Tezzaron
SEMICONDUCTOR

NEPP
The Changing Tide

June 15, 2016

GSFC

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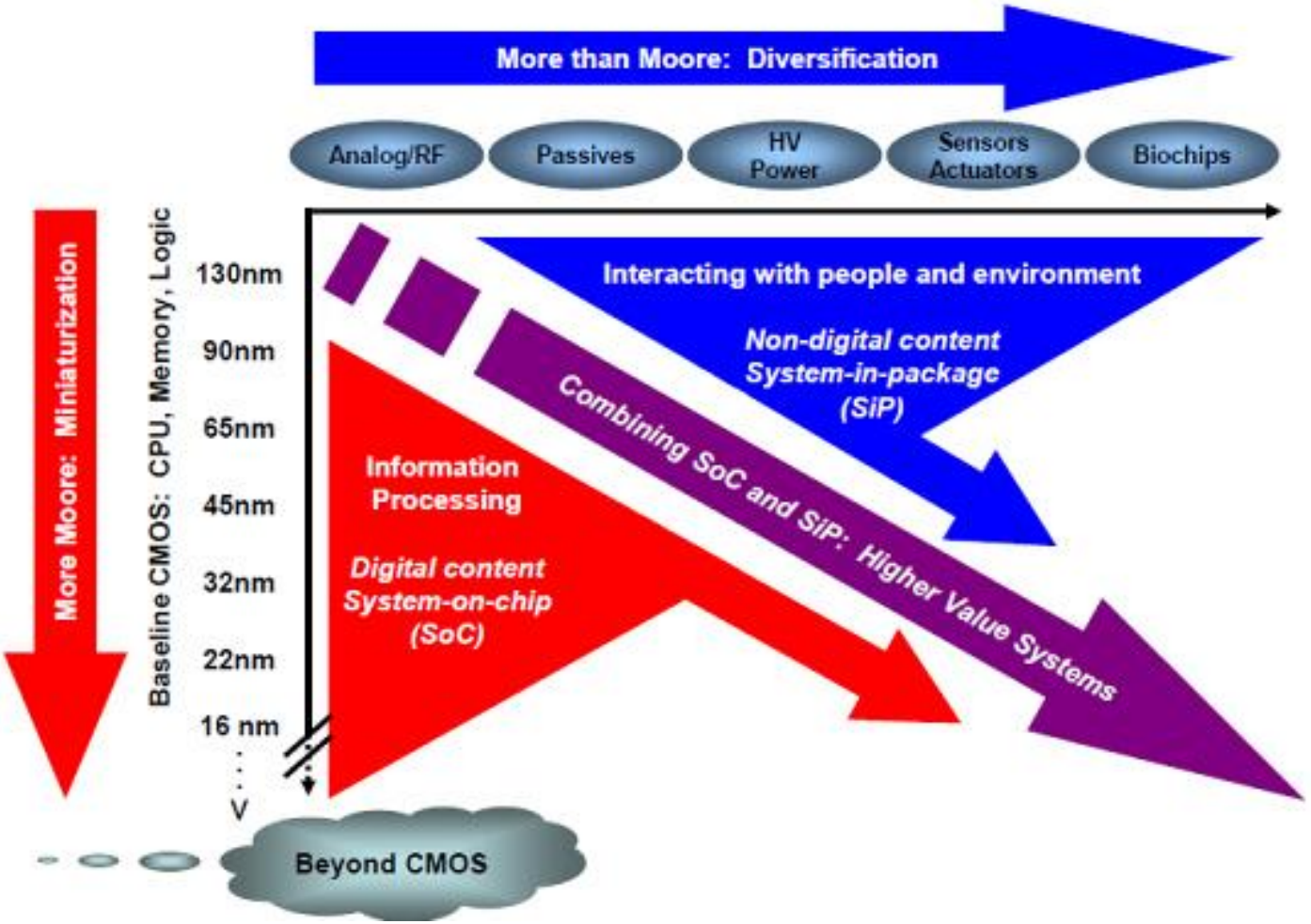
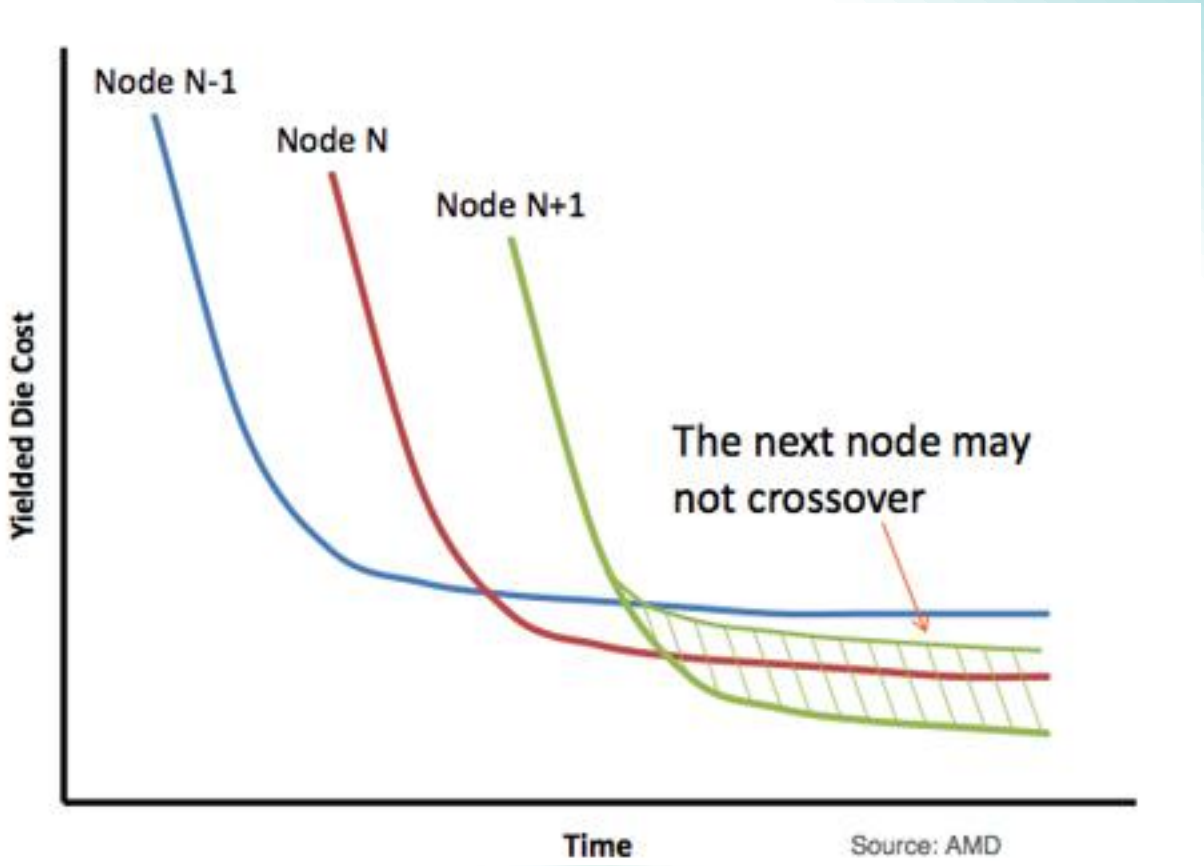
MOORE'S LAW

Moore's Law & More than Moore (MtM)



Expiring Economics



AMD 2014 3D-ASIP

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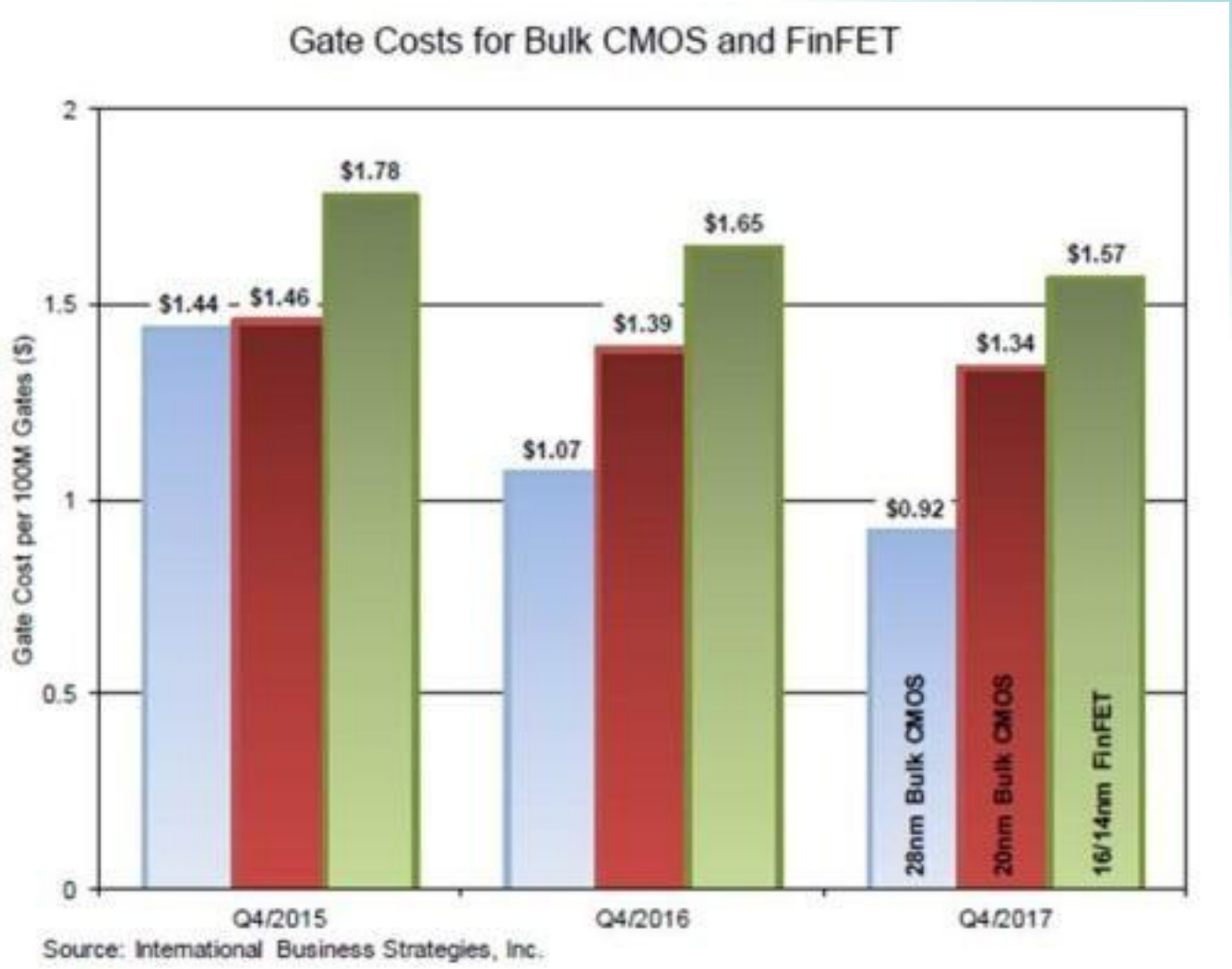
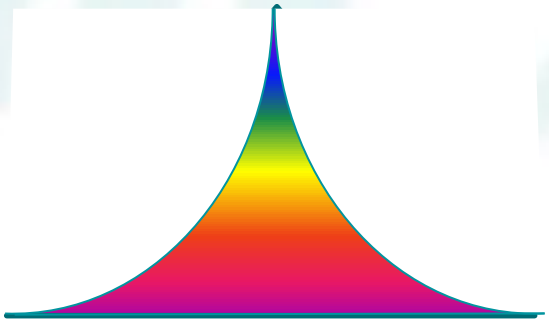
Cost Trend Reversal



More Moore

- The end is near…
  - 16nm, 14nm, 10nm, 8nm, 6nm, 5nm …
  - Maybe its now. Maybe it's in 3 years or 5 years, but the end of scaling is going to happen within the next decade
- Most cost effective node for years…28nm?



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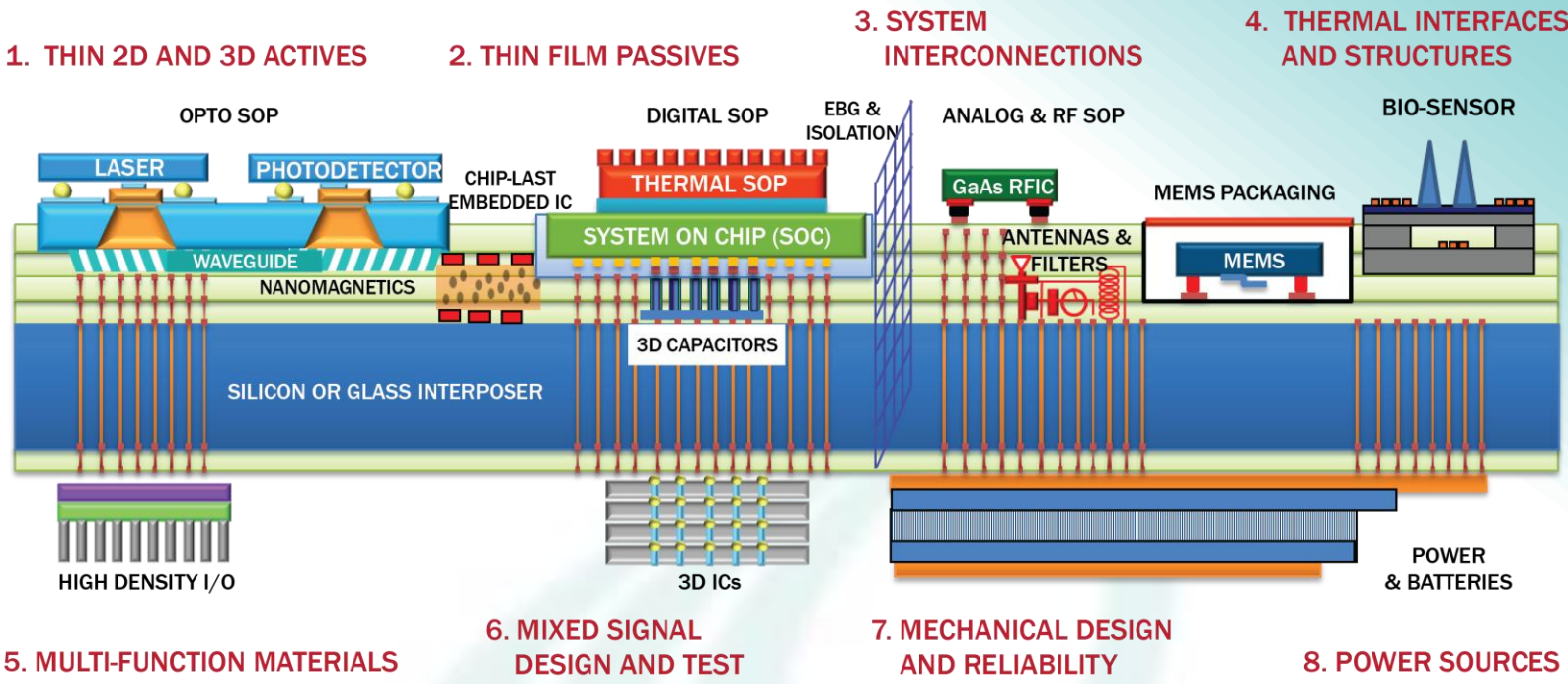
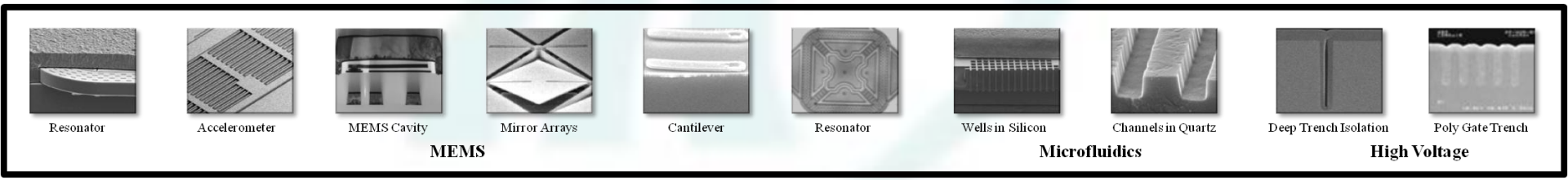
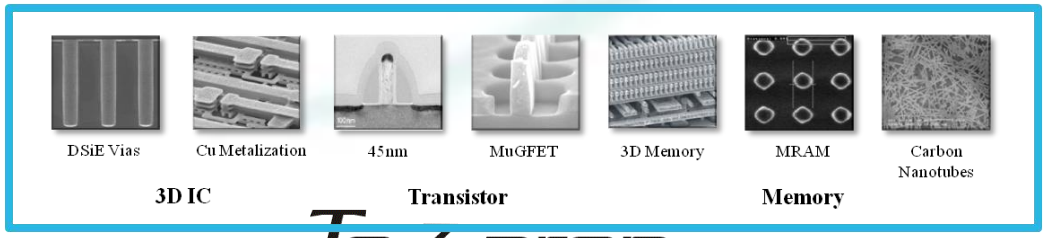
More Than Moore

GEORGIA TECH PRC







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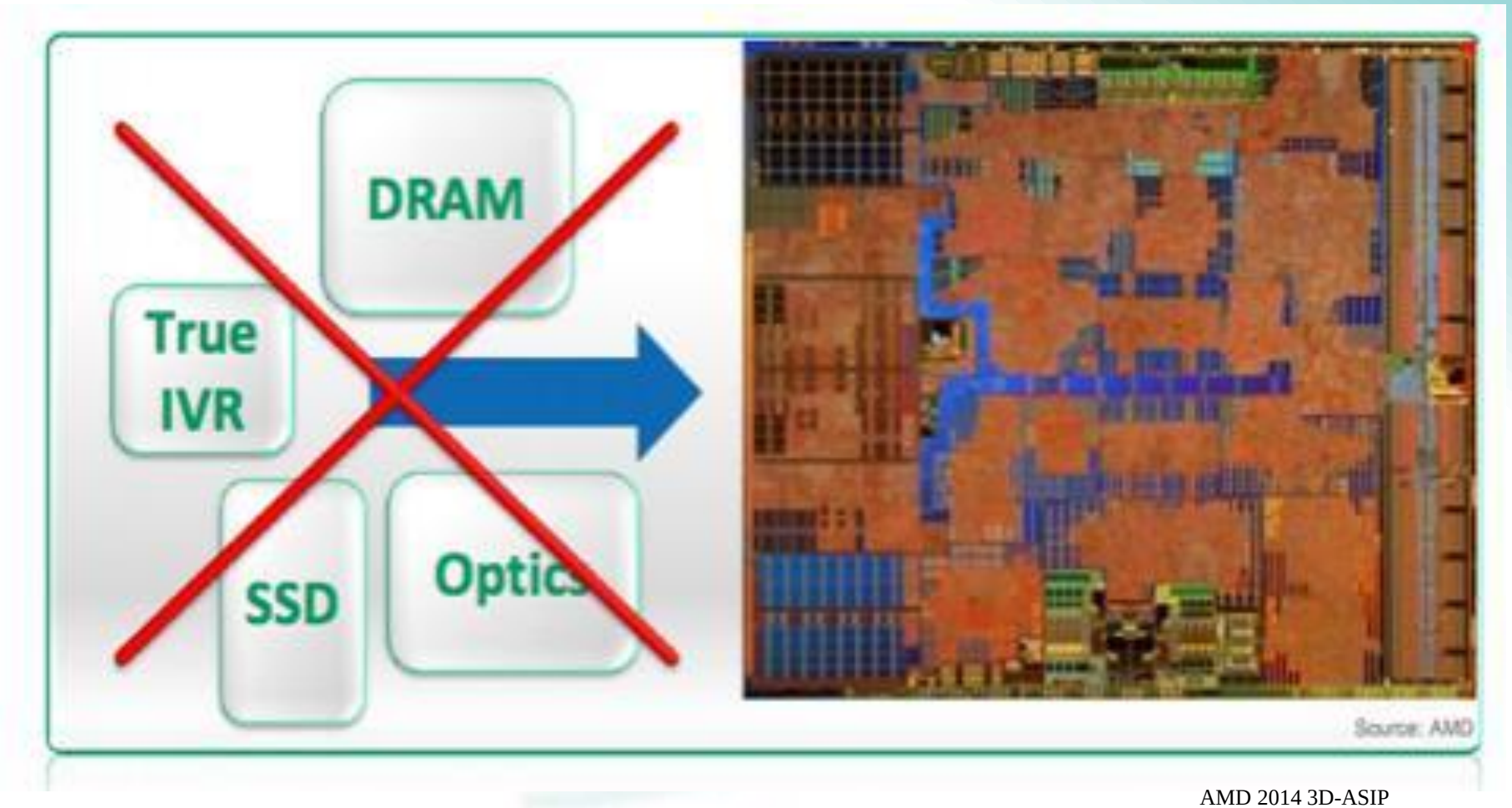
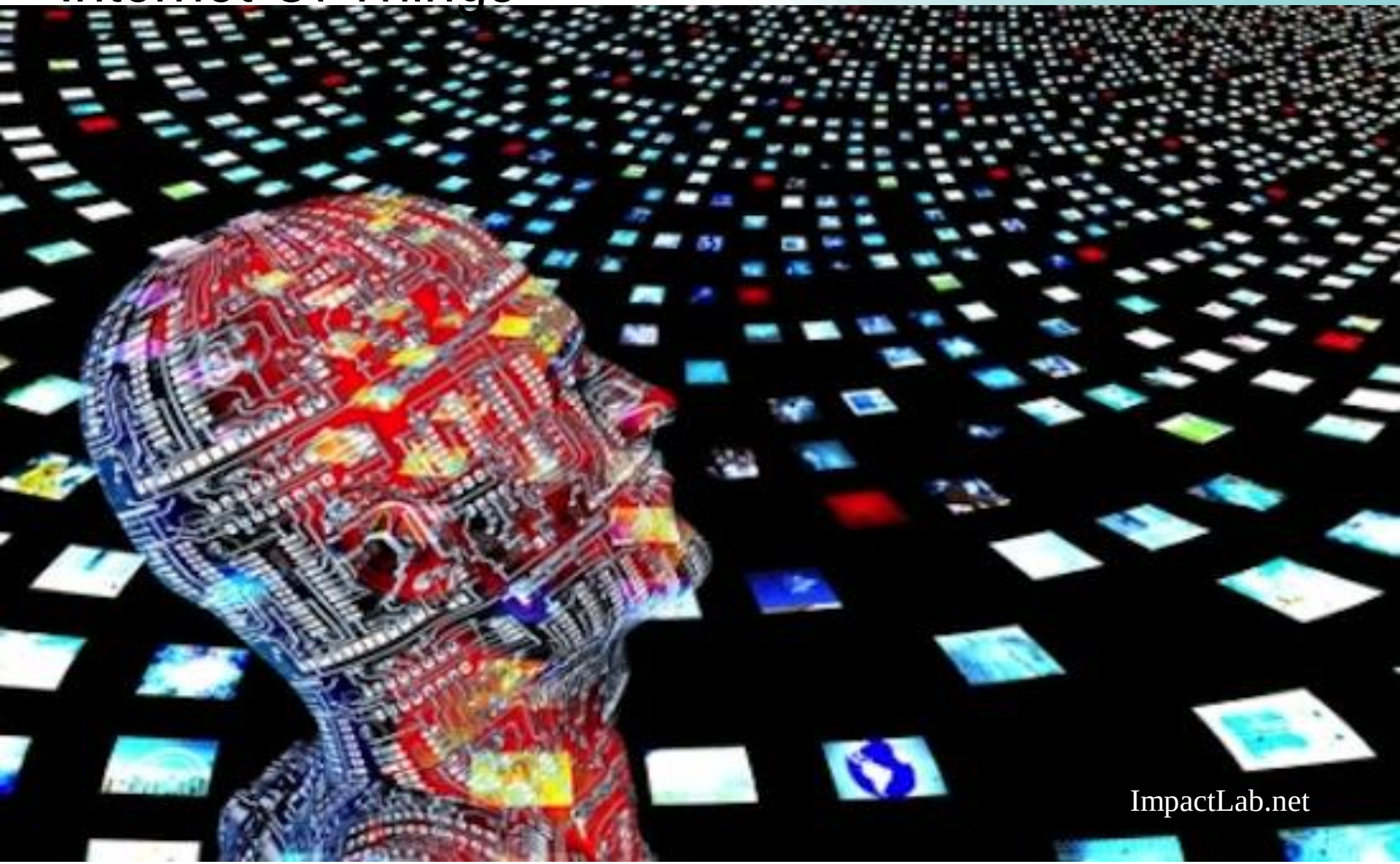
WHAT ARE THE DRIVERS OF CHANGE?

The Apples & Oranges of SOC



AMD 2014 3D-ASIP

Internet Of Things



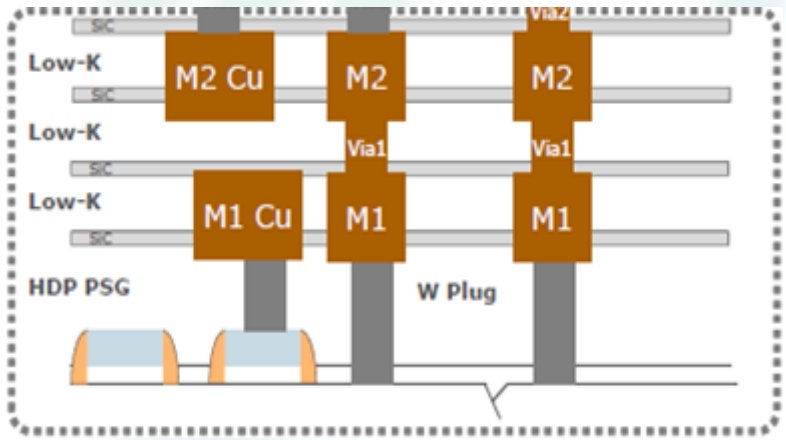
MORE THAN MOORE

The Fabrication Road to More Than Moore

Memories, CMOS, Photonics, III-V, Novel Materials, Microfluidics, MEMS, etc.

Build novel structures BEOL

Start with FEOL CMOS wafer



Integration Paths: Additive Silicon and 2.5/3D

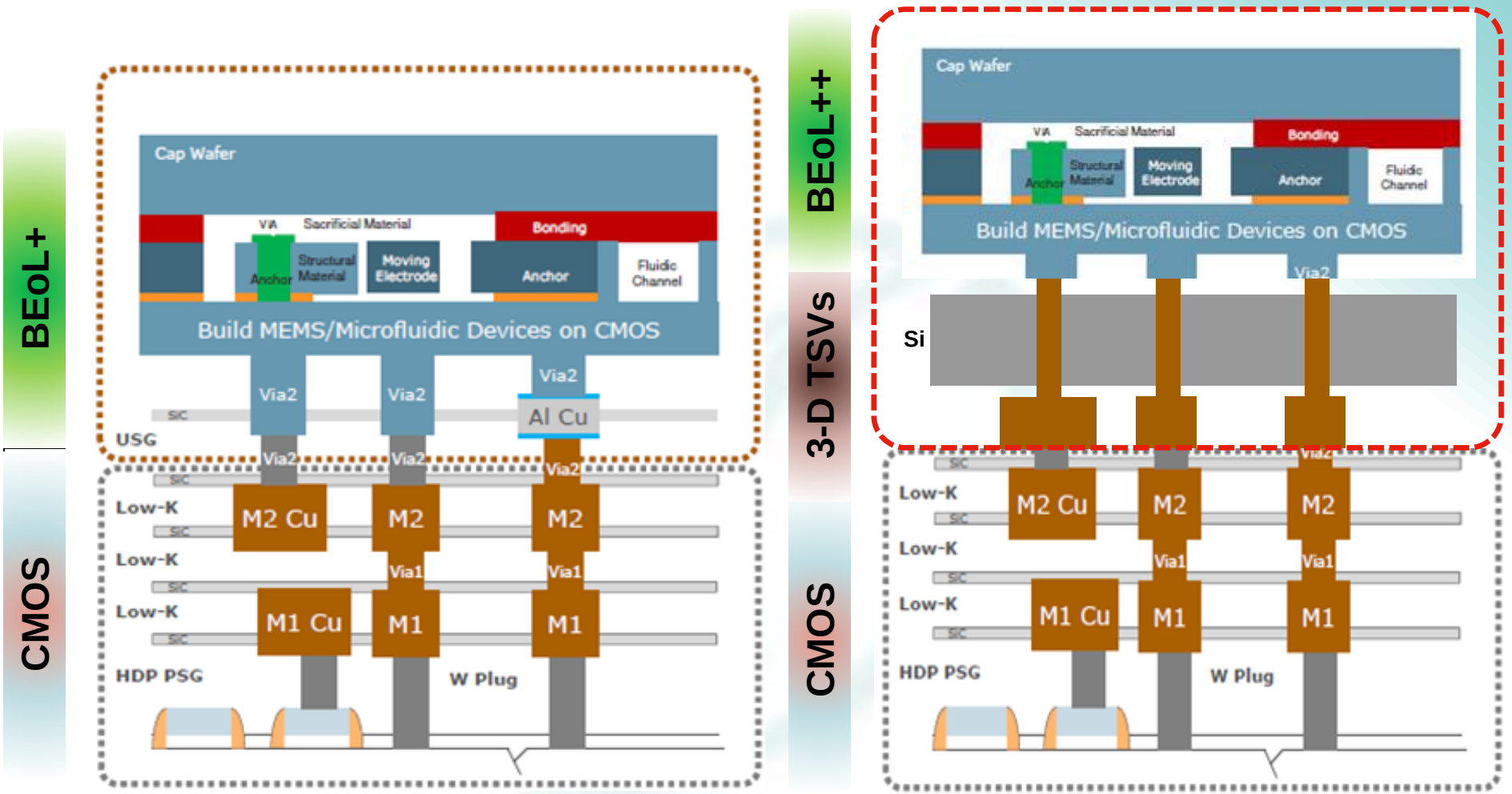
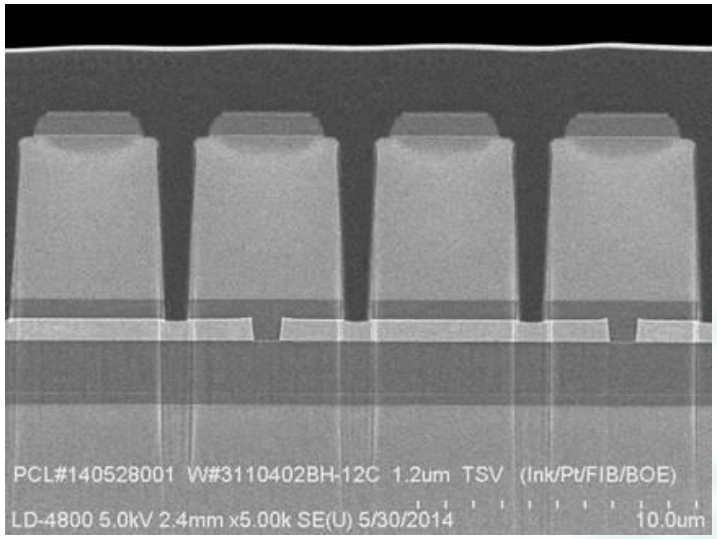
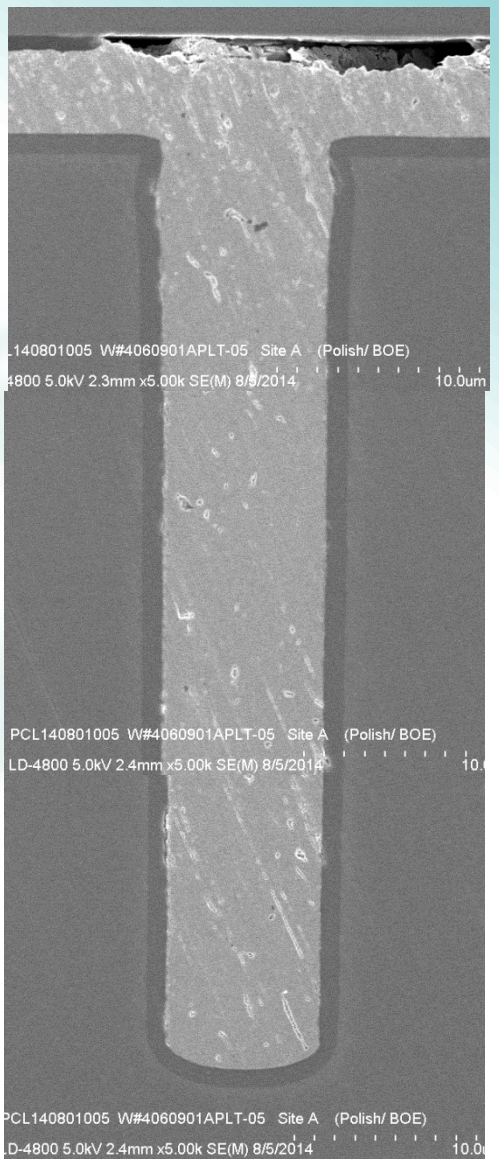


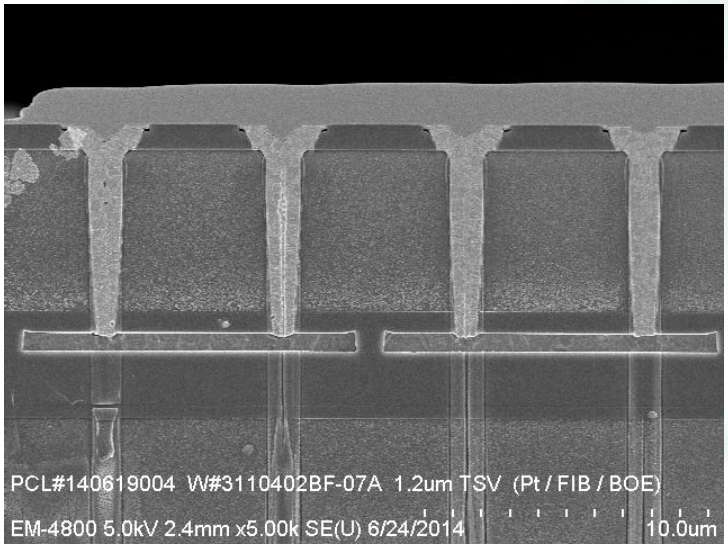
Figure 1: Non-digital devices built directly on CMOS (left), or built separately and joined through 3-D TSVs

TSV Insertion to Create 2.5/3D Assemblies



1.2x6um
Tungsten





10x100um
Copper

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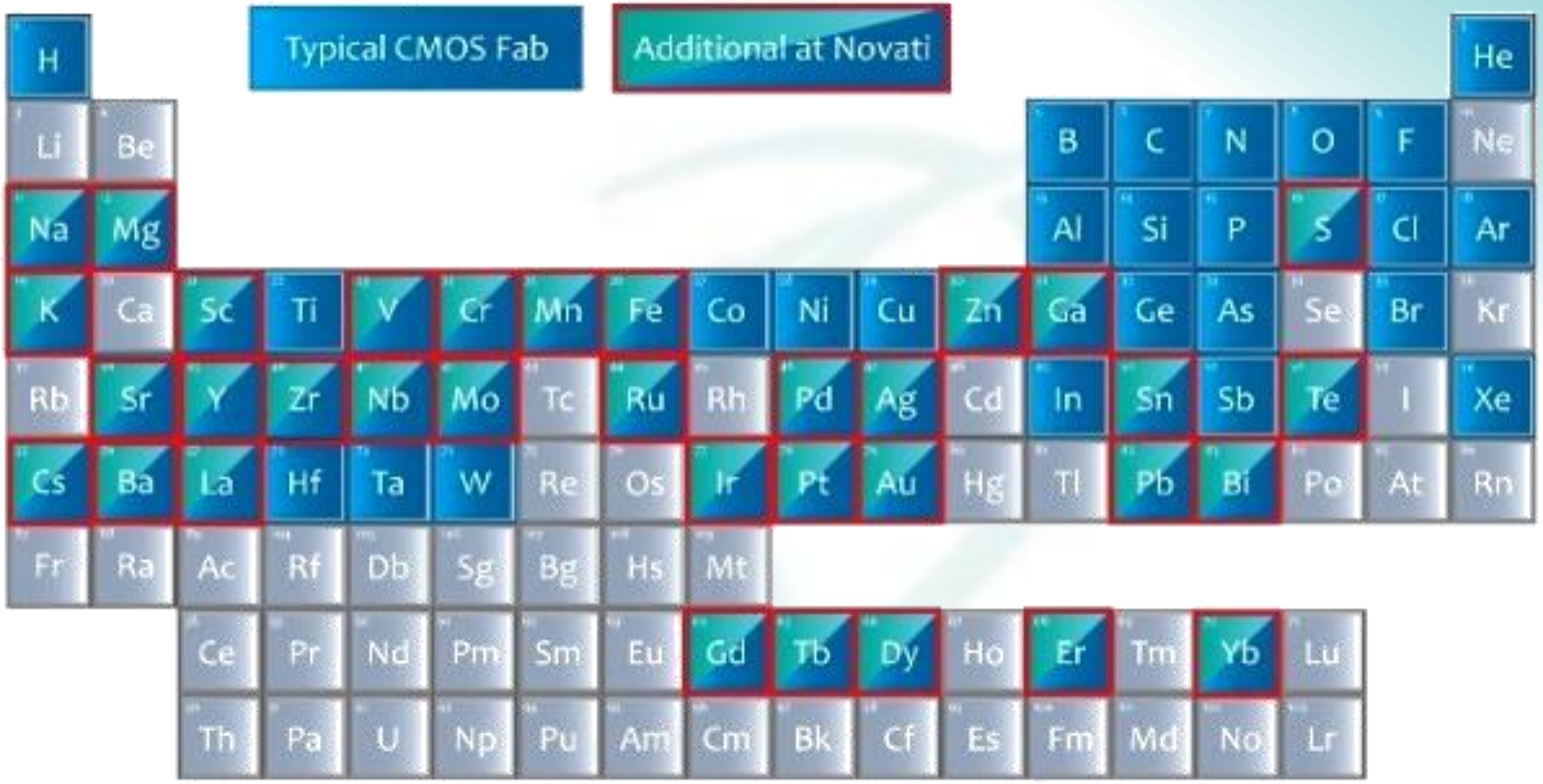
New Elements Introduced to Fabrication



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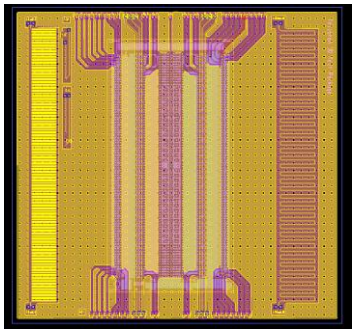
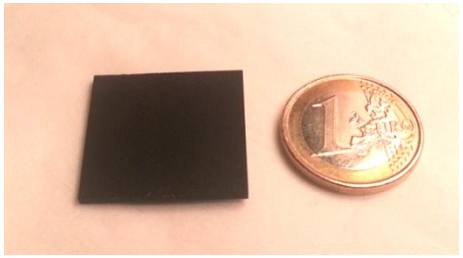
Si Interposers





Interposer Parameters

Layer	Metal thickness	R(mΩ/□) at DC	W	L	Cg (fF)
M1	2μm	9.2	10	2	2.94
			200	10	58
M2	2μm	9.2	10	2	1.83
			200	10	21.0
M3	2μm	9.2	10	2	1.4
			200	10	19.7
M4	2μm	9.2	10	2	0.919
			200	10	13.9

	TSV Diameter	TSV Height	Resistance	Cg (fF)
Filled	10μm	100μm	21.2mΩ	180
Conformal	80μm	300μm	~15mΩ	~600

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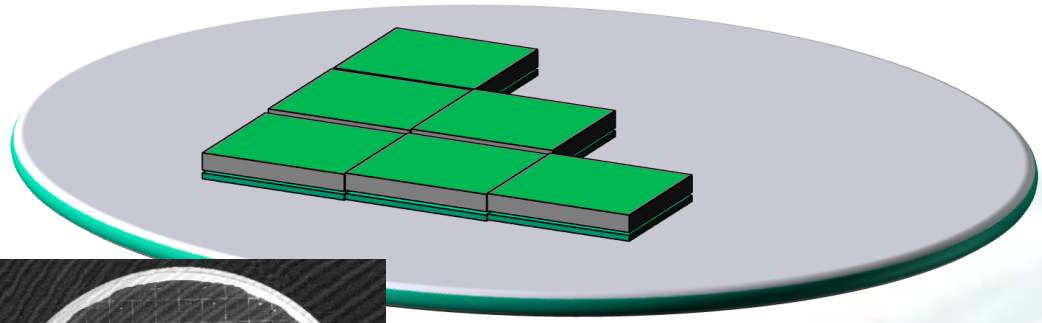
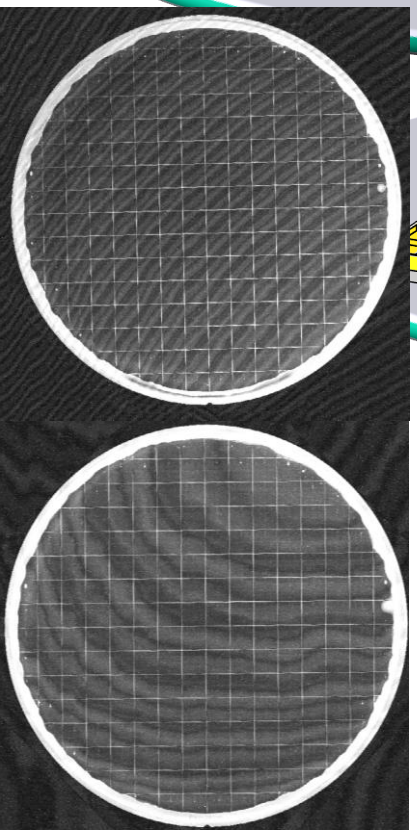
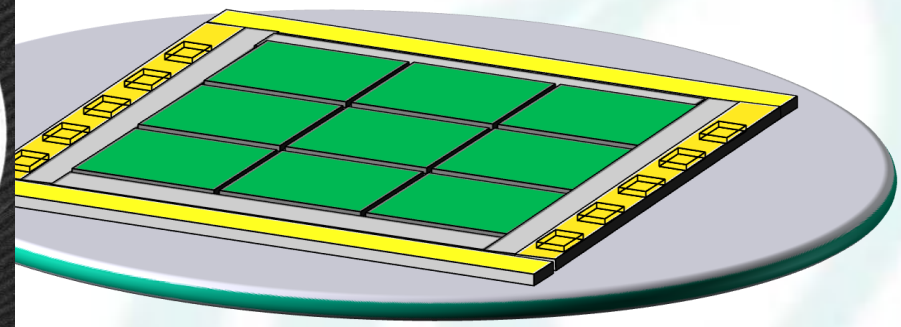
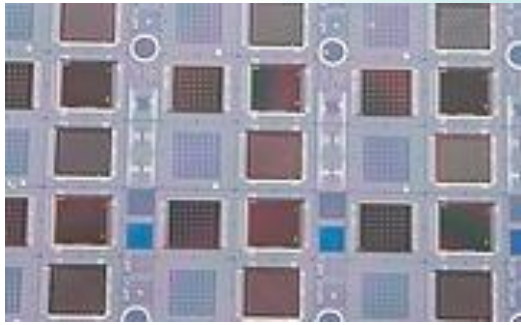
Die on Wafer and Wafer-scale FPA

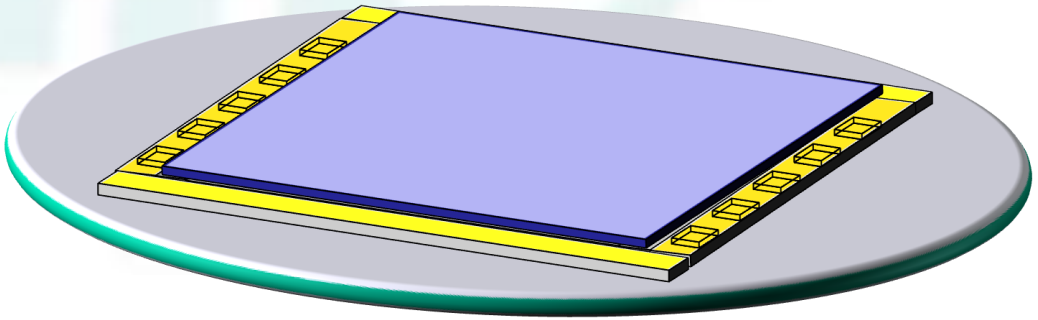
- Waferscale integration
- Up to 85 die assembly
- 10um die space
- 2um placement
- 150/200/300mm











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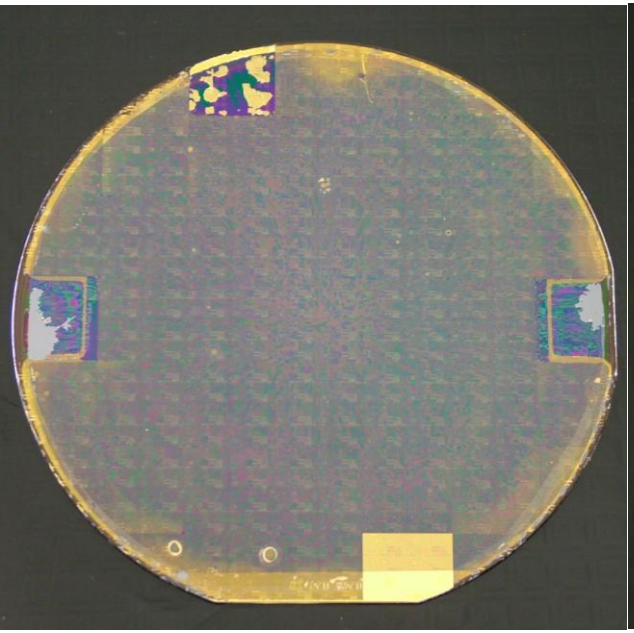
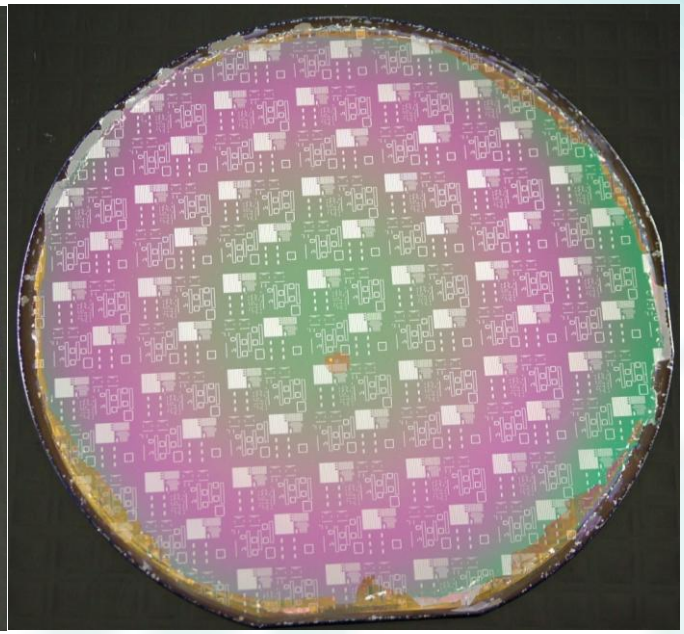
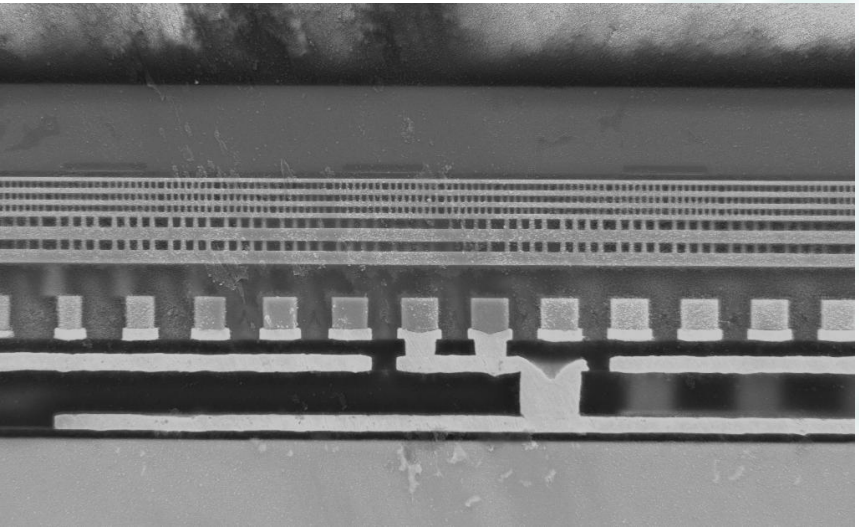
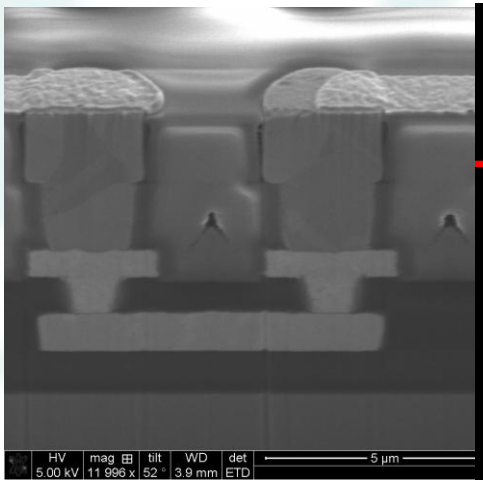
Mixed CMOS-3/5 100mm InP/CMOS

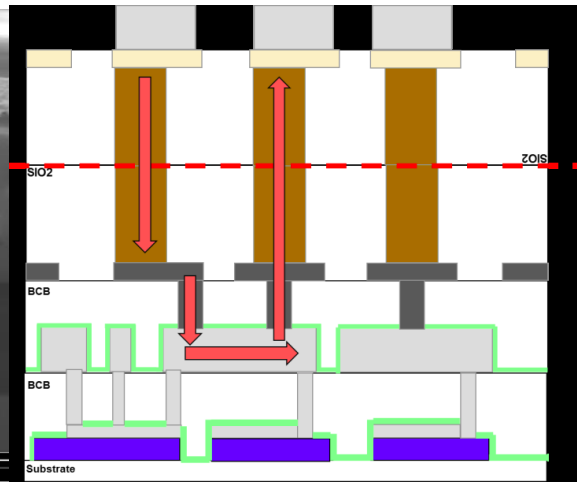


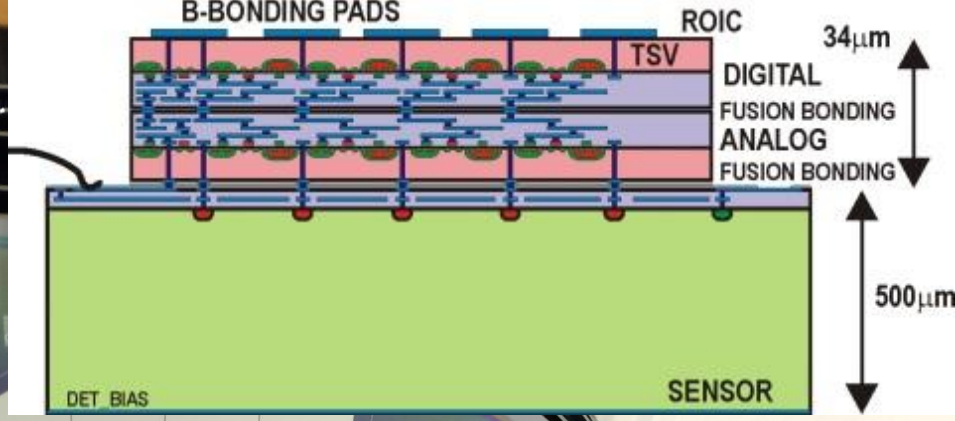


- GaN
- 3D CMOS/InP/GaN
- GaAs
- Graphene

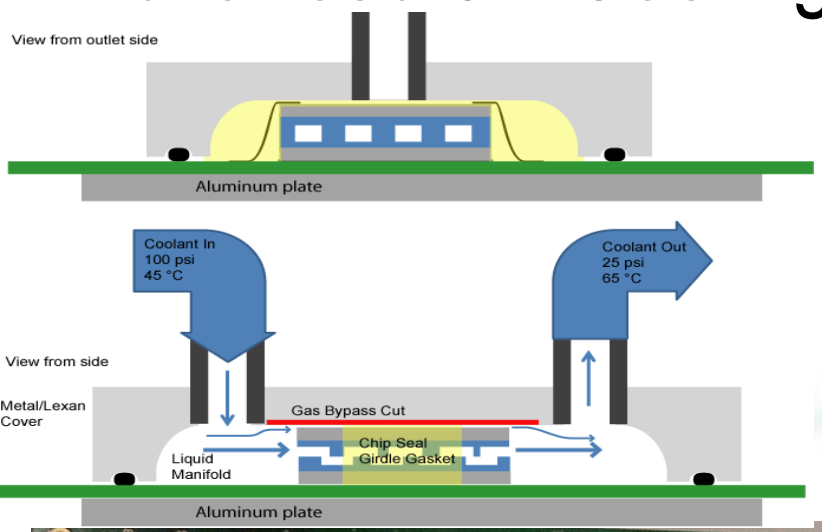


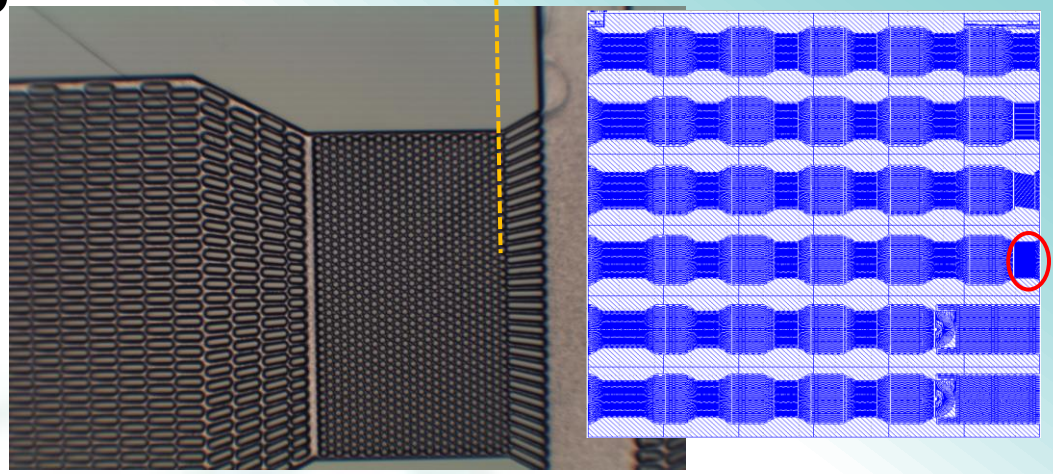


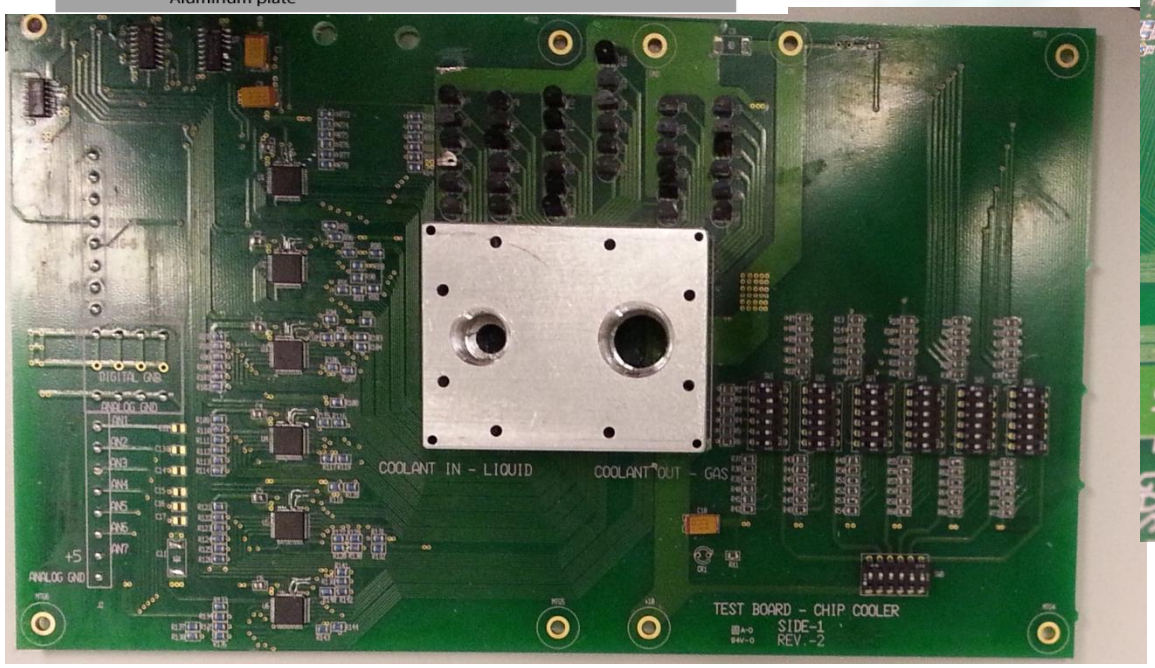


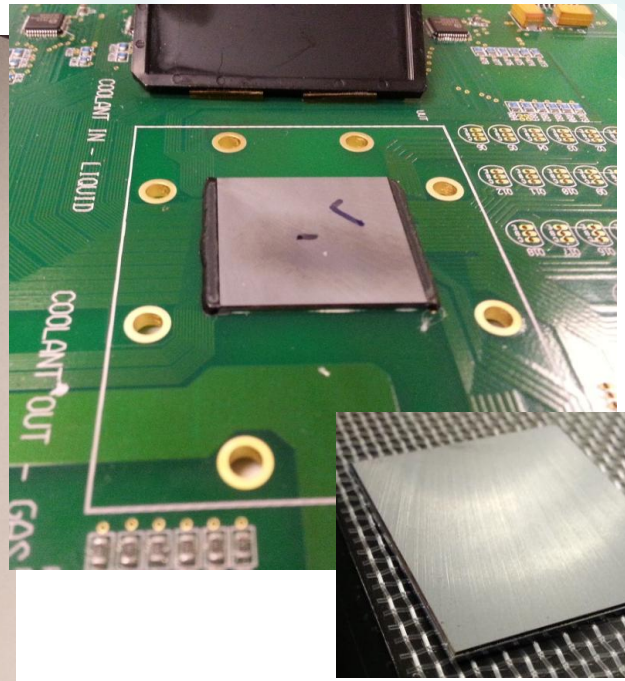

B-BONDING PADS
ROIC
TSV
34μm
DIGITAL
FUSION BONDING
ANALOG
FUSION BONDING
500μm
DET_BIAS
SENSOR

Advanced 3D Cooling

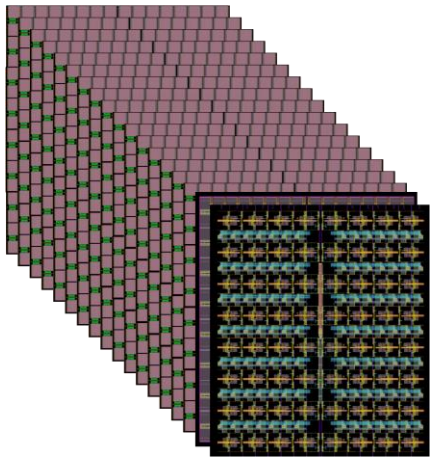


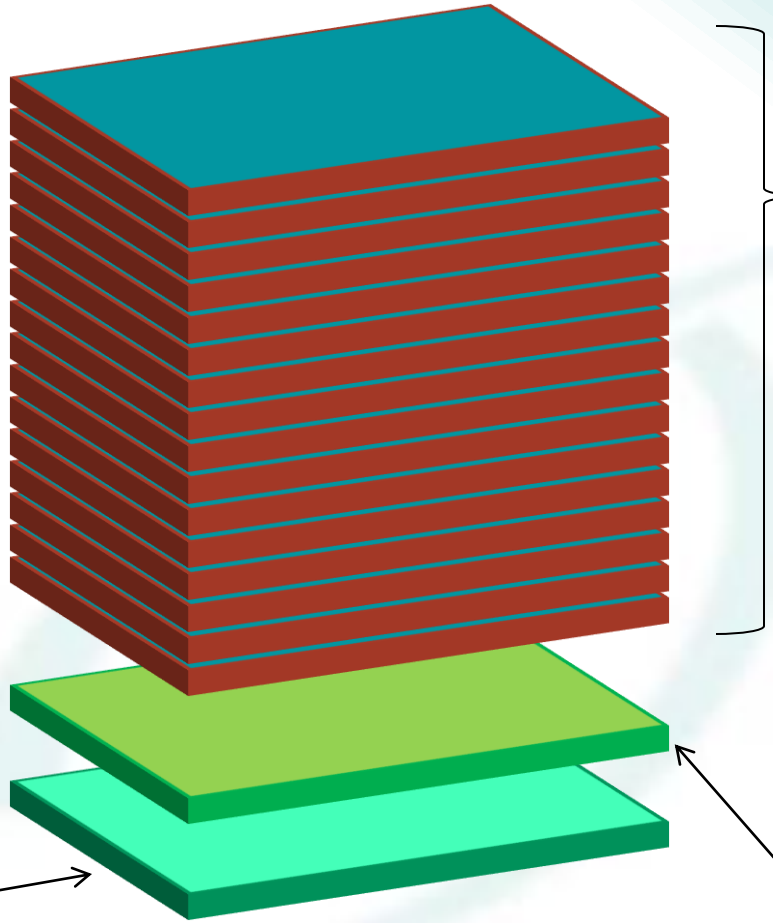






DiRAM4 “Dis-Integrated” 3D Memory





DRAM layers
4xnm node

2 million vertical connections per lay per die

I/O layer contains: I/O, interface logic and R&R control CPU. 65nm node

Controller layer contains: sense amps, CAMs, row/column decodes and test engines. 40nm node

Better yielding than 2D equivalent!

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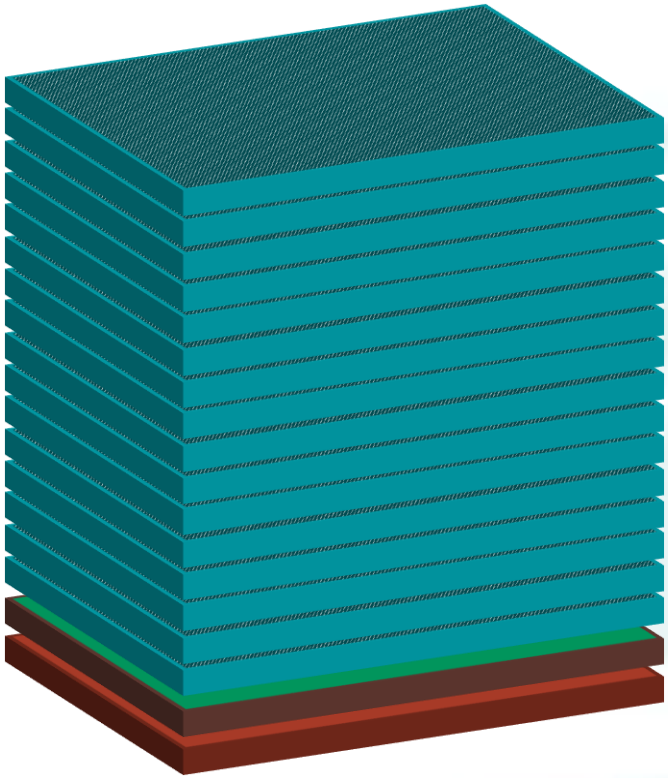
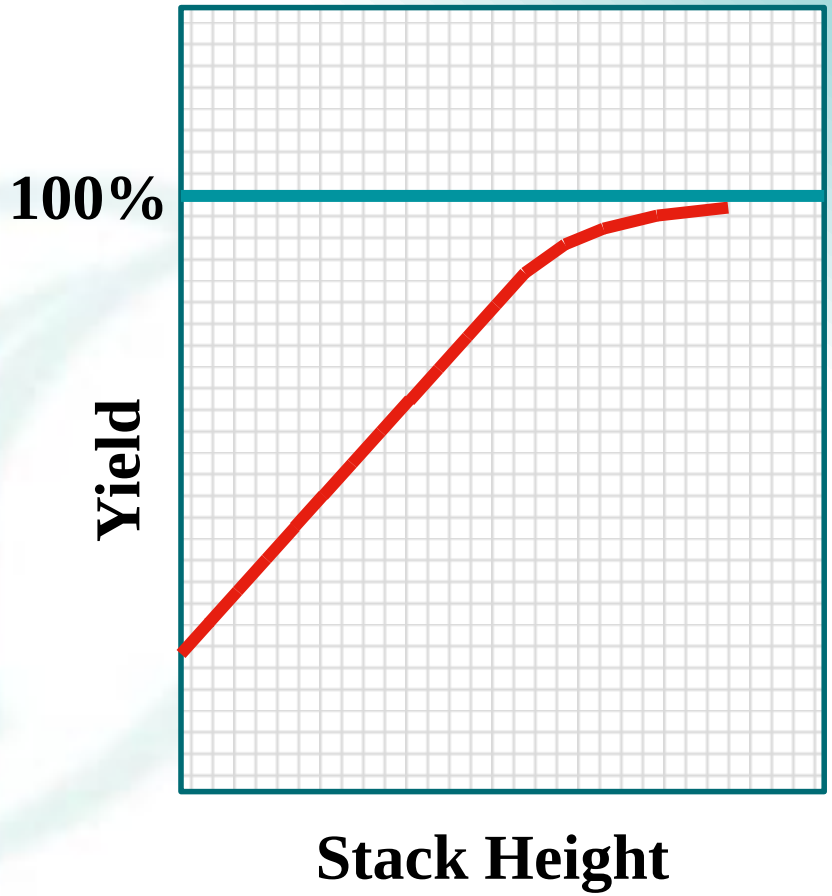
Bi-STAR Repair Improves Yield





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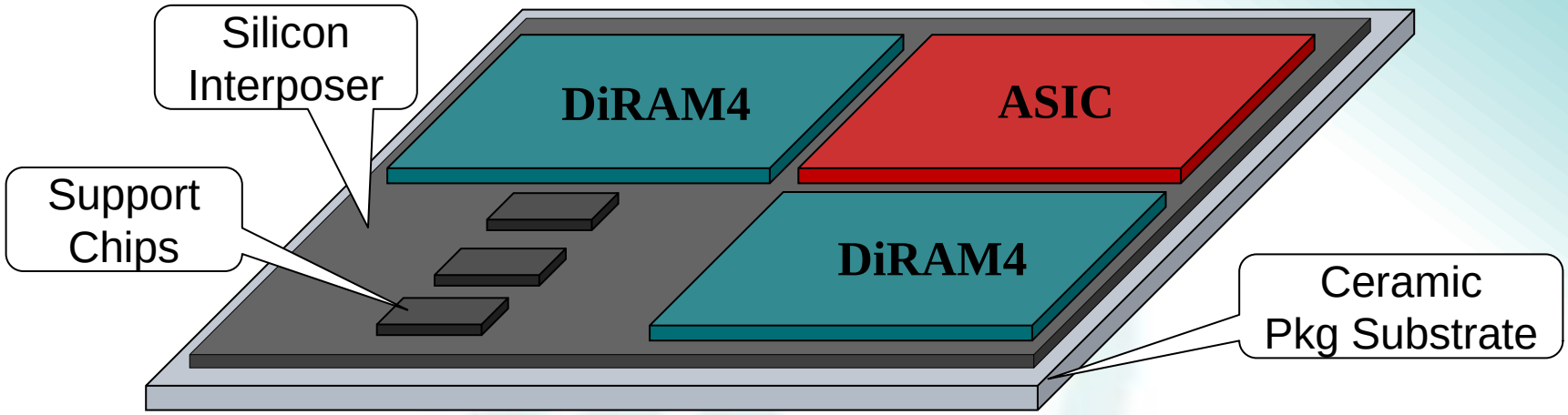
HPC Processor Modules



Si Interposer-based Ceramic Package

e.g. DiRAM4 plus Custom Processor

50 µ - 100 µ pitch Copper Pillar Die-to-Interposer-to-Die Interconnect

~ 10000 Connections – Mostly die-to-die inside package

~250 µ pitch C4 Bump Interposer-to-Ceramic Package Substrate Interconnect

~ 2000 Connections – Lots of replicated power connections

1 mm pitch Solder Bump Package Substrate-to-Customer PCB Interconnect

Several Hundred of Connections

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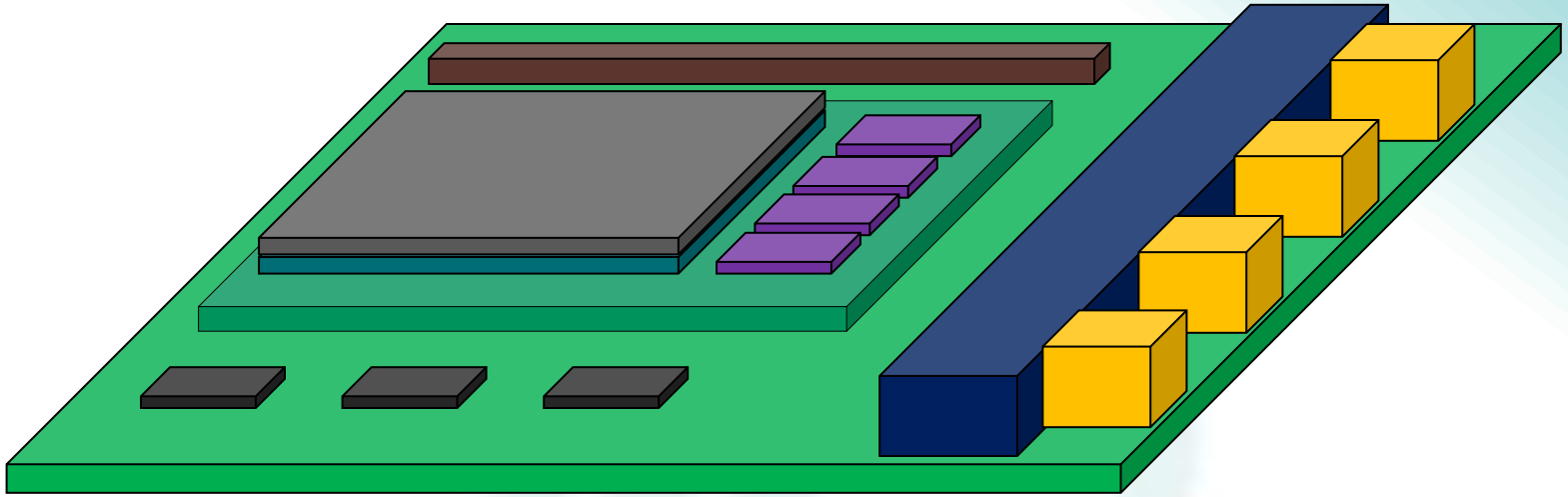
And Full Subsystem Modules



Sub-system Modules

e.g. (Tezzaron / Luxtera Optical Memory Module)

Multiple Packages and /or Die
on High Performance PCB with System Connectors
(Electrical: Card edge or Plugs, Optical: Fiber-optic Cable connectors)

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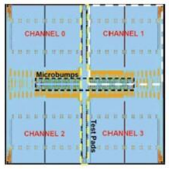
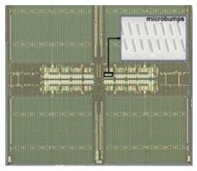
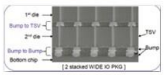
2.5/3D CHANGE IS AT HAND

The Silent Revolution







Samsung

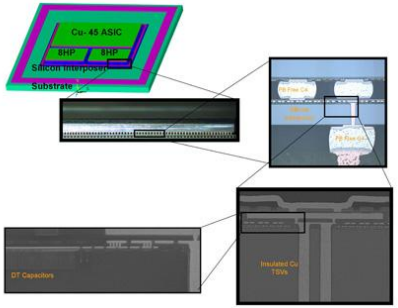
16Gb NAND flash (2Gx8 chips),
Wide Bus DRAM, VNAND

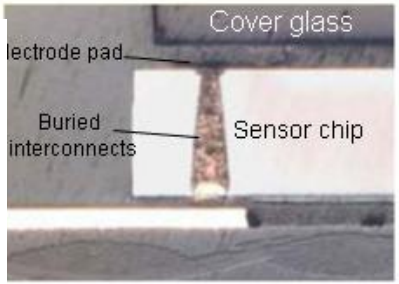
Micron

HMC DRAM

Intel

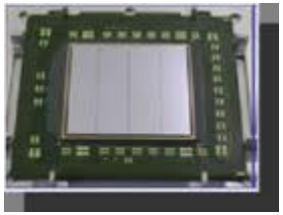
CPU + memory





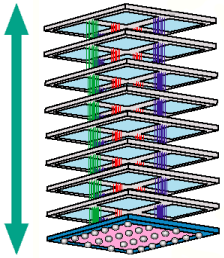
Sony

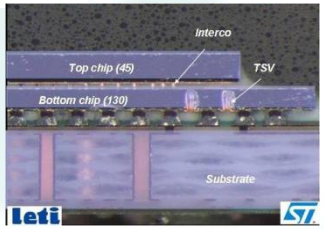
CMOS Sensor

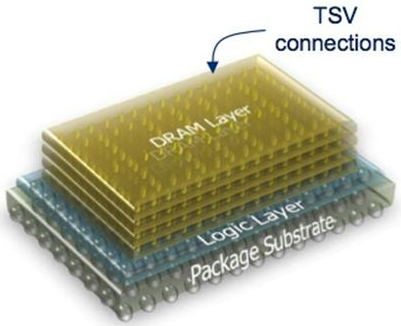


Xilinx

4 die 65nm interposer

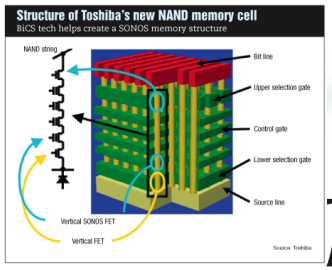


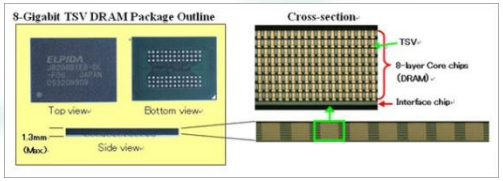




Raytheon/Ziptronix

PIN Detector Device





IBM

RF Silicon Circuit Board / TSV
Logic & Analog

Toshiba

3D NAND

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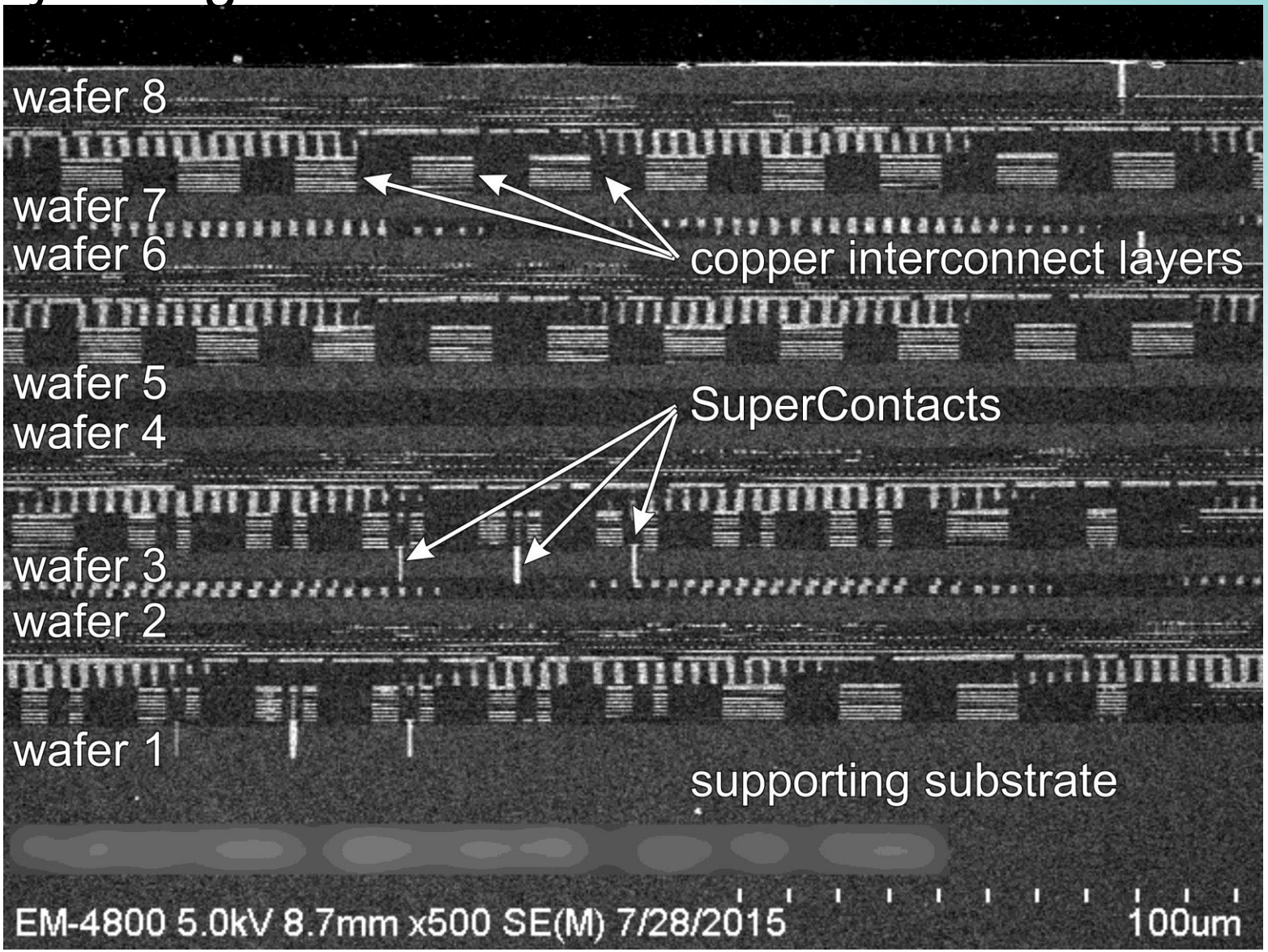
8 Layer Logic Stack



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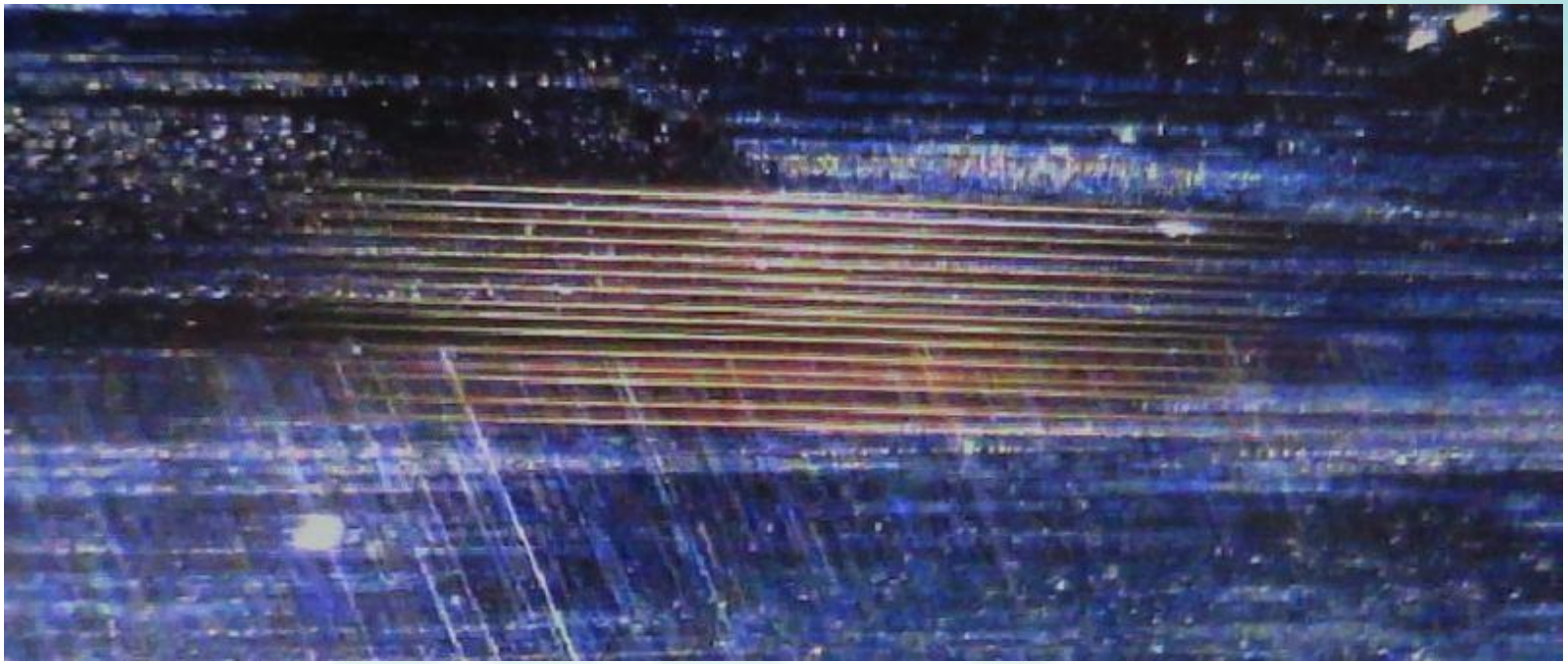
16 Layer Mechanical Device Stack



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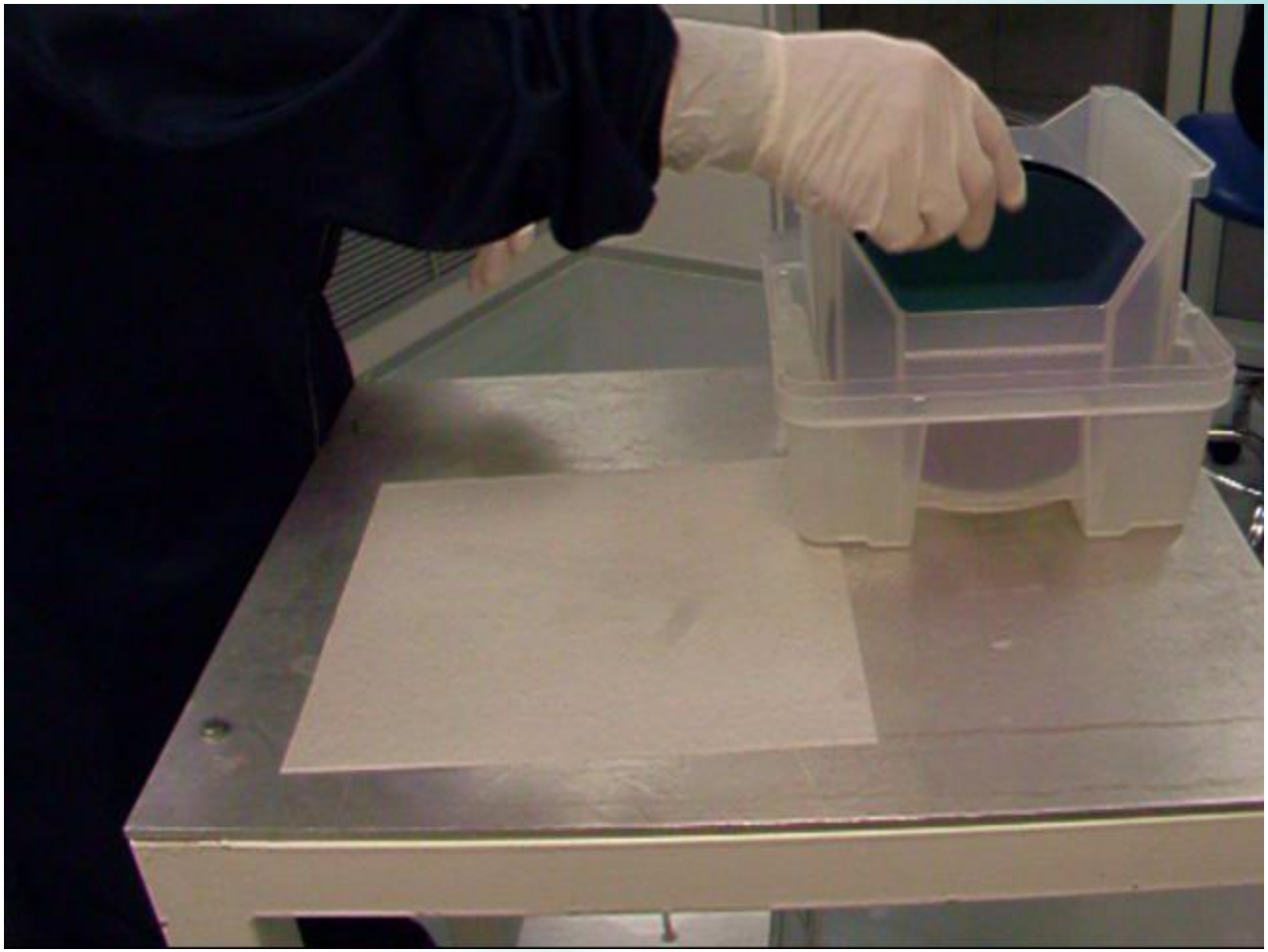
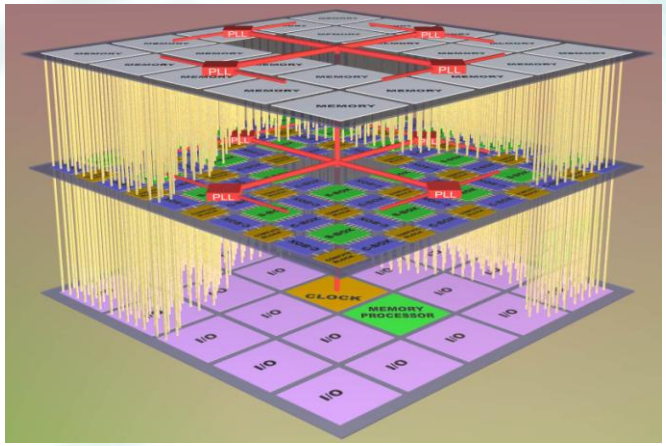
Bonding in Action



Summary

- 2.5/3D market is in the adoption cycle
  - Moving from novelty to mainstream
- Drivers are:
  - Heterogeneous integration
  - SWaP
  - Increasing performance
  - Lower system costs
- First markets are:
  - Logic – Memory
  - Sensors
- Significant industry shifts will happen
  - Silicon circuit cards with “Lego” blocks



Tezzaron SEMICONDUCTOR

Backup

NOVATI OVERVIEW

Austin Facility Overview

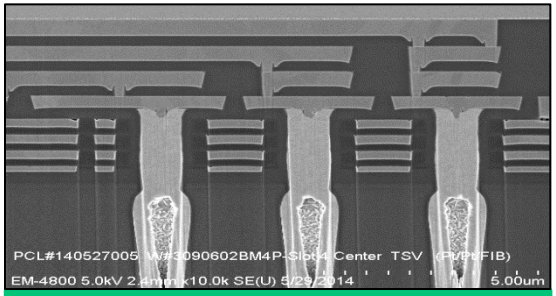
- 110 Employees: 90 in Ops and Engineering
- Over 150 production grade tools
- 68,000 sq ft Class 10 clean room
- 24/7 operations & maintenance
- Manufacturing Execution Systems (MES)
- IP secure environments, robust quality systems
- ISO certified/ITAR registered
- Full-flow 200mm silicon processing, 300mm back-end (Copper/Low-k)
- Process library with > 25000 recipes
- Novel materials (ALD, PZT, III-V, etc)
- Copper & Aluminum BEOL
- Contact through 193nm & IR lithography
- Silicon, SOI and Transparent MEMS substrates
- Electrical Characterization and Bench Test Lab
- Onsite analytical tools and labs: SIMS, SEM, TEM, Auger, VPD, ICP-MS, etc

Tezzaron SEMICONDUCTOR

Our Technology Platform

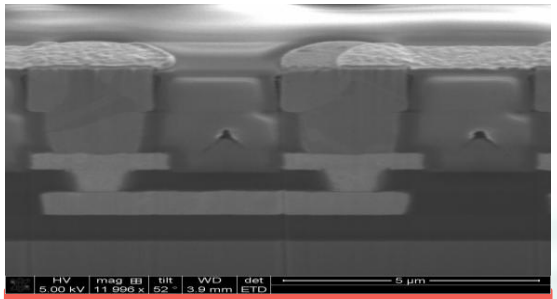
NOVATI TECHNOLOGIES, INC.

Focused on Convergence of Three Critical Areas



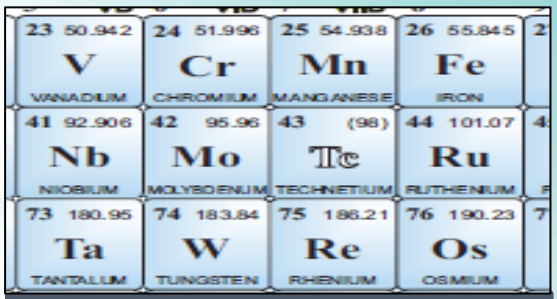
BEoL Split-Fab

- Copper BEoL to support multi-level metal, redistribution, TSV
- High-k capacitors, precision resistors, magnetics, waveguides



2.5D & 3D Integration

- Hybridization of Silicon and non-silicon (quartz, GaAs, InGaAs, GaN) substrates
- Interposers, die-to-wafer, wafer-to-wafer, TSV insertion



Novel Materials

- More than 60 elements from periodic table can be leveraged in the fab today
- World's fastest most flexible on-boarding of new materials

Enabling Advanced Processing, Smart Sensors, Advanced Imagers, RF/Power Electronics

TeZZaron SEMICONDUCTOR

ISO, ITAR and Trust Accreditation


ACCREDITATION OF TRUST

Novati Technologies, Inc.

Microelectronics Trusted Source

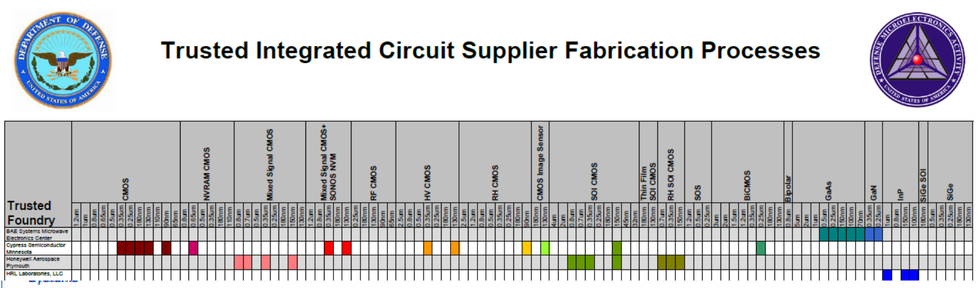
CATEGORY 1A

By these presents the undersigned expresses the confidence of the Department of Defense, Defense Microelectronics Activity (DMEA) in the ability of the organization known as

Novati Technologies, Inc.

to deliver trusted foundry microelectronic goods and services to end users within the United States Government that correspond to Trusted Category 1A which meets Mission Assurance Category 1 as defined by Instruction 8500.2 of the Department of Defense Directives, effective this date.

200	6T0L1	24 Jul 2014	24 Jul 2016	Ted Glum
Site Accreditation Number	CAGE Code	Effective Date	Renewal Date	Director, Defense Microelectronics Activity



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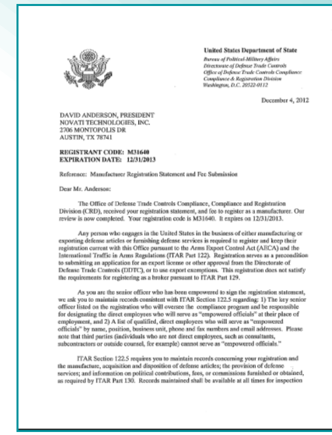
Novati Technologies, Inc.	6T0L1	Austin, Texas	Foundry Services	Tim Scott	tim.scott@novati-tech.com	(512) 356-2007
NSA Microelectronics Solutions Group	98230	Fort Meade, MD	Design; Packaging/Assembly; Test			



ISO 9001:2008 & ISO 13485 Certified

ITAR Registered

US Trusted Foundry

Tezzaron SEMICONDUCTOR