2nd Generation 3D V-Cache^{TM} Enablement

Presenter:
Arsalan Alam
MTS, 3D Stacking Tech, Advanced Packaging

Authors: Arsalan Alam, Chandrasekhar Mandalapu, Patrick Cheng, ChihHsiang Tseng, Sean Liu, Liwei Wang, Mihaela Tanasescu, Mahmudur Chowdhury, Aly Garcia, Anadi Srivastava, Sai Vadlamani, Sireesha Gogineni, Tanmay Mudholkar, Jiali ORiain, Yash Kothari, Yong fui Lee, Litao Yang, Anna Yang, Pawan Kulkarni Aaron Blanchet, Rita Pillman, Bryan Weatherford, Tao Chen, Yolanda Liu, Raja Swaminathan

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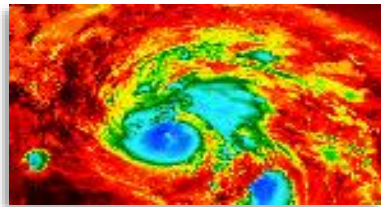
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Outline

- Motivation for 3D Stacking

- Introduction to Hybrid Bonding

- 2nd Generation 3D V-Cache^{TM} Enablement

- Reliability

- Outlook

Relentless Demand for Scientific Computing

World's Fastest Supercomputers
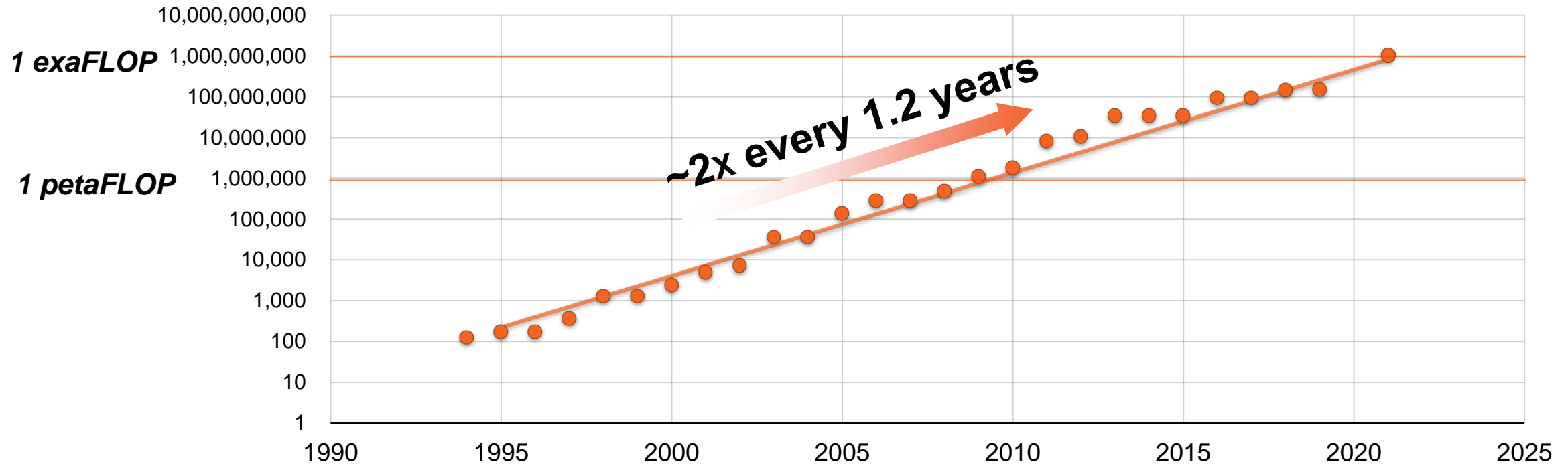
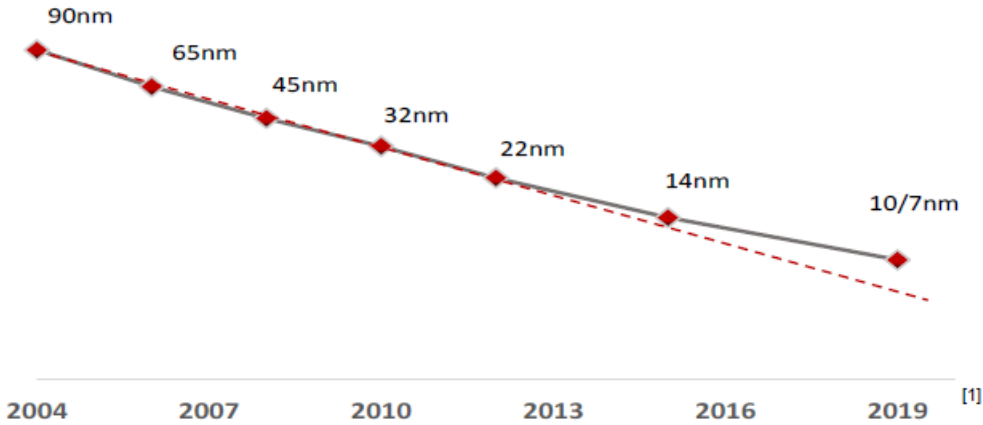

Space Exploration

Climate Change
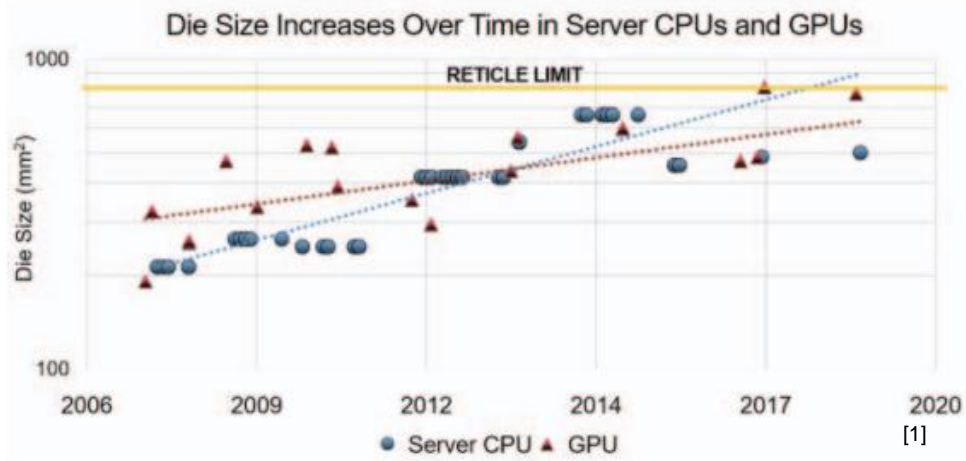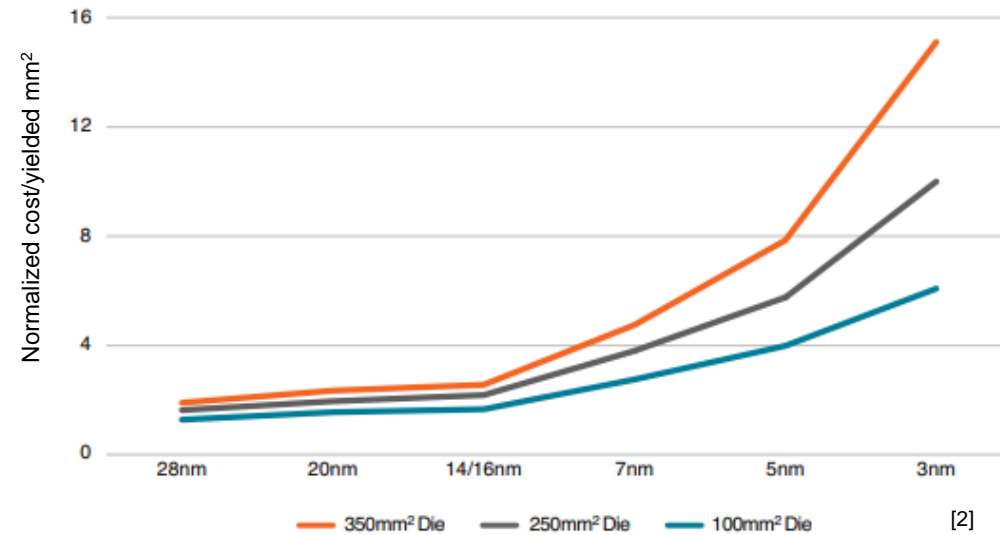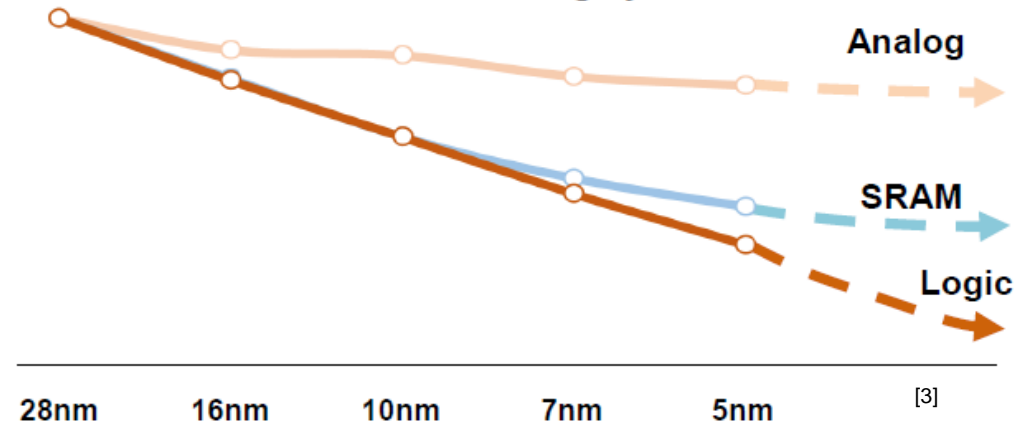
Chemical Sciences

Energy Solutions

Machine Learning

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Motivation

MOORE'S LAW KEEPS SLOWING

Cost Per Yielded mm² for a 350mm², 250mm², 100mm² Die

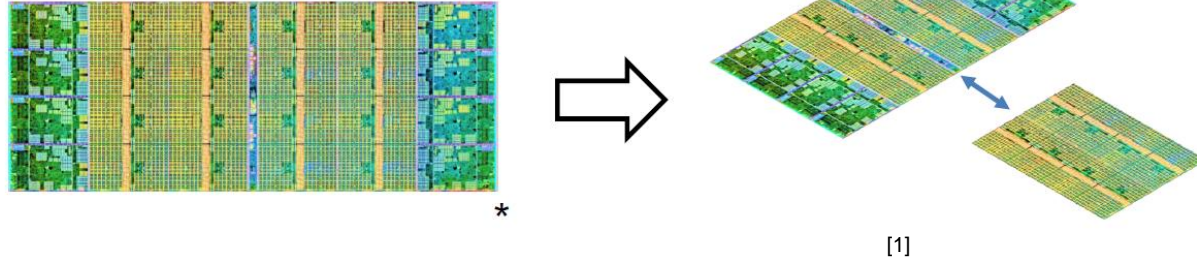## Die Size Increases Over Time in Server CPUs and GPUs

Silicon Area Scaling by Function

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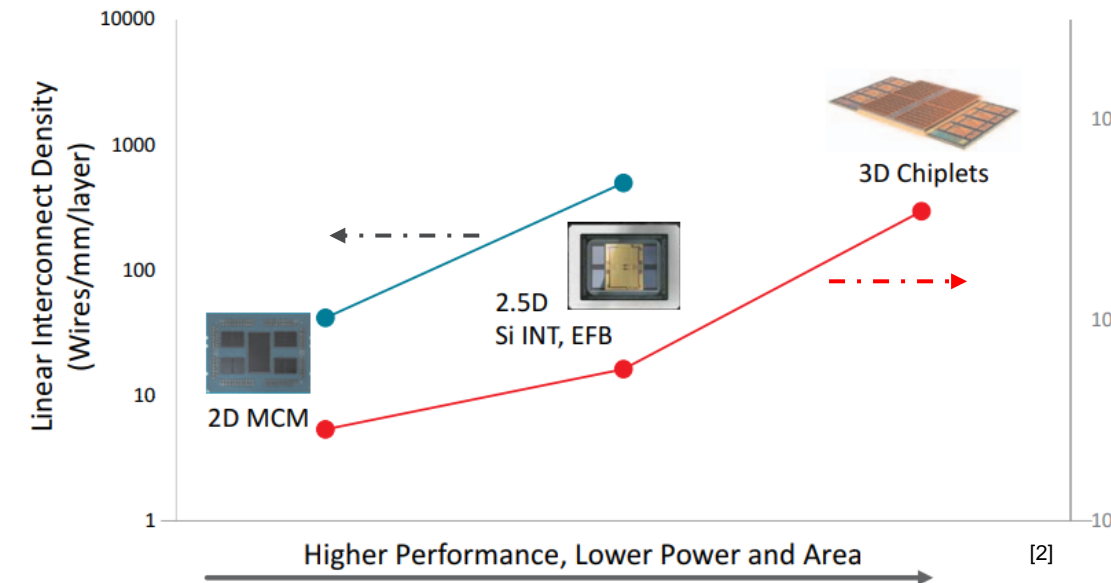together we advance_

Motivation
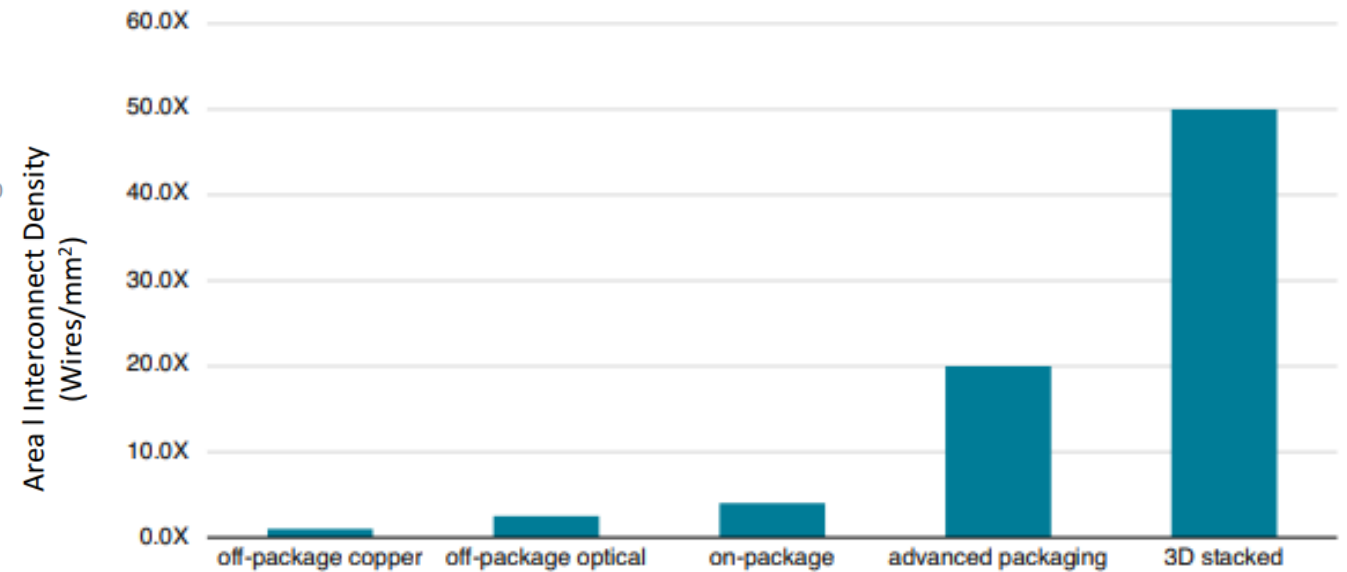
More than Moore

[1]

Heterogeneous Integration with 3D stacking improves system

- Performance
- Power
- Area
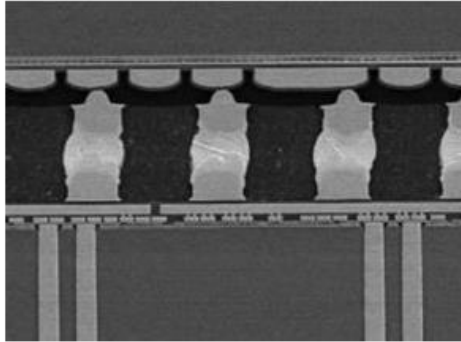- Cost
- Time to market

Packaging Interconnect Density

Relative Bits/Joule

[2]

[1] John Wuu, ISSCC, 2022, [2] Lisa Su, ISSCC, 2023
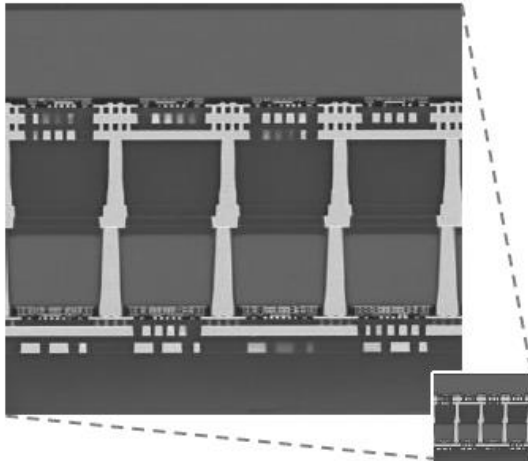
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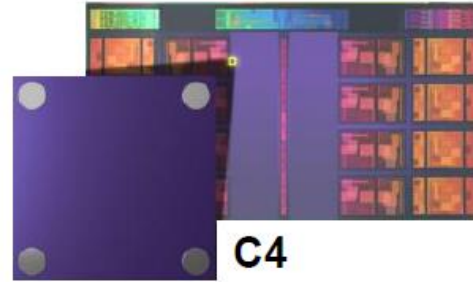**AMD**
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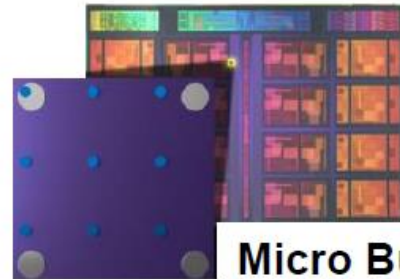# Hybrid Bonding vs. Micro Bump
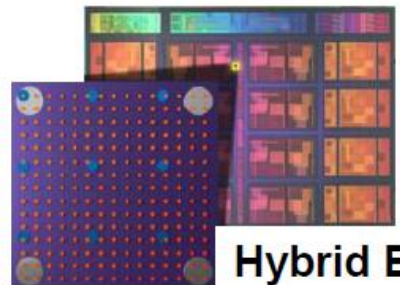
Micro Bump 3D

Hybrid Bond 3D

C4

Micro Bump 3D

Hybrid Bond 3D [1]

- **Compared to Micro Bump 3D solutions, Hybrid Bond offers**
  - \>15x interconnect density
  - \>3x interconnect energy efficiency
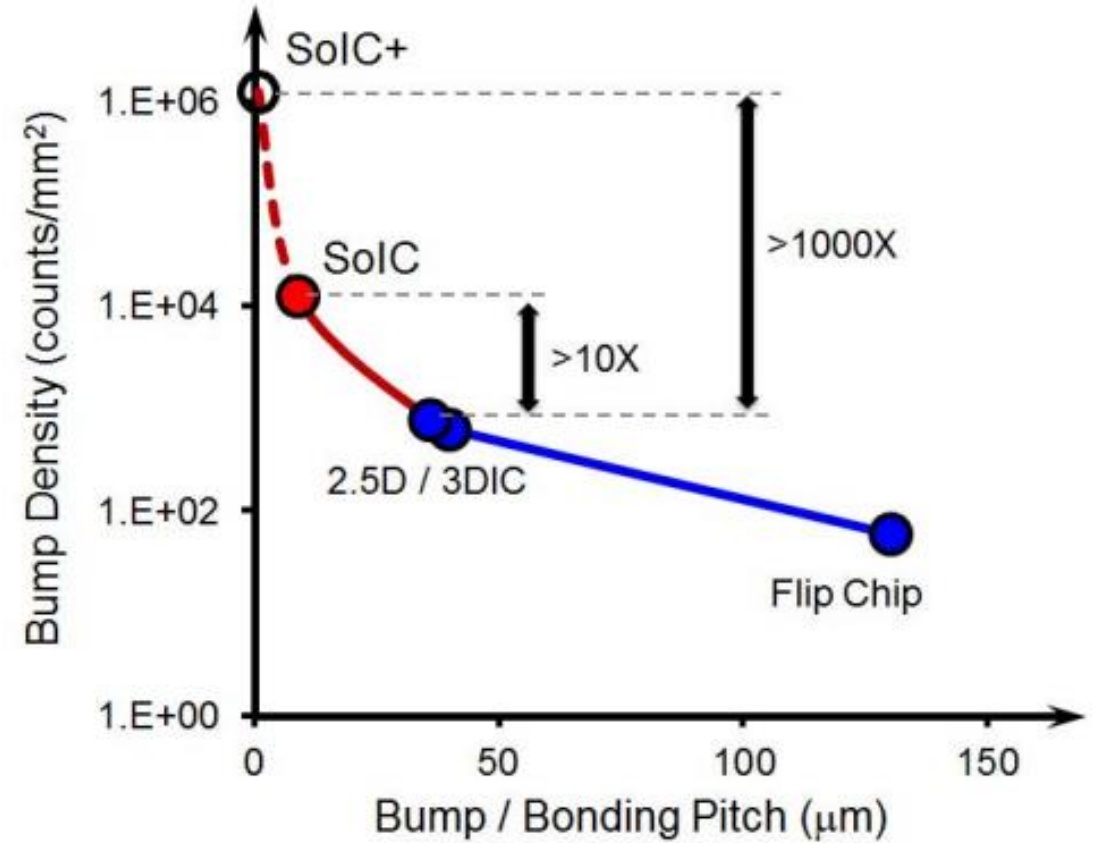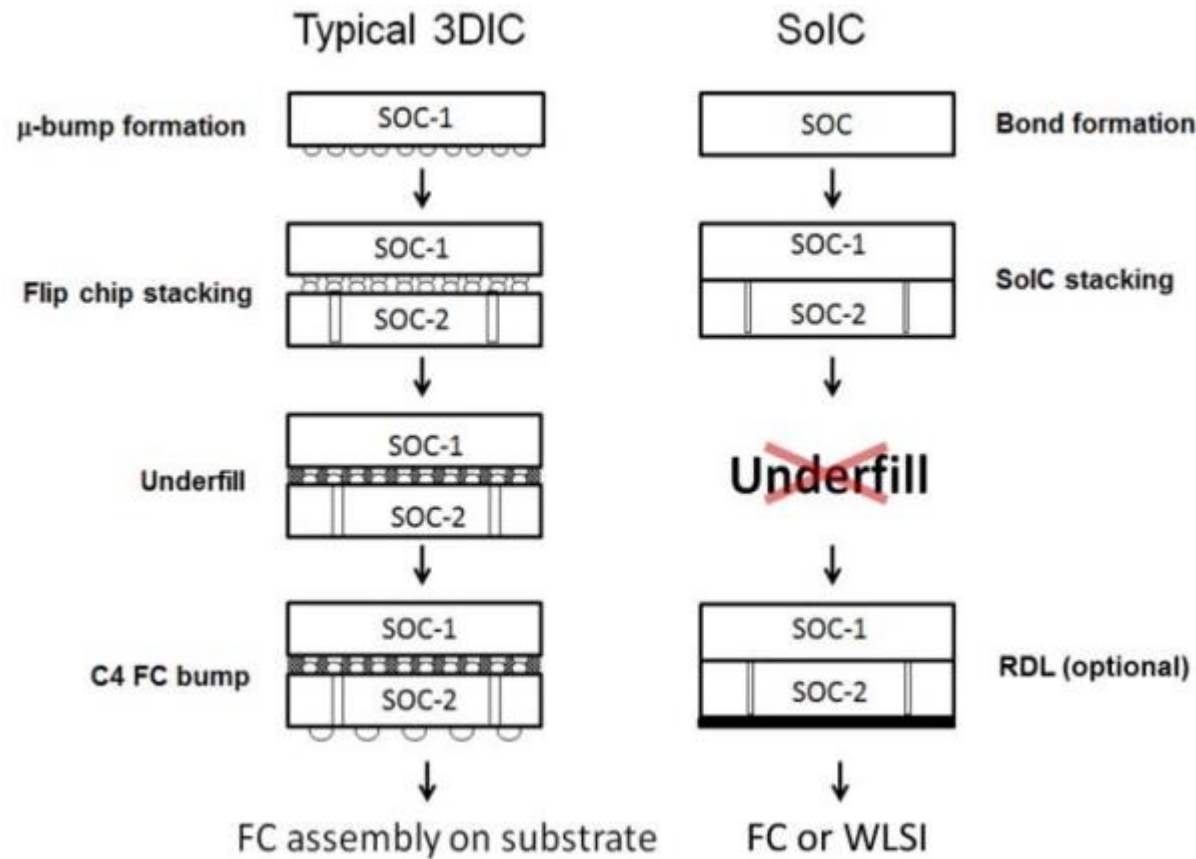 - Superior thermal conductance

SEE ENDNOTES: EPYC-027

C4 and Micro Bump 3D illustrations are hypothetical
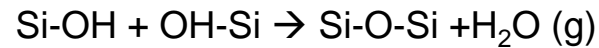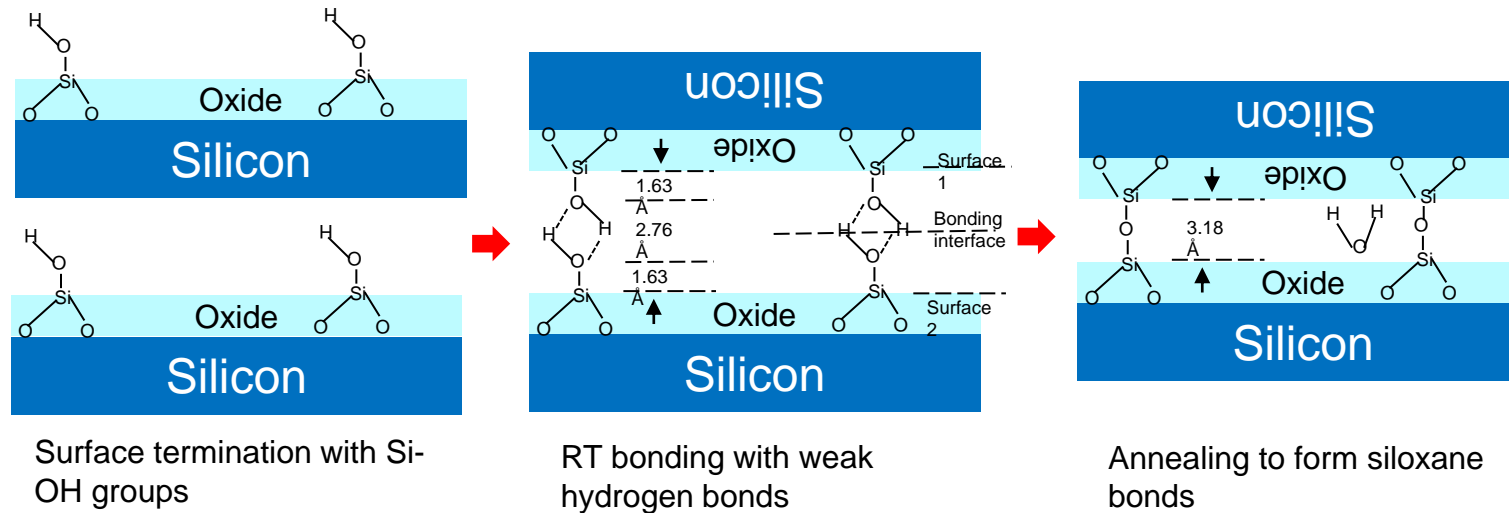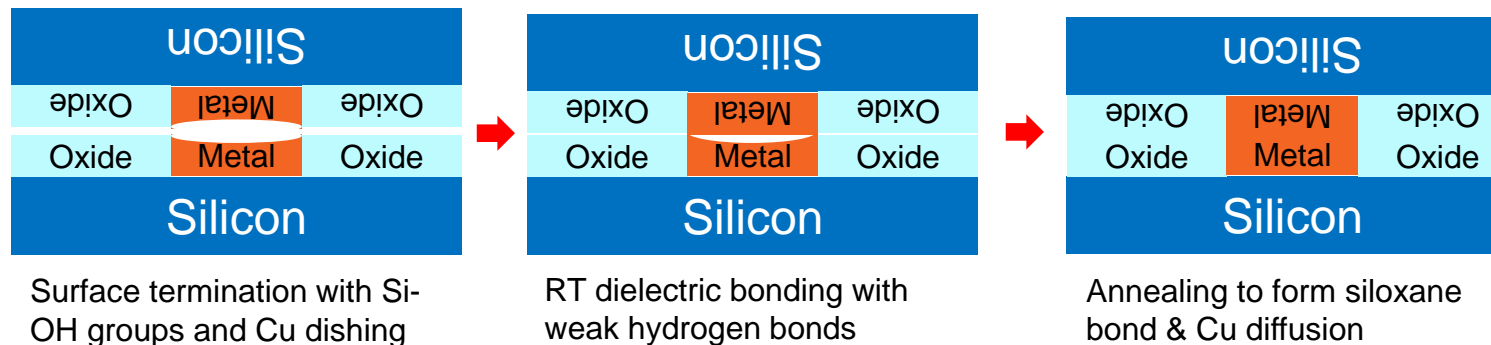
[1] Swaminathan, Hot Chips Tutorial, 2021

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Hybrid Bonding

8   F.C. Chen *et al.*, System on Integrated Chips (SoICTM) for 3D Heterogeneous Integration, ECTC, 2019   1022

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Hybrid Bonding

Fusion bonding: Dielectric materials SiO2, SiON, SICN

Surface termination with Si-OH groups

RT bonding with weak hydrogen bonds

Annealing to form siloxane bonds

$$Si\text{-}OH + OH\text{-}Si \rightarrow Si\text{-}O\text{-}Si + H_2O \text{ (g)}$$

Hybrid bonding: Metal interconnects Cu, Ni

Surface termination with Si-OH groups and Cu dishing

RT dielectric bonding with weak hydrogen bonds

Annealing to form siloxane bond & Cu diffusion

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Hybrid Bonding

	D2W	WoW
Maturity		
Pitch		
Die size (TD/BD)	Need not be same size	Same/similar size
Heterogeneous Integration	Increased functionalities	Limited
Process Complexity	More complex	
Yield	KGD	Wafer dependent
Throughput		
Particle Contamination		

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2nd Gen 3D V-Cache™
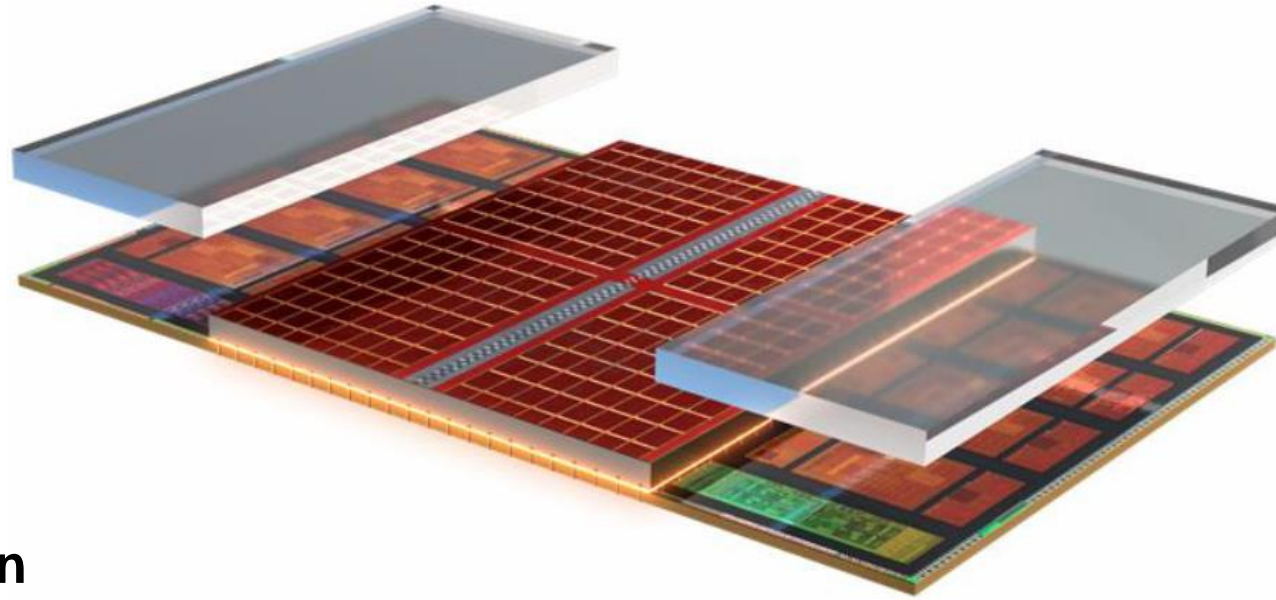
CCD (N5) face-down

- C4 interface to substrate
- TSV interface to L3D
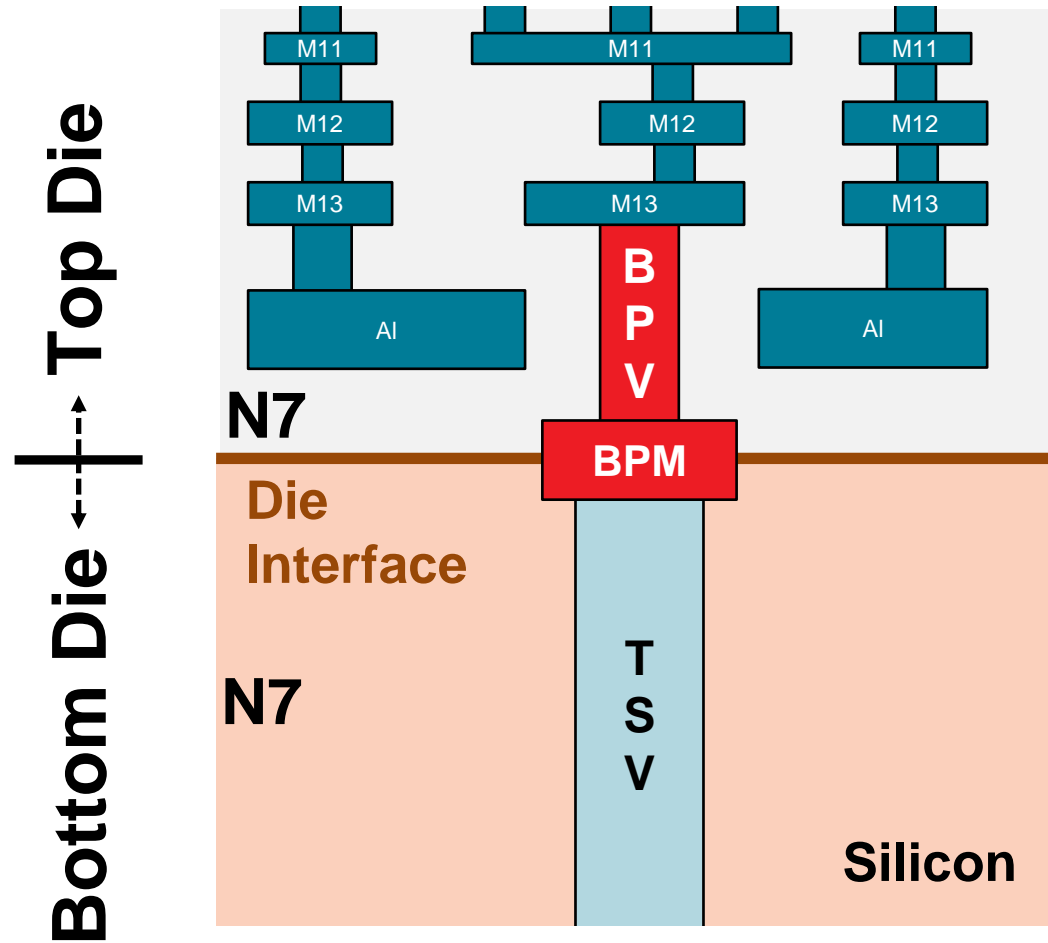
L3D (N7) face-down

- HB to CCD
- 9 um minimum TSV/ Hybrid bond pitch

Structural Dies
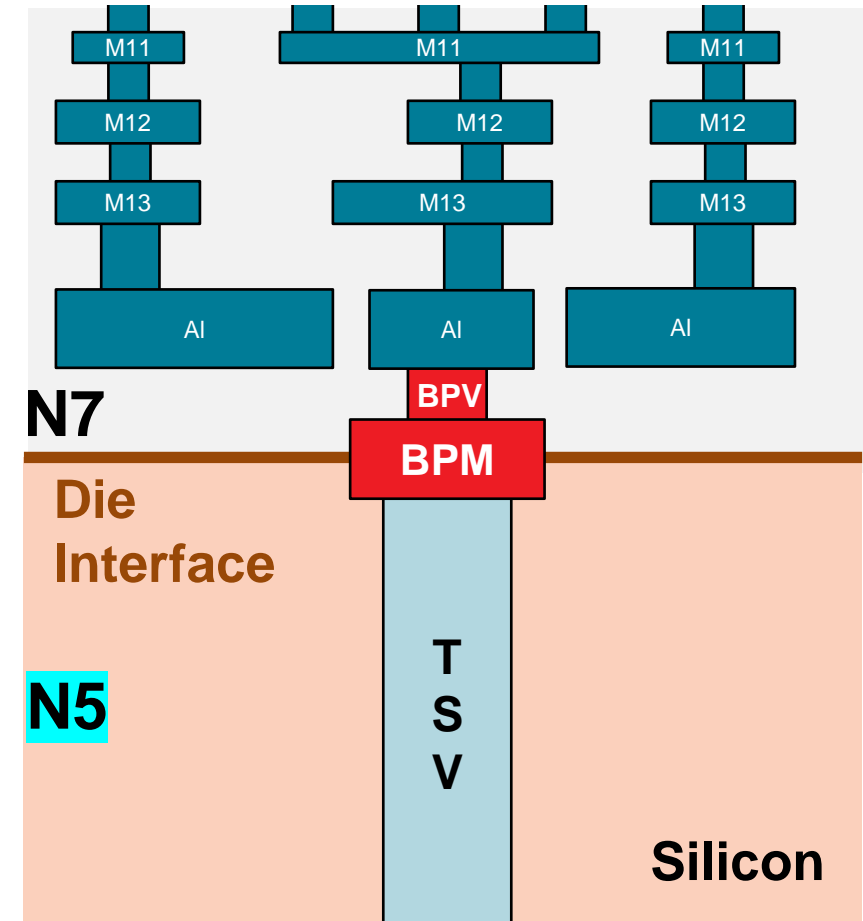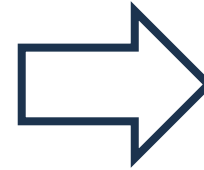
- Oxide bonded to CCD

- Use of face to back (F2B) stacking of 7 nm node cache memory chiplet (SRAM chiplet) on 5 nm node logic chiplet ("Zen 4" compute chiplet)

- Bond pad via (BPV) landing on top Aluminum pad (AP) instead of top metal layer

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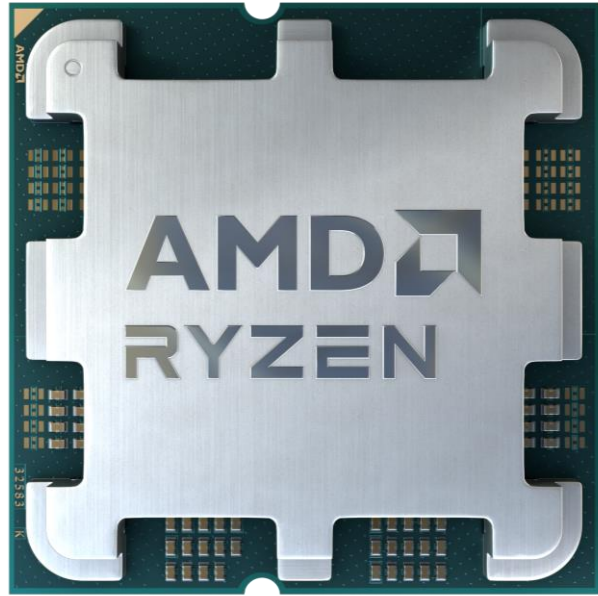together we advance_

2nd Gen 3D V-Cache™

Zen3 3D V-Cache™   [1]

Zen4 3D V-Cache™

[1] J. Wuu et al., "3D Vcache ™: The Implementation of a Hybrid Bonded 64MB Stacked Cache for a 7nm X86 64 CPU," ISSCC, 2022.

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2nd Gen 3D V-Cache™

AMD RYZEN™ 7 7800X3D
With AMD 3D V-Cache™ Technology

up to	up to	up to	
8 Cores 16 Threads	5.0 GHz Boost	104 MB L2+L3 Cache	120W+ TDP

Processor architecture   5nm **Technology**

See endnotes GD-150

1920x1080 Resolution[1]

Ryzen™ 7 7800X3D vs. Ryzen™ 7 5800X3D, High Image Quality Preset

- AMD Ryzen™ 7 5800X3D
- Cyberpunk® 2077 — **10%**
- Shadow of the Tomb Raider® — **13%**
- Borderlands® 3 — **22%**
- F1® 22 — **25%**

L. Su, AMD CES keynote, 2023

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See endnotes RPL-037

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Package Level Rel. Data

UHAST96 hrs	Pass
TCJ2500 cyc	Pass
HTS1000 hrs	Pass

- No apparent damage to the bond interface even after extensive reliability tests

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Future of 3D Stacking

R. Swaminathan, The next frontier: Enabling Moore's Law using heterogeneous integration, Chip Scale Review, 2022
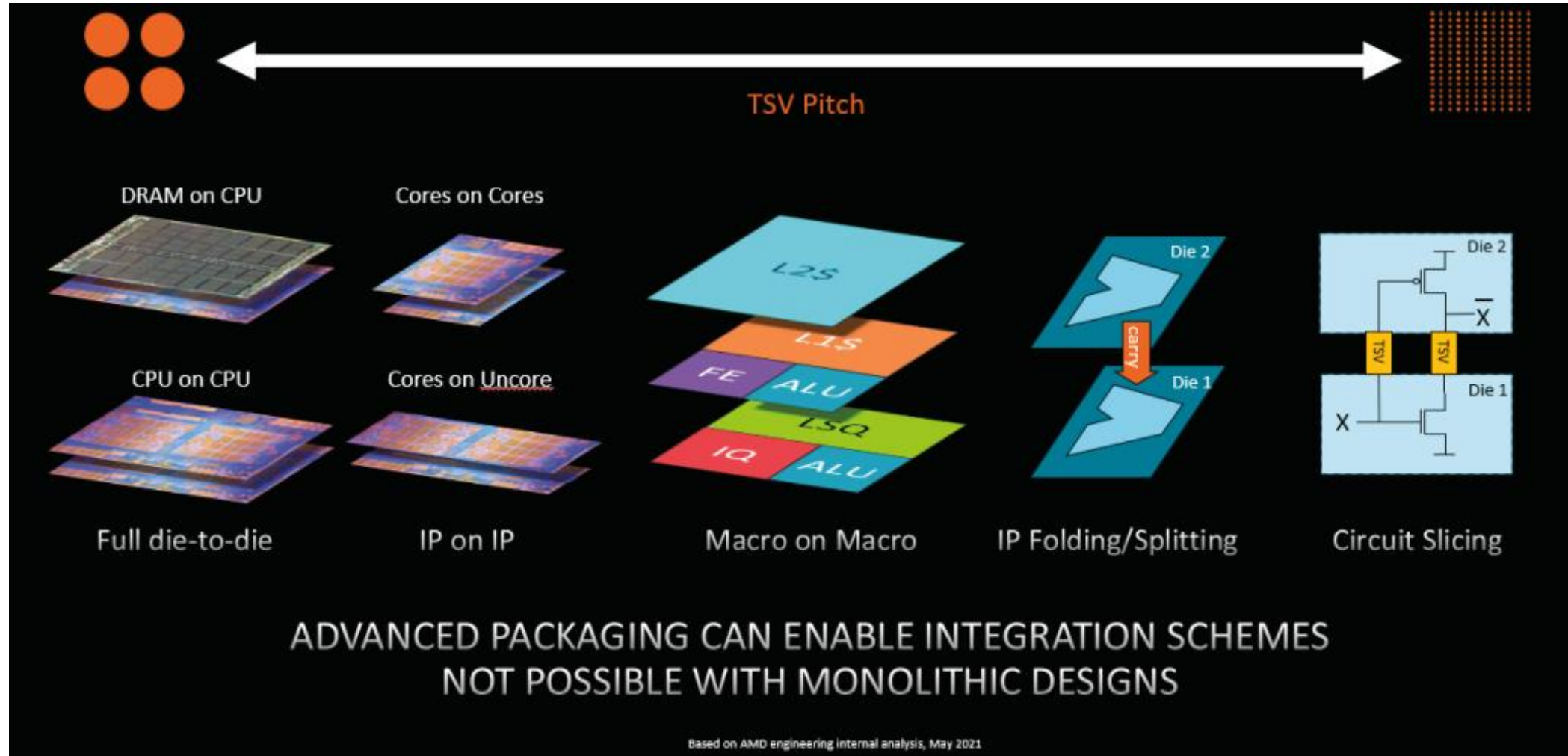
Endnotes

EPYC-027: Based on AMD internal simulations and published Intel data on "Foveros" technology specifications.

Based on testing by AMD as of 12/23/2022. Testing results demonstrated in DaVinci Resolve BlackMagic , V-Ray, Blender, Cinebench R23 nT, Handbrake 1:5:1. Ryzen™ 9 7940HS system: AMD reference motherboard configured with 4x4GB LPDDR5, 1TB SSD, Radeon 780M Graphics, Windows® 11 64-bit. Apple M1 Pro system: Macbook M1 Pro 18 configured with 32GB LPDDR5, 1TB SSD, MacOS Monterey (12.6.1). System manufacturers may vary configurations, yielding different results. PHX-10.

Based on testing by AMD as of 12/23/2022. Testing results demonstrated in Handbrake, Cinebench, GeekBench, PCMArk 10, Kraken, 7-Zip, Lame MP3. Ryzen™ 7 7840HS system: AMD reference motherboard configured with 4x4GB LPDDR5, 1TB SSD, Radeon 780M Graphics, Windows® 11 64-bit. Core i7-1280P system: HP Elitebook 840 G9 configured with 16GB DDR5-4800, 1TB SSD, Intel Iris Xe, Windows 11 64-bit. System manufacturers may vary configurations, yielding different results. Performance may vary. PHX-6.

Based on testing by AMD as of 12/23/2022. Testing results demonstrated in Borderlands 3, Cyberpunk 2077, Rainbow Six Siege, Assassin's Creed: Valhalla, World of Tanks Encore, League of Legends, Far Cry 6, Grand Theft Auto V, Shadow of the Tomb Raider, F1 2021, Strange Brigade, Total War: Three Kingdoms Battle. Ryzen™ 9 7940HS system: AMD reference motherboard configured with 4x4GB LPDDR5, Samsung 980 Pro 1TB SSD, Radeon 780M Graphics, Windows® 11 64-bit. Core i7-1280P system: HP Elitebook 840 G9 configured with 16GB DDR5-4800, 1TB SSD, Intel Iris Xe, Windows 11 64-bit. System manufacturers may vary configurations, yielding different results. PHX-9.

Based on testing by AMD as of 12/23/2022. Testing results demonstrated in Far Cry 6; CS:GO; Warhammer: Dawn of War 3; League of Legends. Ryzen™ 9 7945HX system: AMD reference motherboard configured with 2x16GB DDR5-5200, Samsung 980 Pro 1TB SSD, Radeon 610M Graphics, Windows® 11 64-bit. Ryzen 9 6900HX system: Alienware M17 R5 configured with 2x16GB DDR5-4800, 1TB SSD, Radeon 6850M XT graphics, Windows 11 64-bit. System manufacturers may vary configurations, yielding different results. DRG-03.

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