BBCube 3D: Heterogeneous 3D Integration Using WoW/CoW for Near Memory Computing

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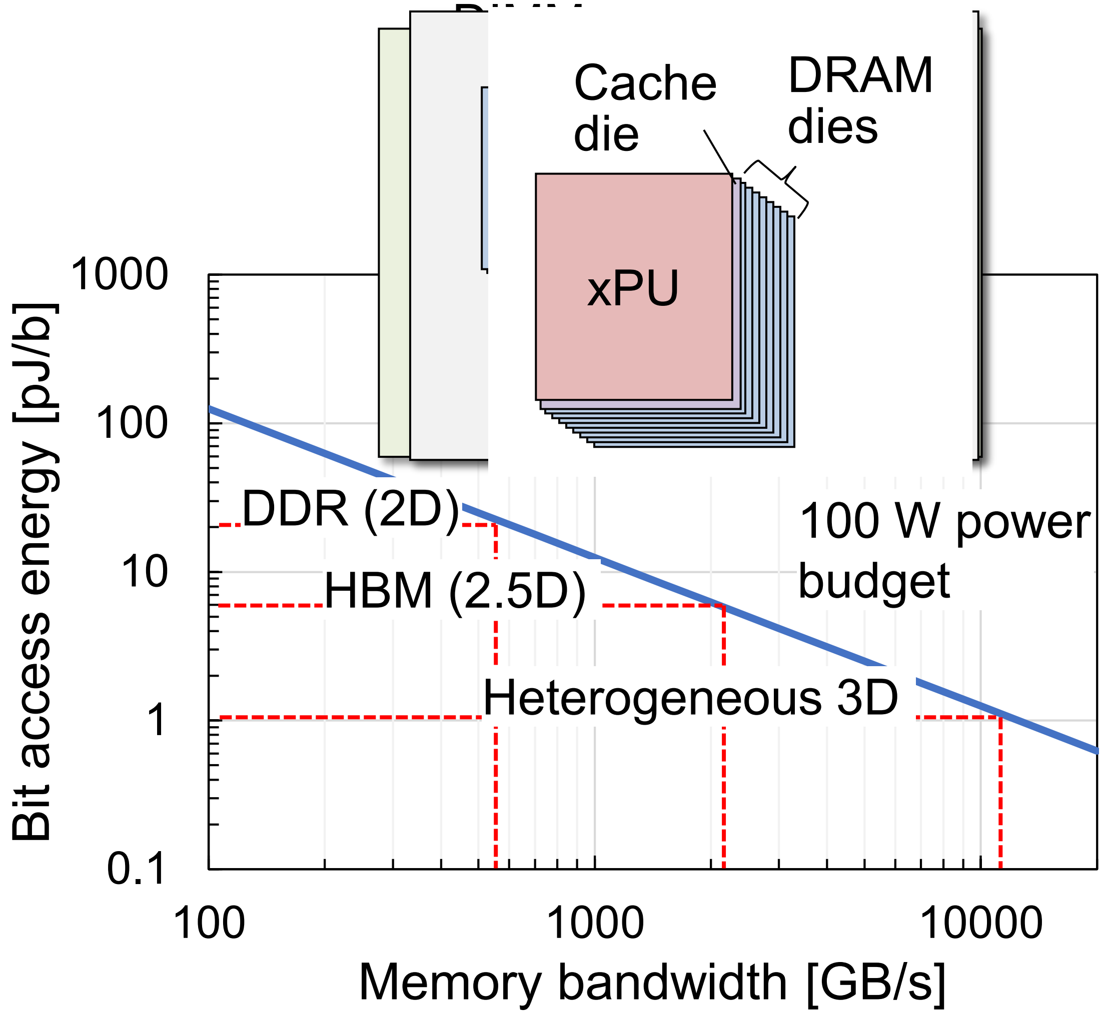
Outline

- Motivation
- Analysis Models
- Analysis Results (Thermal)
- Analysis Results (Electrical)
- Conclusion

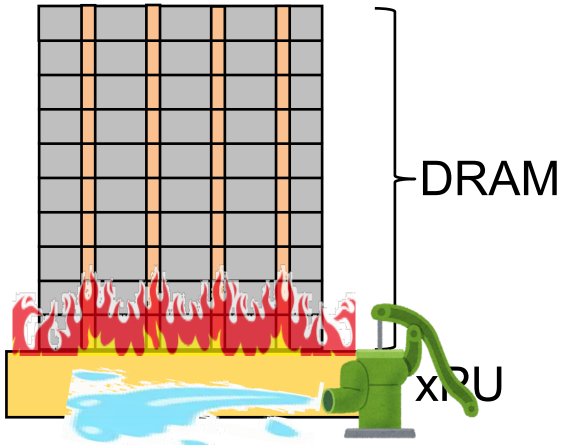
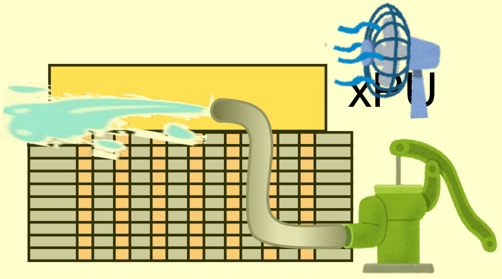
Motivation

- Demands for high data bandwidth are increasing
- HBM has been introduced
  - High bandwidth with the same power
  - 2D transmission prevents improvement of access energy
- Heterogeneous 3D integration
  - Paving the way to 10 TB/s



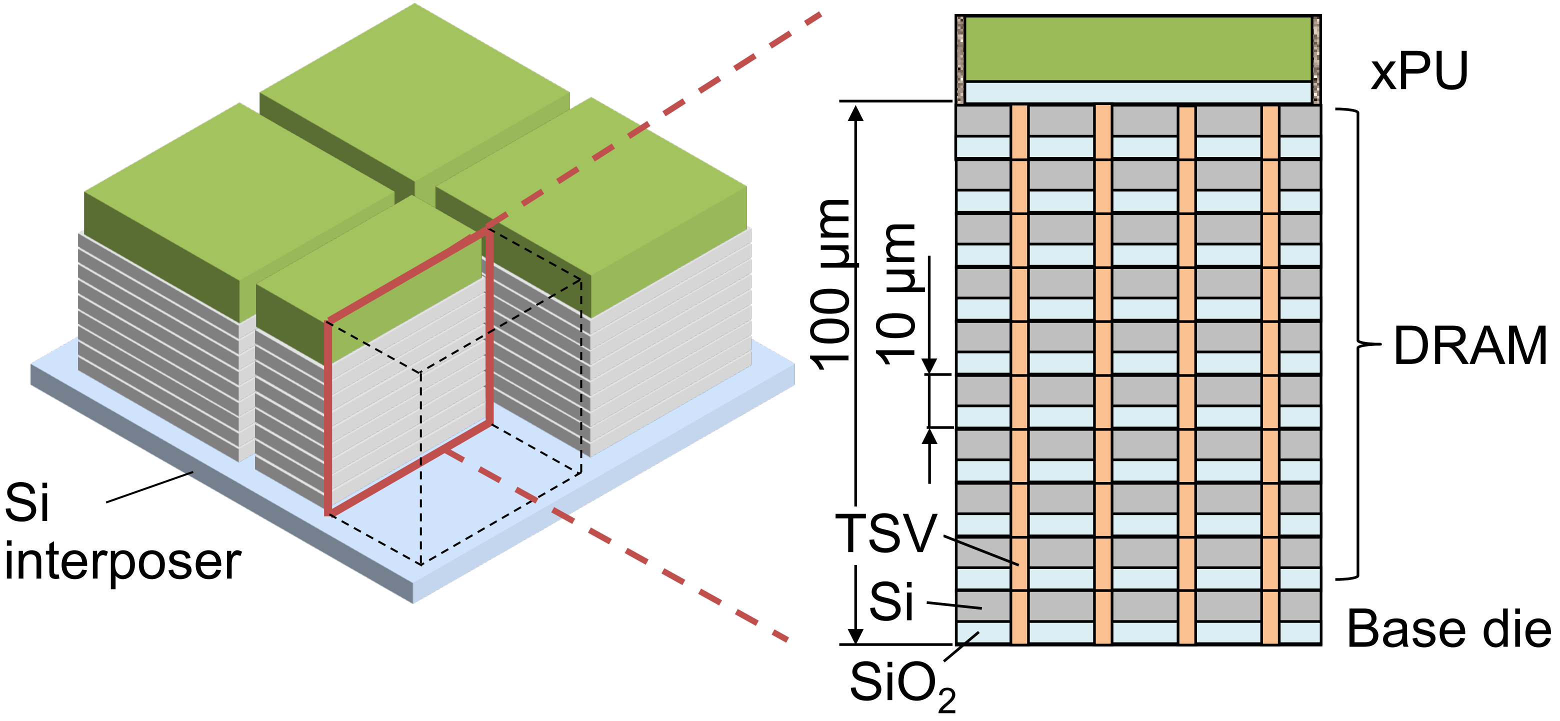
Heterogeneous 3DI challenges

- Cooling
  - xPU cannot dissipate heat sufficiently
- Power delivery
  - Impedance of TSV causes supply voltage drop and large droop
- BBCube has potential to solve 3DI issues
  - Dense TSVs
  - Thin dies

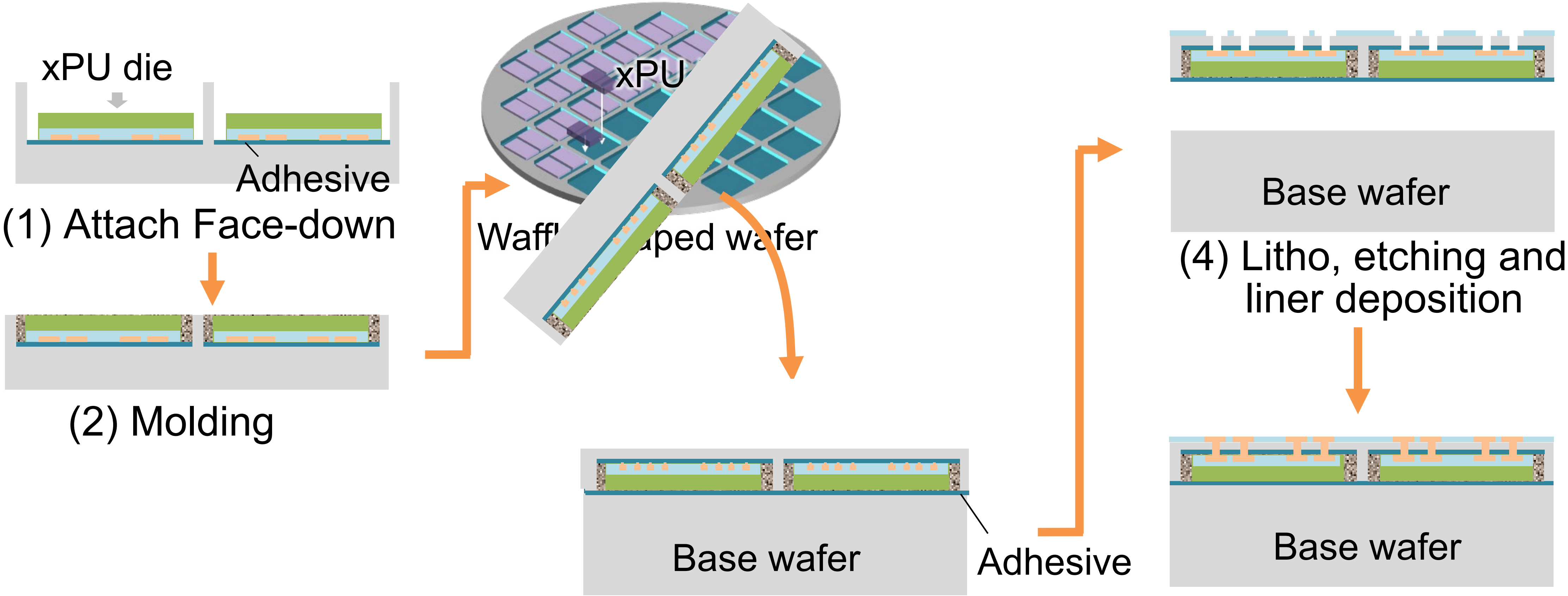
	Memories on top of xPU	BBCube 3D
Structure		
Cooling	Difficult	Easy
Power Delivery	Easy	Easy

Structure of BBCube 3D

- BBCube 3D comprises
  - Multiple xPU chiplets
  - Last level cache die
  - Laminated DRAMs
  - Base die
- Stacked by WoW and CoW



Process Flow of BBCube 3D (CoW)



(1) Attach Face-down

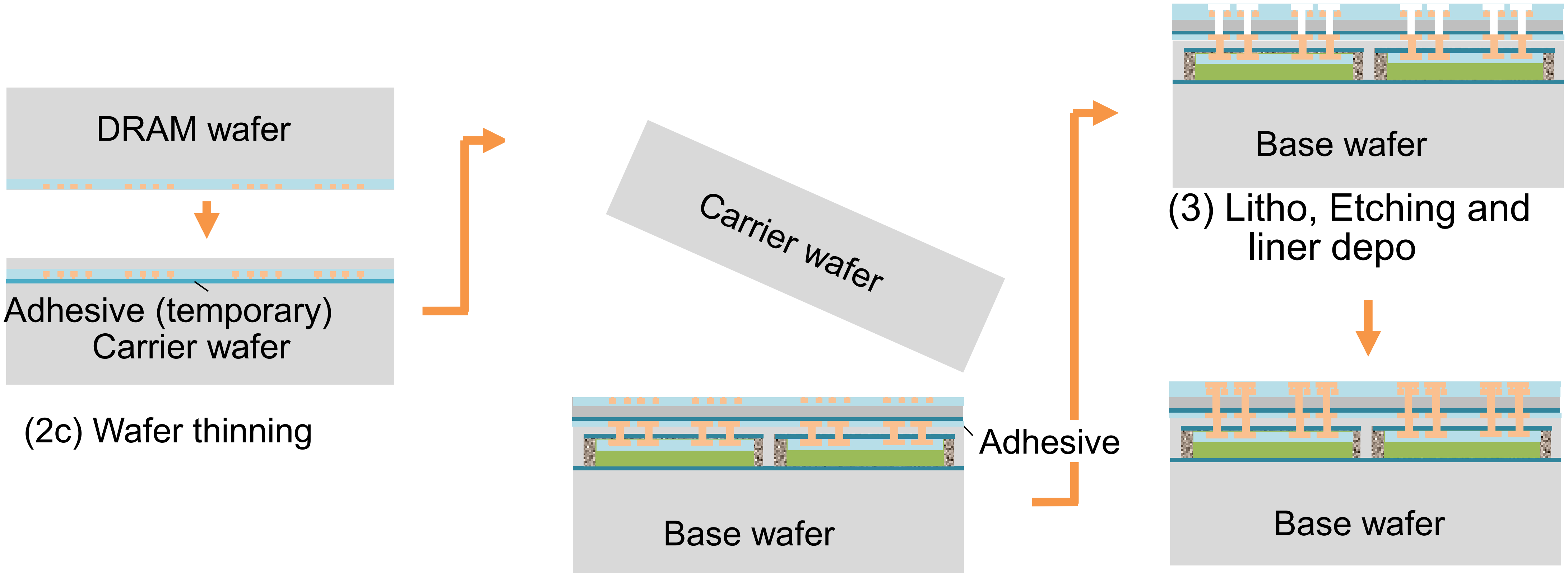
(2) Molding

(3) Bonding and wafer thinning

(4) Litho, etching and liner deposition

(5) Cu ECD and planarization by CMP

Process Flow of BBCube 3D (WoW)



DRAM wafer

Adhesive (temporary)
Carrier wafer

(2c) Wafer thinning

Carrier wafer

Adhesive

Base wafer

(2) Bonding and debond
carrier wafer

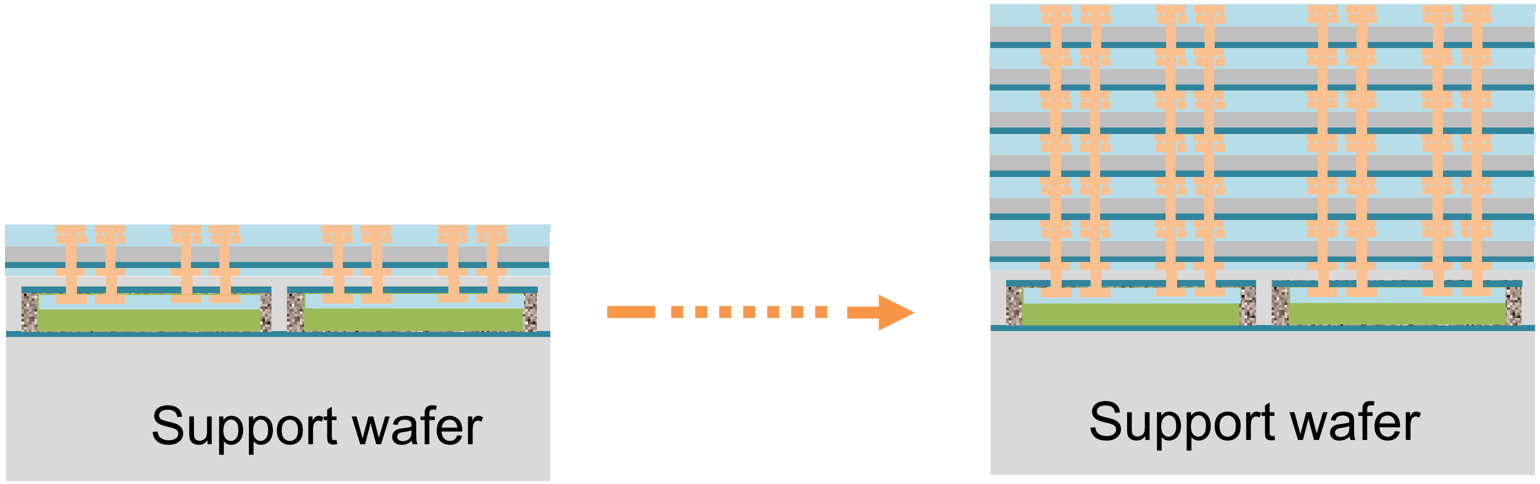
Base wafer

(3) Litho, Etching and
liner depo

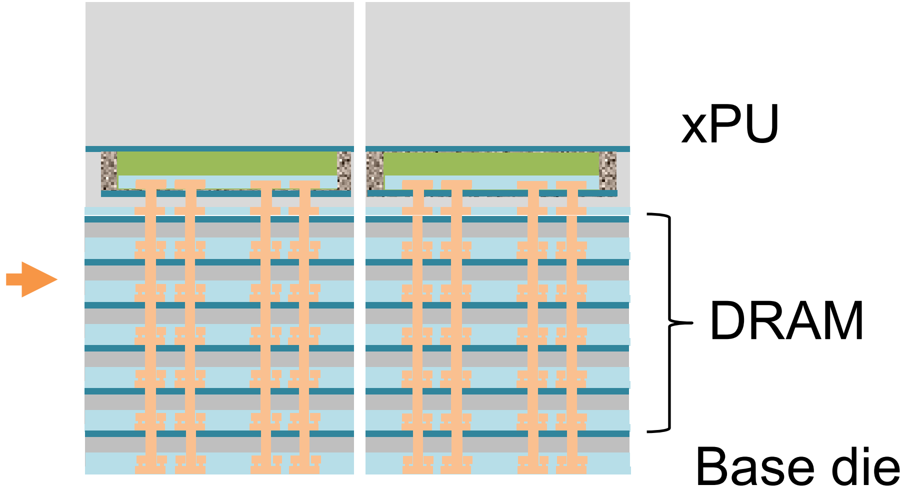
Base wafer

(4) Cu ECD and
flattened by CMP

Process Flow of BBCube 3D (WoW)



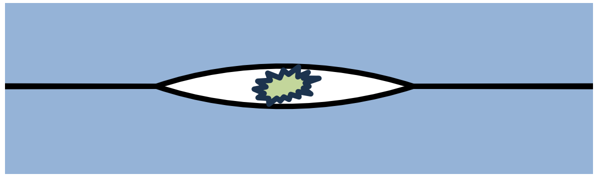
(9) Repeat step 6 to 8



(13) Dicing and singulation

Superior Connectivity of BBCube

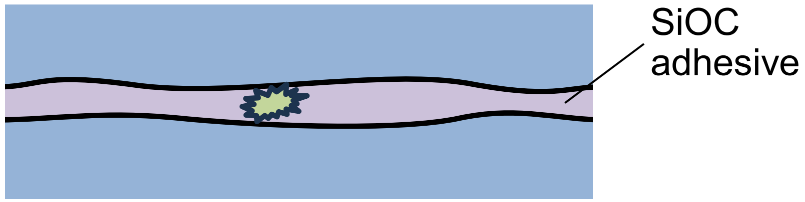
- Bumpless Via-Last interconnect similar to Cu/Low-k BEOL process
  - Stacking and thinning first, TSV formation last
  - Wafer/die bonding used SiOC adhesives. No needs nano-scale planarization
  - BEOL-based high reliability interconnects with low-thermal budget



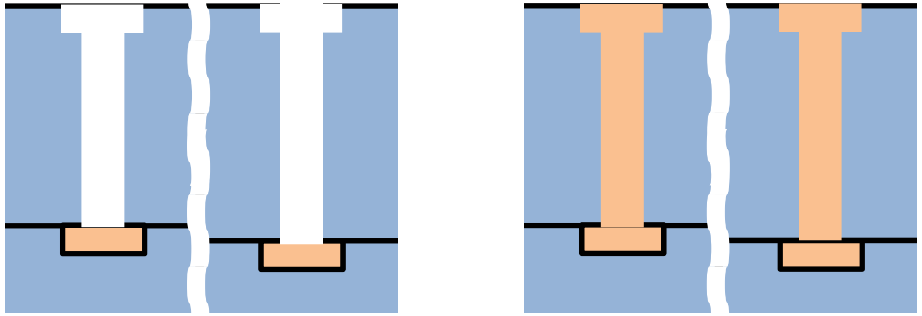
Nanometer-size particles create void

Nanometer-level recess control is needed

Hybrid Bonding



Absorb surface roughness and particles by adhesive layer



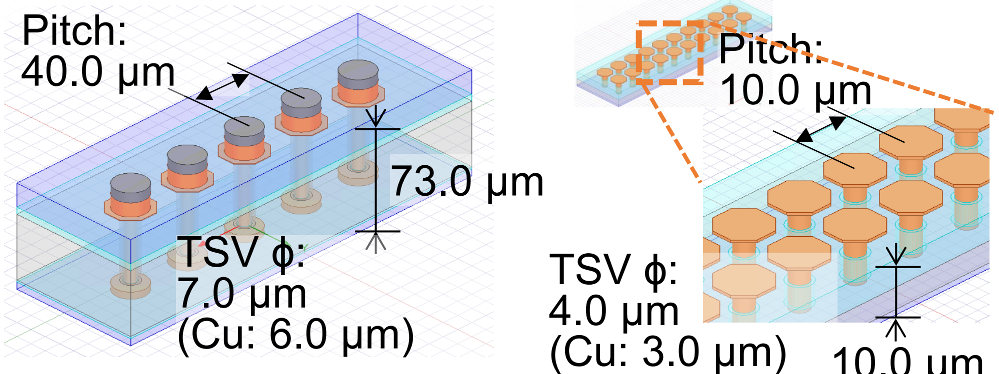
Etching

Metal deposition

BBCube

TSV characteristics

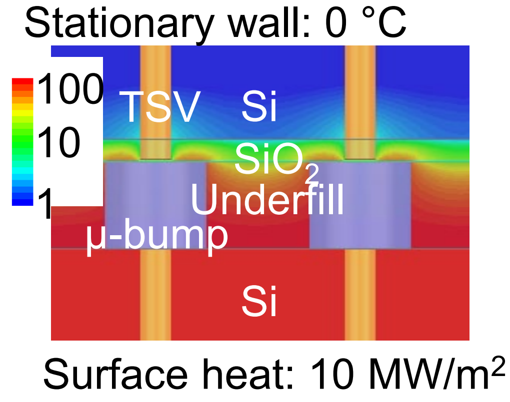
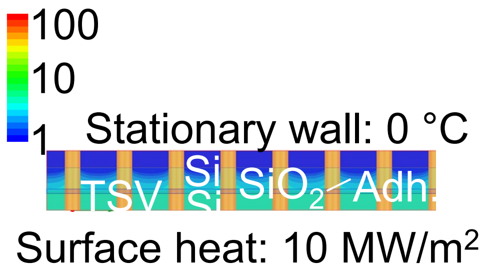
- Dense TSV realize high BW
- Short and slim TSV decreases C
- Direct Cu-Cu contact, thin bonding layer decreases Rth



Conventional 3DI BBCube

Fig. 1 Physical dimension of TSV

Table 1 Thermal resistance of TSV

	Conventional 3DI	BBCube
Temp. [°C] (Log scale)		
$R_{th\ eff}$ [K mm^2/W]	18.02 1/70	0.26

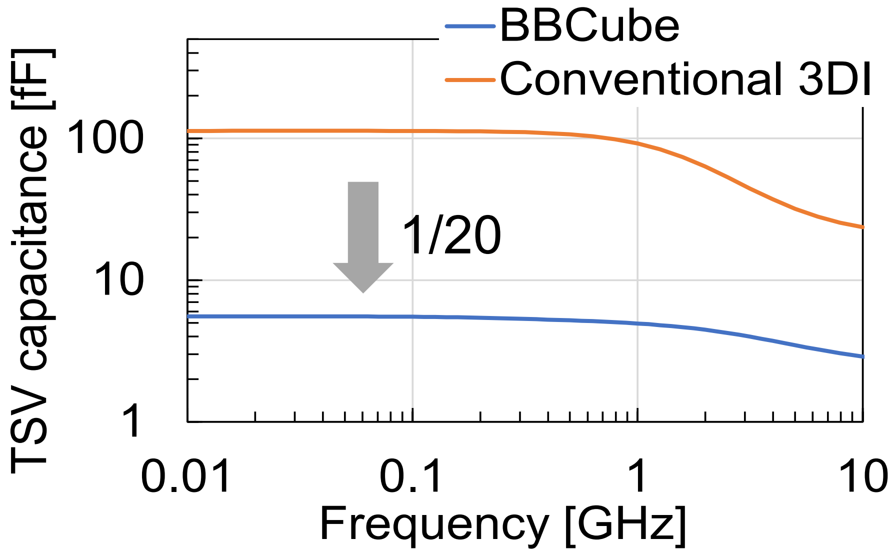


Fig. 2 TSV capacitance

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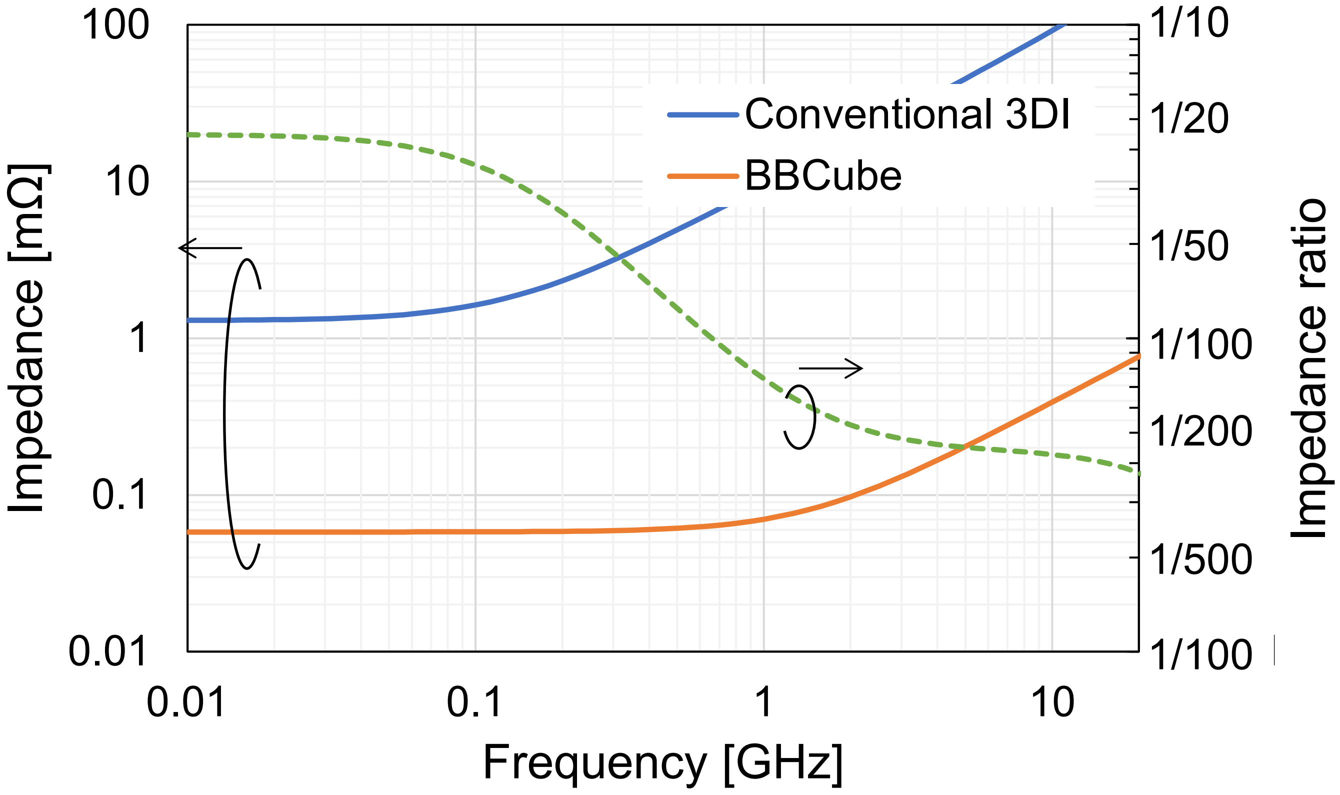
Power supply impedance analysis

- Comparison with BBCube and conventional 3DI in impedance
  - 22-times lower at 10 MHz
  - 220-times lower at 5 GHz
- DC drop is decreased 65.1 mV → 2.9 mV
  - When 45 W (50 A) xPU is stacke on 8 laminated DRAMs



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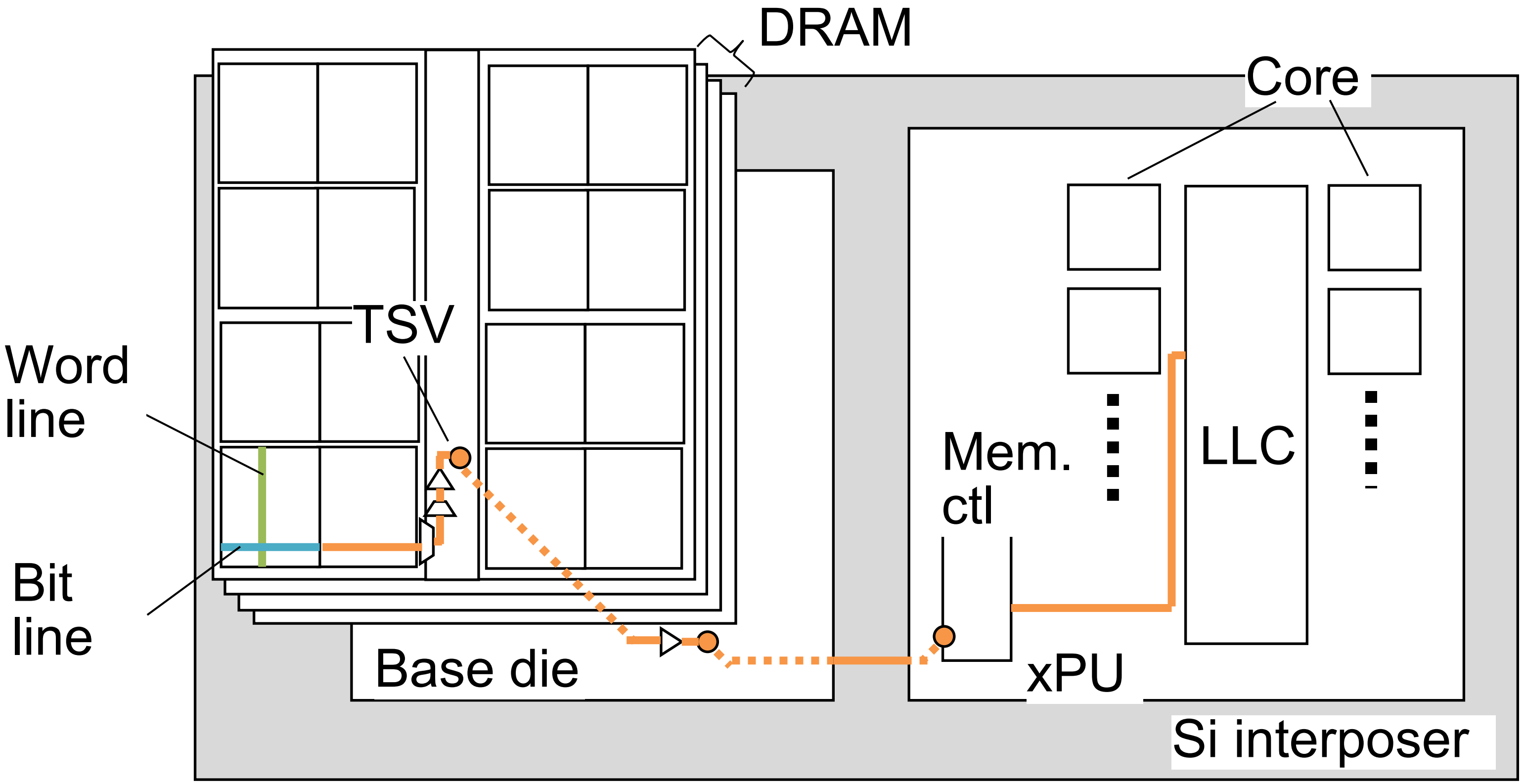
Bit Access Energy Calculation

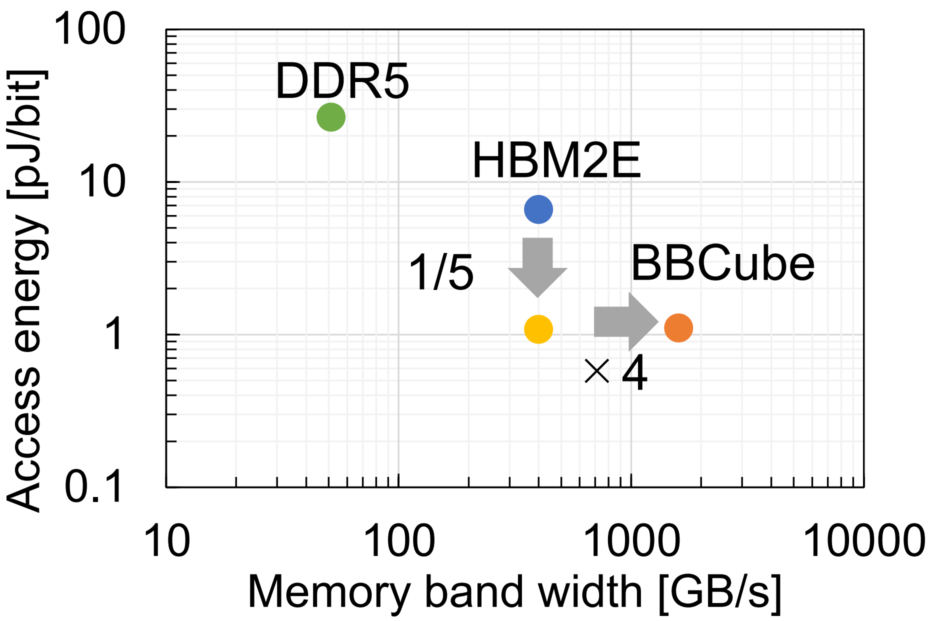
- Calculate energy from row activation to last level cache in xPU

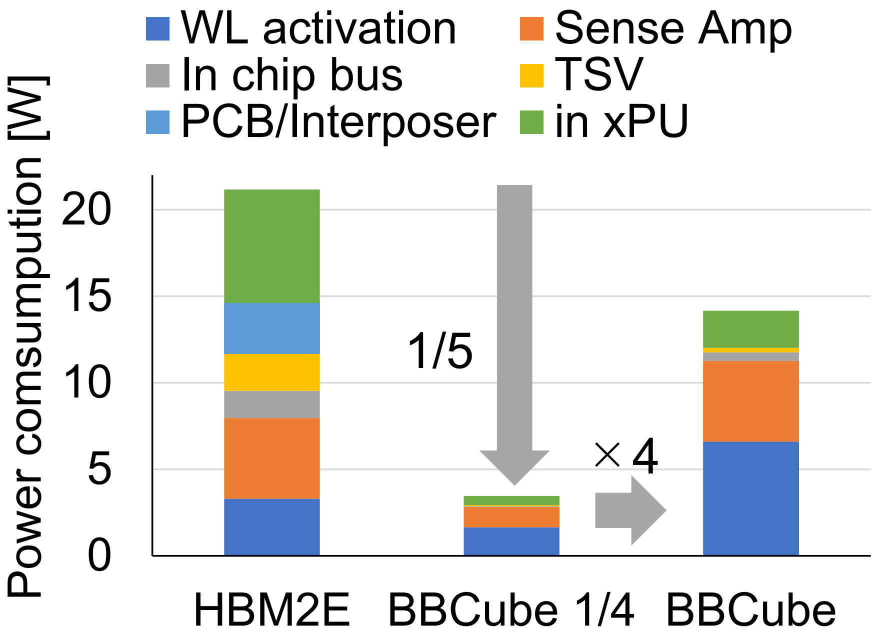


Access route of HBM

Bit access energy

- BBCube 3D reaches
  - 30X higher bandwidth, 20X lower access energy than DDR5
  - 4X higher bandwidth, 5X lower access energy than HBM2E





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DRAM temperature

- In BBCube™ 3D, over 47 W xPUs can be stacked
- If ×9 BBCube (≈ reticle size), over 423 W xPUs can be stacked

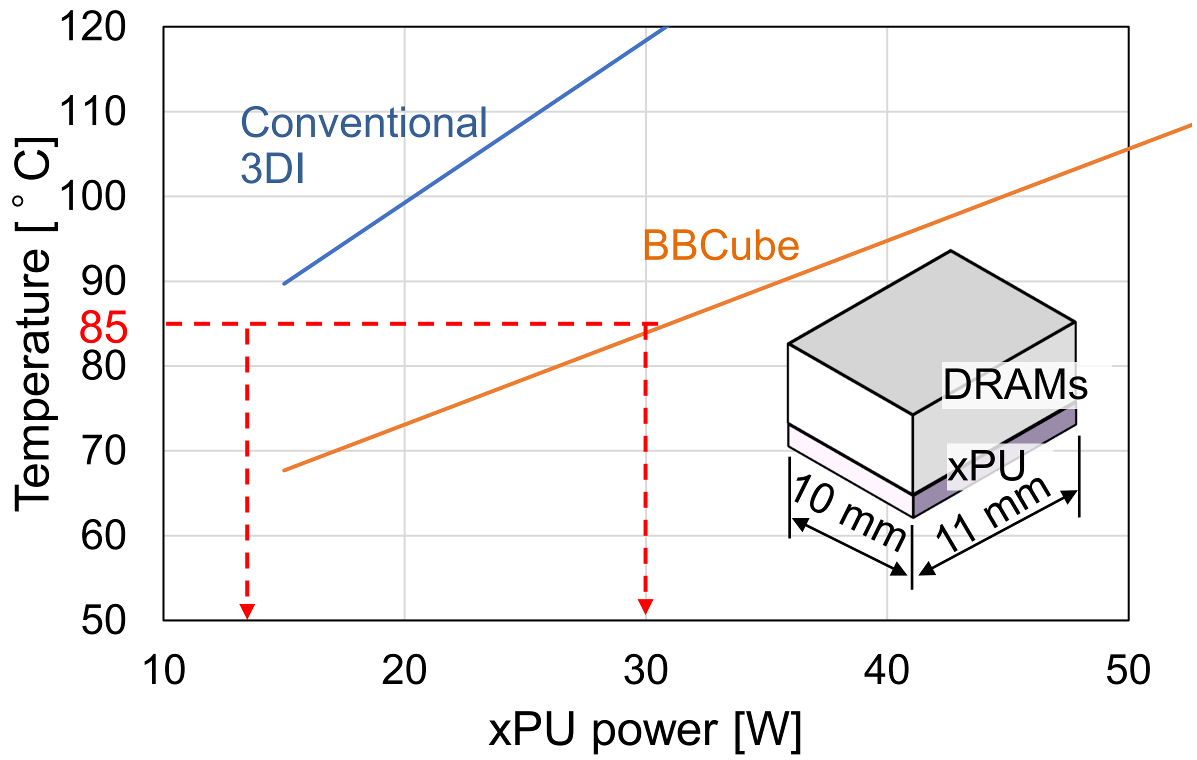

Fig. 1 DRAMs on xPU

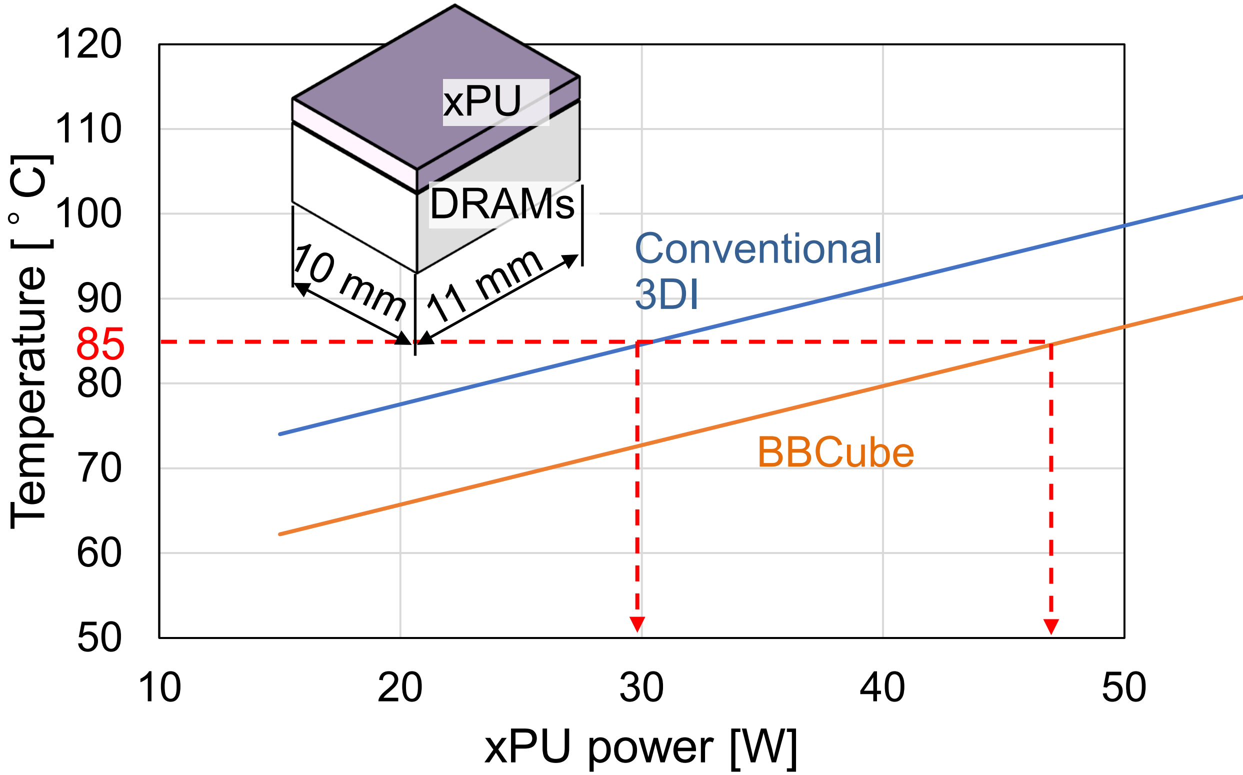

Fig. 2 xPU on DRAMs

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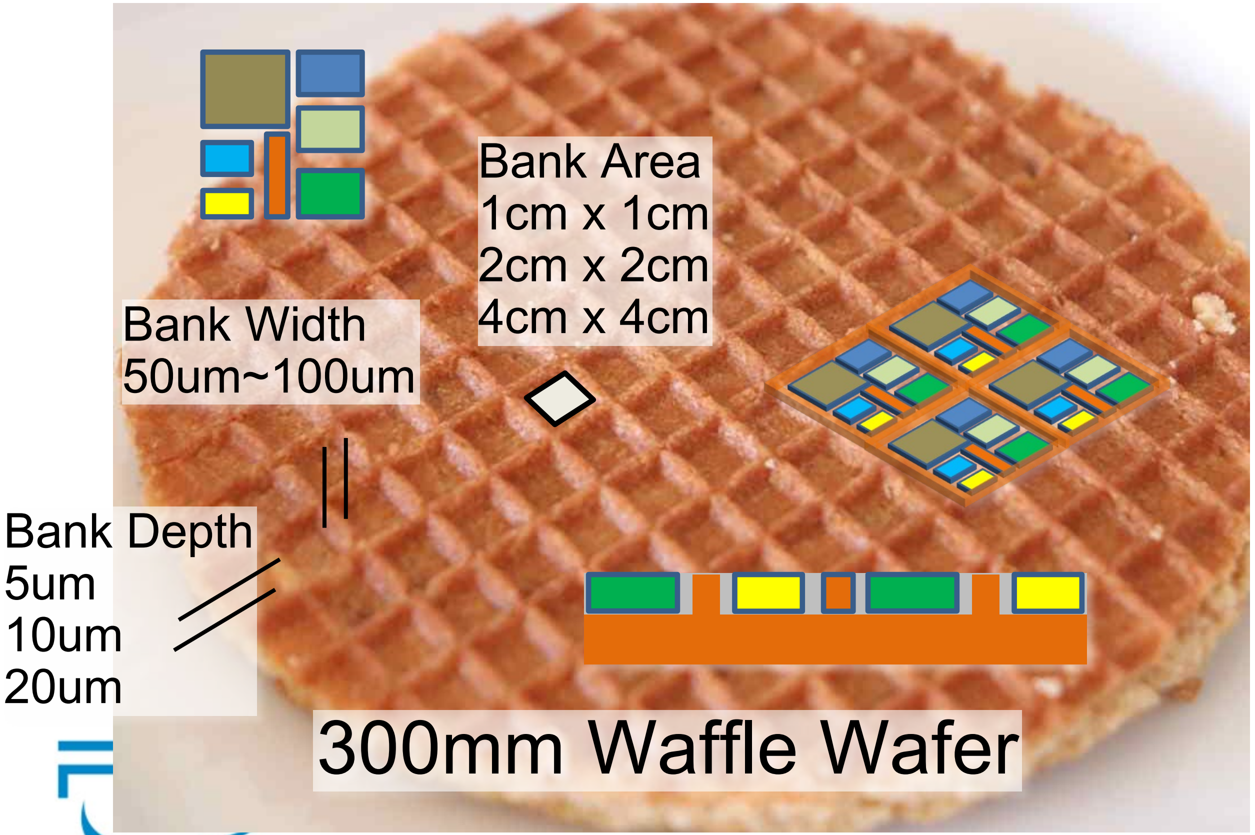
Conclusion

- We proposed a heterogeneous 3DI technology called BBCube 3D
  - Combined use of bumpless WoW and CoW processes with high-density and low-capacitance TSVs
- BBCube 3D achieves
  - High reliability with a low-temp. process
  - 30X higher bandwidth, 20X lower access energy than DDR5. 4X higher bandwidth, 5X lower access energy than HBM2E
  - 45 W xPUs stacked on a DRAM cube. If ×9 BBCube (≈ reticle size), over 423 W xPUs can be stacked

Let’s Eat BBCube!

- TECH EXTENSIONS Co. Ltd. (TEX) handles the WoW and CoW stacking by BBCube.

COW Hetero-Stack



WOW/COW Multi-Stack