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Reuse and Characterization of Laser Lift-off (LLO) of Bonded Wafers for Advanced Packaging

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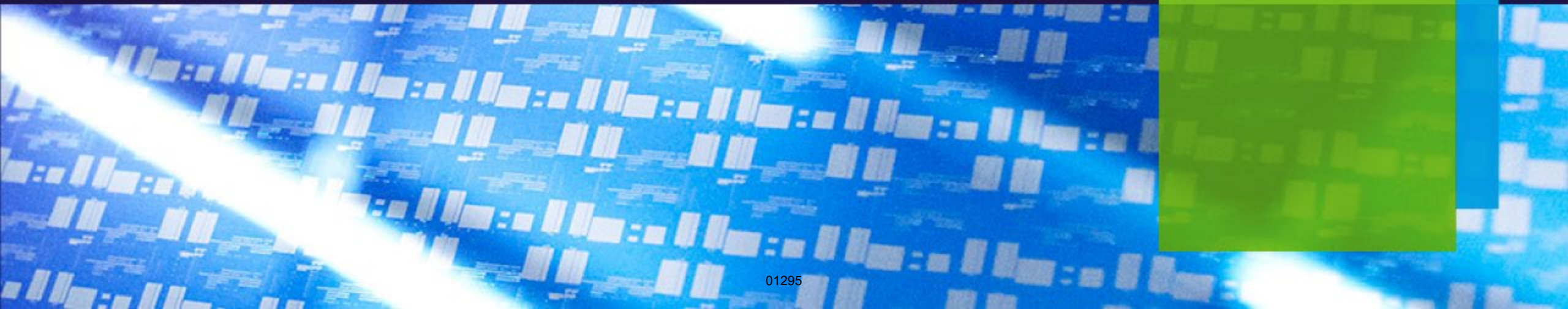


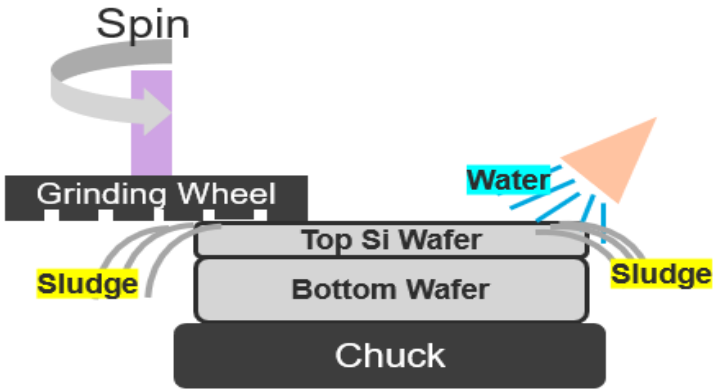
Outline

- Background & Process flow
- Carrier wafer reuse
  - Engineering stack optimization
  - Reuse demonstration
- Thermal characterization
  - Simulations for thermal impact
  - Experimental results
- Summary

IR Laser Lift Off (LLO) Motivation

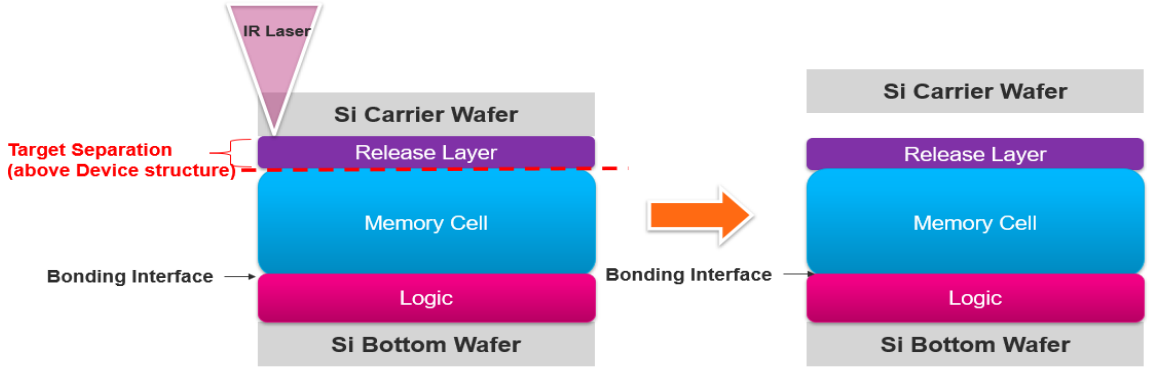
- An alternative method (from Mechanical grinding) to remove ~ 750µm thick of Si substrate from permanent bonded wafers for Device Layer Transfer

Mechanical Back-side Grinding



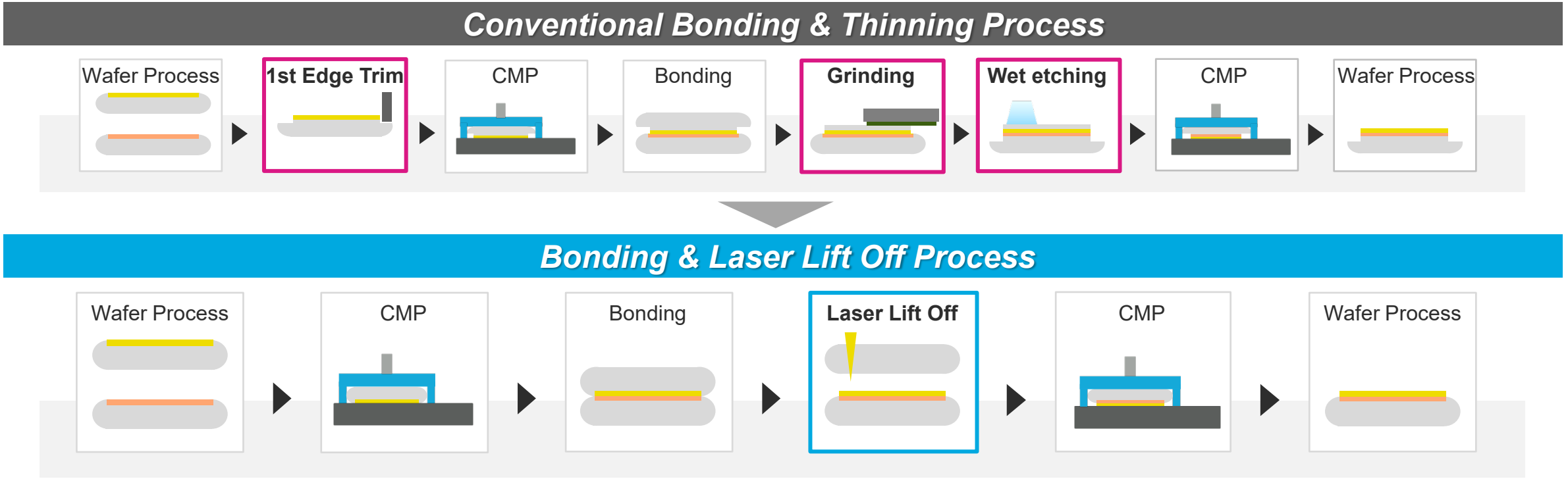
- **High cost for technology insertion**
  - Consumes wafer during process (Cost for Si substrate).
  - Consumable materials (grinding wheel, slurry) for process.
- **Environmentally not-friendly**
  - High water usage.
  - Sludge formation.
  - Additional complicated process steps required for cleaning (sludge).

Laser Approach



- **Low cost for Technology insertion**
  - No consuming wafer as carrier wafer can be reused.
  - No consumable materials usage.
- **Environmentally friendly**
  - No water usage.
  - No formation of the sludge.
  - No complicated cleaning step requirement for re-using Si-carrier wafers.

Laser Lift Off Process Flow



Process Performance

Reduce process step
Replaces thinning related processes

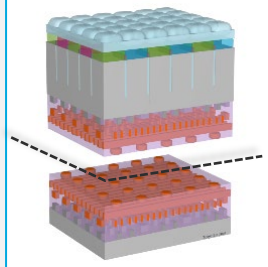
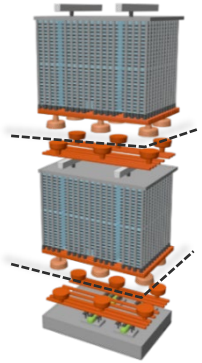
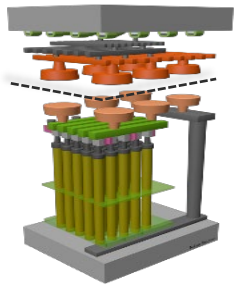
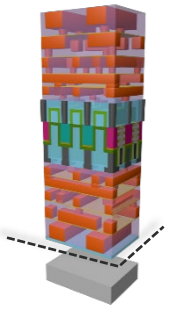
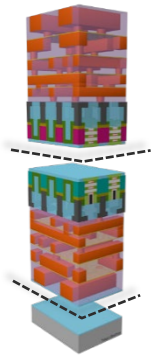
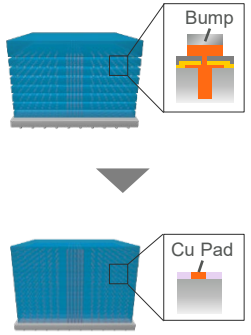
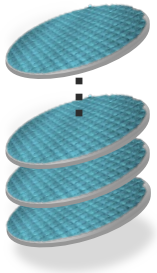
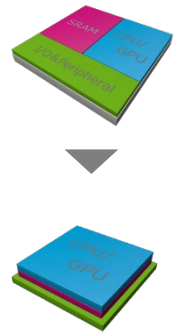
Area Efficiency
Reduced mechanical damage

Environmental Performance

90% reduction of DIW usage
Deionized water does not require in laser process

Wafer Re-use
Reduction of CO2e and Substrate usage

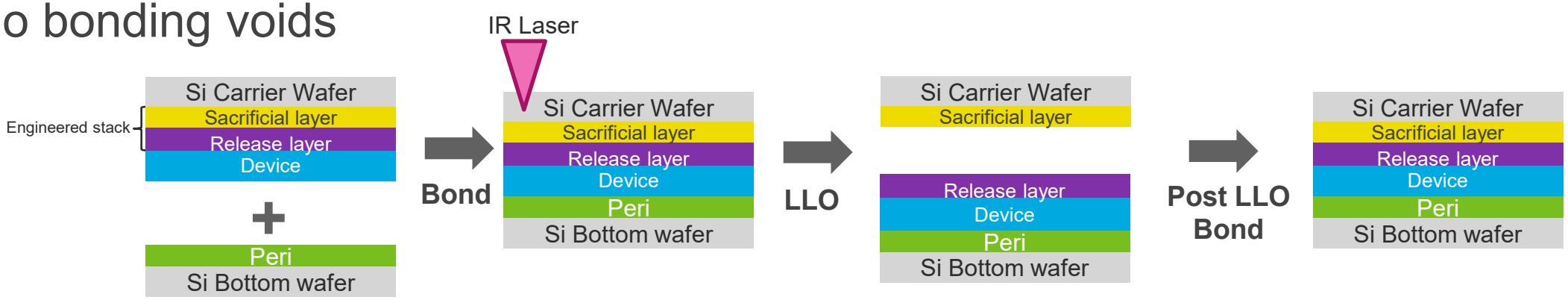
Laser Lift Off Applications

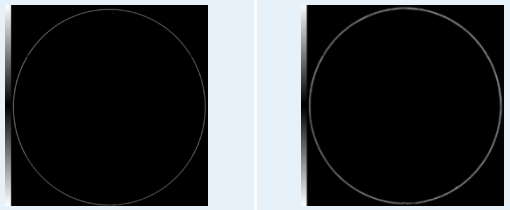
Application	Front End					Advanced Packaging		
	CIS	NAND	DRAM	Logic		Stack Memory		3DIC
Stacking Device	BSI Pixel + (Peripheral) + Logic	3D NAND ⋮ + Cell + Cell + Peripheral	VCT DRAM (Si Substrate) + Peripheral + Cell + (Si Substrate)	BSPDN Logic + Si Substrate	BSPDN+CFET Logic + Logic + Si Substrate	HBM DRAM ( ) Die ⋮ DRAM ( ) Die + DRAM ( ) Die + Logic Wafer	W2W memory DRAM Wafer ⋮ DRAM Wafer + DRAM Wafer + Logic Wafer	SoC Disaggregation A, B, C Die, Die, Wafer
Structure								

Carrier Wafer Reuse by Laser Lift Off

Carrier Wafer reused with different sacrificial layers

- Carrier wafer reworked and bonded after LLO
- No bonding voids



Sacrificial Film A	
Pre LLO Bonded wafer CSAM	Post LLO Bonded wafer CSAM
	

No voids

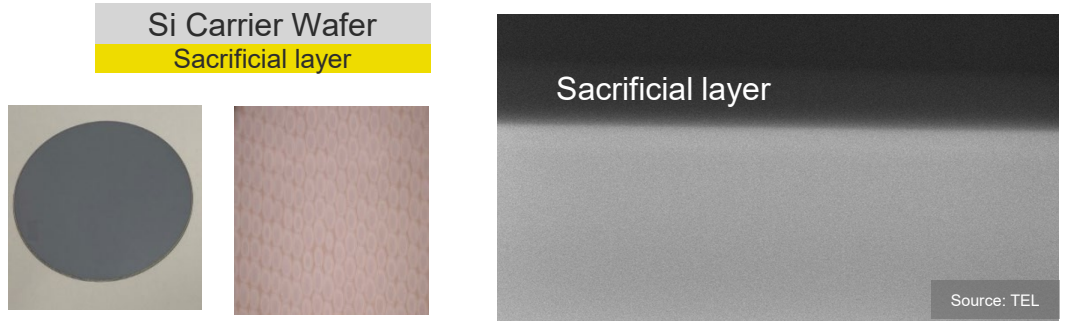
Sacrificial Film B	
Pre LLO Bonded wafer CSAM	Post LLO Bonded wafer CSAM
	

No voids

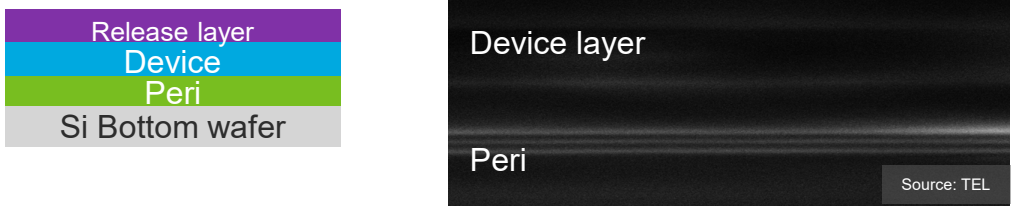
Wafer Separated – no localized damage on carrier wafer.

Sacrificial Film A

- Carrier wafer

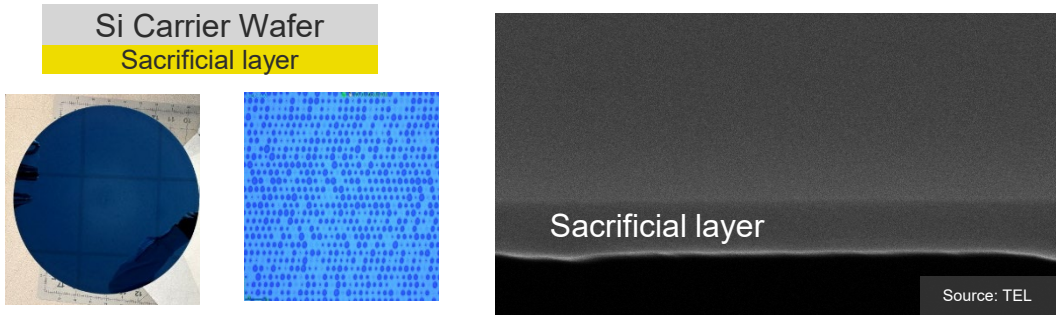


- Product: NAND

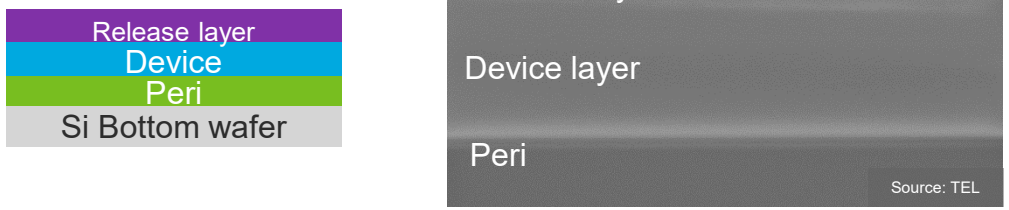


Sacrificial Film B

- Carrier wafer



- Product: W2W Memory

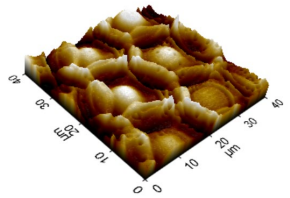


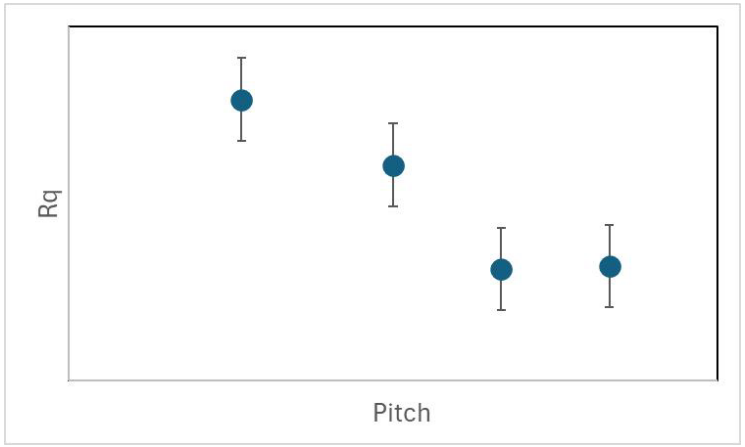
Films A & B cause separation at target layer

Laser ablation effect on carrier wafer roughness

Sacrificial Film A

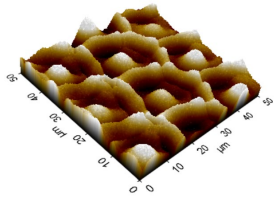
- BKM
  - Rq= 2.320nm
  - TTV=16.340nm

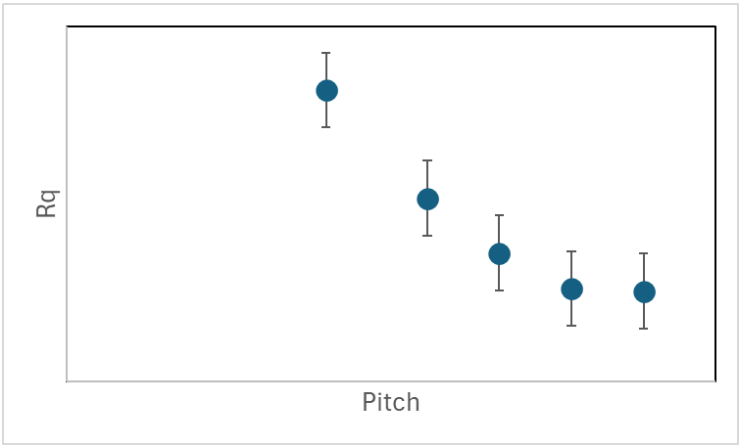




Sacrificial Film B

- BKM
  - Rq= 1.900nm
  - TTV=11.24nm

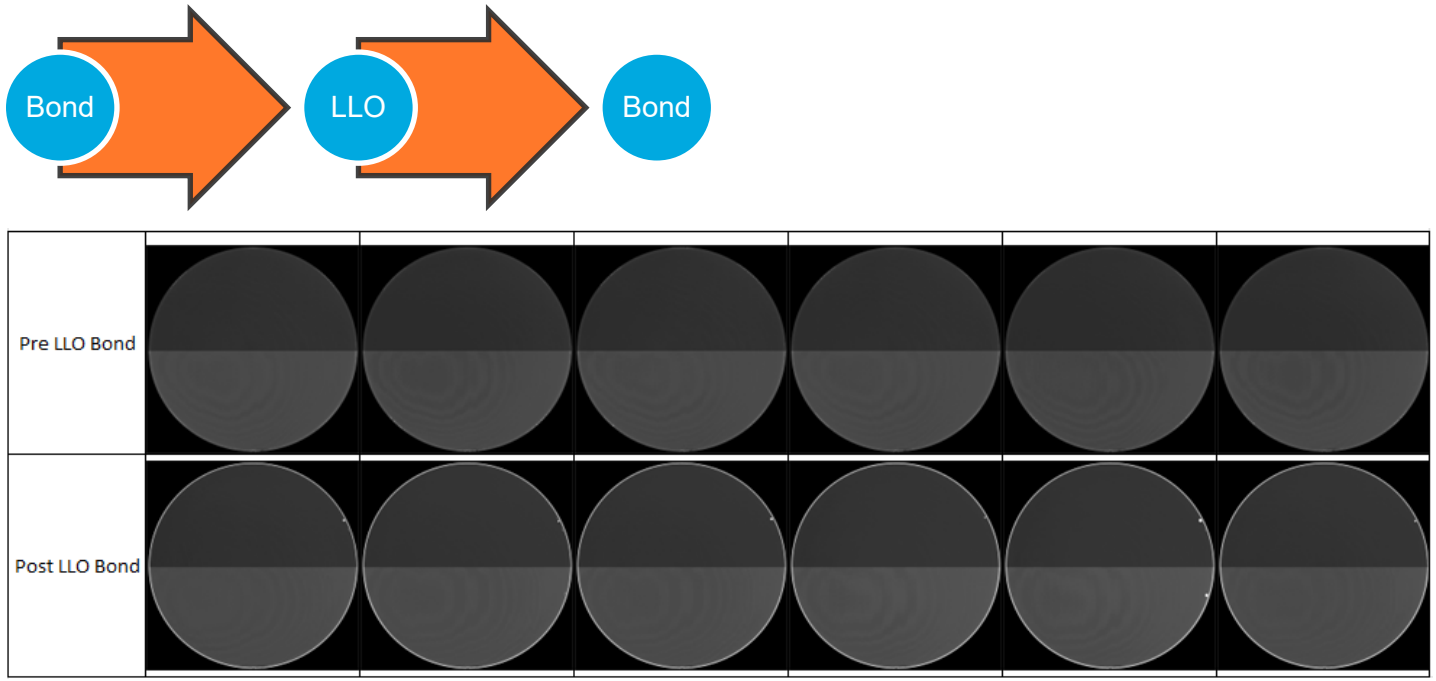




Increasing laser pitch decreases roughness
Improves throughput and surface profile

Sacrificial layer effect of wafer yield

- Sacrificial Layer B successfully reused
- Edge voids caused by bonding tool error
- Different probe used on top and bottom on CSAM resulting in different gradient

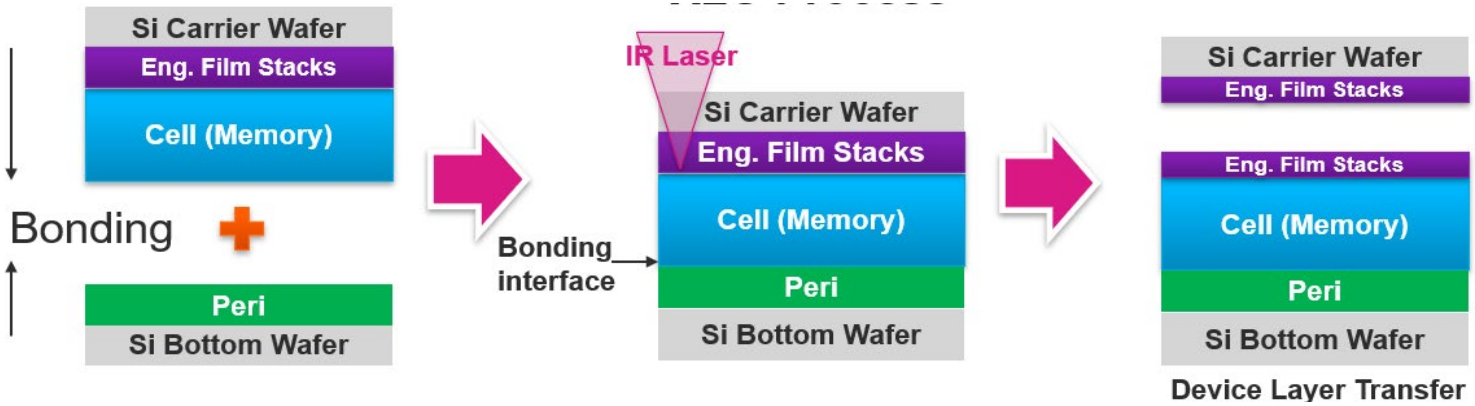


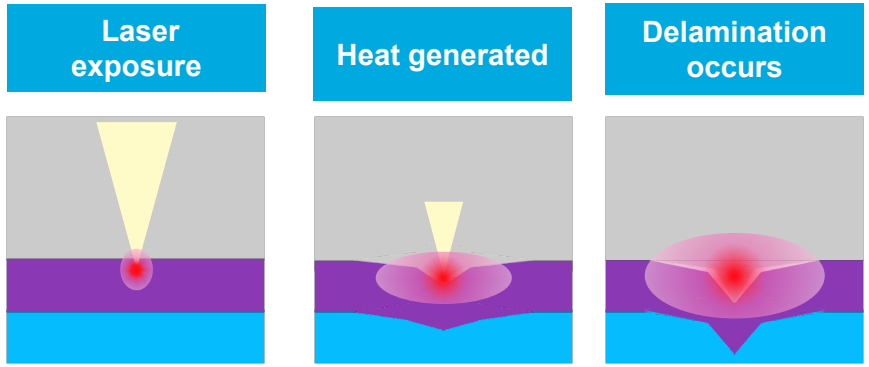
Thermal Damage Detection

Thermal Damage Detection is Critical on Packaging Application

- Laser release method is applicable for packaging applications for AI
- Nanosecond pulse, cannot detect thermal change with conventional methods to optimize engineering stack (buffer films) to lower thermal budget

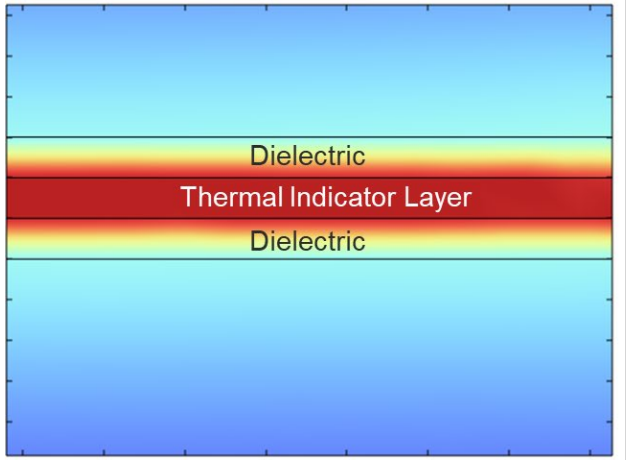
What is the highest temperature caused by the laser?



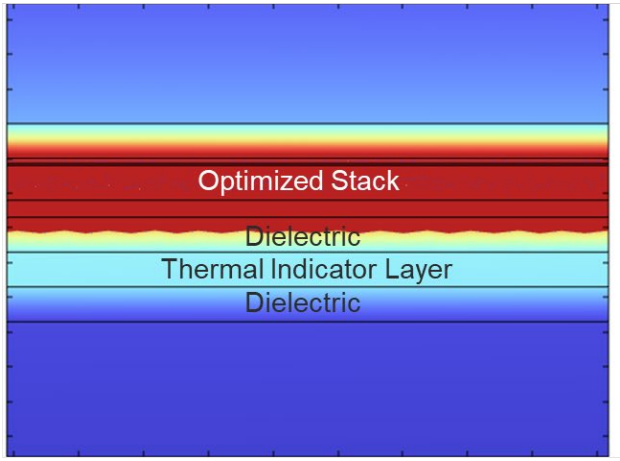


Simulation of layer optimization

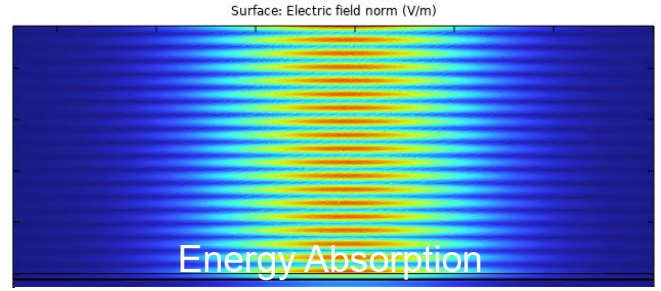
- Materials and thicknesses can be optimized to minimize energy or heat that travels to underlying devices.
- Optimized ENG Stack that reduces heat at the thermal indicator compared to no ENG Stack

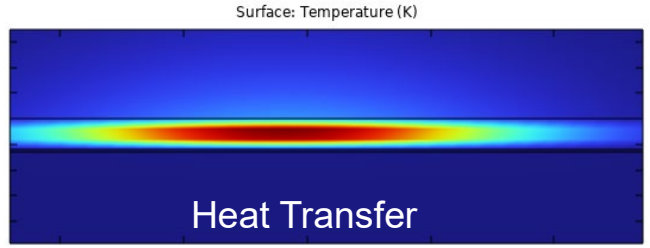


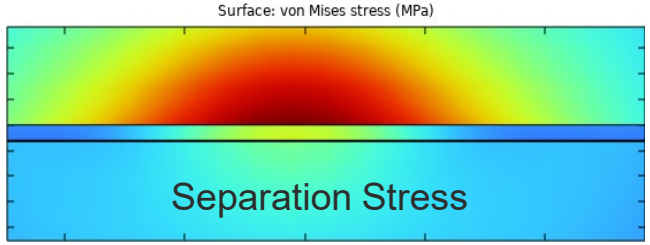
No engineered stack



Engineered Stack



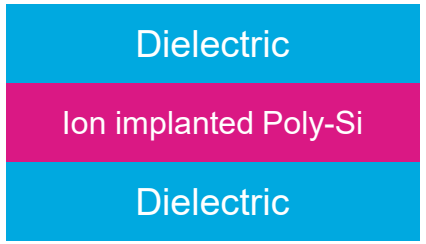




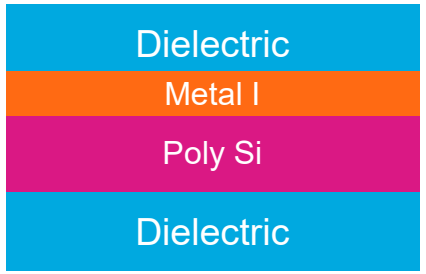
Thermal Damage Detection for laser exposure

- LLO laser exposure had a thermal effect at device

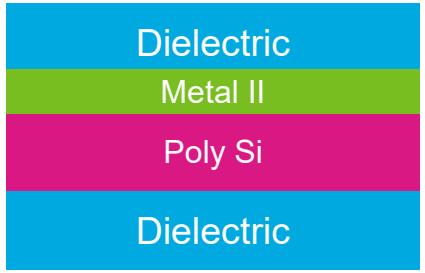
1. Ion Implant:
   - Detection range: 800°C-1000°C
   - Time of Flight SIMS

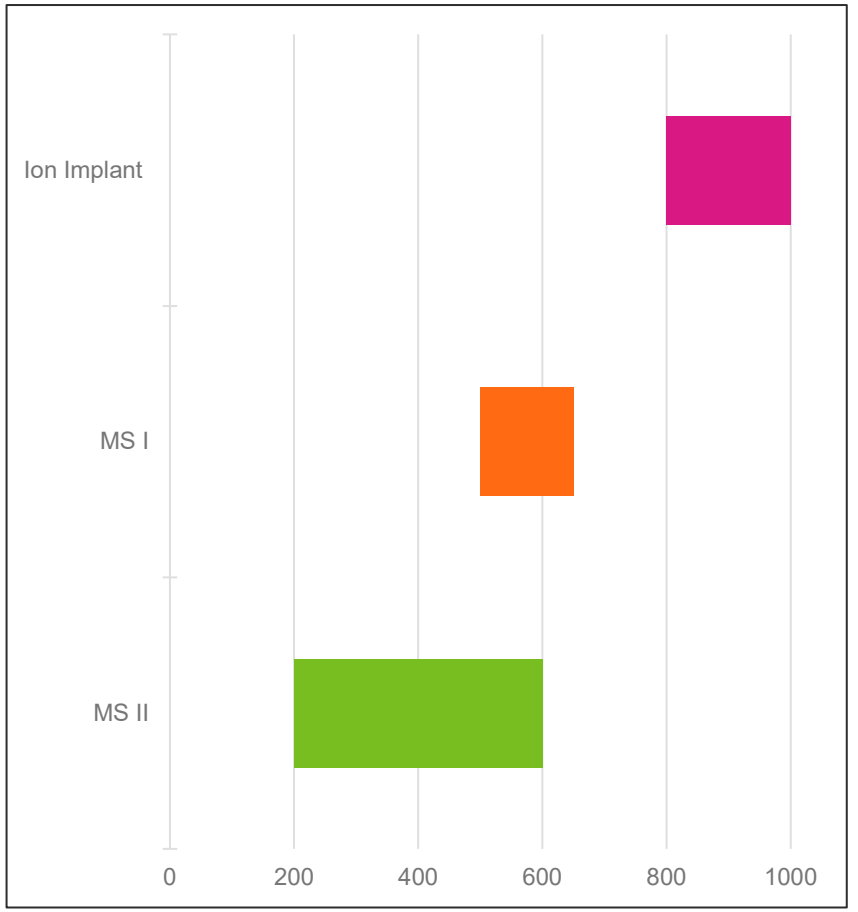


2. Metal Silicide I test vehicle:
   - Detection range: 500°C-650°C
   - X-Ray Diffraction



3. Metal Silicide II test vehicle:
   - Detection range: 200°C-600°C
   - X-Ray Diffraction

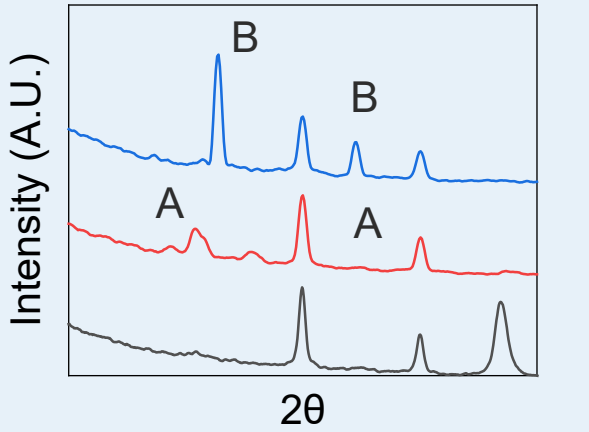


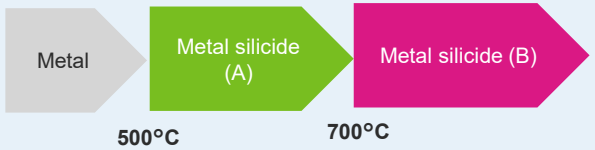


Engineered film stack acts as an effective insulator

Metal Stack I

Reference Anneal





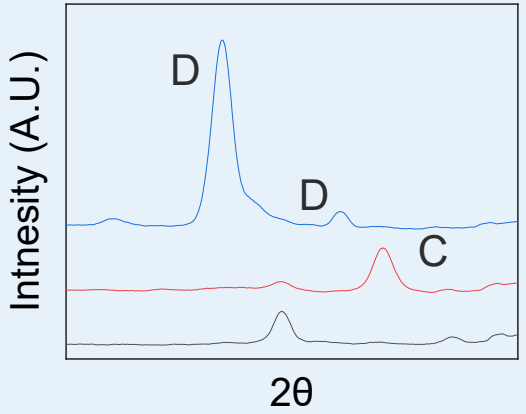
LLO

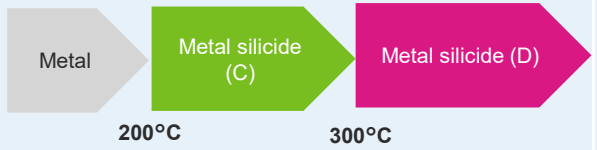
<500°C +ENG layer
Lower detection limit



Metal Stack II

Reference





LLO

<200°C +ENG layer
Lower detection limit



Summary

- Demonstrated reuse of top carrier wafer after laser lift off.
- A quantitive thermal detection method for laser processing was shown based on temperature models.
- Laser induced thermal damage physically characterized by test structures
  - >800°C, Ion implantation
  - <700°C, XRD phase transition
- Engineered film stack protected device from laser release process. Metal silicide II stack showed less than or equal to 200°C with engineered film stack.
- Reproducibility of thermal evaluation ongoing.

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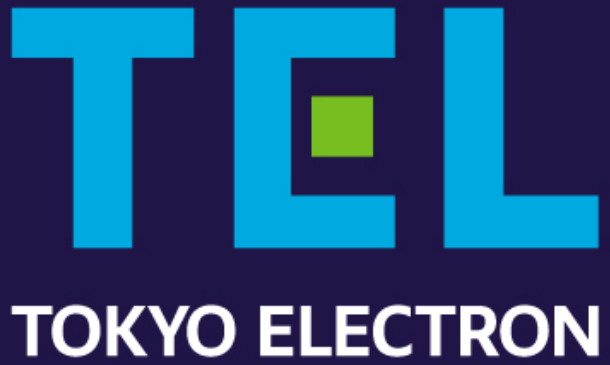
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