APPLIED MATERIALS®
make possible

Device Packaging 2021

Innovative PVD Technology Solutions

Advanced Substrate, EMI Shielding, & Backside Metal

Jeff Turner – Applied Materials®

March 2021

Jeff Turner

KPU Head Tango Products – Packaging Business Unit, Applied Materials

With over 25 years of experience in Semiconductor Packaging, Jeff is leading the Tango product group after acquisition by Applied Materials. He got his start in packaging as a process engineer for Semitool, specializing in electroplating and wet cleans. Post acquisition of Semitool by Applied Materials, his career transitioned into product management and then business management supporting electroplating and PVD systems in Applied's Packaging Division.

Applied Materials Acquired Tango Systems

APPLIED MATERIALS® + TANGO SYSTEMS

- ✓ Broad customer & supplier network
- ✓ Extensive product support infrastructure
- ✓ Broadest portfolio for Packaging products
- ✓ Largest investment in Packaging roadmap

- ✓ Flexible, high performance, & cost competitive PVD platform
- ✓ Wafer, Film Frame (EMI) and Panel
- ✓ Leading positions in EMI and Panel PVD

Leverage Applied's global footprint to better support Tango's customers
Accelerate development of technology and productivity solutions for Advanced Packaging

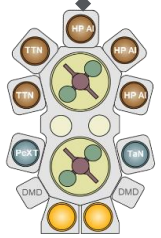
Tango Products Integration to Applied Materials

Applications: TSV , Advanced Bump

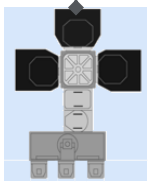
Applications: Bump , Fan Out

Applications: EMI Shielding , Backside metallization, Panel Fan Out , Advanced Substrates

Film Quality

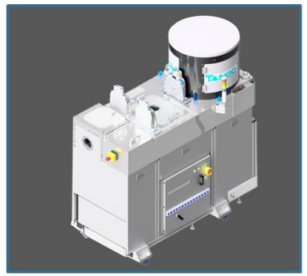


Applied Endura® PVD



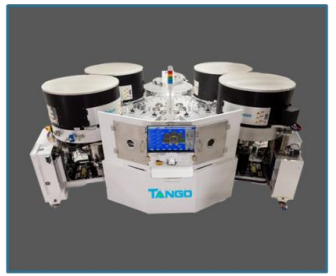
Applied Charger® PVD

Pika™ PVD



- ✓ Smallest multi-target system and footprint in the industry

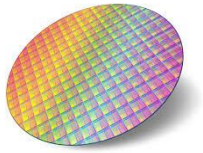
Axcela™ PVD



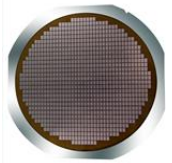
- ✓ Batch processing; 5x 300mm
- ✓ EMI, BSM and RDL

Topaz™ PVD

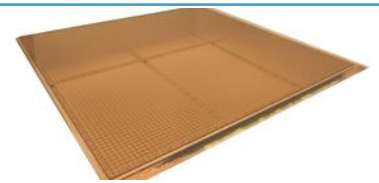
- ✓ Panel up to 600mm x 600mm
- ✓ RDL FO & HD PCB Substrates



Wafer Form



Film Frame (EMI)



Panel (Advanced RDL FO & HD PCB Substrates)

Source: Applied Materials Internal

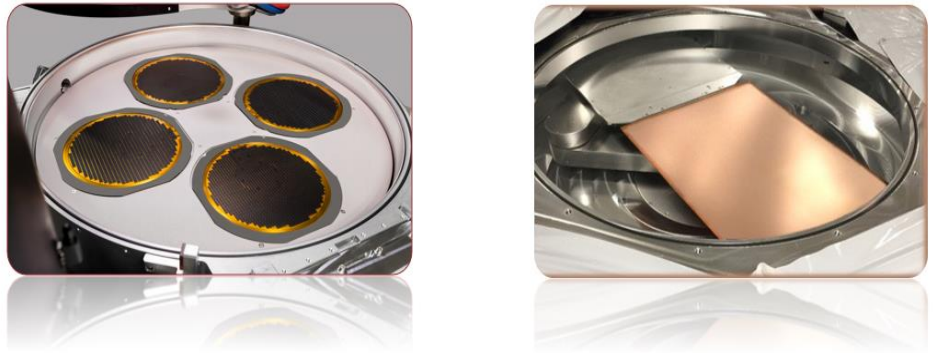
Large Area Panel Processing

Strategic Initiatives: Large Area Processing

Large Area Processing | Where we have traction

4 | Applied Materials Confidential

MARKETS



EMI

Fast and continuously growing application in the global marketplace for 5G: Mobile, Auto and IoT

5G DEVICES

For increased bands, antennas and filters, and higher package densities

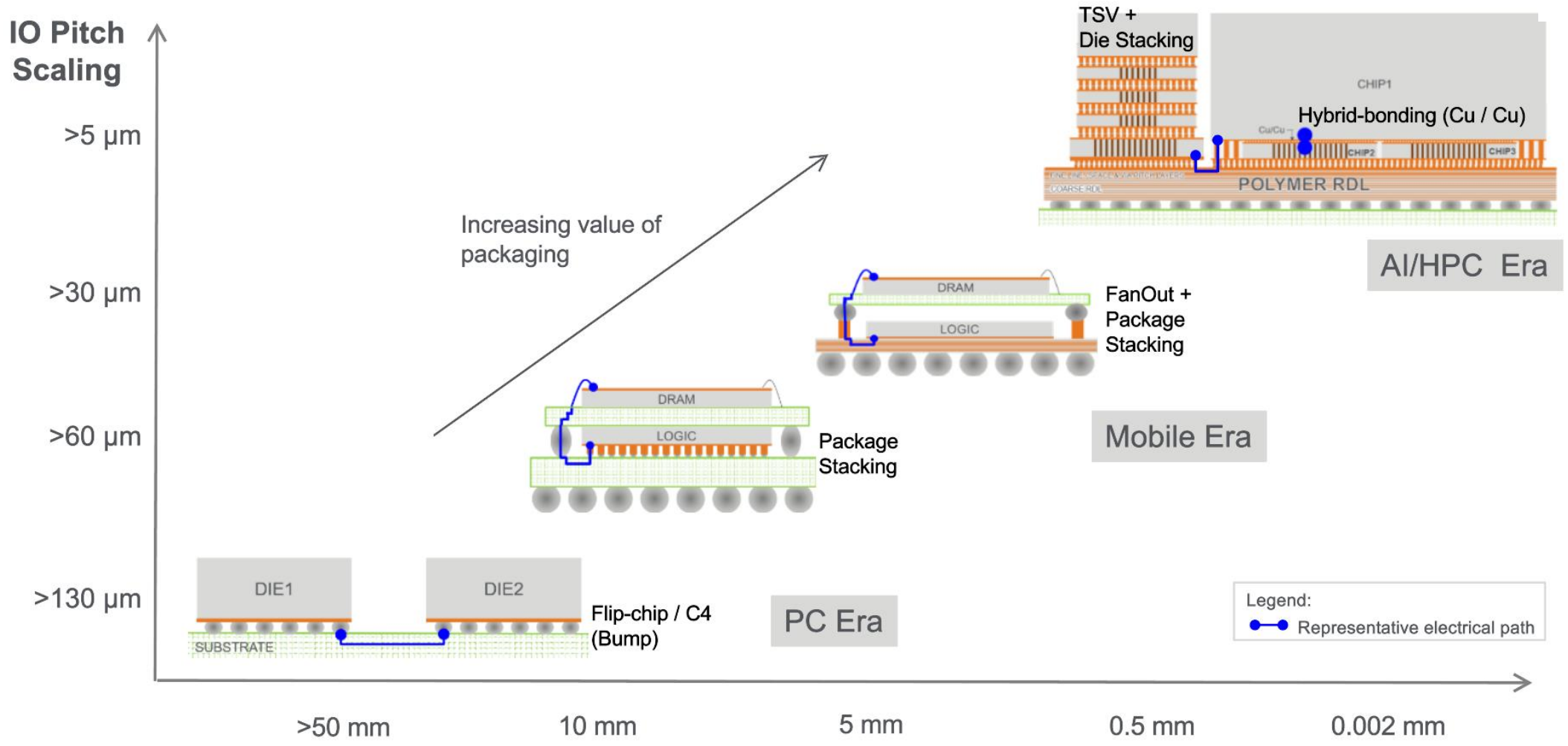
PANEL LEVEL PACKAGING

Tango leading the way

Best in class performance

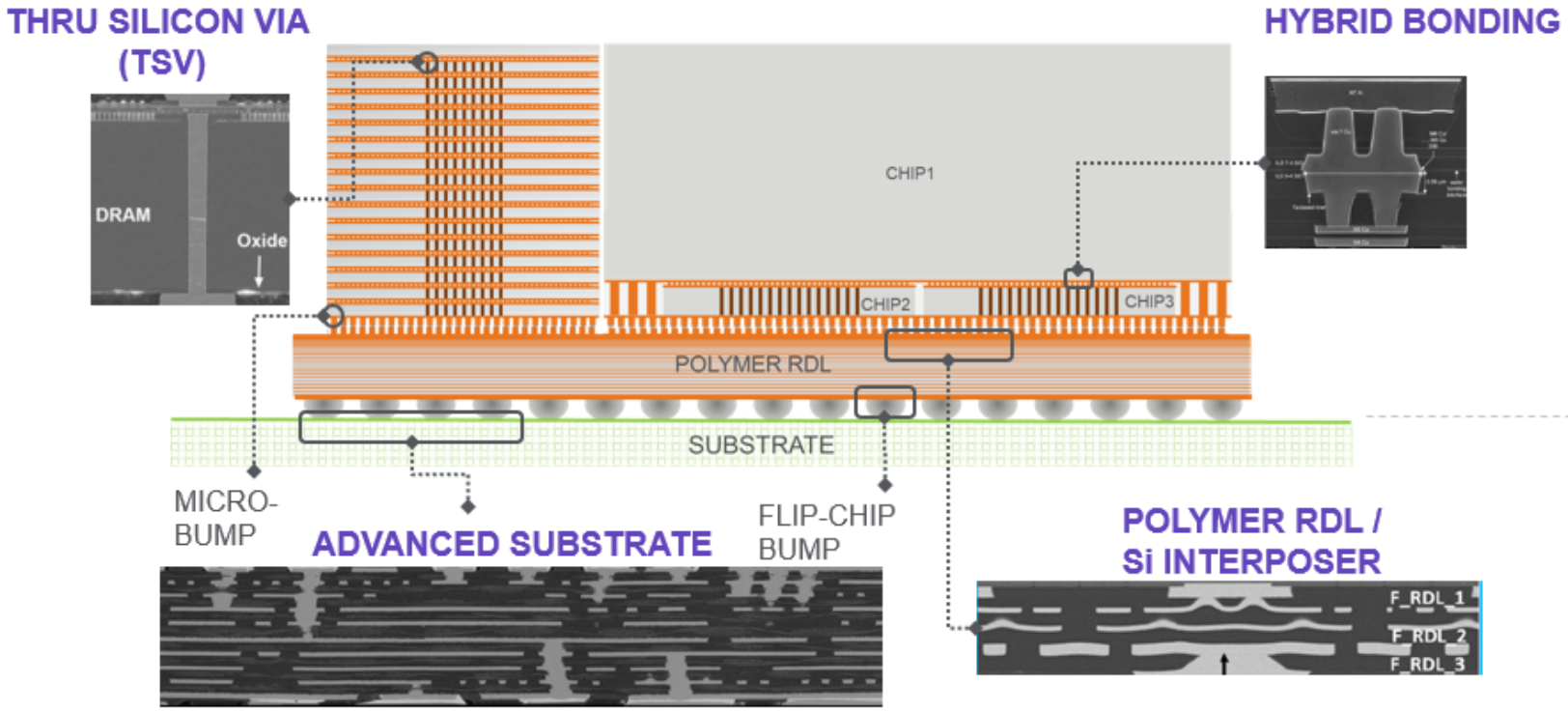
Source: Applied Materials Internal

System Interconnect Scaling Roadmap



System Interconnect Length Scaling

System Integration with 2D & 3D Interconnects



3D Interconnects

- Thru Silicon Via (TSV)
- Hybrid bonding [Emerging]

2D Interconnects

- Redistribution layer (RDL) (Bump, bond-pad)
- Advanced substrate [Multiple Platforms Emerging]

Broad technology portfolio and ability to deliver integrated solutions for both 2D & 3D

Panel PVD Applications, Materials, & Equipment

- Panel Applications
  - RDL
  - BSM
  - EMI Shielding
- Panel Materials
  - ABF (Ajinomoto Build-up films)
  - Glass
  - Molded Compound
- Equipment: Topaz™
  - Panels up to 600mm x 600mm
    - Frameless handling
    - Glass carrier handling for panels
  - Automation: Warped Panel Capability
  - Semiconductor grade capable processes
    - Degas, Preclean, Deposition

Applied Material Topaz™

Source: Applied Materials Internal

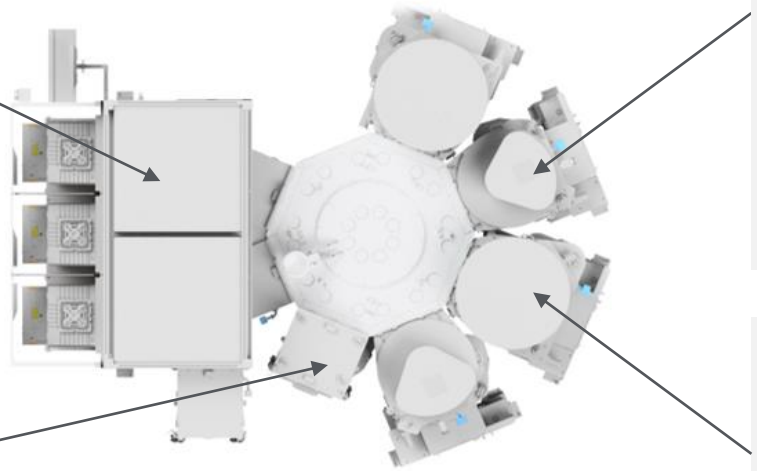
Topaz™: Wafer Grade Capability in Panel Form

Load Lock Degas

- Multi panel load lock
- Increased degas capability in LL

Staged Degas

- Multi panel batch degas
- Heating capability
- Moisture monitoring for process control



Preclean Chamber

- ICP preclean technology
- Process temperature control <120C
- Contaminant control for superior Rc performance
- Enabling superior adhesion strength

PVD Chamber

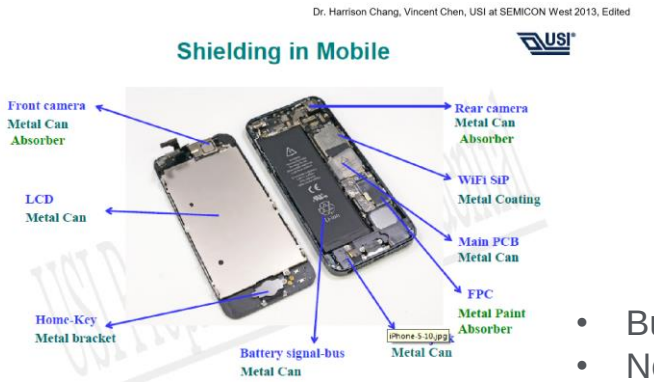
- Ti or Cu deposition
- Process temperature control <120C
- Uniform film deposition
- Capability for high AR vias

Fully automated high throughput low cost of ownership operation

Source: Applied Materials Internal

EMI Shielding

EMI: Advances in Shielding Technology



Metal Cans

- Bulky
- Not possible for high functional devices
- Worked well
- Mech structure

1990s-2006

Spray Shields

- Not effective shield
- High Overall cost
- Quality issues
- Easy to implement
- Low capital costs
- Low temperature

2007-2013

Inline Sputter

- Large Footprint
- High Overall cost
- Contact Resistance
- Adhesions challenges
- Temperature
- Better shielding

2013-2015

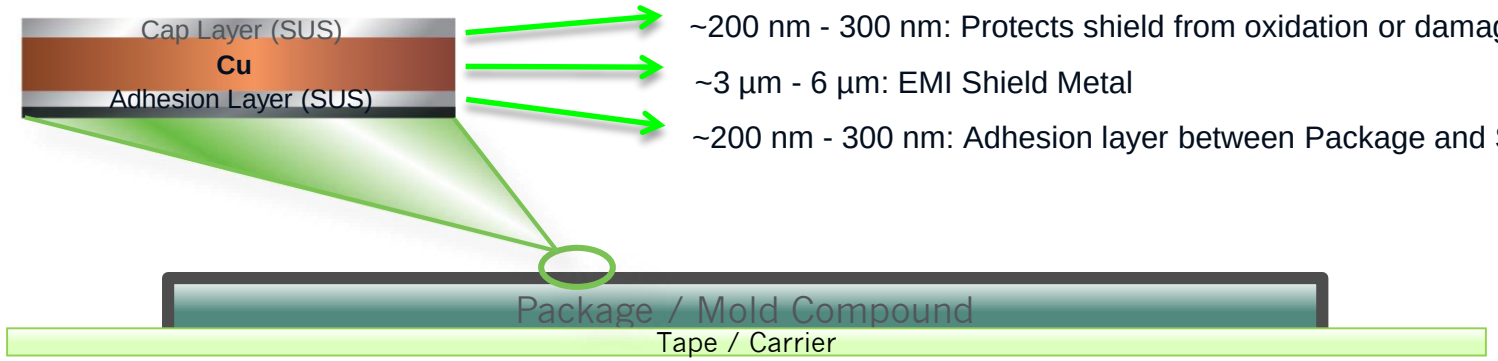
Cluster Sputter

- Higher Capital cost
- Small Footprint
- Low cost of ownership
- Low Contact Resistance
- Best Adhesion
- Best in class for high and Low frequency shielding

From 2015

High & Low Frequency Shielding Scenarios

High Frequency

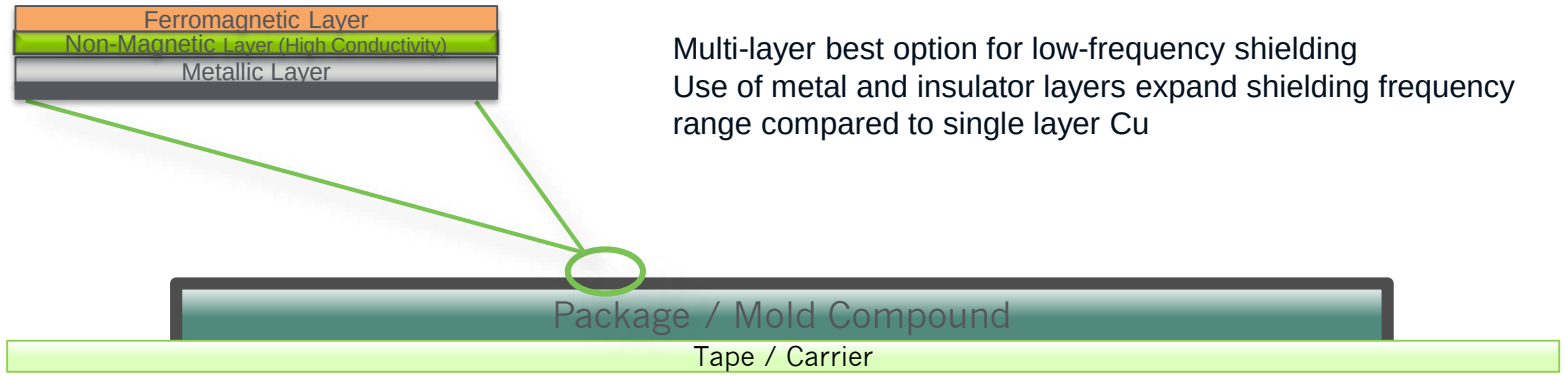


~200 nm - 300 nm: Protects shield from oxidation or damage

~3 µm - 6 µm: EMI Shield Metal

~200 nm - 300 nm: Adhesion layer between Package and Shield Metal

Low Frequency



Multi-layer best option for low-frequency shielding
Use of metal and insulator layers expand shielding frequency range compared to single layer Cu

5G Shielding Requirements

- Lower contact resistance
  - 100X improvement required
  - 1-2 ohm to 0.01-0.02 Ohm
  - Less Noise required for 5G
- Higher Step Coverage
  - Package thickness increase >0.8mm
  - Addition of Antenna on modules
  - Coverage > 40% for lower CoO
- Higher Conductivity
  - Higher conductivity to reduce shield thickness
    - **Tango™ <4um** Vs competition >5um

Rc Specification Trends

	5G	4G	3G
Rc Spec (Ohm)	0.02	0.20	2

Applied Rc Performance

Contact resistance as low as **4.5 mOhm!!**

Contact Resistance (mOhm)	
Measurement	**Tango**
Min	4.5
Max	4.6
Ave.	4.6
St. Dev.	0.01

EMI Platform Comparison

Attribute	Axcela™	Inline Tools	Axcela™ Key Differentiators
Contact resistance	1X	10X	**10x Lower Rc performance**
Adhesion	> 5B	≤ 4B	**Best in Class** (Mold/Si/Exposed Wires)
Required deposition thickness	1X	1.5X	Small dense grains; **requires less deposition** to achieve device performance
Process Temperature & Control	Low	High / Unstable	**Eliminates thermal budget concerns**
Sputter Materials	Ti/Cu/SUS/Ni/Nife/Co …..	Ti/Cu/SUS	Capability to do both **High & Low Frequency** Shielding
Package Type	BGA/LGA/STRIPS/DSBGA	LGA/BGA	**Preferred vendor** of choice for all 5G products
Footprint (m2)	1X	3X	3x Tools in same Clean room space
Uptime	Modular = > uptime	Full system down for PM	Modular cluster, one chamber is down for PM - others running production

15

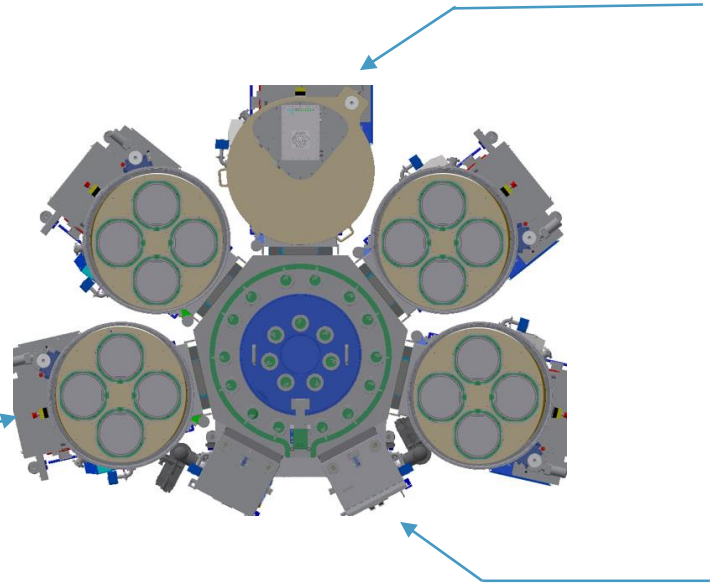
Axcela™ – The best choice for today and extendibility for next generation requirements

Axcela™: Industry Solution for EMI

Axcela - 7

- Batch processing system
- 4 – 5 carriers/chamber
- Up to 4 PVD chambers to enable highest throughput and lowest cost of ownership
- Semiconductor based architecture for exceptional process performance & control

Axcela 7



Multi-Target & Multi-Frame PVD

- Up to 3 targets per chamber
- Co-sputtering of multiple films in same chamber
- High throughput & low operation cost

Multi-Frame Preclean

- ICP preclean technology
- Process temperature control <120C for low temp etching
- Combination of Bias / Source for high etch rates & throughput
- Enables superior adhesion strength & Rc performance

Load Lock Degas

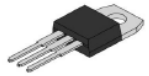
- Multi frame load lock
- 380mm/350mm/330mm Film Frames
- Batch degas process for moisture removal

Source: Applied Materials Internal

Backside Metal (BSM)

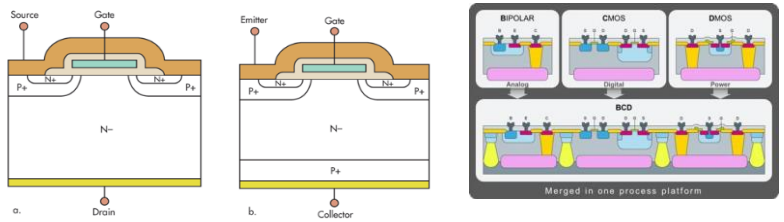
Power Devices

- Controls electrical energy from source to the load according to load demand at high efficiency and with outstanding reliability
- Discrete Power Die (single die)



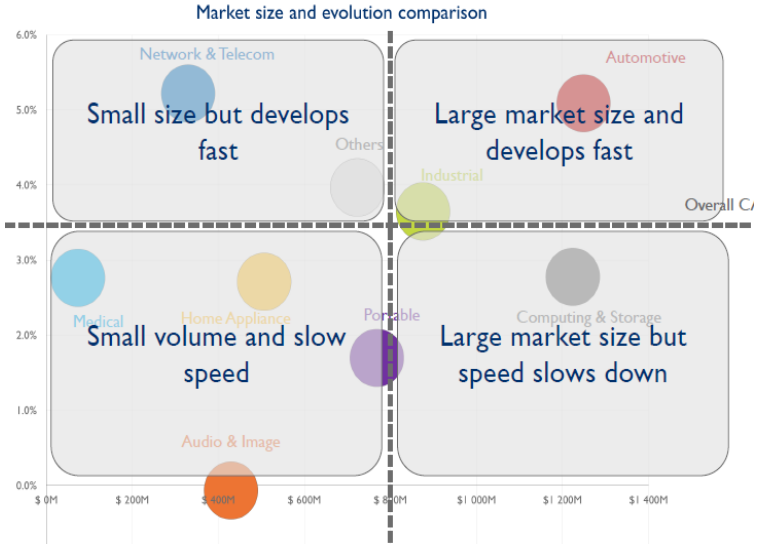
  - IGBT: Med/High V → Automotive ; Energy ; Industry
  - MOSFET: Low/Med V → Consumer-based ; Computing & storage
- Power Module (several dies)
  - Inverters → renewable energy and EV

MOSFET **IGBT** **BCD**



Demand Drivers:

- Climate change / Environmental Issues
  - EV/HEV
- Arrival and expansion of data era
  - Smartphones, AI, Autonomous Vehicle, 5G network, IoT

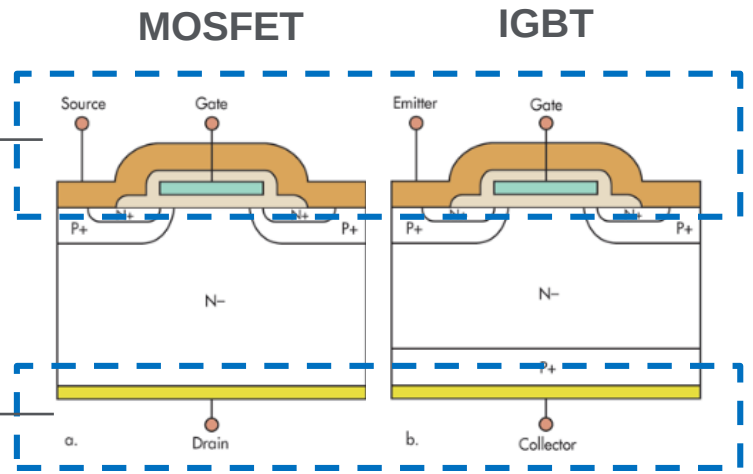


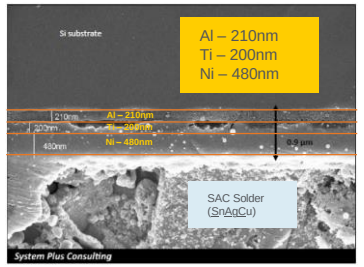
Source:
https://www.electronicdesign.com/power/are-you-kidding-harvest-power-rust
2018 Power Market Yole report , BCD Technology - STMicroelectronics

Power Device Metallization

- **Frontside Metallization: Thick Al**
  - Thick layer for high current carrying capability
  - High thermal load

- **Backside Metallization: Al, Ti, Ni, NiV, Au, Ag**
  - Create ohmic contact between Si-solder metal stack interface
  - Improve thermal management of the chip
  - ***(Ti, Al)*** → Seed layer to Si forming ohmic contact
  - ***(Ti)*** → Barrier and adhesion layer
  - ***(Ni, NiV)*** → Solder layer (reacts easily with common soft solders)
  - ***(Ag, Au, Au alloys)*** → protection/solder layer (prevent oxidation)
  - *Also used in HPC*



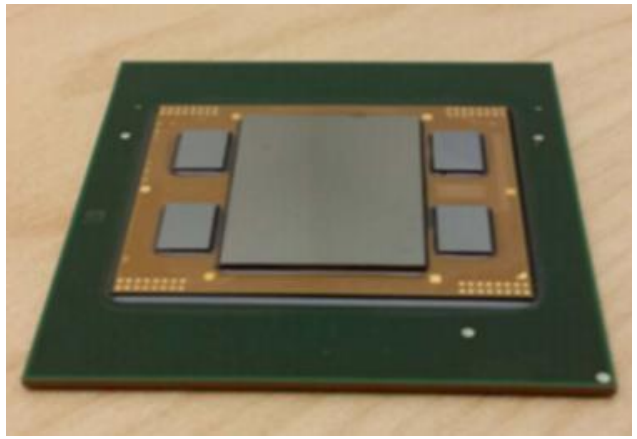


Infineon SJ MOSFET

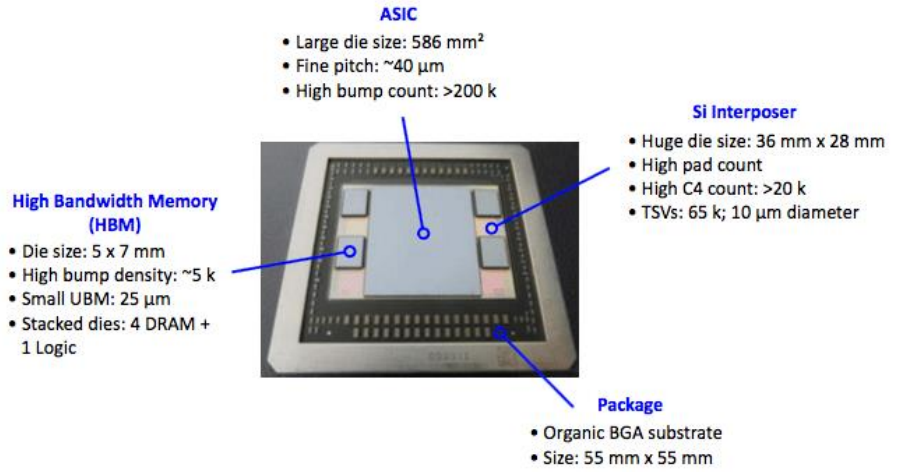
Source:
https://www.electronicdesign.com/power/are-you-kidding-harvest-power-rust
Teardown: Techinsights

Backside Metal on 2.5D Packages

- Capabilities to do BSM at Package level with Tape and Film Frame Handling
- BKM's Developed for film stack stress optimization and adhesion performance
- Demonstrated Ti/NiV/Au film stacks on Packages with exposed Dies
- Capability for low temperature control of Package



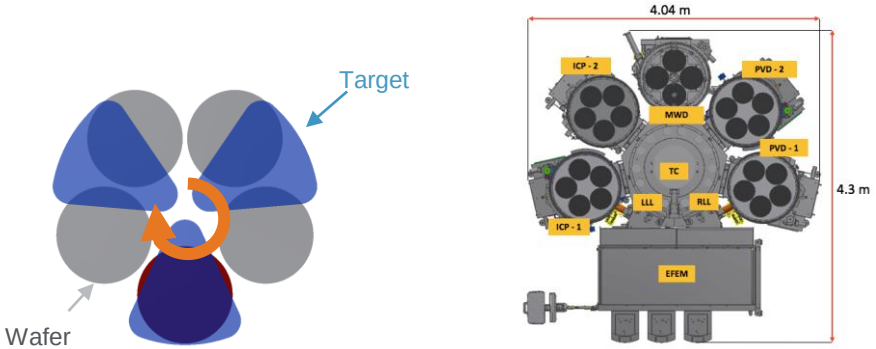
Source : Li, Li, et al "3D SiP with Organic Interposer for ASIC and Memory Integration," Proc 66th Electronic Components and Technology Conf, Las Vegas, NV, June 2016, pp. 1445-1450.



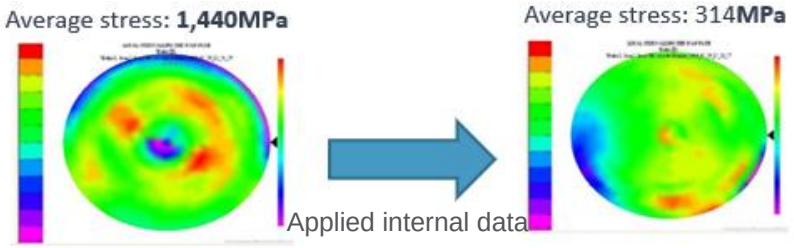
Source: Tech research international : AMD Fiji Chip

Axcela™ for BSM

- Lower cost batch process to enable low COO requirement
  - Multi film Dep in same chamber
  - Multiple material capability: Al, Ti, Ni/NiV, Au/Ag
- Flexible Architecture
  - Taiko / Glass Bonded / Tape ring Handling solutions
- Wafer handling solutions
  - Wafer flipping in FI
  - No Bevel/backside deposition
  - No Front side Contact
- Low thermal Budget <120C
- Stress engineering & control to meet application needs



Multi Wafer Multi Batch Architecture



Stress Engineered Films

Source: Applied Materials Internal

Applied Materials

Your Partner For Technology Advancement | Packaging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MATERIALS®
make possible