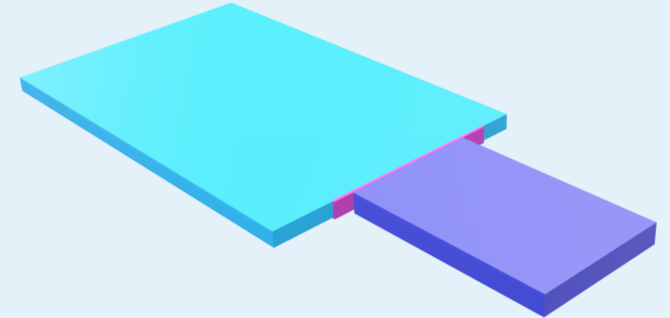






DELO DUALBOND D2

1) FAU to PIC



	Coupling efficiency [dB]	
	loop #1	loop #2
Before curing	-3.73	-3.79
After curing	-3.73	-3.84
After release	-3.73	-3.84
After 24 h	-3.76	-3.81
After 1000 h 85/85	-3.72	-3.94
After Reflow 240'C 10mins	-3.74	-3.90

- High curing speed results in low postcuring
- Very low loss after rel.-testing

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Wafer Level Photonics – Edge coupling concept

EIC EIC PIC PIC EIC EIC PIC PIC

Carrier wafer

UV adhesive to encapsulate and protect

UV adhesive to secure and protect

Carrier wafer

Molding of wafer

Carrier wafer

Carrier wafer

Debonding of carrier wafer

Solder ball attach

Wafer sawing

Wafer saw through UV adhesive to create "window"

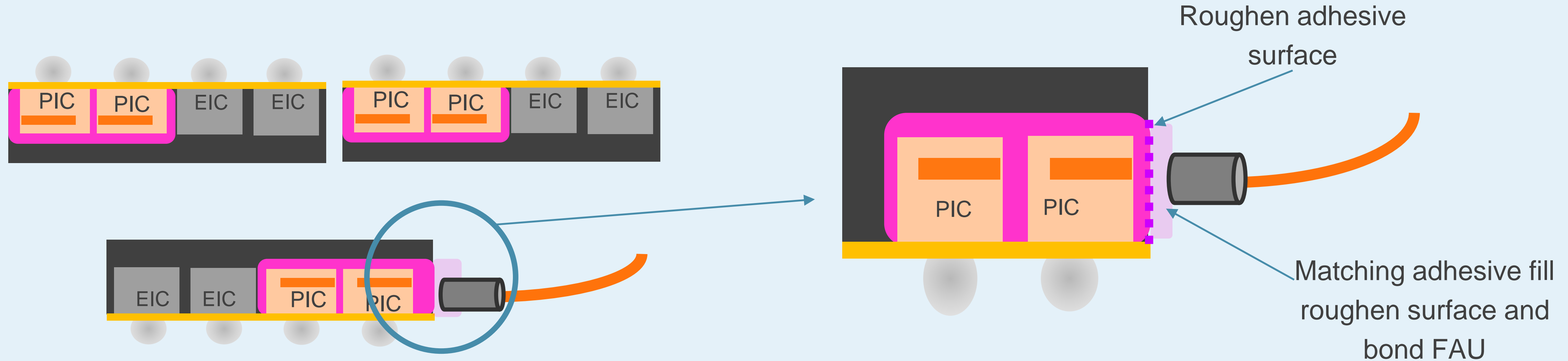
DELO adhesive create a "window" for optics coupling after sawing for classically FAU bonding process

Using the same encapsulant epoxy for coupling bonding to cover the edge roughness from sawing process and for best RI matching in standard AA process

01094

Wafer Level Photonics

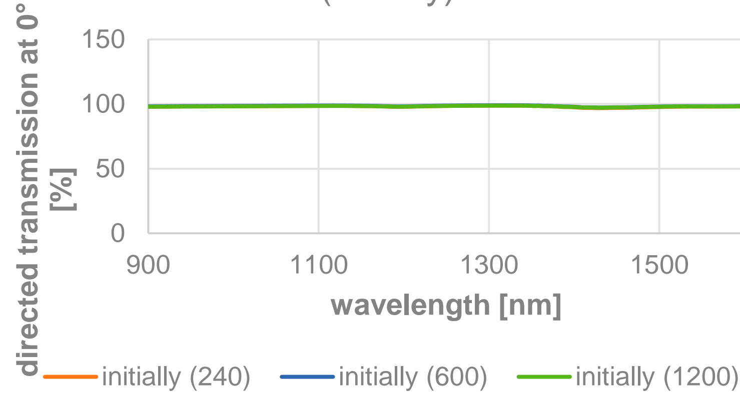
DELO

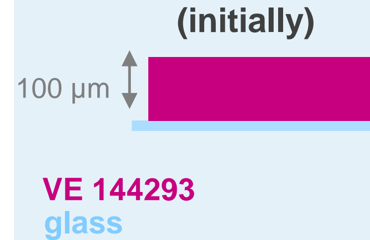


- Adhesive side-wall is roughened due to sawing or grinding process
  - » Reduce optical transmission and create reflection/refraction losses
- Matching adhesive used to bond and fill roughen surface
- Eliminate expensive and time-consuming polishing process
- Single step fiber bonding with coupling surface improvement
  - » Eliminate uneven surface due to processing
  - » Improve transmission and reduce losses

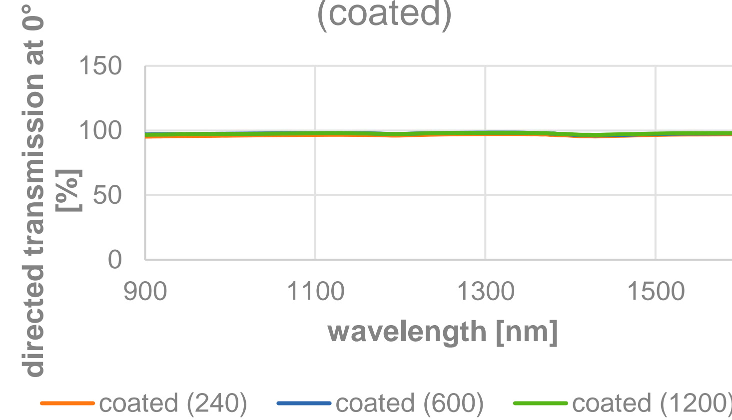
DELO DUALBOND VE 144293 & VE 144674

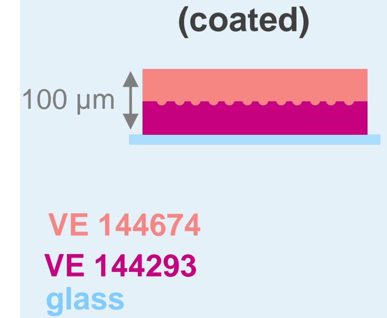
DELO



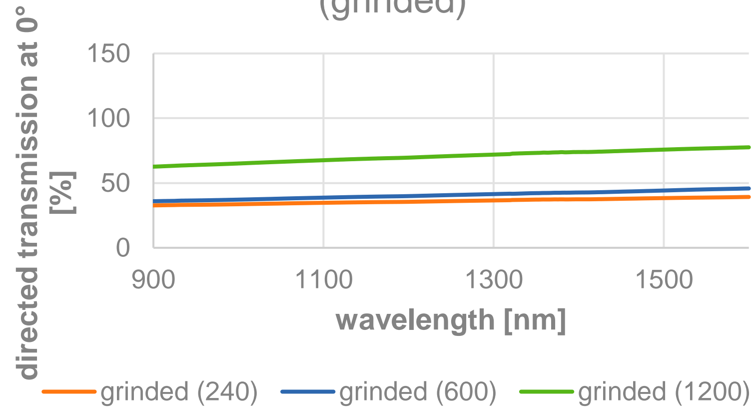


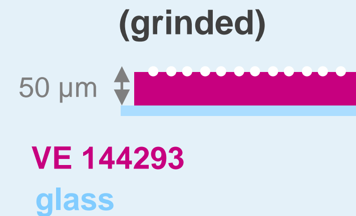
VE 144293
glass





VE 144674
VE 144293
glass





VE 144293
glass

Transmission @ **1310 nm** [%]			
grainsize	initially	grinded	coated
P240	98,8	36,6	97,3
P600	99,0	41,6	98,3
P1200	98,8	72,1	98,2

Transmission @ **1550 nm** [%]			
grainsize	initially	grinded	coated
P240	98,0	38,8	96,9
P600	98,3	45,1	97,6
P1200	98,2	76,7	97,8

Matching adhesive can recover transmission lost

Outline

DELO

- DELO introduction
- Silicon photonics bonding task and adhesive applications
- Optical coupling evaluation
- Wafer level photonics coupling solution
- Summary

Summary

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- PIC packaging is technically challenging
- Adhesives play a crucial role
- Adhesives must be carefully selected matching the requirements (process & reliability)
- Adjusting of adhesive properties by chemistry and fillers
- DELO offers adhesive-solutions for various bonding applications (i.e. DELO DUALBOND OB6268 for optical coupling)
- We are open for collaborations!

Visit us at booth # 600

We Are Where You Are

- DELO with engineering lab
- DELO office
- DELO covered countries

Germany · Windach / Munich

China | Czechia | France | Italy | Japan | Korea
Malaysia | Singapore | Thailand | USA

Discuss your project and get in contact with our team:
photonics@delo.de