

# Hybrid Wiring Layers for Fine Pitch Wiring and Assembly

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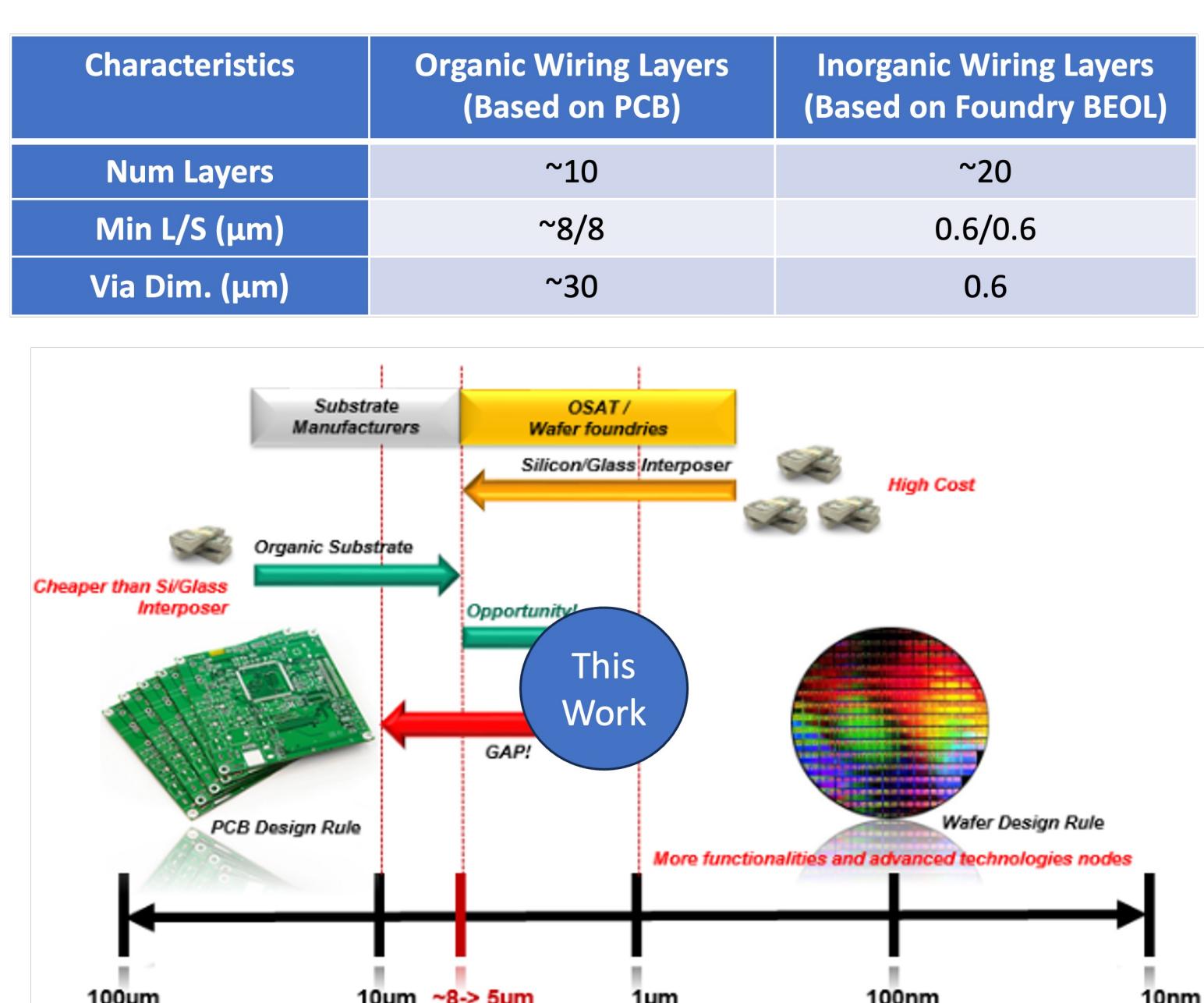
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## The Substrate Technology Gap in Advanced Packaging

- Two approaches to advanced substrates:

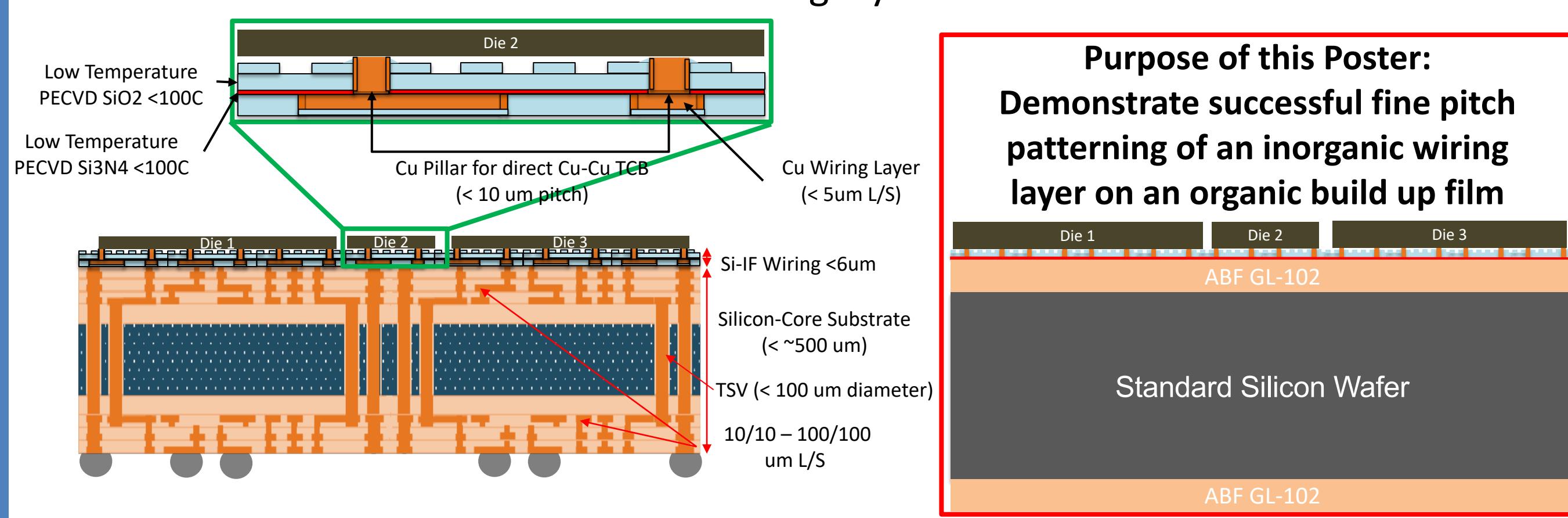
- Organic substrates based on PCB processes have coarse trace and bond pitches using mass reflow (solder)
- Silicon based substrates (Si-IF) routinely achieve sub  $\mu\text{m}$  trace pitch and sub 10  $\mu\text{m}$  bond pitch

- By combining inorganic terminating layers on organic build up layers we can achieve the best of both worlds



## Overall Goals and Objectives

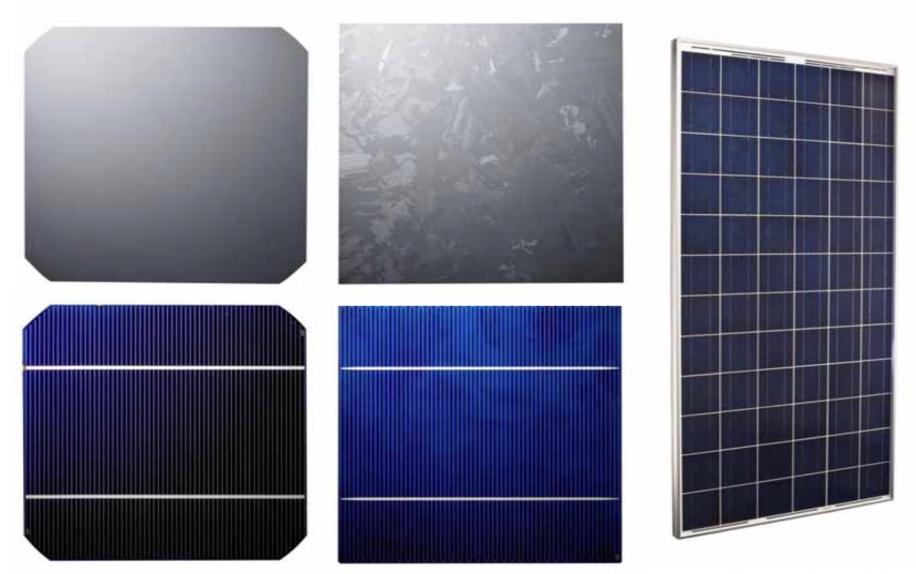
- Integrate Si-IF's CMOS BEOL wiring layers for inorganic frontside fine pitch wiring layers for I/O Routing
- Utilize organic dielectric solutions for backside coarse pitch wiring layers for power delivery
- Bond dies at <10  $\mu\text{m}$  pitch using direct Cu-Cu TCB
- Implement novel TSV processes in using innovative material solutions to interconnect frontside and backside wiring layers at low cost



## Innovative Material Solutions for Low-Cost Implementation

### Solar Grade Silicon

- Solar grade silicon can be Single Crystal or Multi Crystalline
- Significant substrate cost reduction ~ \$1 per panel vs \$25 per test/prime grade 100mm wafer
- Can be processed in panel or cored into wafer form
- Wafer is already thin and around 180  $\mu\text{m}$  (good for TSV formation)
- Issue: Significant Bow/Warpage with rough surface from saw damage



### Solar Grade vs. Prime Grade Silicon

M2 Solar Grade SCS <100>	100mm Polished SCS Wafer <100>
Growth Method	Cz
Thickness	180 + 20/−10 $\mu\text{m}$
Oxygen Concentration	$\leq 9.0 \times 10^{17} \text{ atoms/cm}^3$
Carbon Concentration	$\leq 5 \times 10^{16} \text{ atoms/cm}^3$
Resistivity	$0.8 \sim 2.6 \Omega \cdot \text{cm}$
Cutting Method	Diamond Wire Cut
TTV	$\leq 30 \mu\text{m}$
Bow	$\leq 50 \mu\text{m}$
Warpage	$\leq 50 \mu\text{m}$
Saw Marks / Steps	$\leq 15 \mu\text{m}$

### Comparison of Organic Dielectric Materials

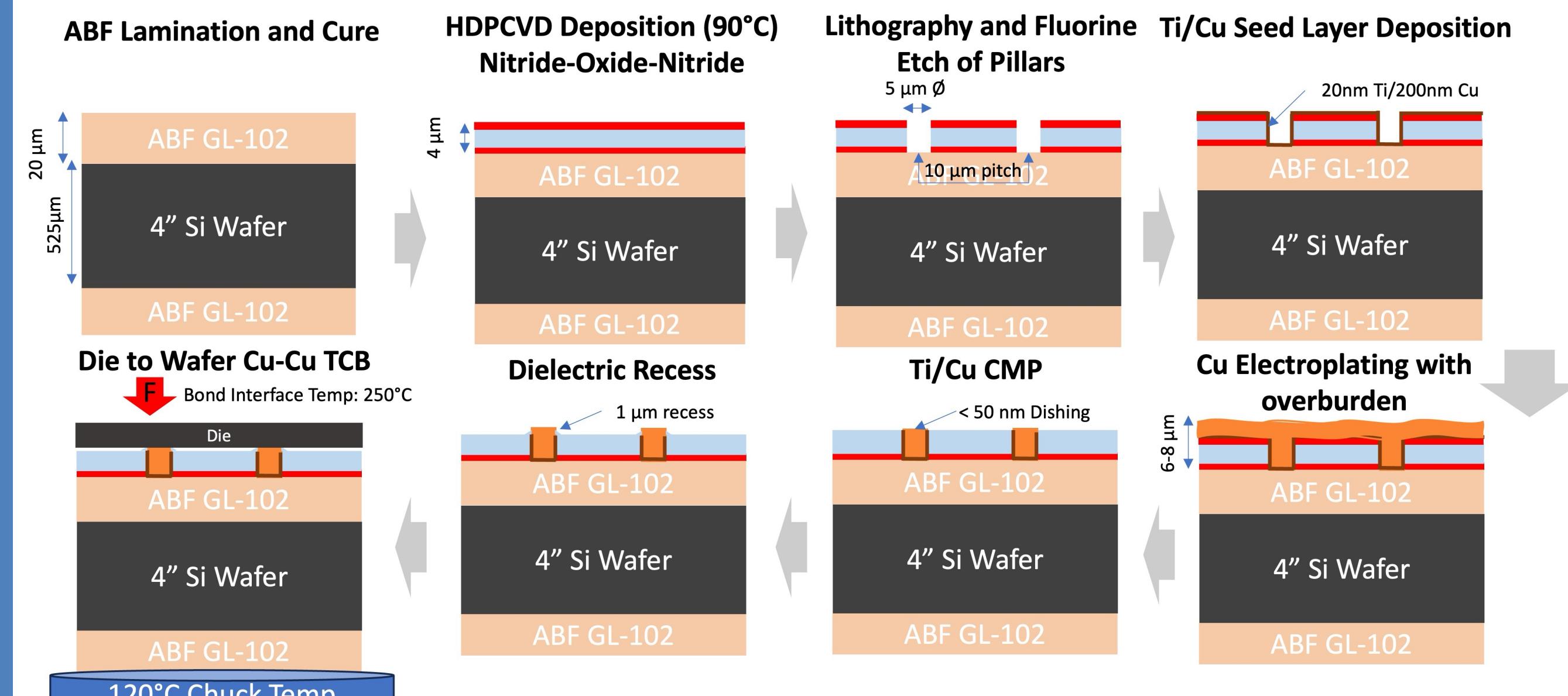
Characteristics	Unit	BCB	Polyimide	ABF GL-102
CTE	ppm/ $^{\circ}\text{C}$ (x-y) (25-150 $^{\circ}\text{C}$ )	70	34	20
Elongation at Break	%	5.5-10.5	6	1.5
Young's Modulus	GPa	2.7-3.1	2.5	13.0
Tensile Strength	MPa	93	200	130
Dielectric Constant	-	2.65	3.2	3.3
Loss Tangent	-	0.002	0.002	0.0044 @ 5.8GHz

### Ajinomoto Build Up Film

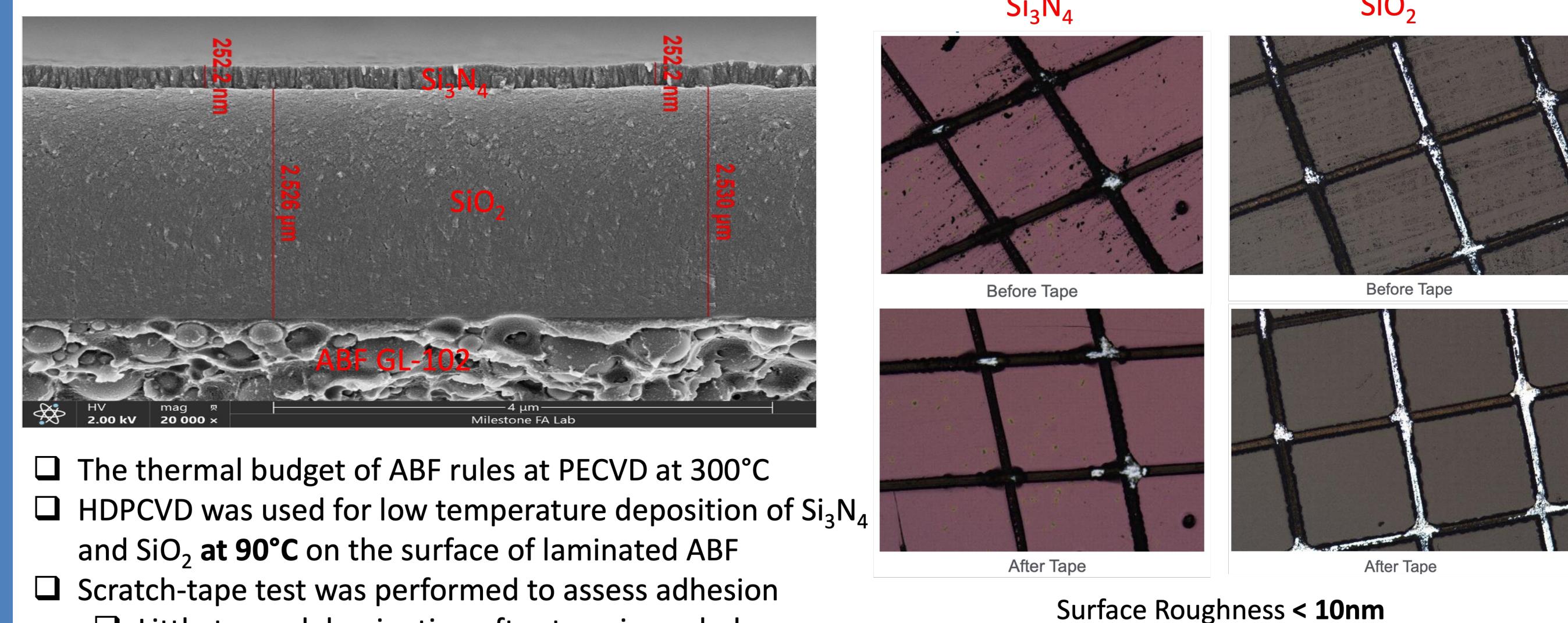
- Low Cost of Processing
  - Vacuum Lamination of dry film with curing step
  - Metal layer formed using SAP with vias drilled with a laser
- Embedded silica filler in build up film reduces CTE and increase Young's Modulus
  - Reduction in CTE leads to less mismatch with copper (17 ppm/ $^{\circ}\text{C}$ ) reducing stress and maintaining its flatness for subsequent levels of patterning post curing
  - Higher Young's modulus is beneficial in our case due to its ability to not deform during CMP steps
- Thermal degradation when exposed to temperatures above 250  $^{\circ}\text{C}$  for extended periods of time
- Films can contribute significant bow/warpage limiting CD as more layers are fabricated

Source: Datasheets of BCB, PI, ABF GX-92, Solar-Grade Silicon, and Prime Grade 100mm Silicon

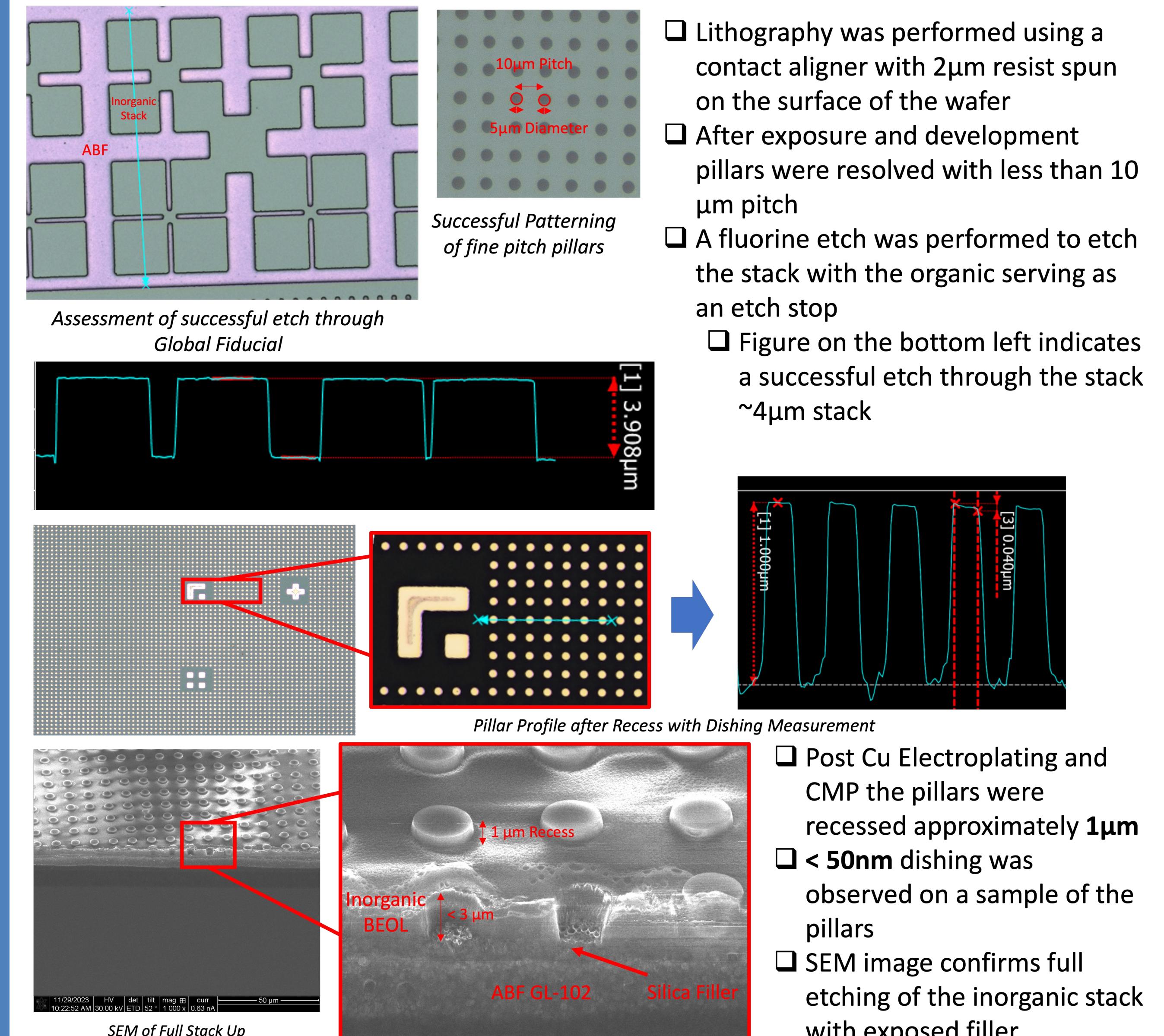
## Technical Approach



## Low Temperature Nitride and Oxide Adhesion Assessment



## Fine Pitch Pillar Patterning of Inorganic Layers



- Lithography was performed using a contact aligner with 2  $\mu\text{m}$  resist spun on the surface of the wafer
- After exposure and development pillars were resolved with less than 10  $\mu\text{m}$  pitch
- A fluorine etch was performed to etch the stack with the organic serving as an etch stop
- Figure on the bottom left indicates a successful etch through the stack ~4  $\mu\text{m}$  stack
- Post Cu Electroplating and CMP the pillars were recessed approximately 1  $\mu\text{m}$
- < 50 nm dishing was observed on a sample of the pillars
- SEM image confirms full etching of the inorganic stack with exposed filler

## Conclusions and Acknowledgements

- Integration of SiO<sub>2</sub> and Si<sub>3</sub>N<sub>4</sub> on ABF GL-102
- Developed a process for patterning fine pitch (< 10  $\mu\text{m}$ ) features on top of an organic build up film

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