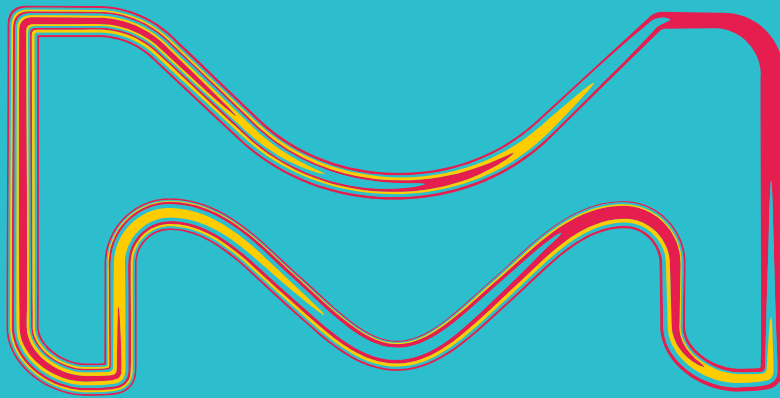


Advanced packaging dielectric for 5G

**Combining low-Dk properties with fast
processing and low temperature curing**

Pawel Miskiewicz, Gregor Larbig, Noboru Satake,
Jens Pradella, Frank Meyer, Matthias Koch



EMD
ELECTRONICS

Agenda

1. Current challenges
2. Material concept and UV-only cure
3. Materials properties
4. Photolithography
5. Reliability
6. Conclusions



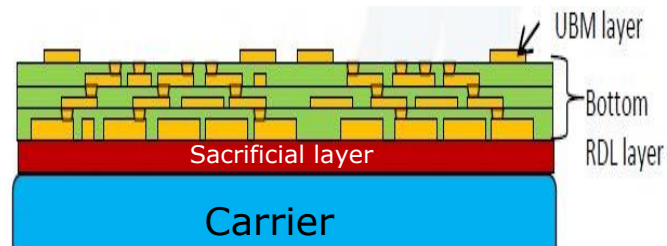
Pawel Miskiewicz
Senior Manager the Electronics business
of Merck KGaA, Darmstadt, Germany
Received PhD and MSc in Technology of
Polymers at Faculty of Chemistry, Lodz
University of Technology in Poland.



Current challenges

Current material sets and associated assembly processes have been at their limits

New generation of polymers dielectrics is required



**Direct high-resolution litho
and low stress materials**



$$\text{Dielectric loss} = K \times f \times \sqrt{Dk} \times Df$$



Current challenges

Polymer designs

Challenge	Material properties
Low stress	Low CTE
	Low cure temperature
	Good interface adhesion
	High elongation at break
	Low shrinkage
Fine feature size (L/S and via)	Direct photo-patternability
	Good planarization
5G+	Low and stable Dk and Df through varied humidity conditions

Novel dielectric insulating materials and approach to their application procedures are required to address these properties.



performance, yield, and reliability

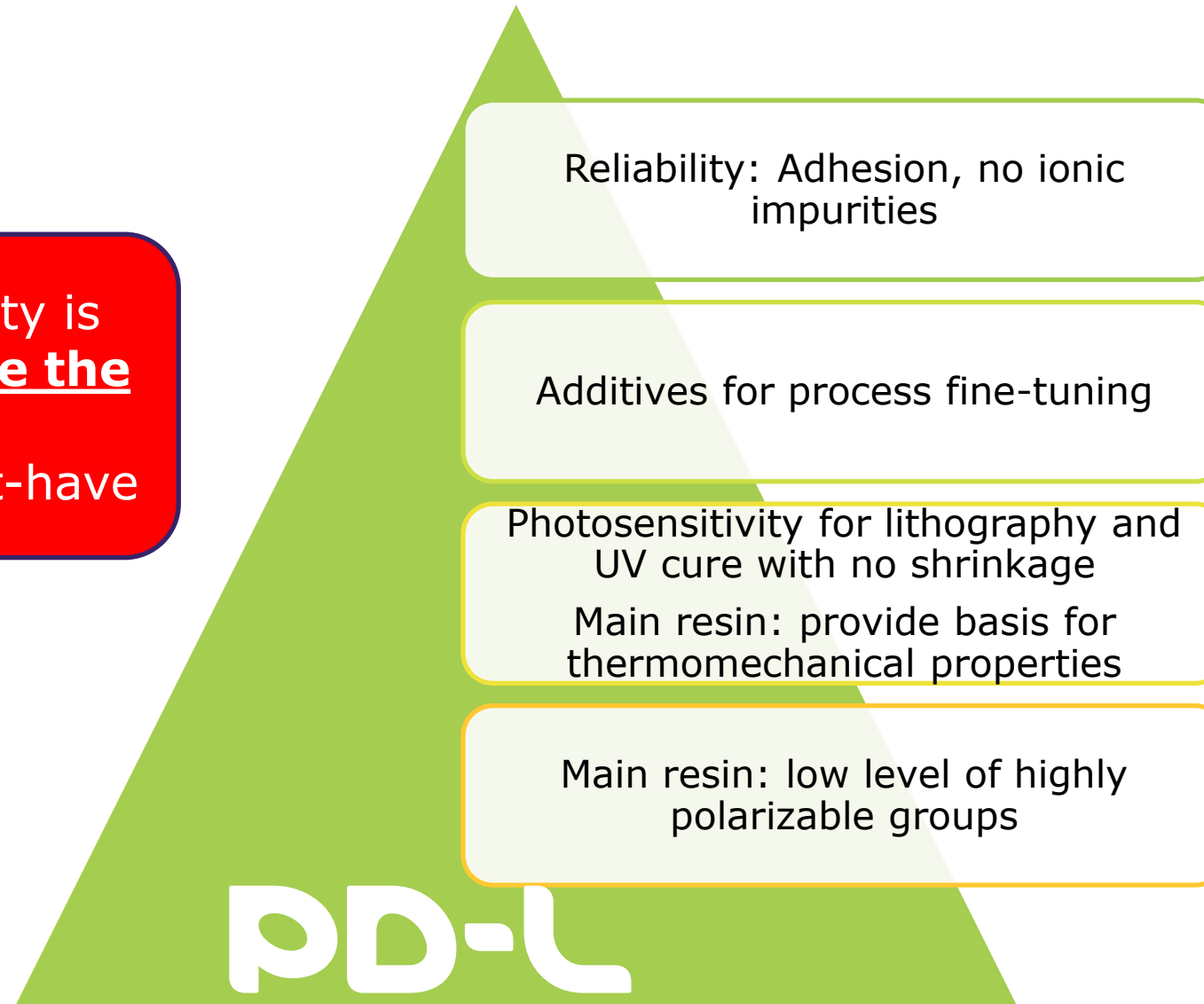
Advanced packaging and **heterogeneous integration** require dielectric materials with cutting edge electrical **and thermo-mechanical** properties, that will provide **competitive manufacturing** conditions, higher **process yield**, and **improved reliability on large scale substrates**

Our new **low-stress, low-Dk, low loss dielectric**, PD-L for **photo-patterning and non-patterning processes** enables you to design and build advanced packages with reduced warpage yield loss and improved reliability through an **NMP-free** solution

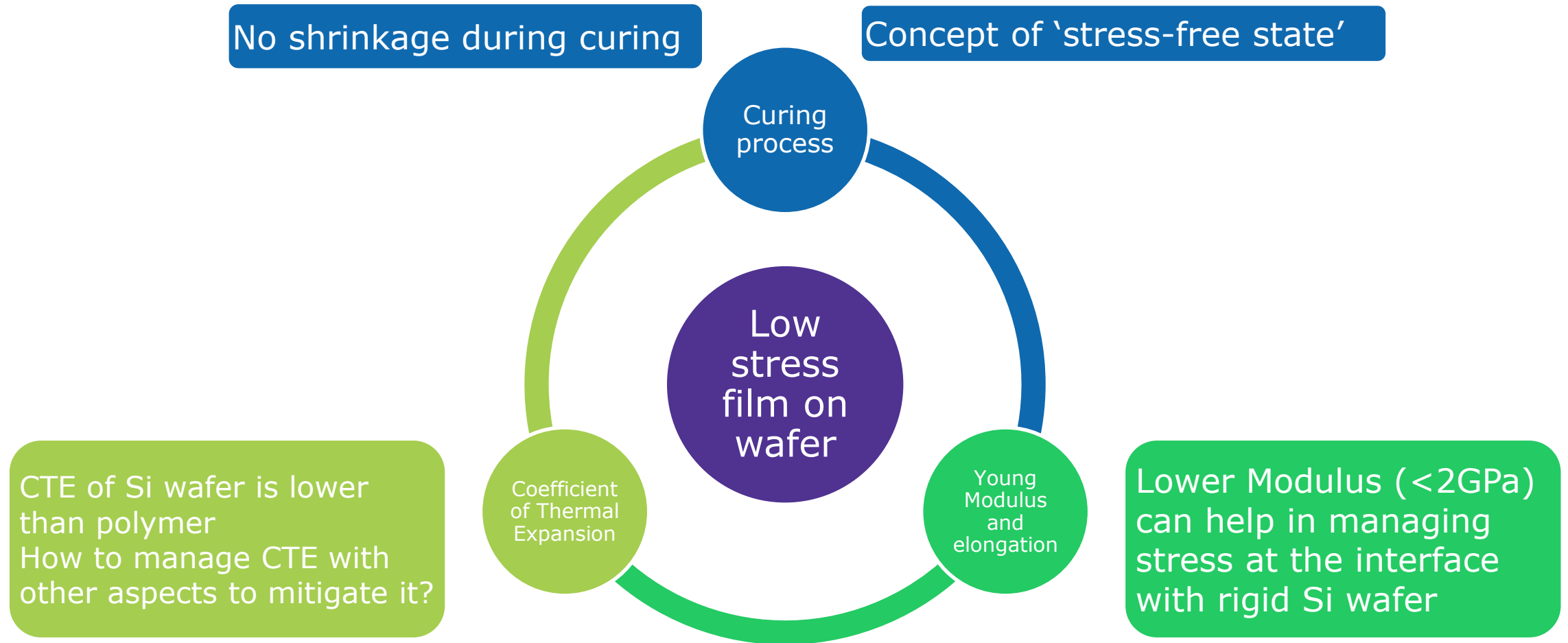


Material concept

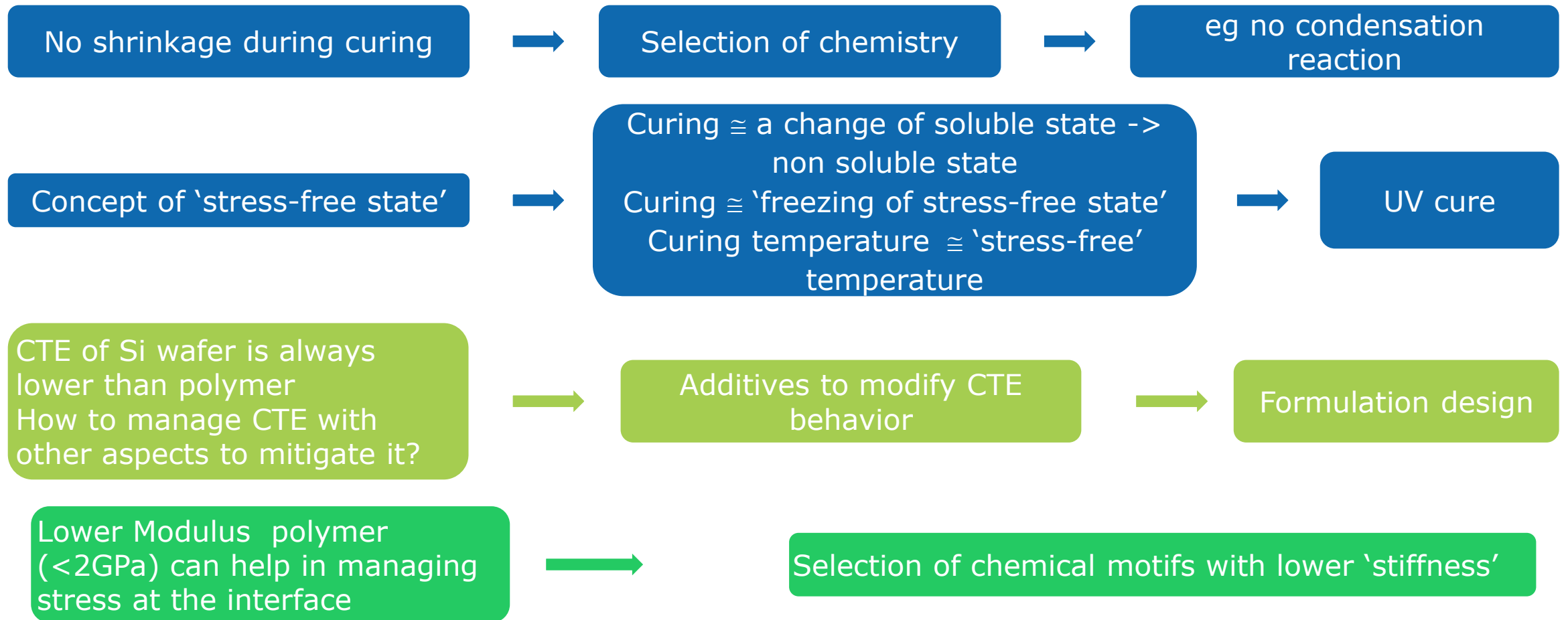
Single chemical entity is
not enough to make the product!
Formulation is a must-have



Material concept – low stress by design



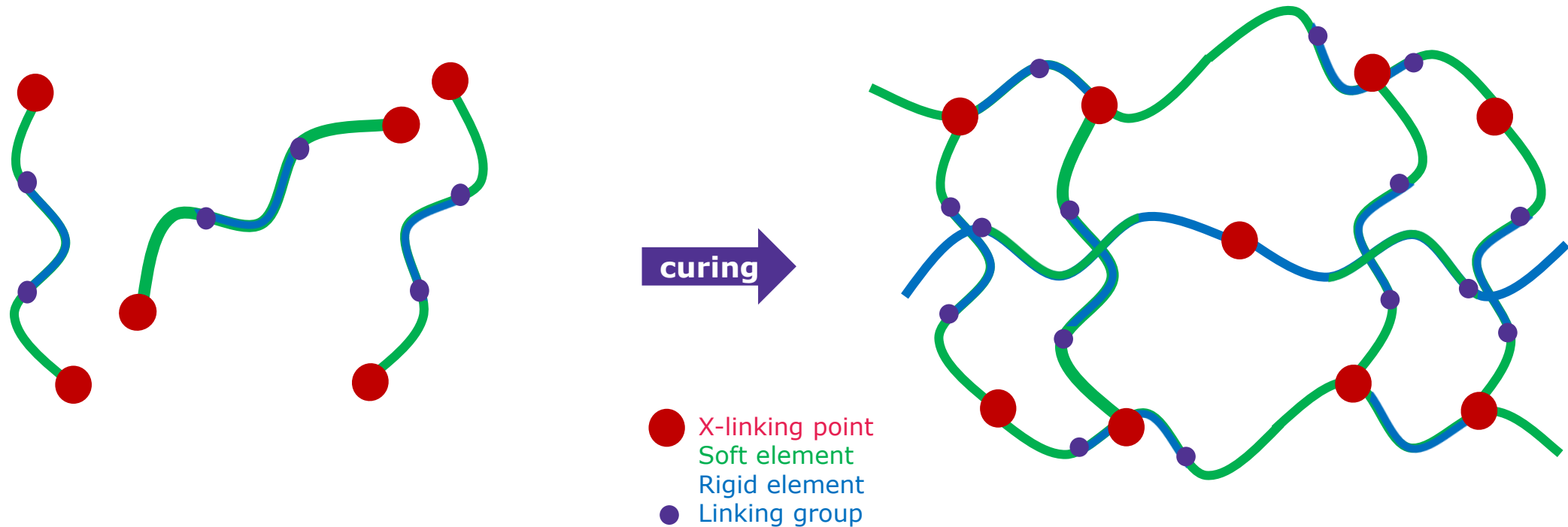
Material concept – low stress by design



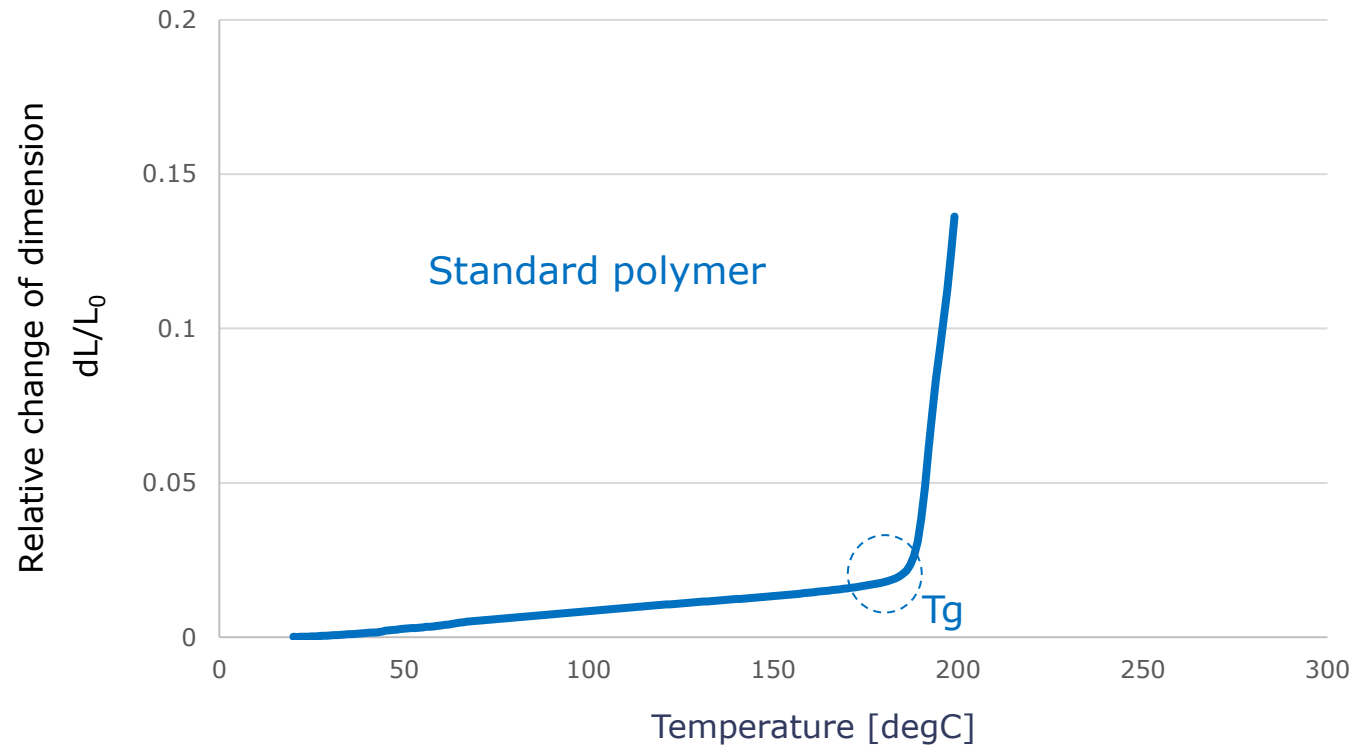
Low stress by design

Polymer architecture perspective

- Low MW precursor with UV-sensitive groups for photolithography and hard cure
- Proprietary design of flexible and rigid elements into the material to achieve unique thermomechanical properties
- Design of composition for balancing film properties



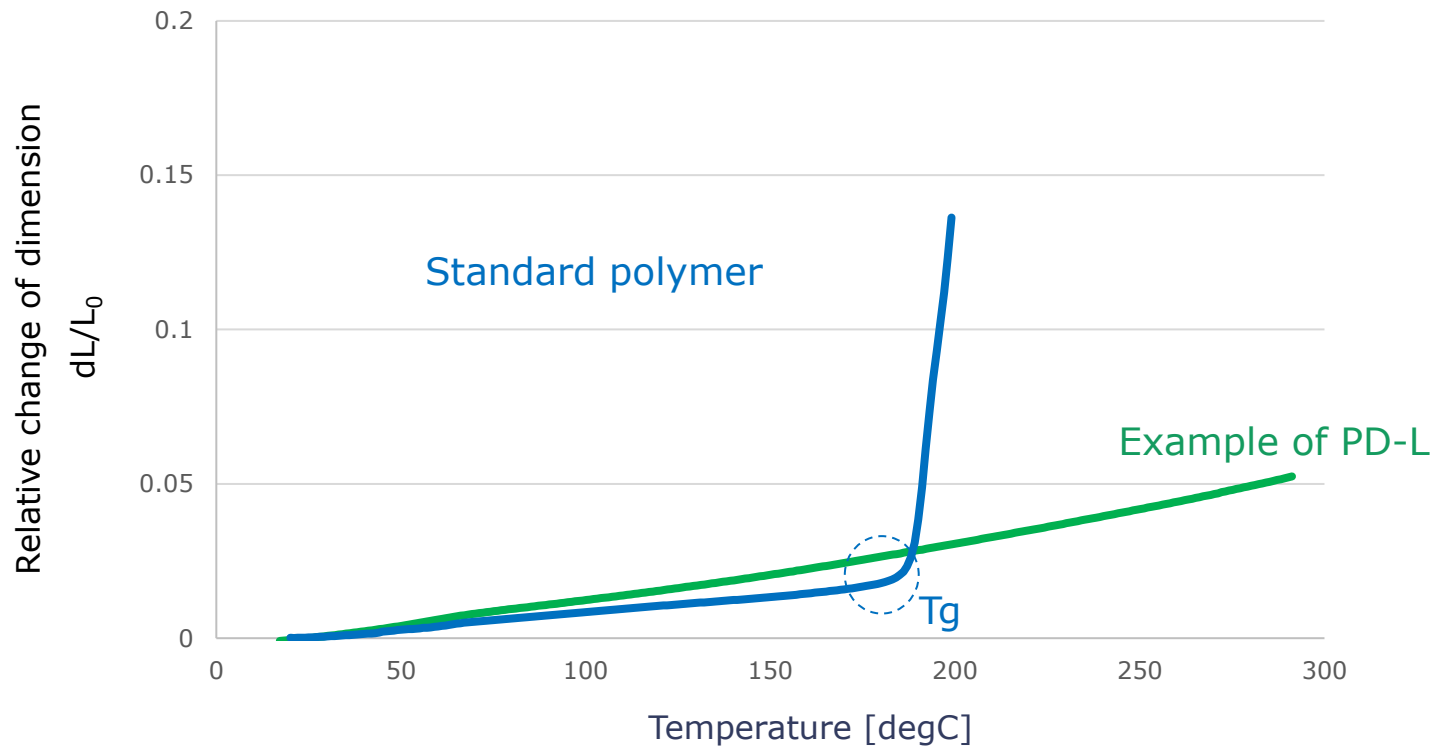
Material properties – CTE of cured film



Standard polymers show significant increase of CTE above Glass Transition



Material properties – CTE of cured film

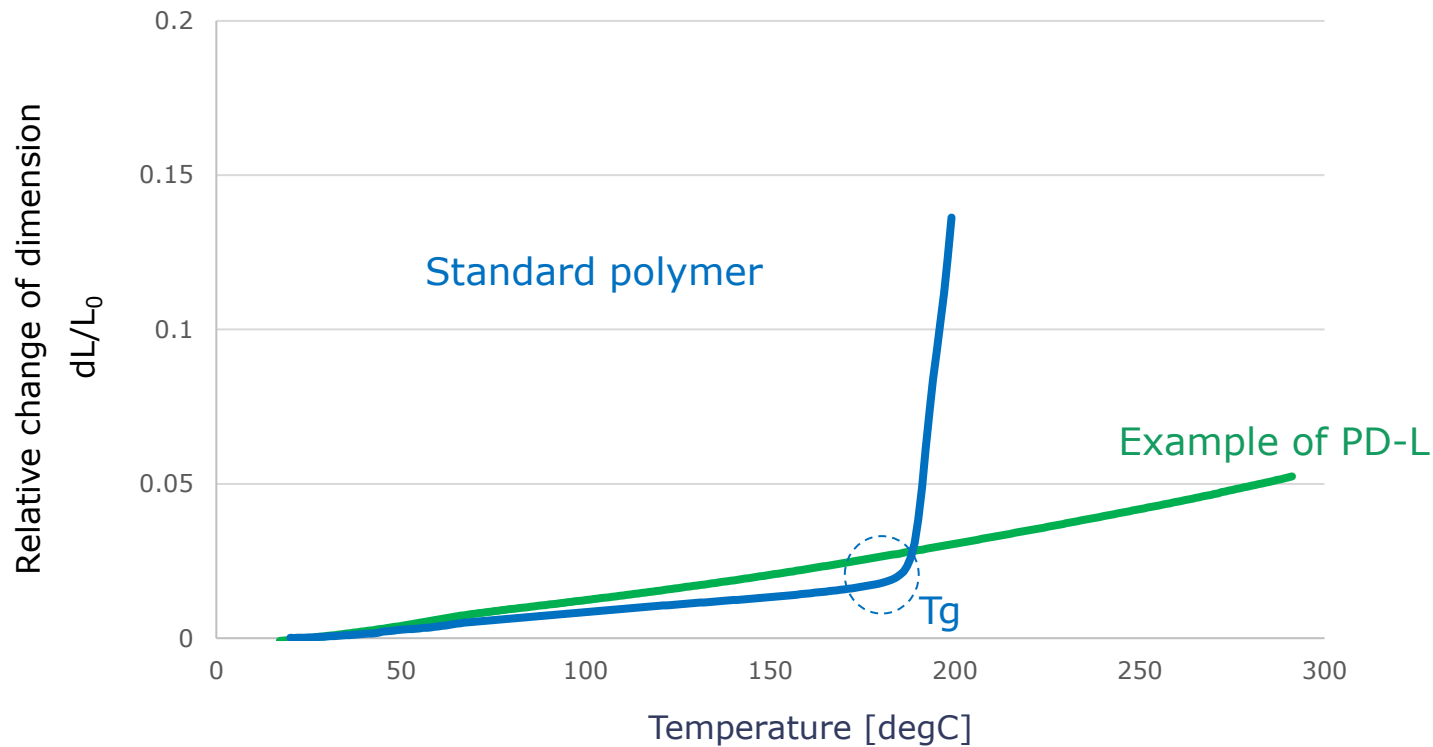


Chemical motifs designed into our PD-L material create unusual thermal expansion behavior:

-> PD-L's CTE is not impacted by T_g , it remains around 100ppm/K for CTE_{a1} (below T_g) and CTE_{a2} (above T_g)



Material properties – CTE of cured film



Chemical motifs designed into our PD-L material create unusual thermal expansion behavior:

-> PD-L's CTE is not impacted by T_g , it remains around 100ppm/K for CTE_{a1} (below T_g) and CTE_{a2} (above T_g)

PD-L enables stress mitigation at elevated temperatures through unique elastic properties

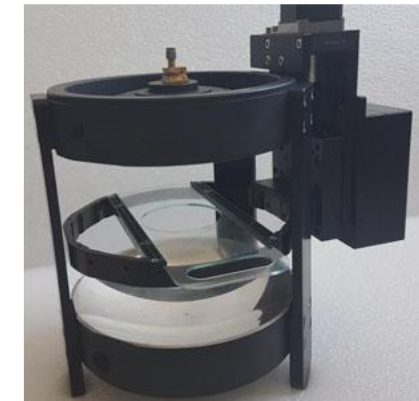
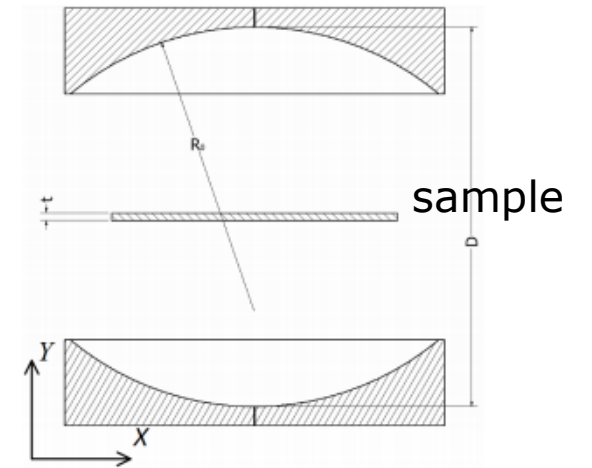
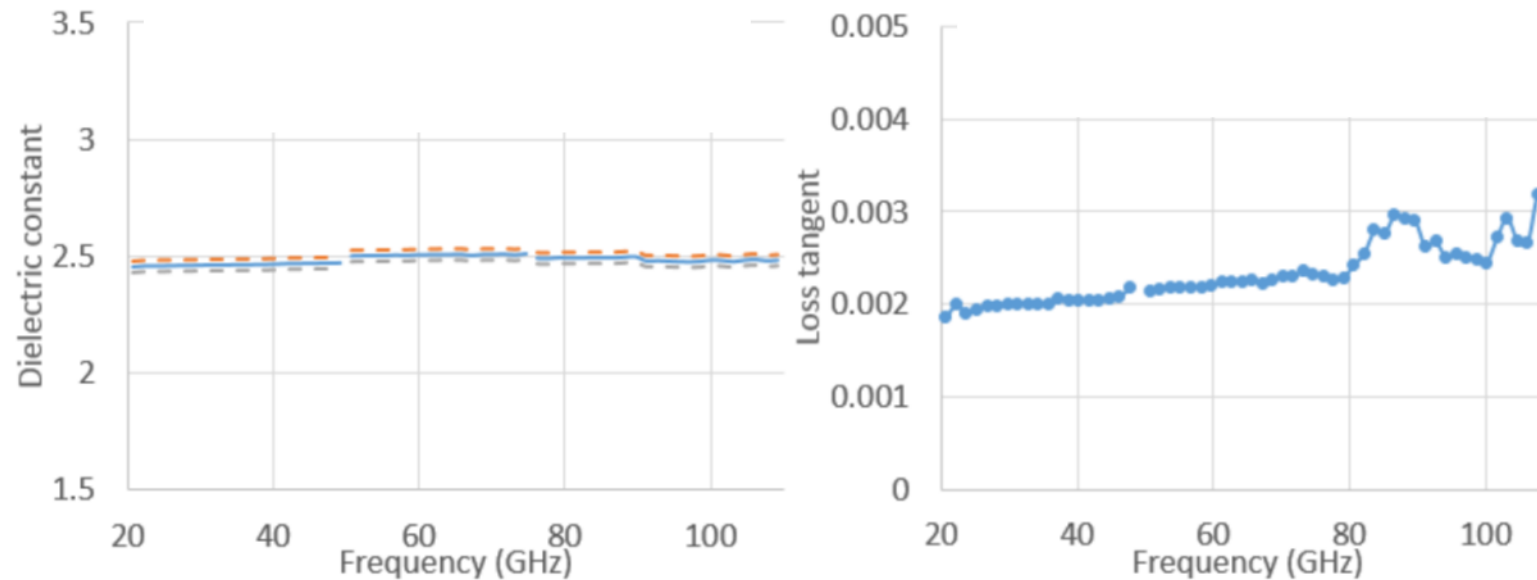


Suitable for 5G applications

Low dielectric constant and loss factor

Measured by Fabry-Pérot Open Resonator method

Low Dk & low loss for a range of formulations from PDL family



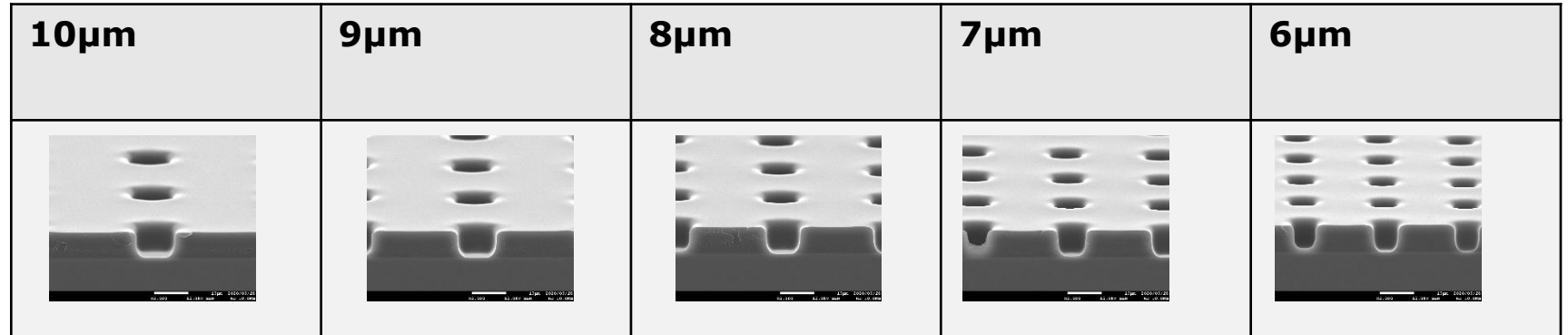
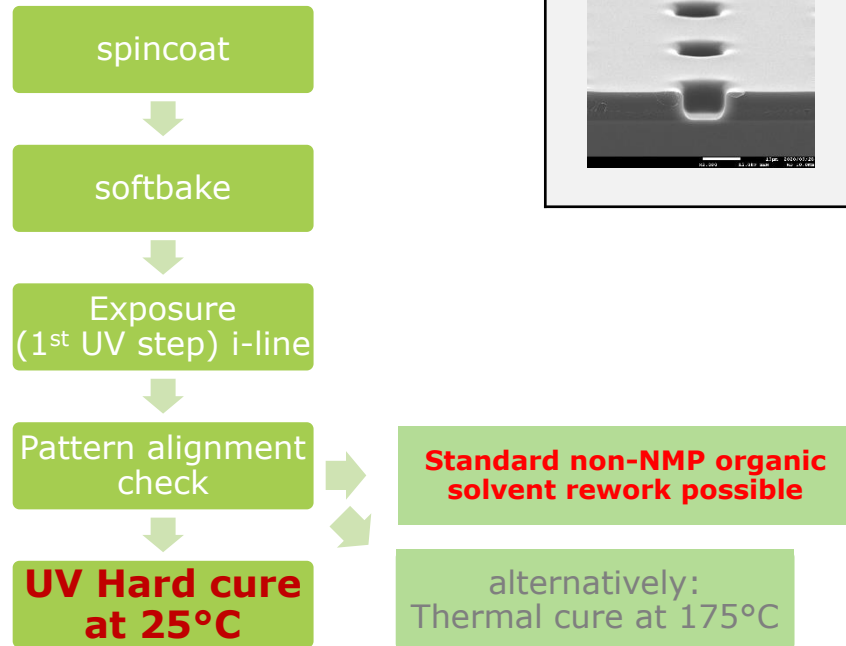
Very low Dk and Df up to frequencies above 100GHz



Process flow for PD-L

A rapid low thermal stress exposure and curing process

UV-only curing and solvent based rework



- Negative tone, CPN developer
- Photolith resolution 8μm film: 7 μm via
- Exposure energy window <140- 240 mJ/cm²
- Curing UV @ RT or thermal @ 175°C

Standard tools can be used to process this advanced material



Reliability – a must have for any polymer in the package

Chemical resistance for processing chemicals

UV cured film tested against:

acids

bases

common organic solvents

Cu plating and etching

Ti plating and etching

Photoresist strippers (AZ Kwik Strip and Remover 910)

Pass

Compatible with all process chemicals used in WLP, except TMAH in organic strippers

Various tests according to JEDEC standards

uHAST

bHAST

TC-B

HTS

MSL1 (wafer level)

Multi-reflow simulation

Pass

Full compatibility with industry standard tests



Low warpage, rapid processing, high photolithography resolution

PD-L's unique processing and mechanical properties

Low stress though processing

- **UV curing at room temperature** while retaining full reworkability (alternative: 175°C, 30')
- **Negative tone litho:** 7µm vias @ AR ~1
- <5% shrinkage during curing

Reliability

- bHAST 900hrs+ (130°C, 85%)
- Thermal shock (-55°C - 125°C) 1000 cycles
- HTS (150°C) 1000hrs
- uBHAST 96hr (130°C, 96hr)
- HSL 20

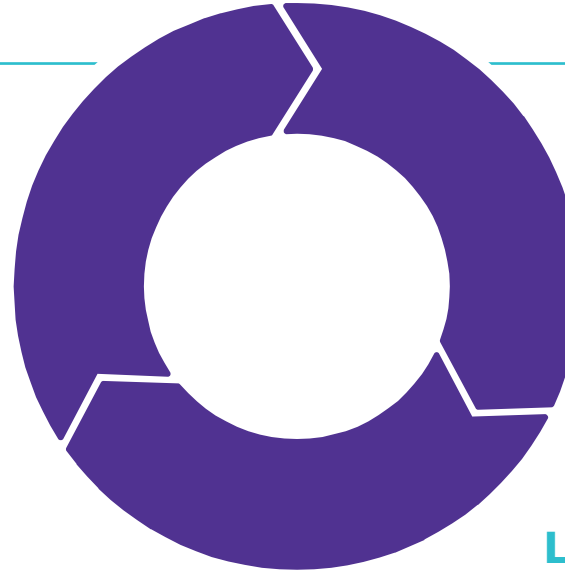
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passed



5G compatible

- **Dk 2.4-2.6 for 2.5-110GHz**
- **Df: 0.002-0.005 for 2.5-110GHz**
- <0.3% water absorption

Low stress by material design

- **Very stable CTE over temperature range**
- Mechanical stability above T_g
- 10 – 30% adjustable e2b combined with Young's modulus < 2GPa
- Thermal stability >390°C



Advanced dielectric

PD-L demonstrates dielectric properties suitable for high frequency 5G-type applications

Our development continues and we want to invite you to join us in further work towards your specific needs

PD-L



your benefits

1

Exceptional no-shrinkage UV-curing at room temperature enables stress free films on the substrate



2

Unique CTE behavior independent of T_g , dissipating stress above T_g without starting to flow



3

Dk and Df suitable for mmWave 5G+ applications without using fluoro-chemistry





**the science of today is the
TECHNOLOGY of tomorrow**

Thank you!!!



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