12th International Conference
and Exhibition on Device Packaging

March 15 - 17, 2016
WeKoPa Resort and Casino
Fountain Hills,
Arizona, USA

- Session WP1 3D Device Fabrication Processes, Materials and Yield (2)

Laser Direct Patterning of Dry Etch BCB Adhesive Layers for Low Temperature Permanent Wafer-to-Wafer Bonding

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2.) DOW

3.) Technische Universität Berlin

Outline

Introduction

Review of BCB based adhesive wafer bonding processes

New BCB patterning process by laser ablation

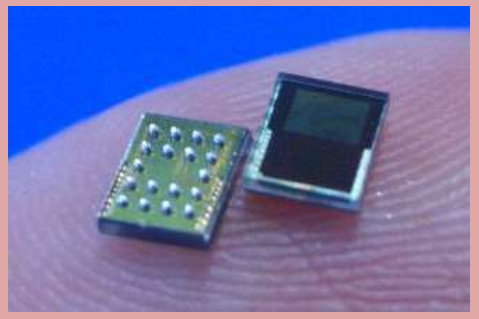
Summary

Introduction – Applications for Adhesive WtW Bonding

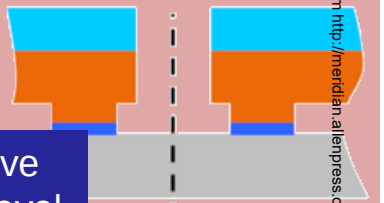
CMOS Image Sensor Packaging

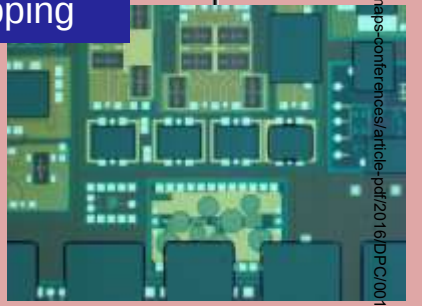
FSI CIS

BSI CIS

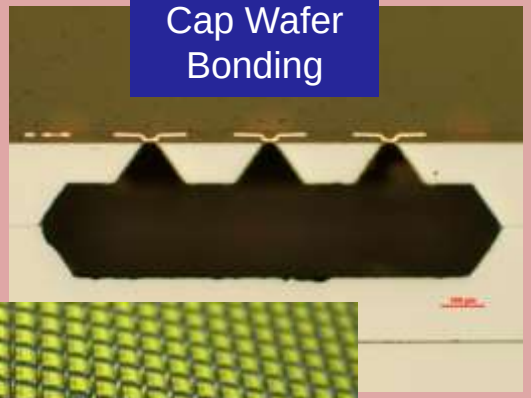


Selective Wafer Level Capping

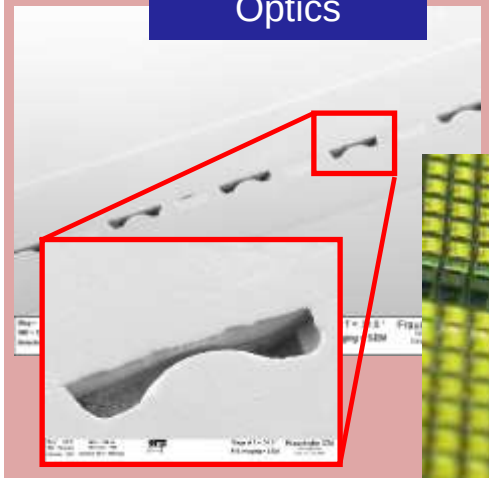


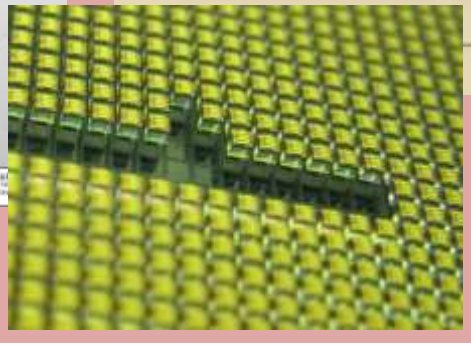


Cap Wafer Bonding

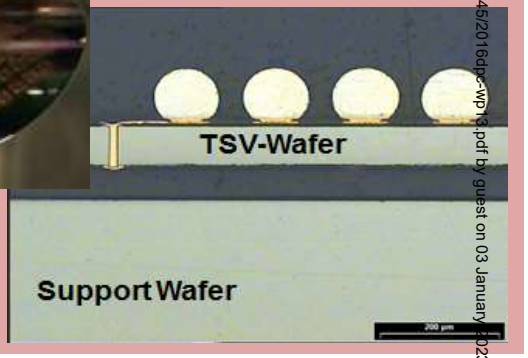


Wafer Level Optics

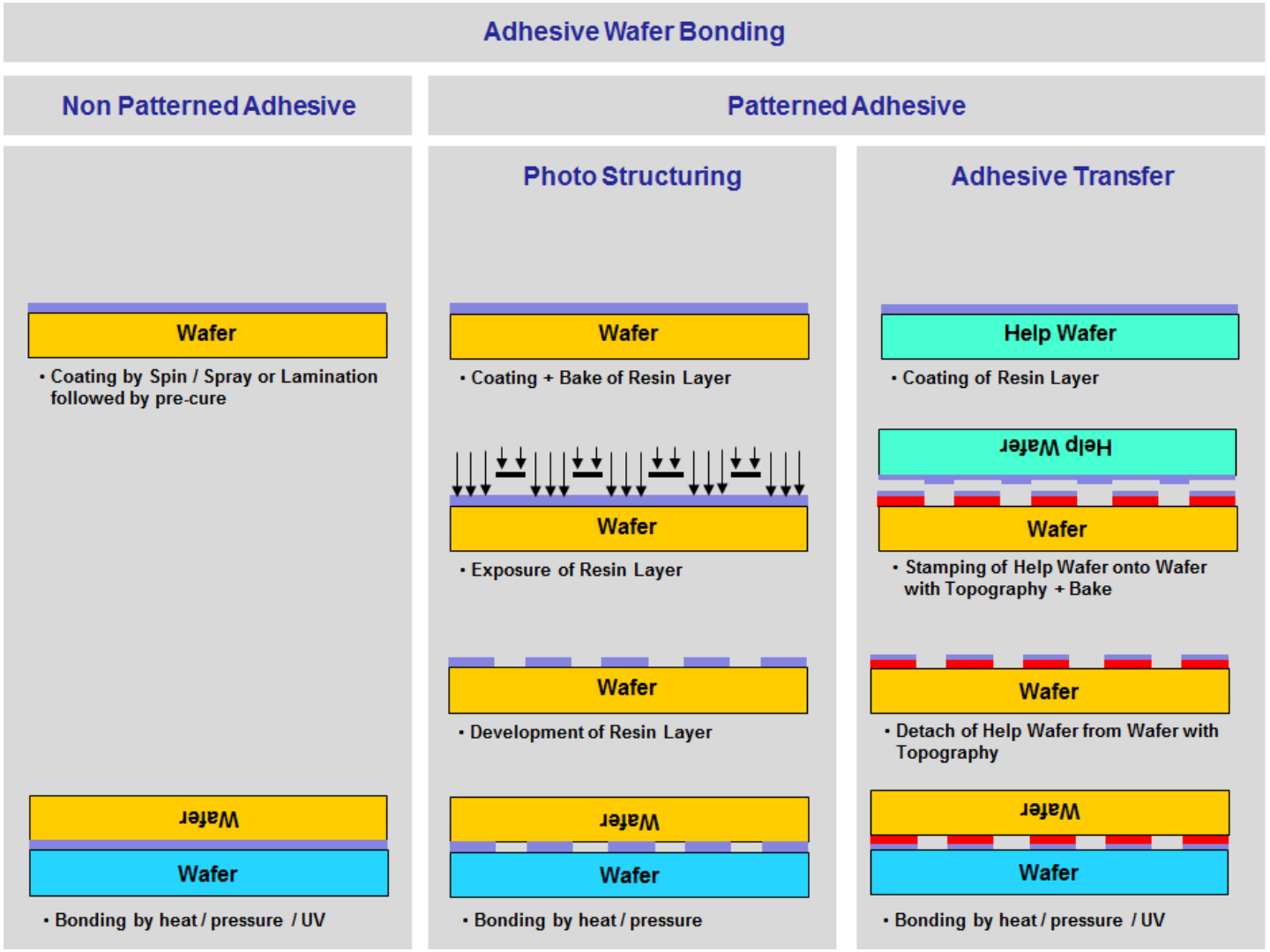




Thin Wafer Handling (3DTSV)



Introduction –Adhesive WtW Bonding Processes



Outline

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New BCB patterning process by laser ablation

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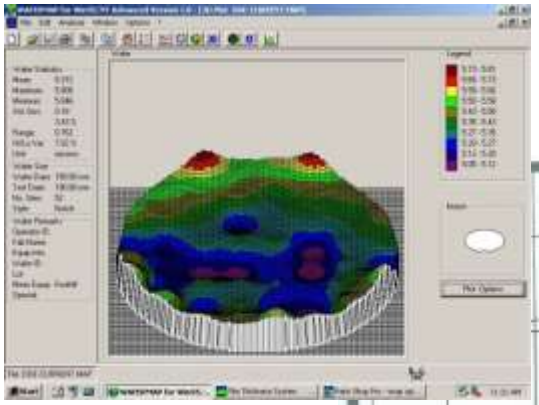
Review of BCB based adhesive wafer bonding processes

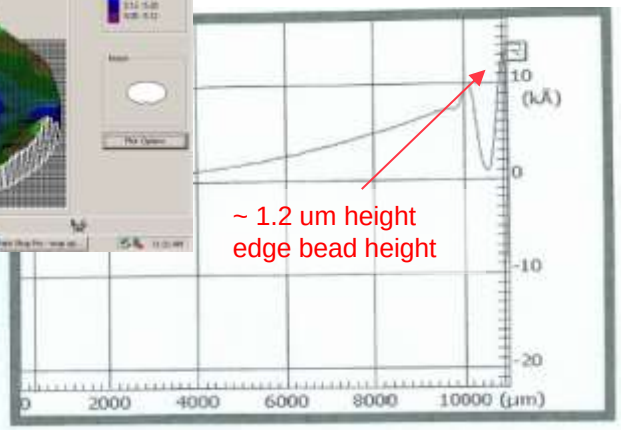
Non patterned adhesive bonding

Coating of Cyclotene™ 3022

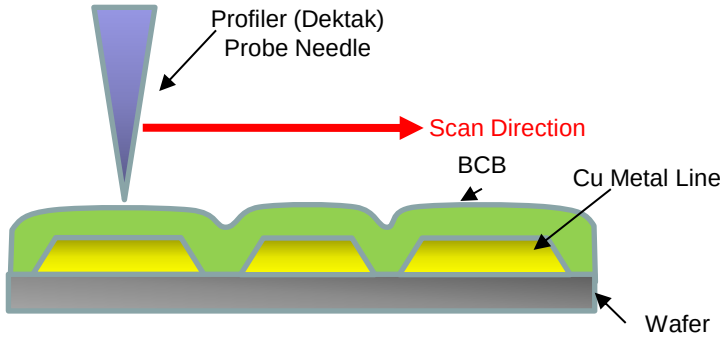
Priming:
Dispense :
Spread :
Spin On:
Dry:
Snap:
Bake:
Soft Bake:

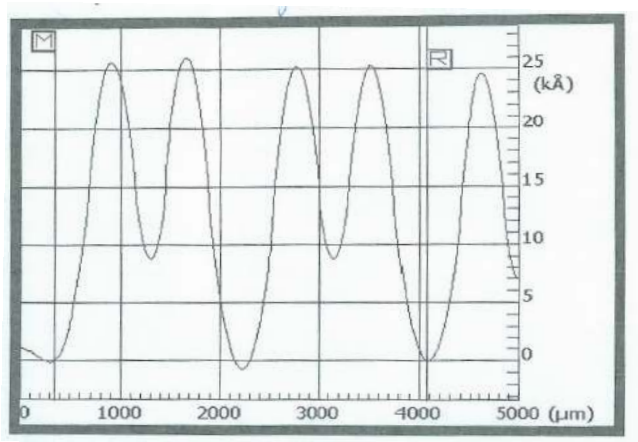


Mean: 5,3 µm
TTV 0,7 µm



Coating Result of Cyclotene™ 3022-57 target (5 um) on Cu Pattern height (3 um)

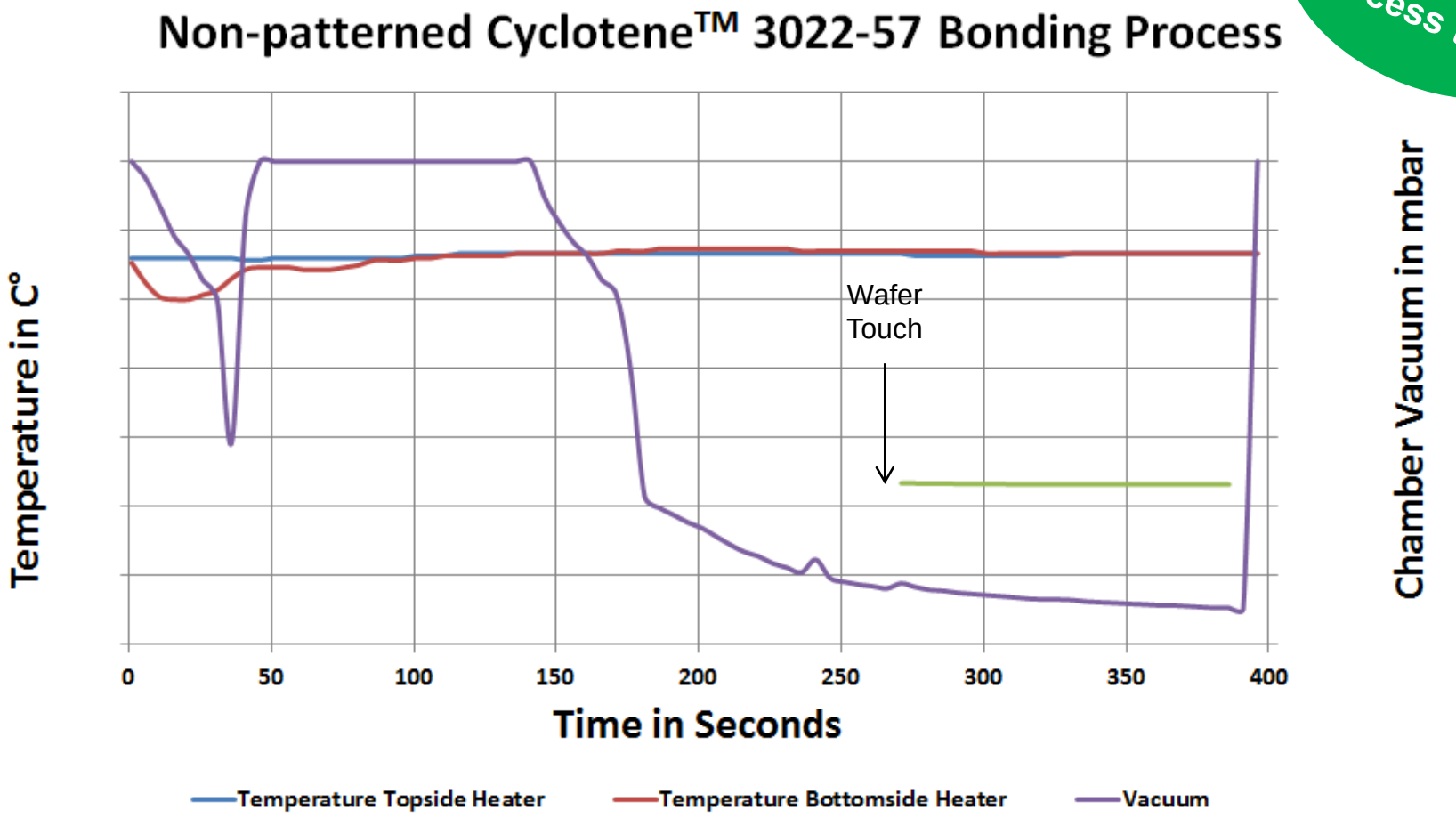




Review of BCB based adhesive wafer bonding processes

Non patterned adhesive bonding

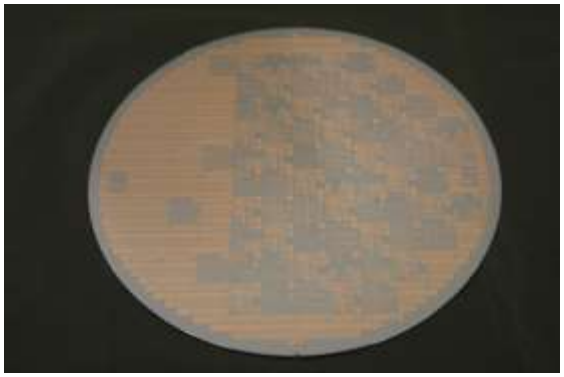
6.5 min process time!

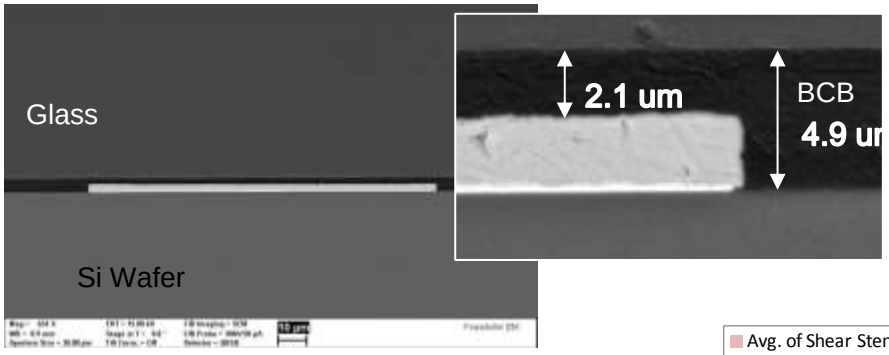


Review of BCB based adhesive wafer bonding processes

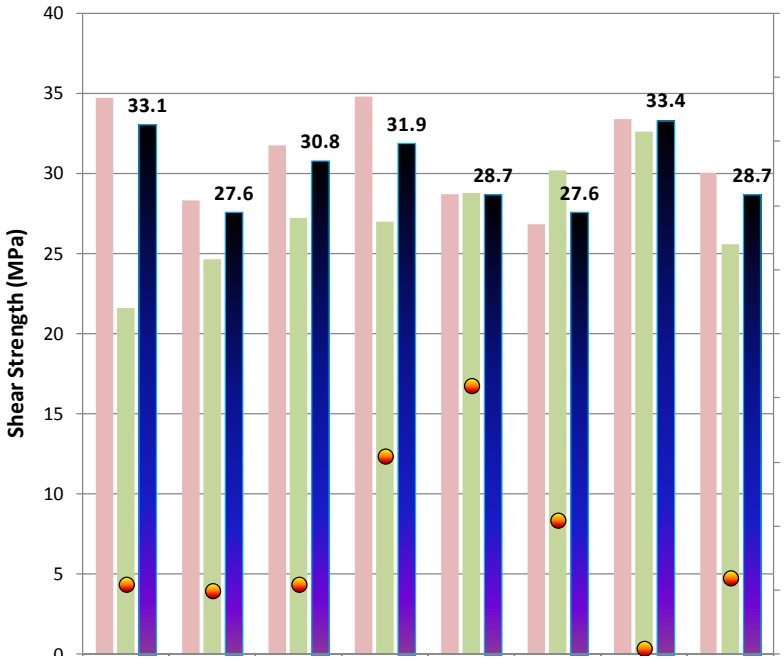
Non patterned adhesive bonding

Post Bond Batch Cure with different conditions possible





Cu Pattern height (3 um) + BCB target (5 um)

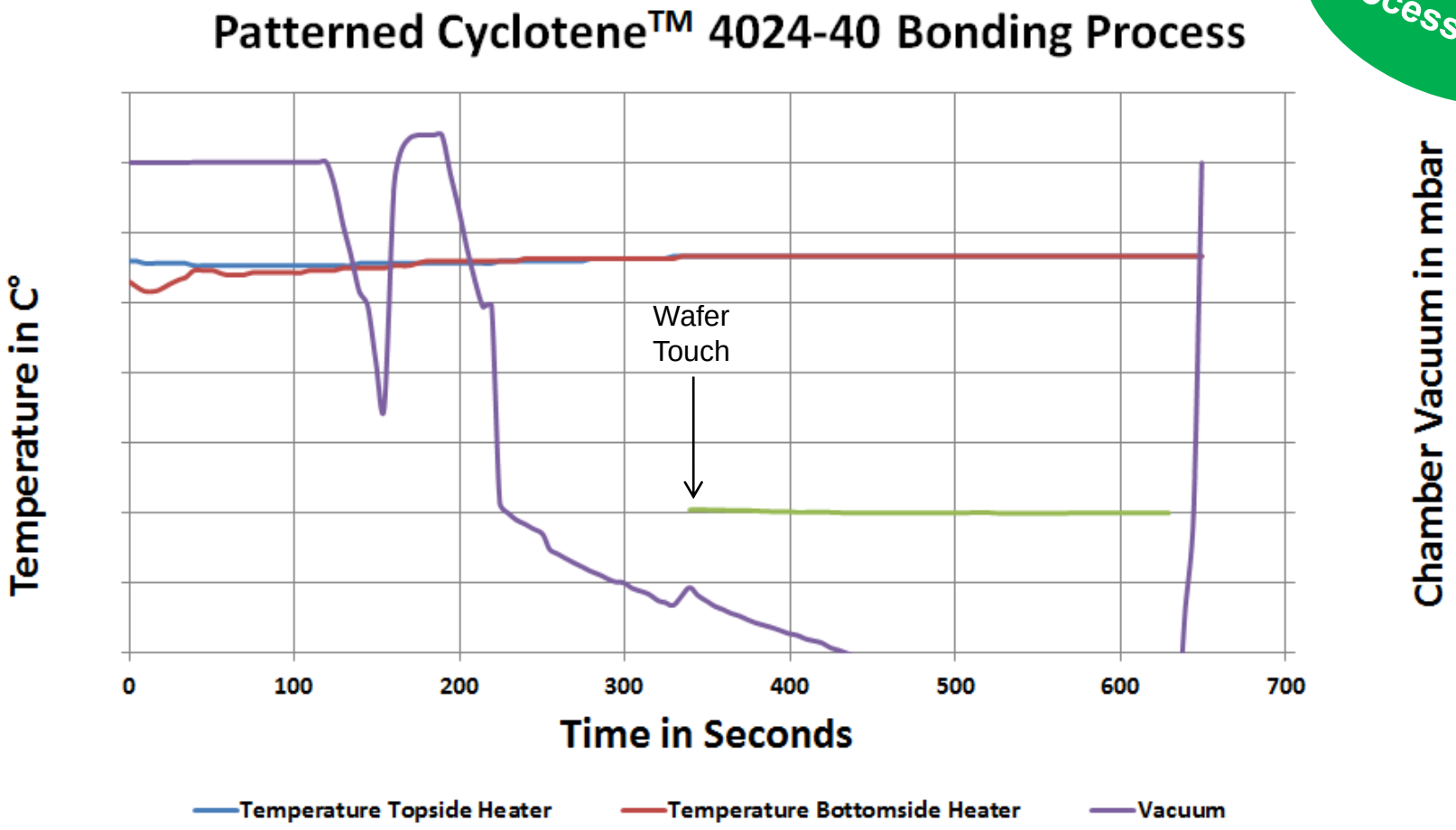


Avg. of Shear Stength Mode A (MPa)	34.76	28.30	31.78	34.78	28.69	26.82	33.38	30.01
Avg. of Shear Stength Mode C (MPa)	21.61	24.63	27.21	26.97	28.77	30.17	32.65	25.56
Avg. of Shear Stength total (MPa)	33.06	27.60	30.84	31.90	28.72	27.60	33.35	28.72
Ratio of Mode C	11%	10%	11%	31%	42%	21%	1%	12%

Review of BCB based adhesive wafer bonding processes

Patterned adhesive bonding by Photo Structuring

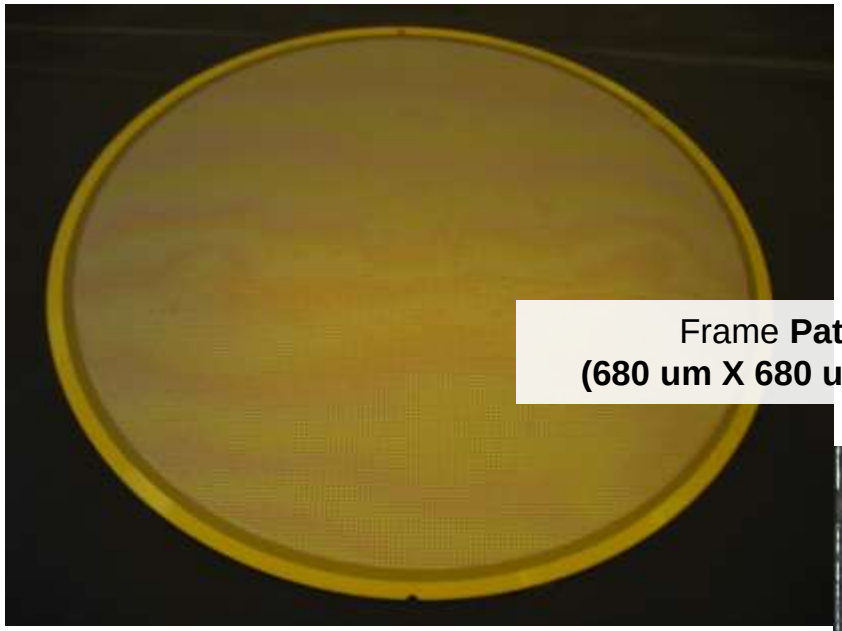
11 min process time!



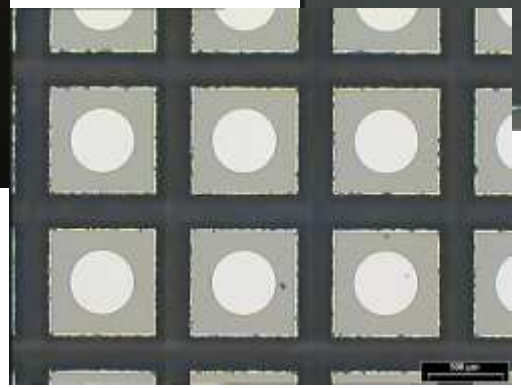
Review of BCB based adhesive wafer bonding processes

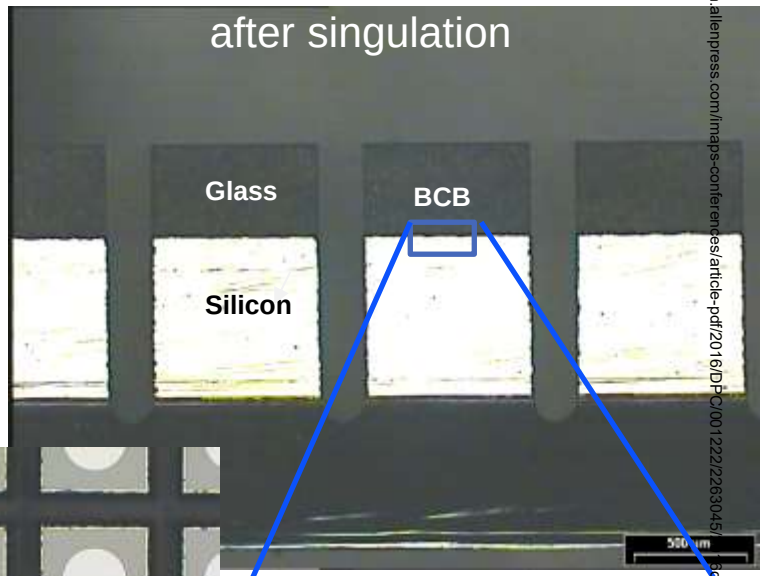
Patterned adhesive bonding by Photo Structuring

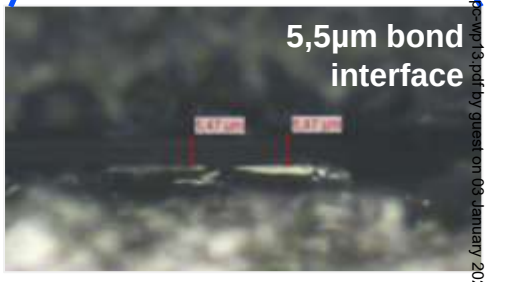
Cyclotene™ 4024-40 / 4024-46 bonded samples after post bond batch cure



Frame **Pattern Size**
(680 um X 680 um; dia. 430 um)







Limited topography compliance of Cyclotene™ 4000 after exposure!

Review of BCB based adhesive wafer bonding processes

Example: $LiTaO_3$ Capping of SAW filters by adhesive wafer bonding using Cyclotene™ 4000

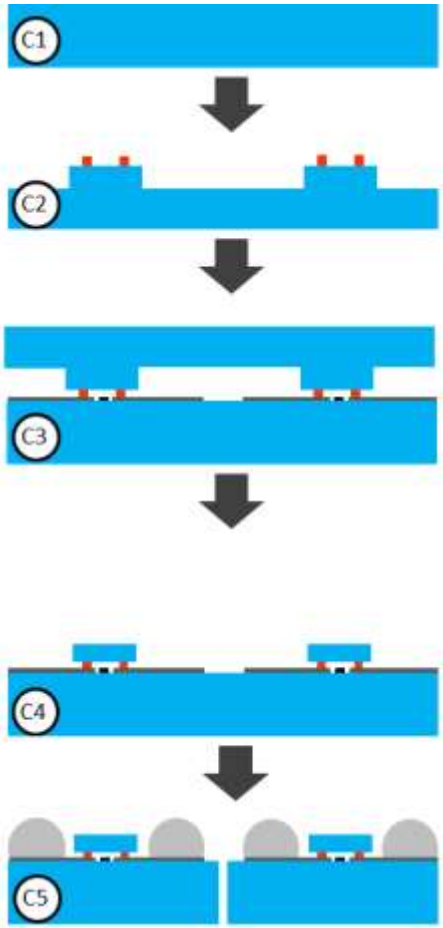
$LiTaO_3$ blank wafer

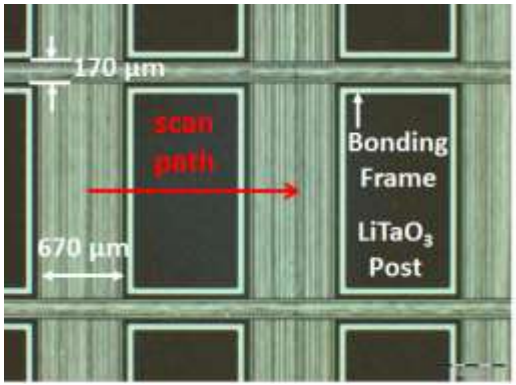
processing of Cyclotene™ bond frames and partial cutting

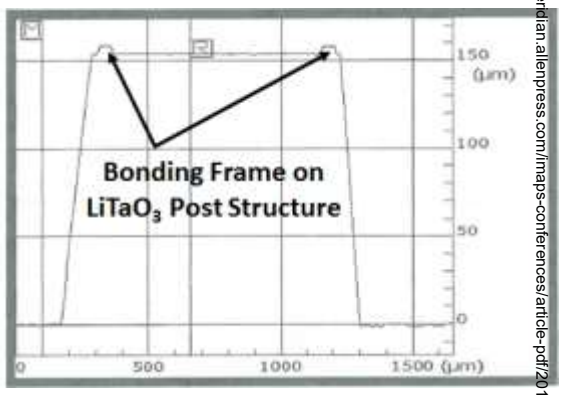
thermo compresion based wafer bonding to SAW wafer and post bond cure

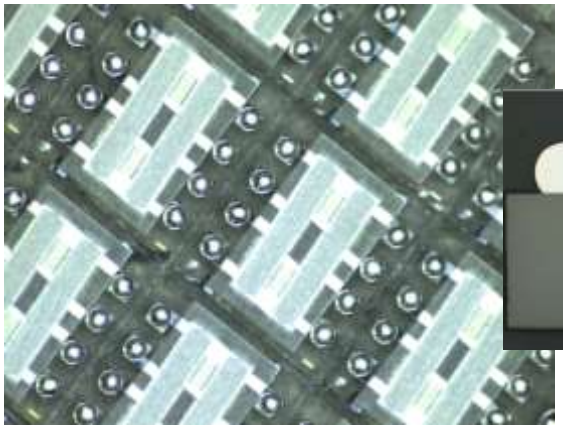
cap wafer grinding for cap separation

balling / singulation



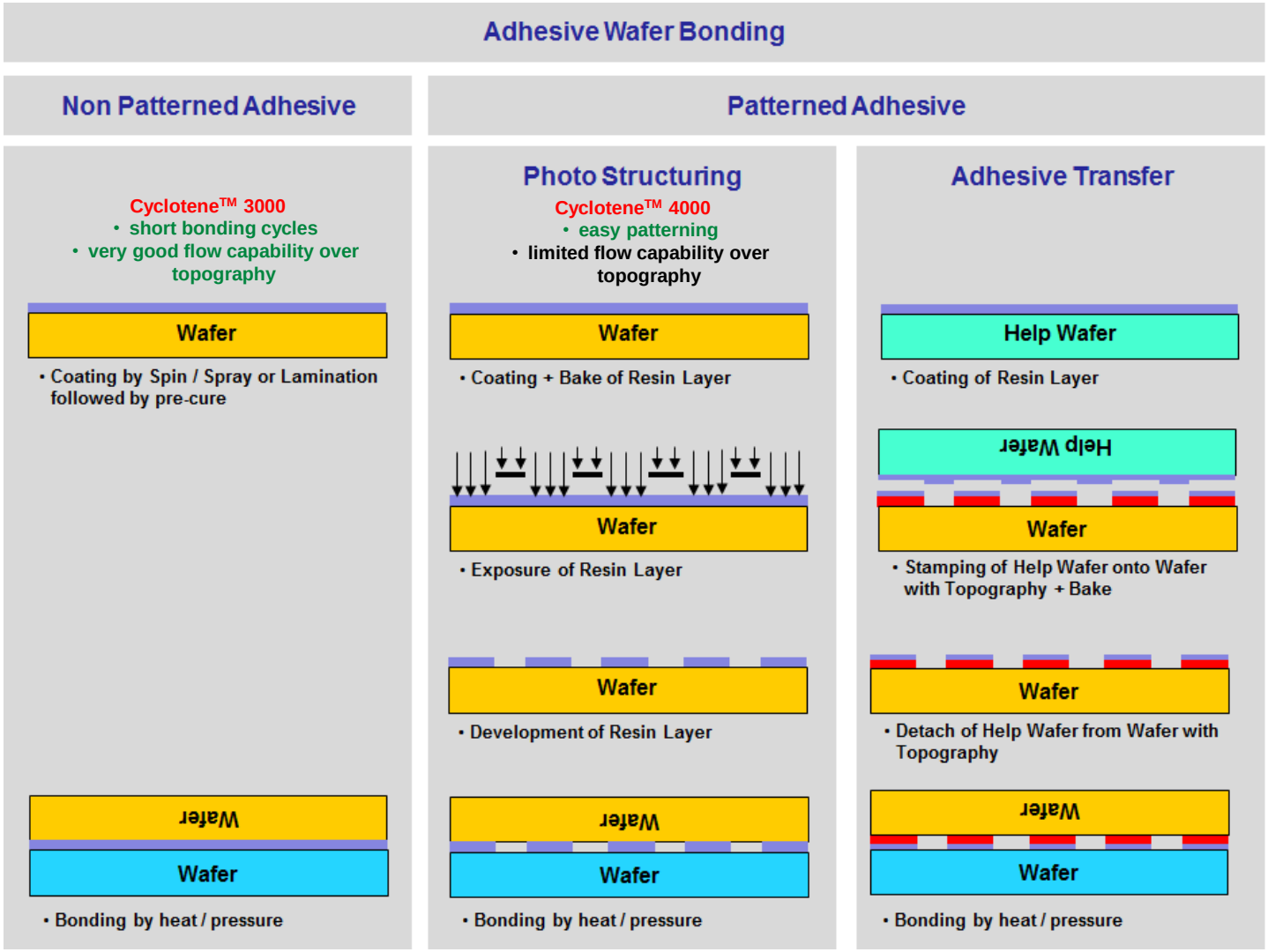






to be presented at ECTC 2016

Review of BCB based adhesive wafer bonding processes

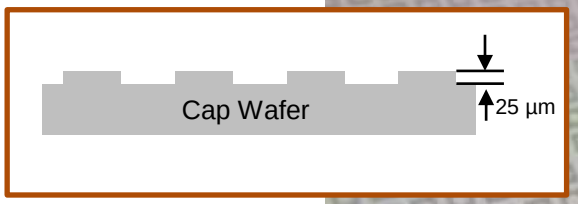


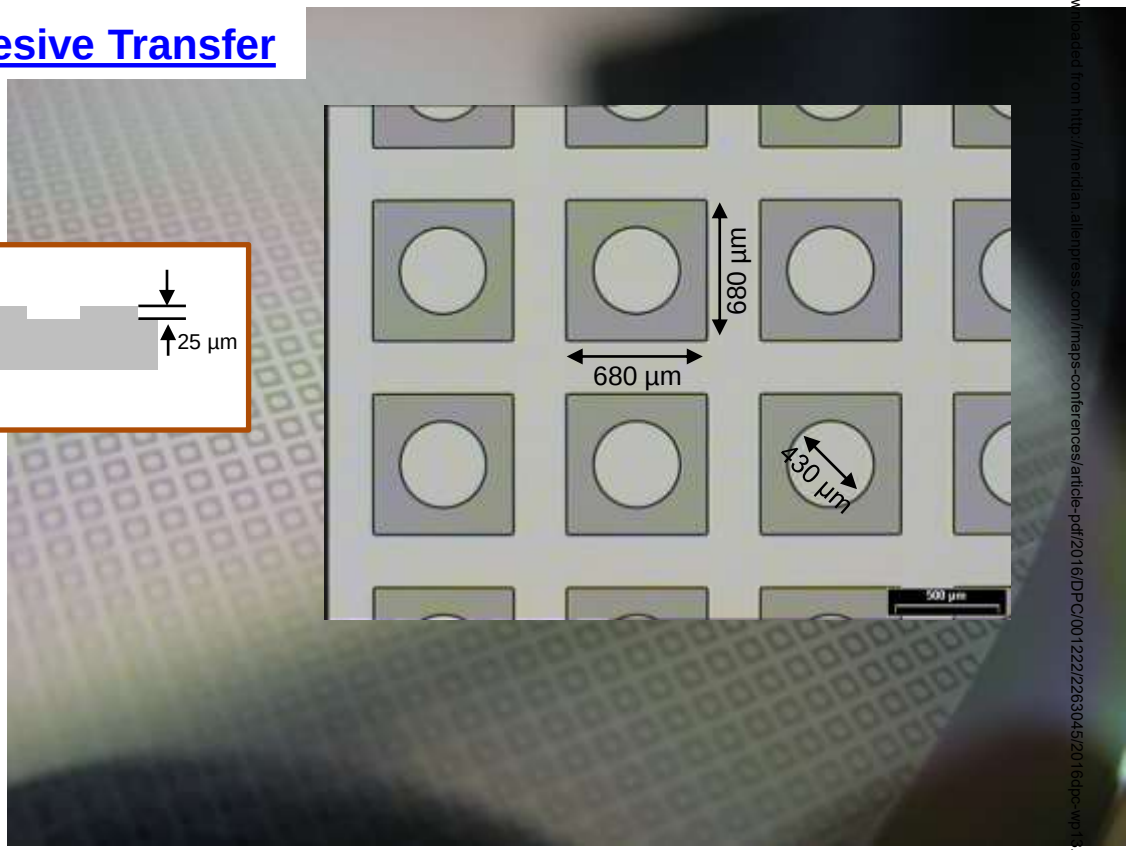
Review of BCB based adhesive wafer bonding processes

Patterned adhesive bonding by adhesive Transfer

Preparation of 200 mm
Testwafers with Topography

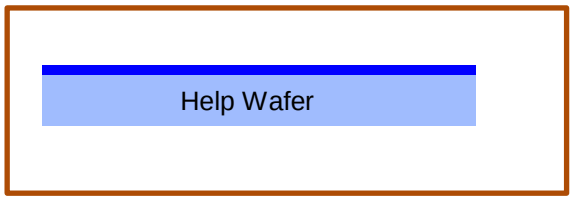
- Lithography
- Silicon dry etching
- Resist removal
- Priming: AP3000





Spin Coating at Help Wafer

Deposition of thin layer
Cyclotene™ 3022-46
Target thickness 4µm

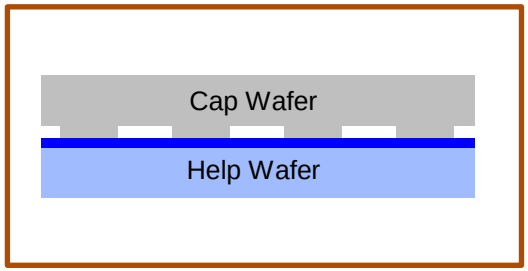


Review of BCB based adhesive wafer bonding processes

Patterned adhesive bonding by adhesive Transfer

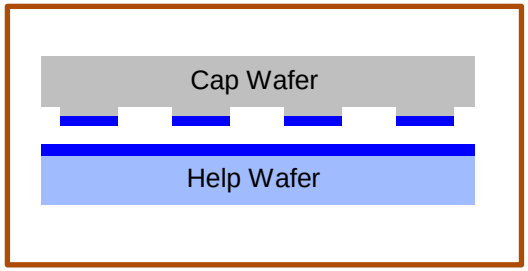
Glue Transfer

- Contact pressure 0,05 MPa
- wait 30 s

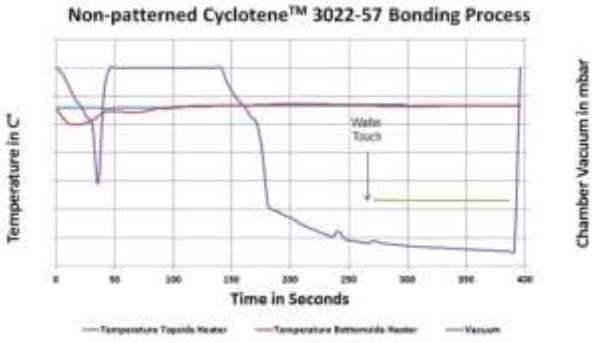


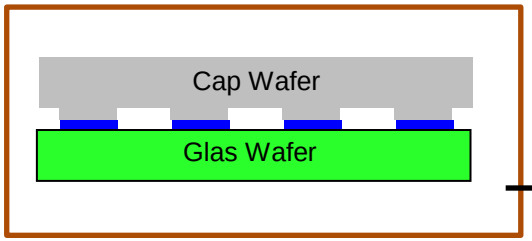
Cyclotene 3022-46 transferred to Topography on Cap Wafer

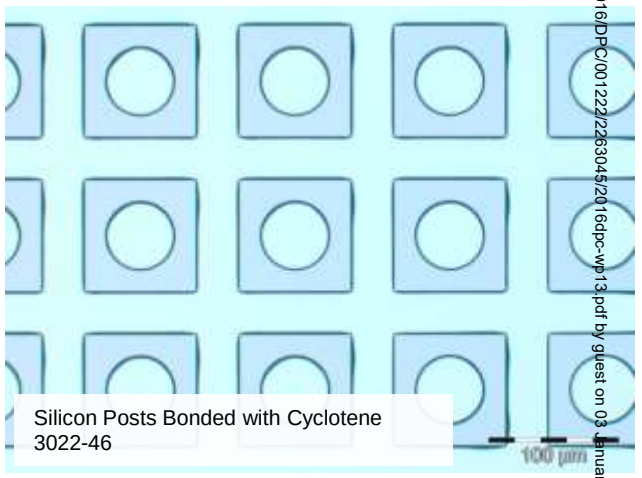
- release manual at vacuum chuck with vacuum tweezor
- Soft Bake



Bond Recipe (same as for non patterned Cyclotene 3022)

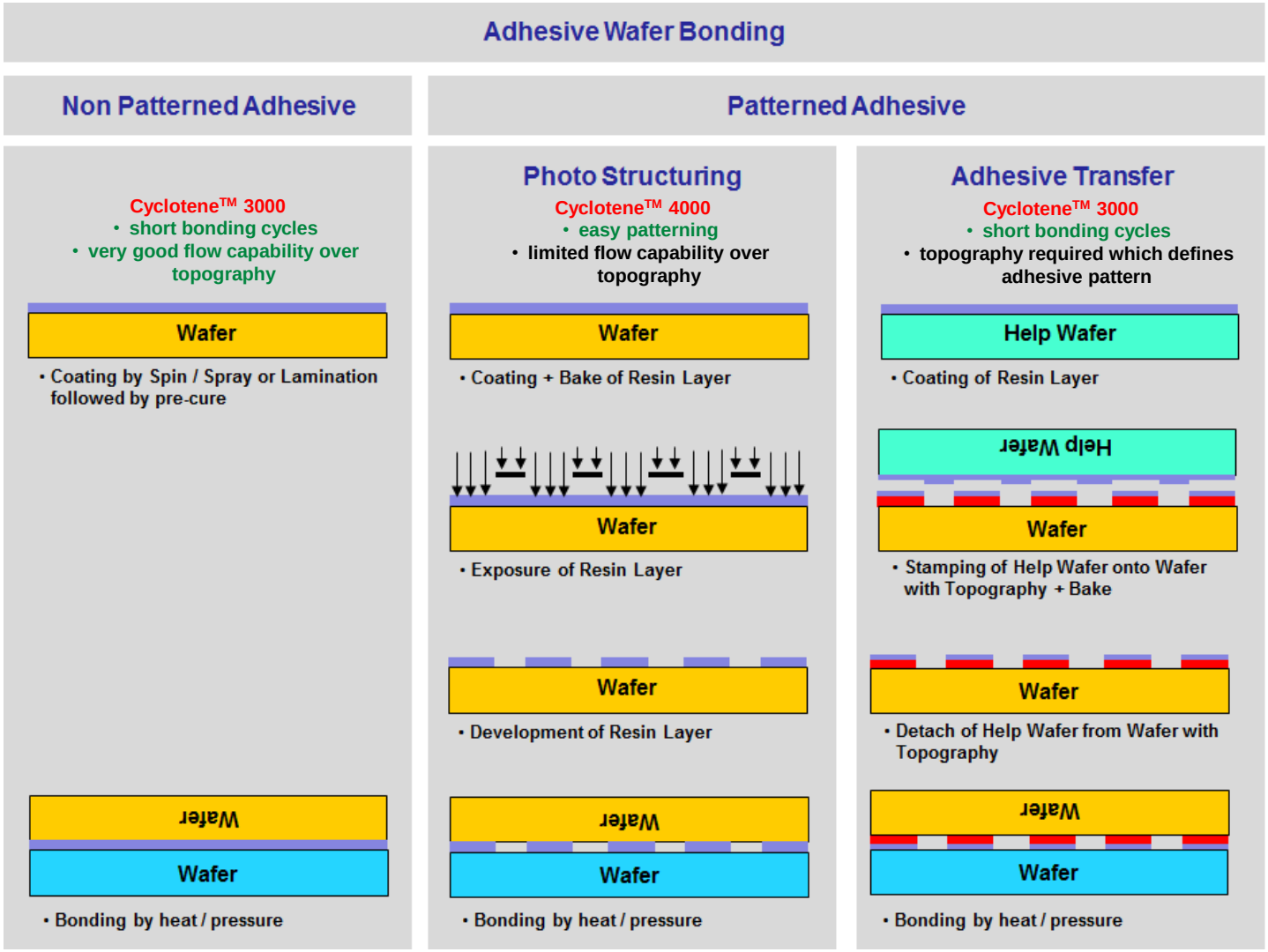






Silicon Posts Bonded with Cyclotene 3022-46

Review of BCB based adhesive wafer bonding processes

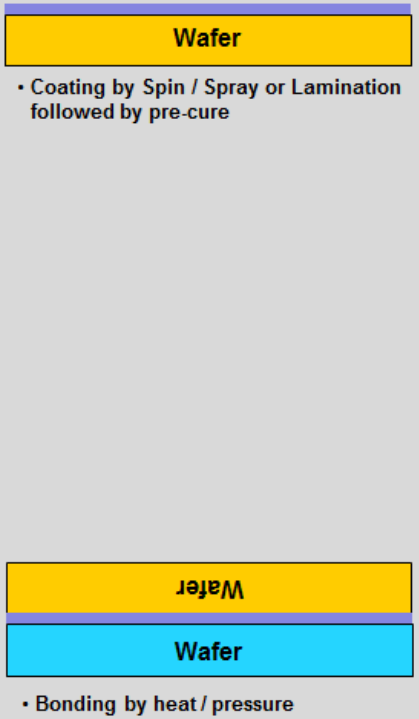


Review of BCB based adhesive wafer bonding processes

Adhesive Wafer Bonding

Non Patterned Adhesive

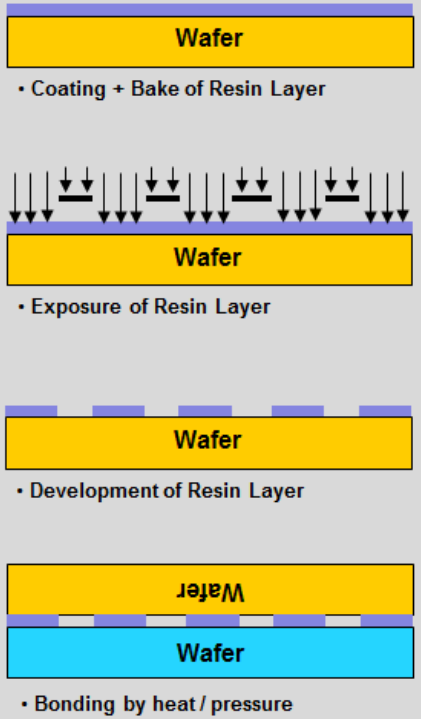
Cyclotene™ 3000
- short bonding cycles
- very good flow capability over topography



Patterned Adhesive

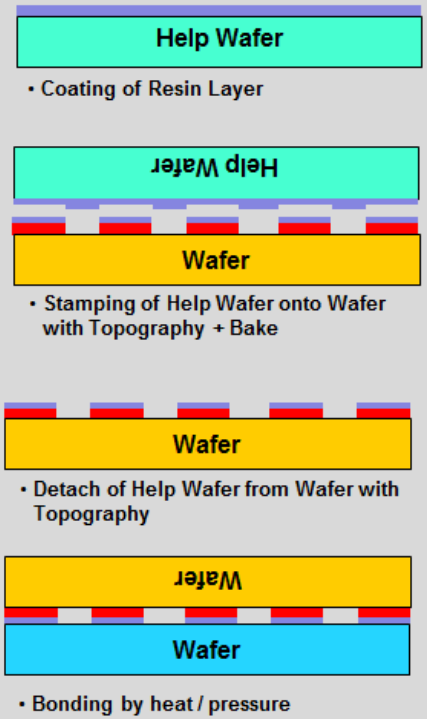
Photo Structuring

Cyclotene™ 4000
- easy patterning
- limited flow capability over topography



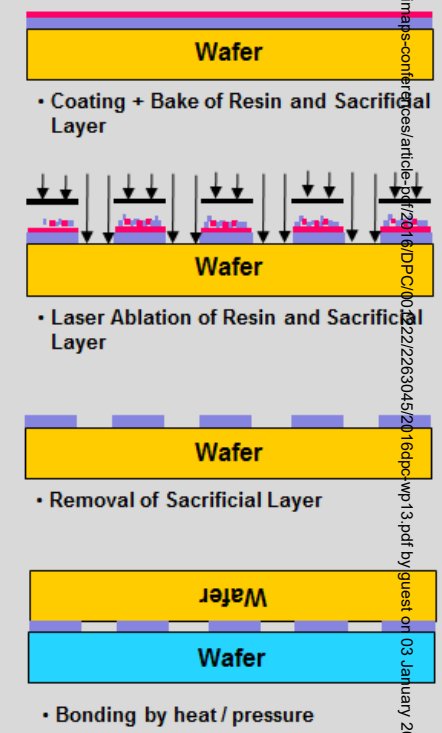
Adhesive Transfer

Cyclotene™ 3000
- short bonding cycles
- topography required which defines adhesive pattern



Laser Structuring

Cyclotene™ 3000
- short bonding cycles
- no initial topography required
- adhesive pattern is fully mask defined



Outline

Introduction

Review of BCB based adhesive wafer bonding processes

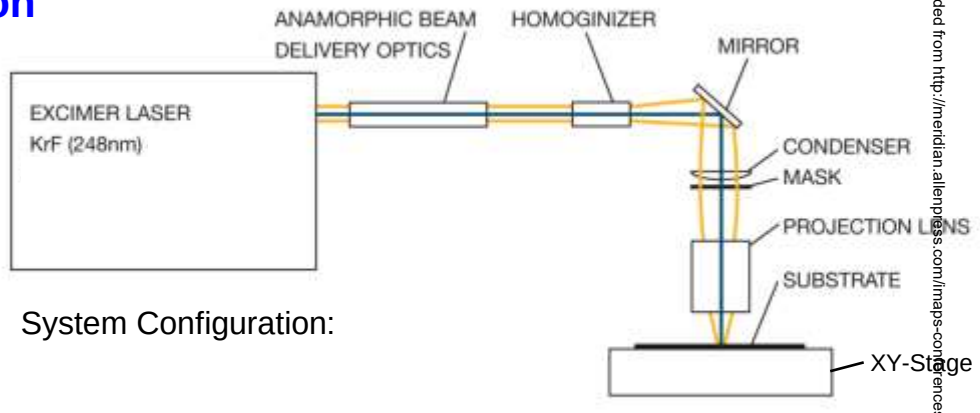
New BCB patterning process by laser ablation

Summary

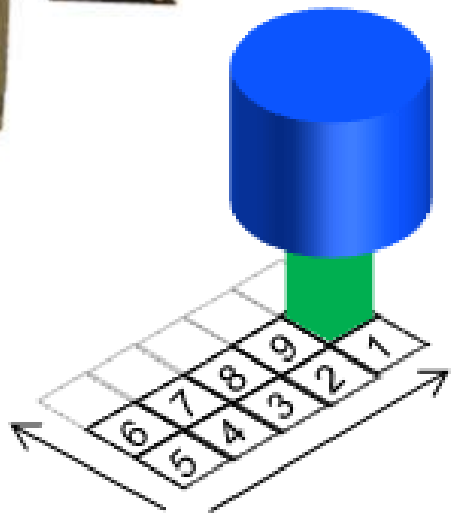
New BCB patterning process by laser ablation

Laser Ablation Equipment and Configuration

SÜSS ELP300
LASER ABLATION SYSTEM



System Configuration:



Laser Characteristics:

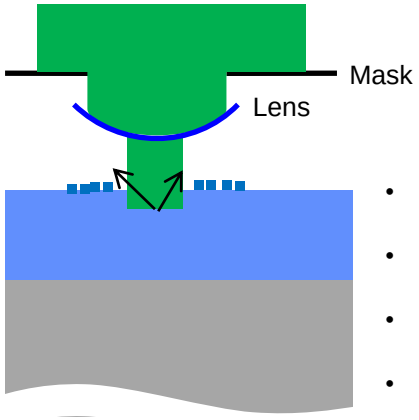
- wave length: 248 nm (KrF)
- shoot repetition rate: 50 Hz
- puls length: ≈30 ns
- beam spot size: 6,5 x 6,5 mm^2
- fluence range: 50-650 mJ/cm^2

Ablation Mode:

- XY stage directs substrate underneath the laser beam spot
- reticle wise ablation of mask pattern defined by step and repeat coordinates or shoot map

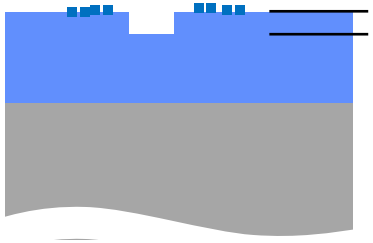
New BCB patterning process by laser ablation

Laser Ablation Principle



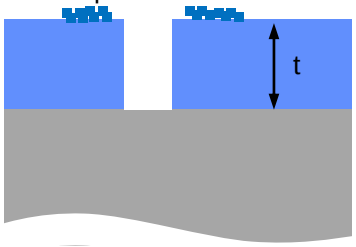
- laser pulses with 30 ns puls length transmit through mask and lens
- rapid absorption of light in polymer causes mechanical shocks
- molecular bonds of the material are broken causing its physical ablation
- decomposed polymer deposits as debris on the surface

after 1 puls



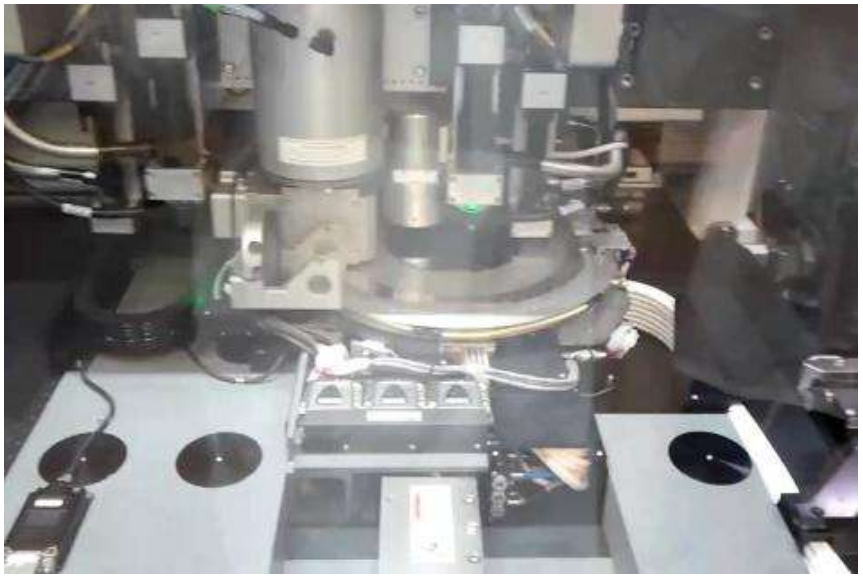
- Ablation rate (R) per puls is dependent on polymer material

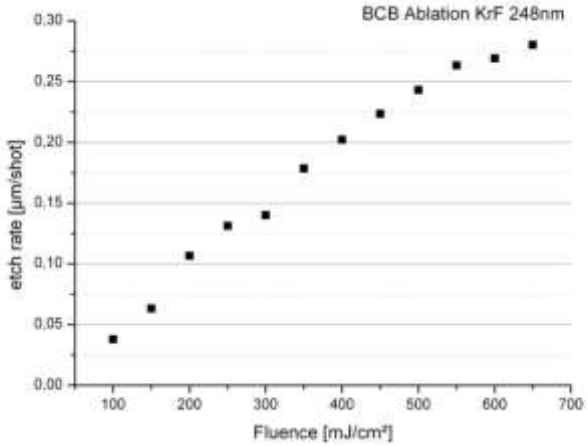
after N pulses



- Number pulses (N) required for ablation through full layer with thickness t.

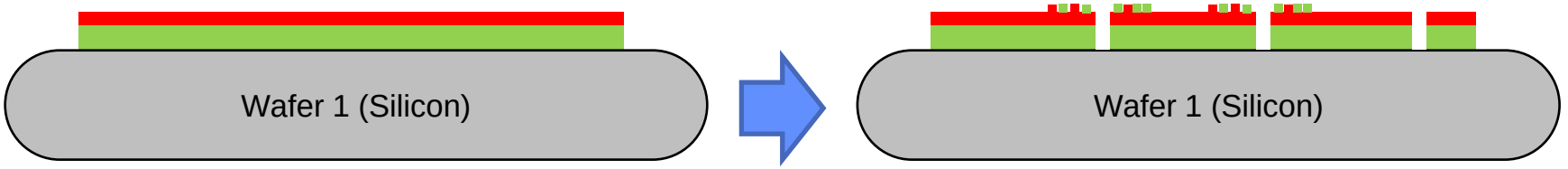
N=t/R





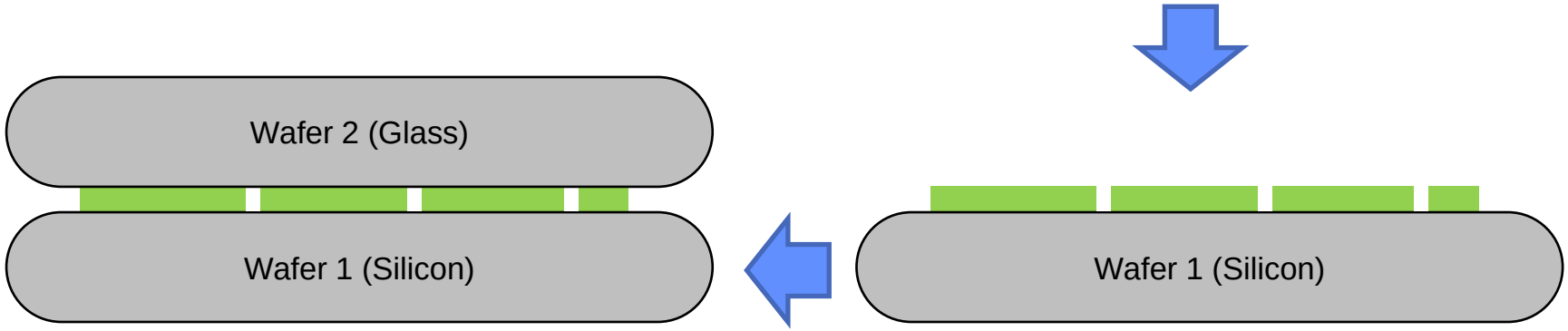
New BCB patterning process by laser ablation

Process Flow - Schematic



- AP3000 priming
- Spin Coating of Cyclotene 3022-46+Bake
- Spin Coating of Sacrificial Layer

- Patterning of layer sandwich by laser ablation
- Deposition of debris at surface

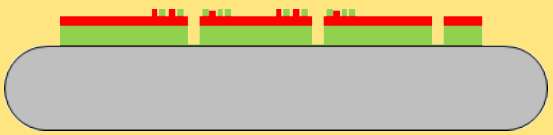
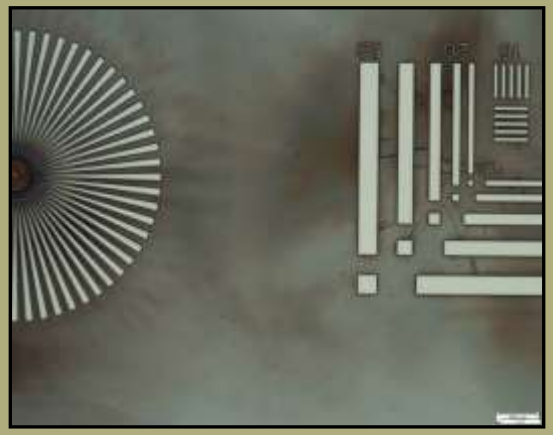
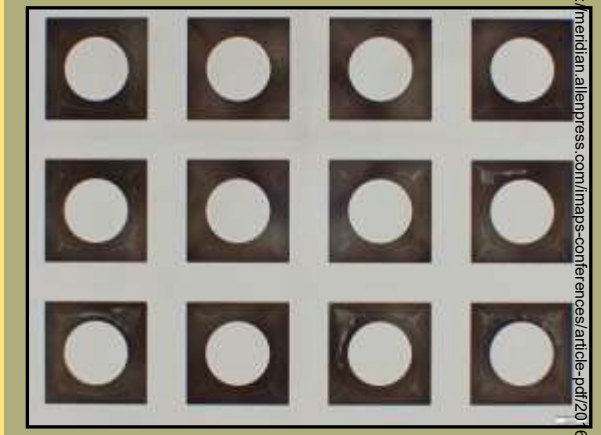
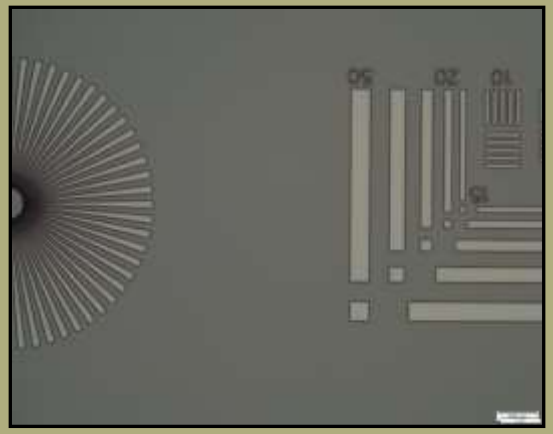
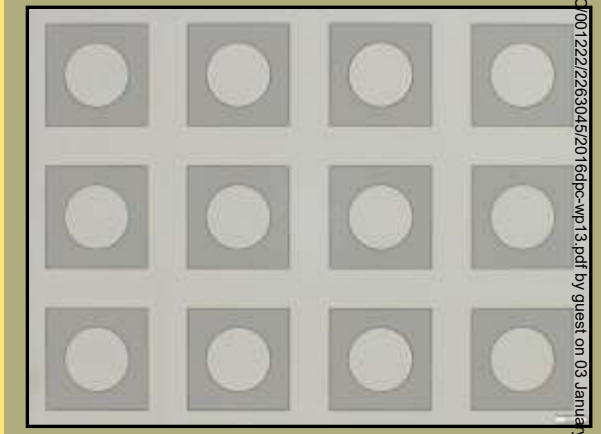


- Wafer to wafer Alignment & Bonding, Cure

- Removal of Sacrificial Layer

New BCB patterning process by laser ablation

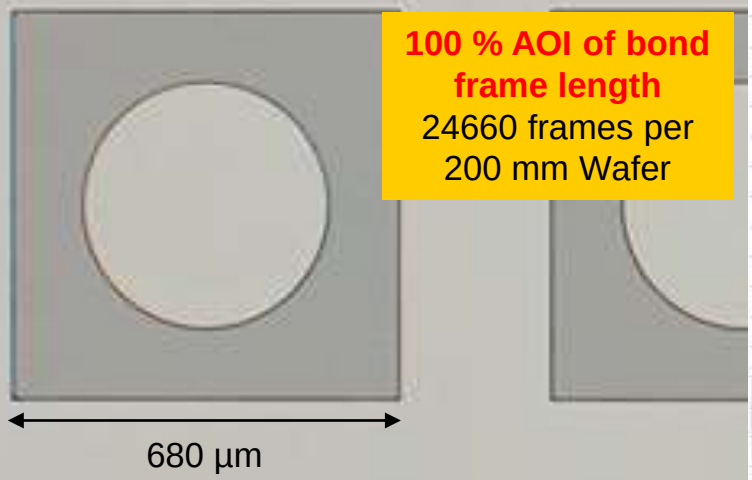
Laser Ablation Process and Results

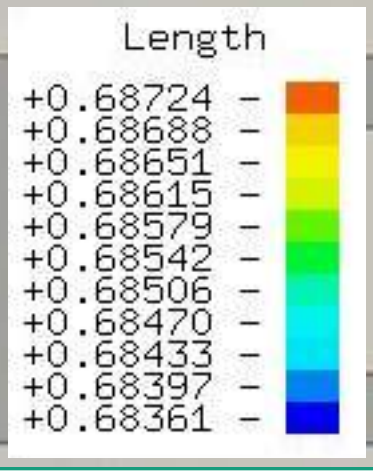
	Resolution Test Pattern	Bond Frame Pattern
Patterned double layer of 5 µm non-cured Cyclotene™ 3022-46 + Sacrificial Layer  24 pulses @ 650 mJ required to ablate trough!		
5 µm non-cured Cyclotene™ 3022-46 after removal of Sacrificial Layer by DI-Rinse 		

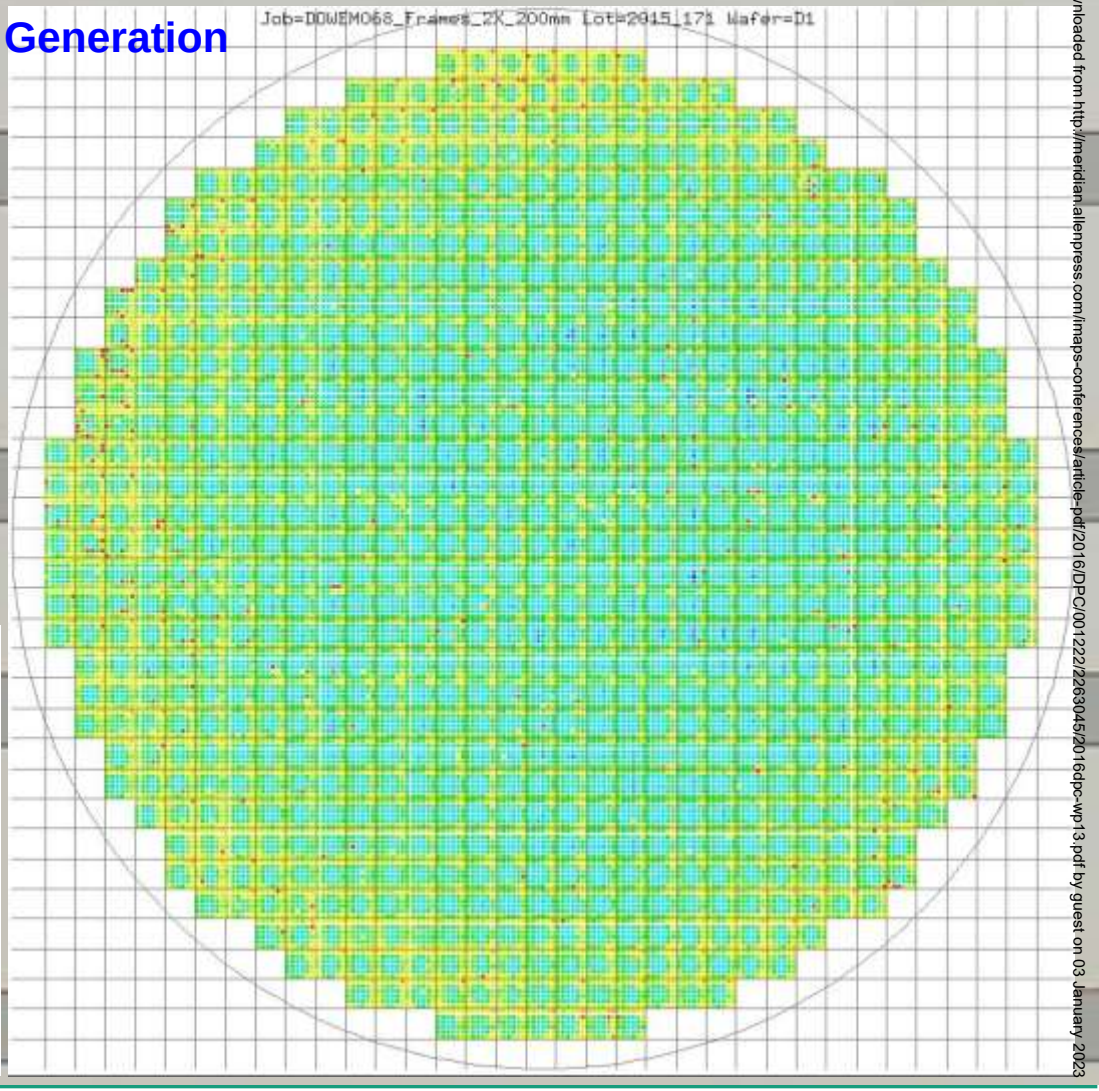
New BCB patterning process by laser ablation

Quality and Repeatability of Pattern Generation by Laser Ablation

100 % AOI of bond frame length
24660 frames per 200 mm Wafer

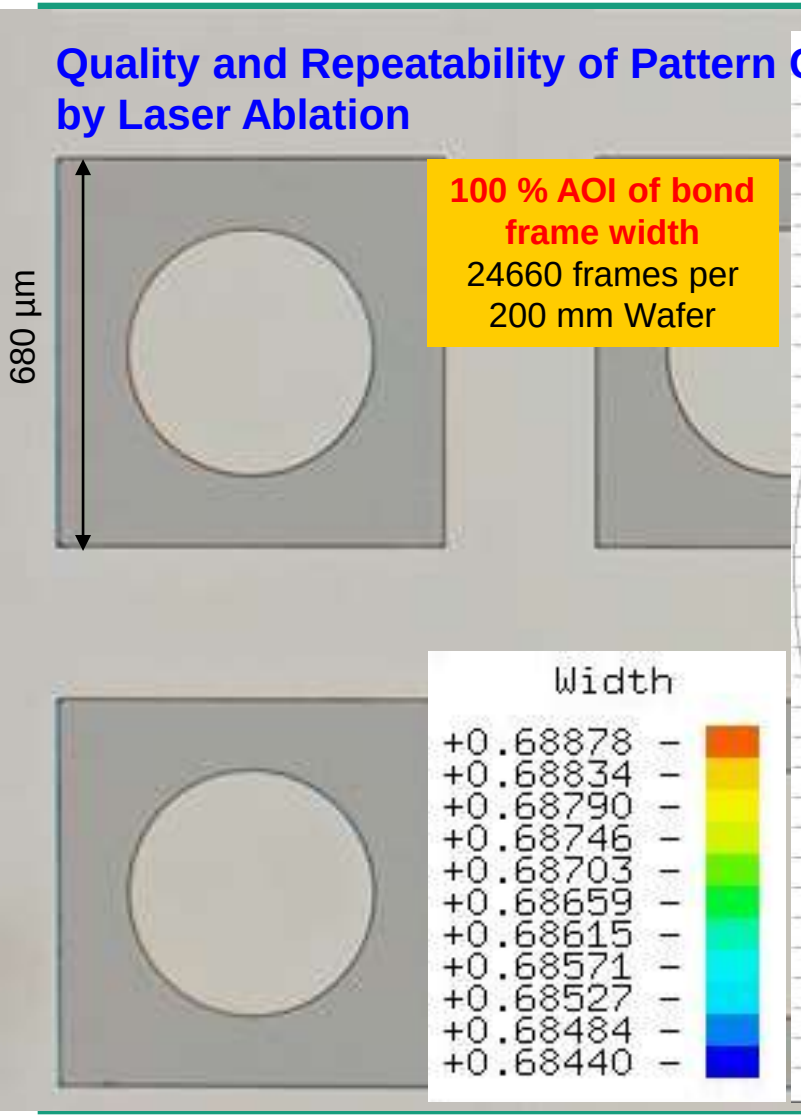




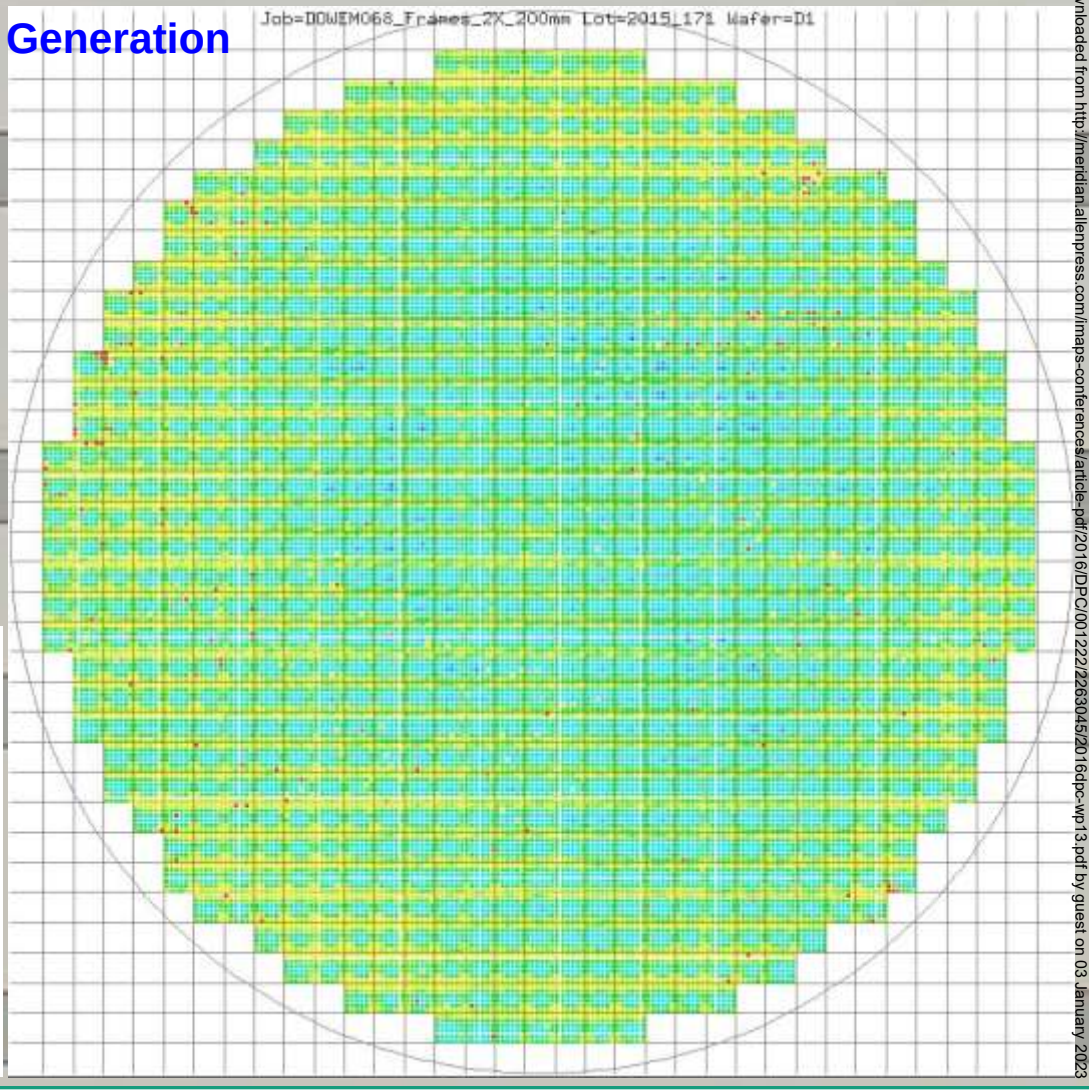


New BCB patterning process by laser ablation

Quality and Repeatability of Pattern Generation by Laser Ablation

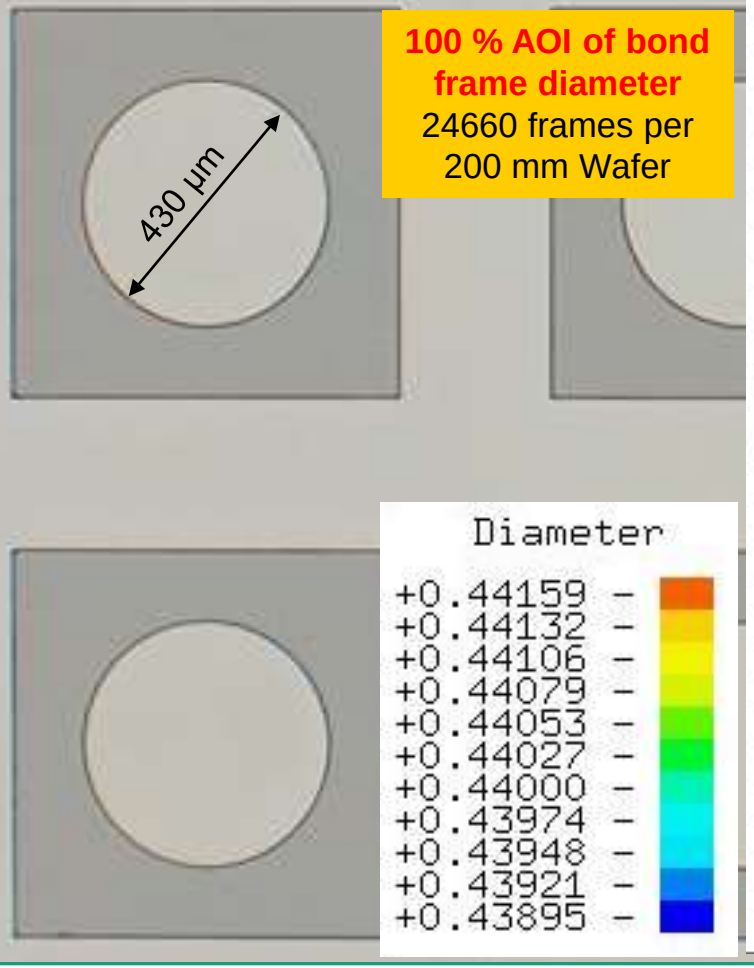


100 % AOI of bond frame width
24660 frames per 200 mm Wafer

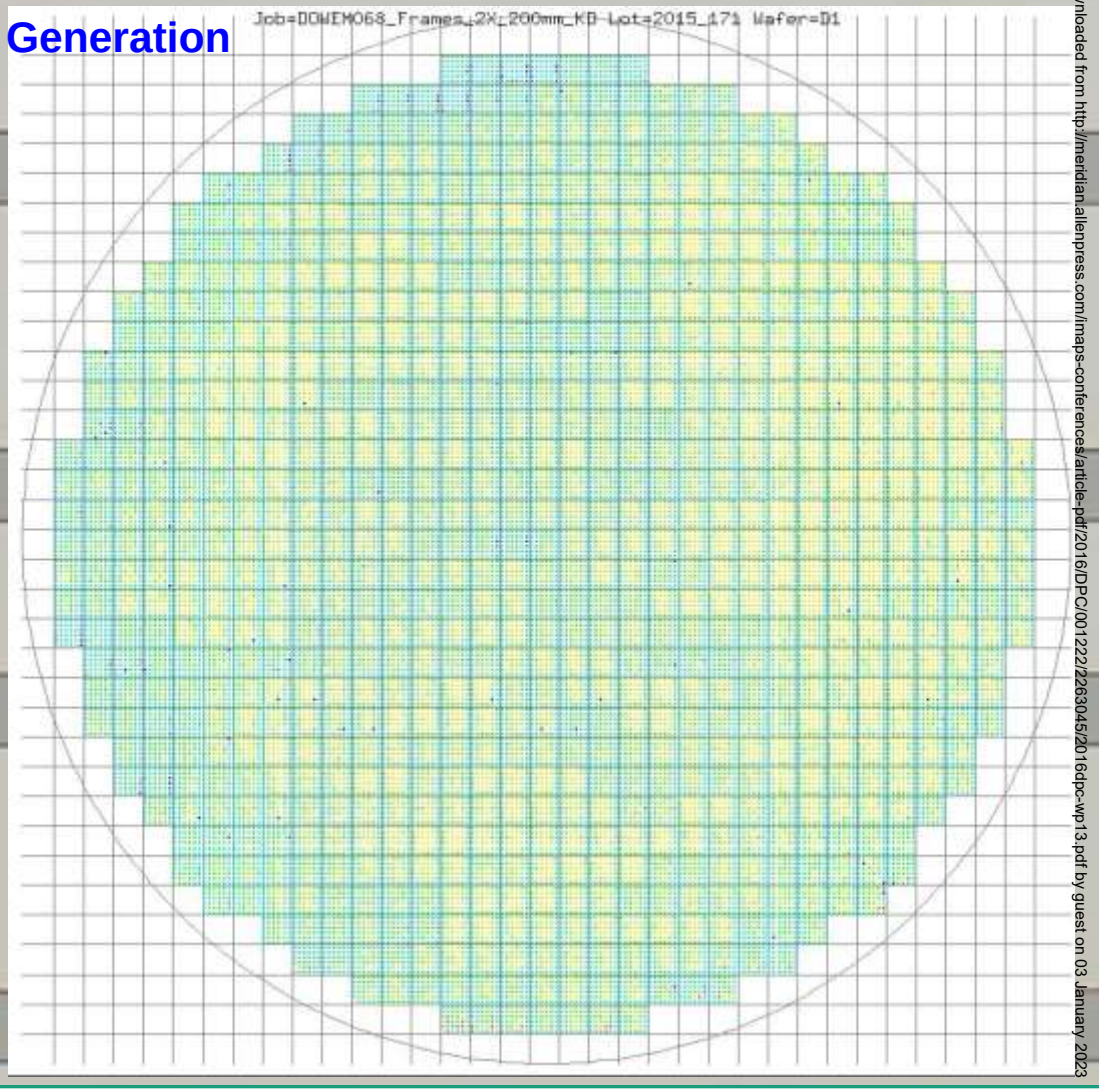


New BCB patterning process by laser ablation

Quality and Repeatability of Pattern Generation by Laser Ablation



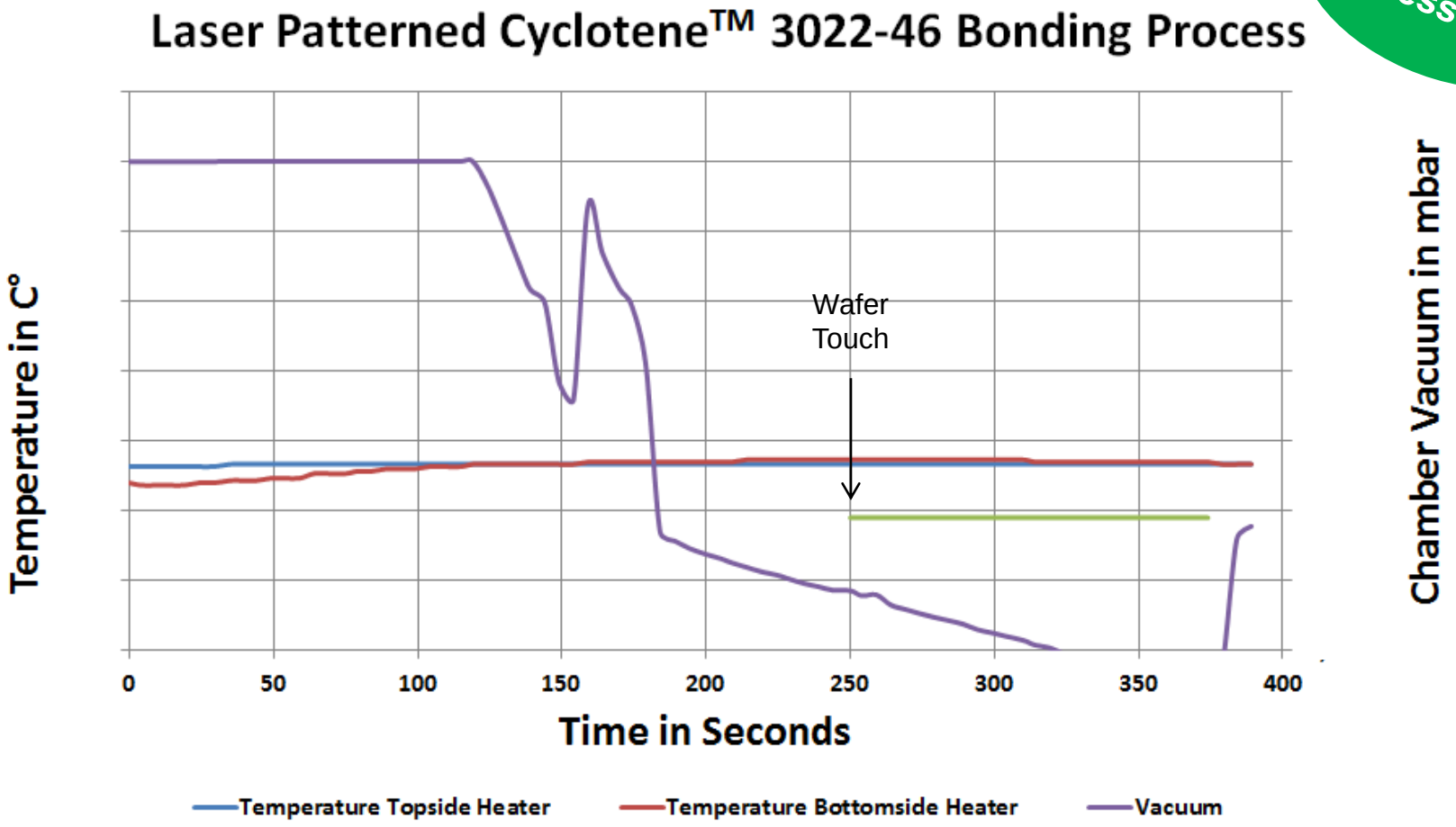
100 % AOI of bond frame diameter
24660 frames per 200 mm Wafer



New BCB patterning process by laser ablation

Wafer Bonding Process

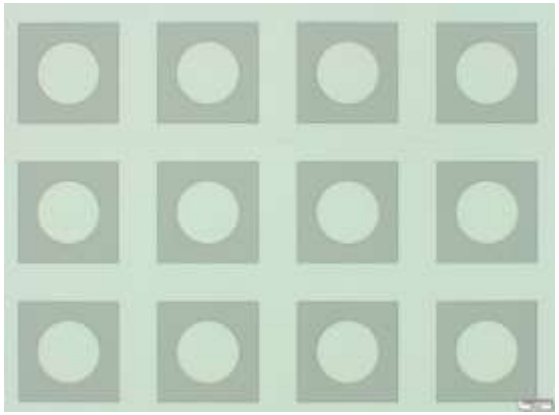
6.5 min process time!

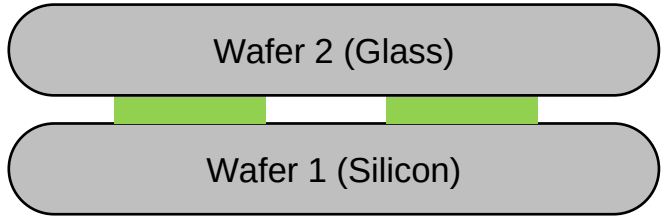


New BCB patterning process by laser ablation

Wafer Bonding Results

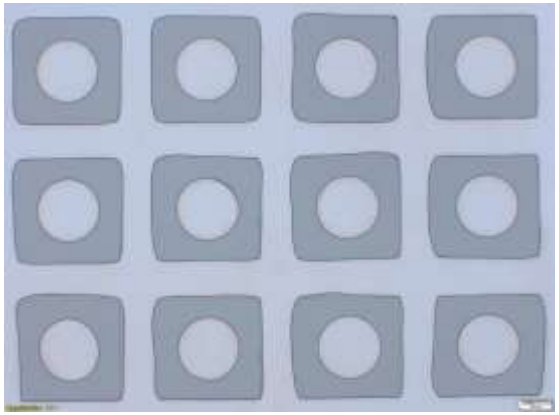
Result after Bonding (ok)

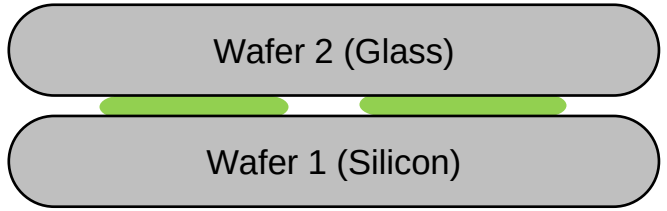




Low bonding temperature keeps viscosity up und prevents structure reflow!

Result after Cure (not ok)

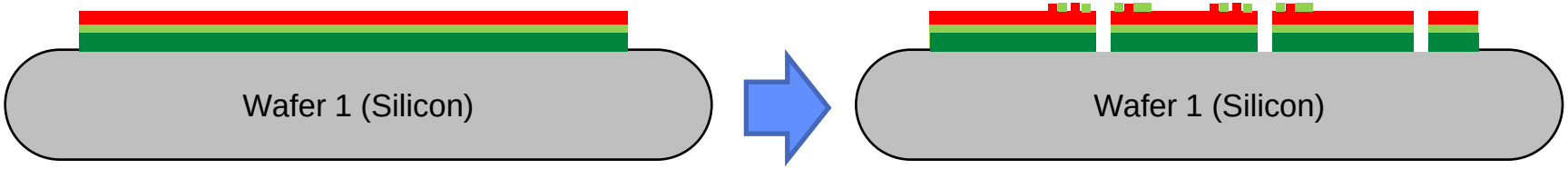




Viscosity drop during cure causes structure reflow!

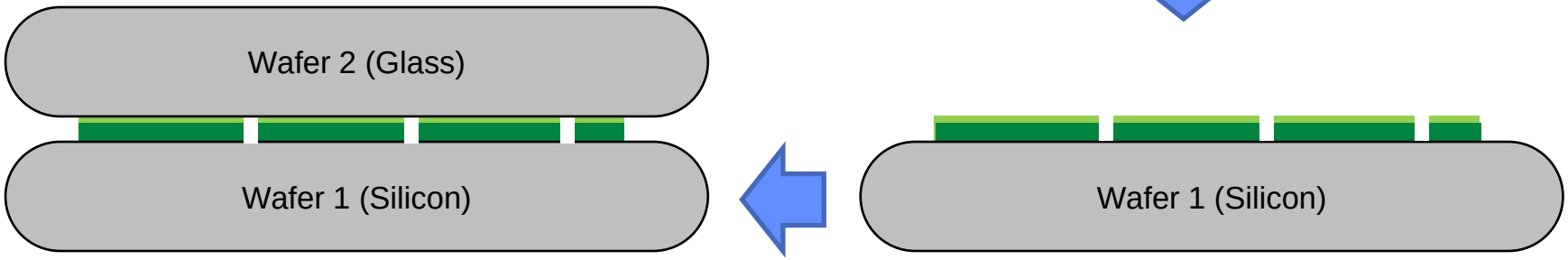
New BCB patterning process by laser ablation

Process Flow – Schematic (adapted)



- AP3000 priming
- Spin Coating of Cyclotene 3022-46+Cure
- Spin Coating of Cyclotene 3022-35+Bake
- Spin Coating of Sacrificial Layer

- Patterning of layer sandwich by laser ablation
- Deposition of debris at surface



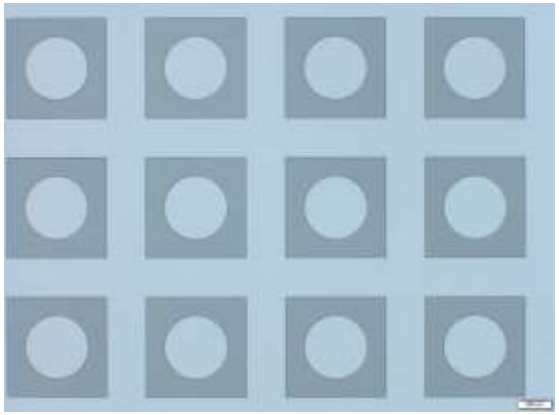
- Wafer to wafer Alignment & Bonding, Cure

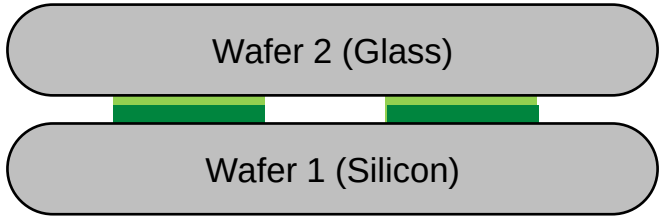
- Removal of Sacrificial Layer

New BCB patterning process by laser ablation

Wafer Bonding Results (adapted Process)

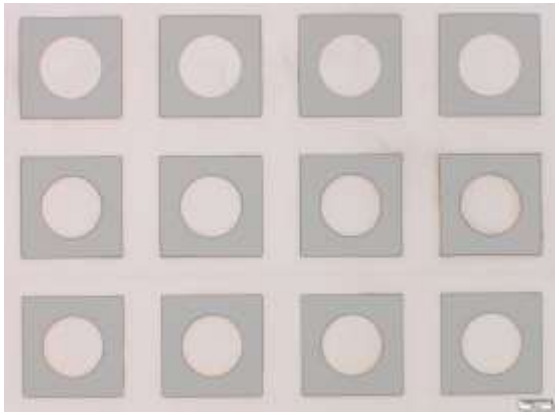
Result after Bonding (ok)

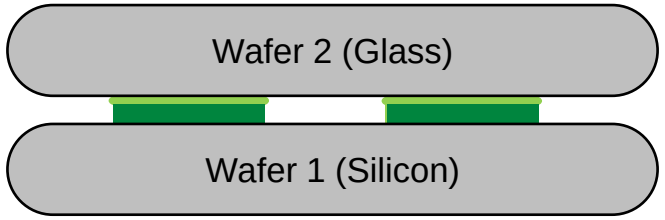




Low bonding temperature keeps viscosity up und prevents structure reflow!

Result after Cure (ok)

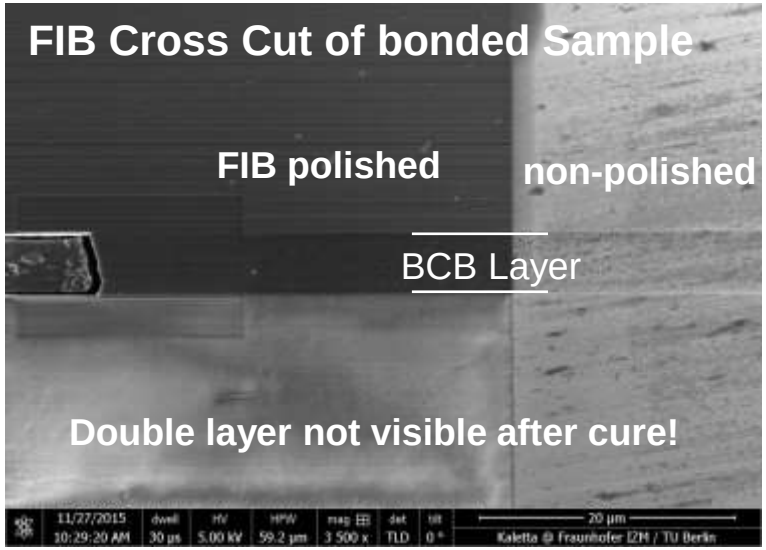


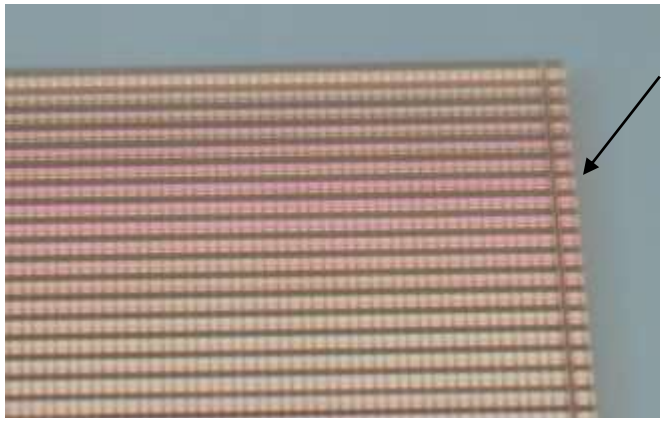


Viscosity drop during cure causes structure reflow but squeeze out is very limited due to small portion of non cured material!

New BCB patterning process by laser ablation

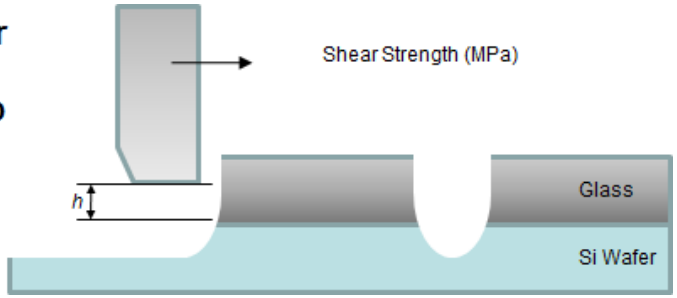
Sample qualification after Post Bond Cure



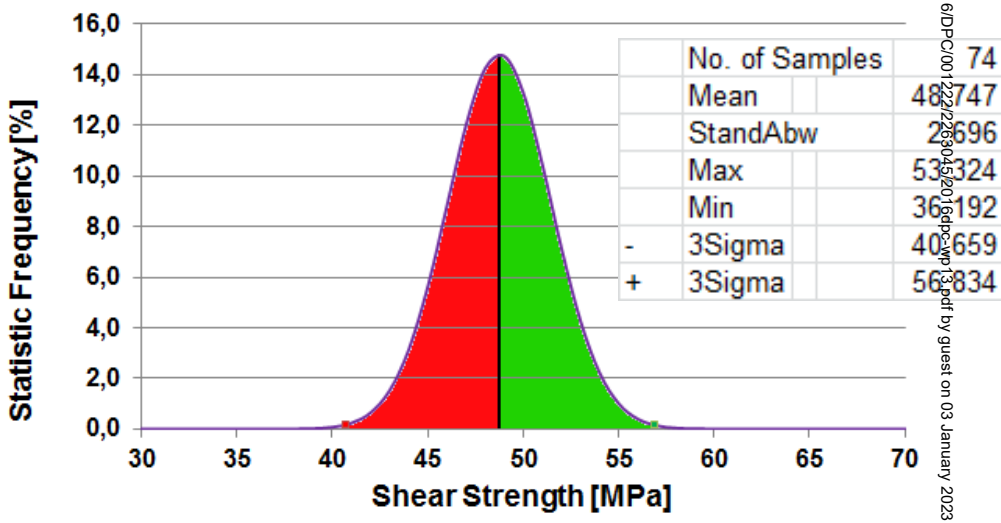


Samples prepared for shear tests along outside row of mother die.

Shear Test Setup



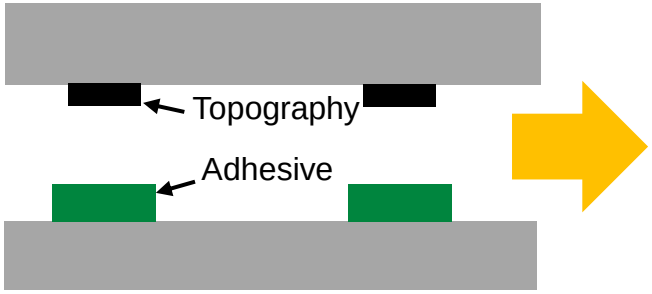
Statistic Distribution of Shear Strength



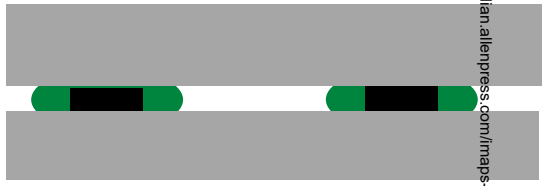
New BCB patterning process by laser ablation

Advantage of new patterning process

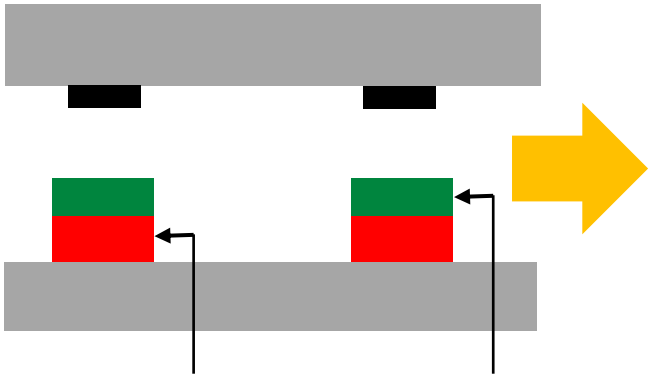
Void free bonding over topography requires sufficient flow capability of adhesive.



Lateral squeeze of adhesive during bonding due to good flow capability. Final gap height close to height of topography.



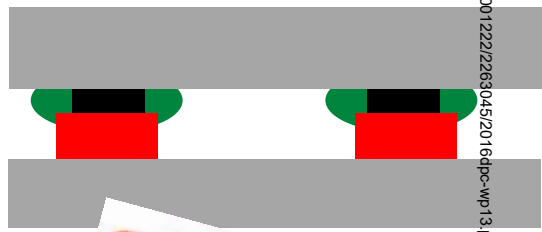
New patterning approach allows parallel structuring of adhesive double layers with different flow capability.



Socket of material with reduced flow capabiliy, e.g. cured polymer.

Material with good flow capabiliy adjusted to topography height.

Solid socket enables extended gap height. Topography can be bonded void free due to portion of material with good flow capability.



Outline

Introduction

Review of BCB based adhesive wafer bonding processes

New BCB patterning process by laser ablation

Summary

Summary

- **Cyclotene™ Resins allow non patterned and different types of patterned adhesive wafer bonding**
- **All processes support short bond cycle times between 6 min and 11 min and post bond batch cure**
- **Cyclotene™ 4000 Resins support easy patterning by direct lithography and void free bonding to partners with low topography**
- **Cyclotene™ 3000 resins have superior flow capabilities and support void free bonding to partners with increased topography**
- **Laser direct ablation was introduced as new method for patterning of non-cured Cyclotene™ 3000 Resins**
- **The new structuring method has shown excellent pattern reproducibility and supports parallel patterning of layers with different cure condition**

Cont@ct Information

Thank you for your attention!

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email: kai.zoschke@izm.fraunhofer.de

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