Heterogeneous Integration Roadmap

Supply Chain Technical Working Group Update

6th Annual HIR Workshop

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HIR Supply Chain (SC) Technical Work Group

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Outline

- Supply Chain TWG – Background & Objectives
- Supply Chain – Global Spotlight & HIR TWG
- Overview of Supply Chain Chapter – 2022 Edition
- Future Supply Chain Directions

BRINGING THE SUPPLY CHAIN TOGETHER THROUGH KEY SEMI INITIATIVES

A.I.

ML →Machine Learning

Blockchain

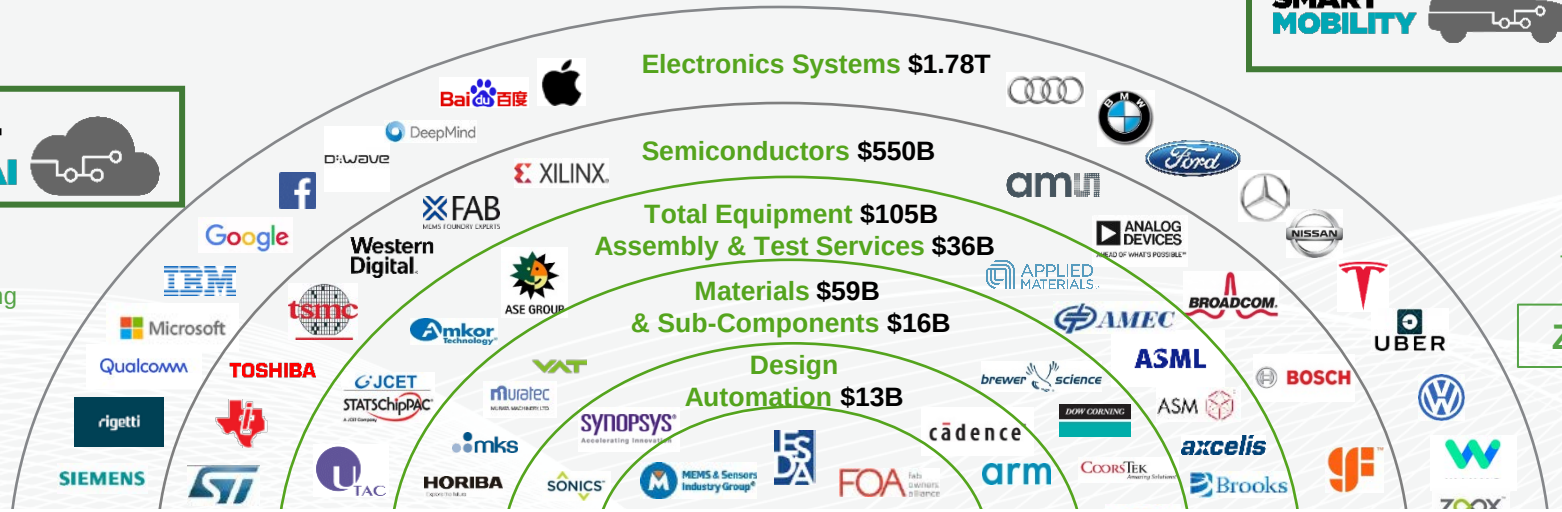
SMART DATA-AI

Quantum Computing

Digital Economy

Bitcoin Mining

5G to 6G



SMART MOBILITY

Autonomous Vehicles

Smart City

Fleet

Driver Assistance

Trucking

Electric Vehicles

Zero Emissions

Near-zero fatalities

SEMI...Your Gateway to the $2.8T+ Electronics Supply Chain

Realtime Configuration

Adaptive Manufacturing

Robots

Smart Infrastructure

3D Printing

SMART MANUFACTURING

Industry 4.0 on Fast Track
Industry 5.0

Wearables

Fitness Tracking

AR/VR

SMART MEDTECH

Dosage Monitoring

Digital Health

Human Performance Monitoring

Biometrics

CRISPR

Health Span to Life Span

Supply Chain Expected to Grow to $4T+ by 2030

2021 Market Data Estimates Sources: SEMI, IC Insights and VLSIresearch

Large Enterprises Globally Integrated & Connected Landscape*

Multi-enterprise collaboration – integrated with upstream and down stream suppliers.

Predictive Intelligence enabling supply chain awareness

Horizontally integrated Process (procure, manufacture, fulfill)

Cost and process Optimization

DDSN (demand driven supply network)

Focused risk management

Enterprises Globally Integrated & Connected (IOT)

Flexible and Agile

Strategic Outsourcing

Supply Chain Transformation through the Years

HETEROGENEOUS ROADMAP

Silo'ed Structure 1990's

- Unit / geographic structure with product Mfg. in each silo
- Fragmented and Inconsistent Processes
- Disparate and incompatible software tools both inside and outside the silo's
- Very Tactical
- Geographic owner of Procurement & Cash Collection

Horizontally Integrated ~2000 to 2010

- Multi-enterprise collaboration
- Horizontally integrated Process (procure, manufacture, fulfill)
- Worldwide Organization for Procurement and Mfg.
- Demand Driven Supply Network (DDSN)
- Deploying Common processes, common tools, metrics and governance
- Striving for consistent data collection and analysis internally and externally with suppliers

Globally Integrated & Connected (IOT) 2010 on

- Integrated wherever possible with upstream suppliers and downstream customers (retailers, 3rd Part, Wholesalers, direct end customers)
- Multi-enterprise collaboration
- Internet leads to more B2B (business to business) and B2C (business to consumer)
- DSDN means becoming more agile
- Predictive Intelligence enabling supply chain awareness
- Business Optimization Continues
- Risk Management a Focus

Supply Chain Transformation Continues

HETEROGENEOUS INTEGRATION ROADMAP

Collaboration People and Robots???

Smart Factory

Smart Manufacturing

Globally Integrated & Connected (IOT) -Today

Applications Driving Growth of Market Share of Semiconductor Packaging

Artificial Intelligence / Machine Learning [2]

- Automation in Manufacturing
- Use to guide robotics in pick-and-place
- Part of production monitoring
- Develop algorithms for more qualitative analysis
- Requires lots of data

Industrial IOT [3]

- Digitalization and automation of manufacturing/production
- Collect, understand and use massive amounts of data
- Combination of real and the digital world

High Performance Computing [5]

- Can involve superconductors
- Healthcare
- Enables digitization of complex processes
- Digital twins – physical object is represented by its digital twin
- Cloud computing

5G Communications [4]

- Deliver unified, low latency multi Gbps network to end users
- High-density connectivity
- Better coverage for IOT

Mobile Technology [6]

- Major driver for electronics innovation
- Represents large portions of electronic packages
- Used by about 70 to 80% global population

Automotive [7]

- Computers on wheels
- Require zero-defect chips
- Process complex calculations real-time
- 5G and autonomous driving

Unprecedented Growth of Application Spaces -- Innovation Thriving Today Enabling Future Semiconductor Requirements

- Addressing supply chain dynamics. Electronics have shifted from monolithic systems to sense/compute where supply chain dynamics are more complex
- Awareness and guidance for the industry and for different technical paths
- Specific focus on processes from RDL and bump to final inspection for different package architectures
- Not limited to integration of silicon-based devices but is inclusive of other device types including compound semiconductor or other

These Markets & Applications will be further transformed through the power of AI!!

Integration Components
Single Chip and Multi Chip Integration (includes substrates)
Photonics
Power Electronics
MEMs and Sensors
5G Communications & Beyond
Other Consumer Electronics

Package Architectures
Substrate-based • Wirebond • BGA
Multi-chip • 2.5D • 3D • SiP
WLP • Fan-out • Fan-in
Chiplets
Panel / Embedded Dies

Applications
Autonomous Vehicles 
Data to Cloud Data Center 
Smart Mobile Everywhere 
Medical Health and Wearables 
IOT to IOE 
Aerospace & Defense 

supply chain
cross cutting all towers

SEMI CONNECTS THE GLOBAL ELECTRONICS DESIGN AND MANUFACTURING SUPPLY CHAIN

CONVERGENCE AND NEW DISRUPTIONS ARE ENABLING TRANSFORMATION OF MANY NEW COMPANIES TO DIGITAL ERA

SEMI Technology Communities

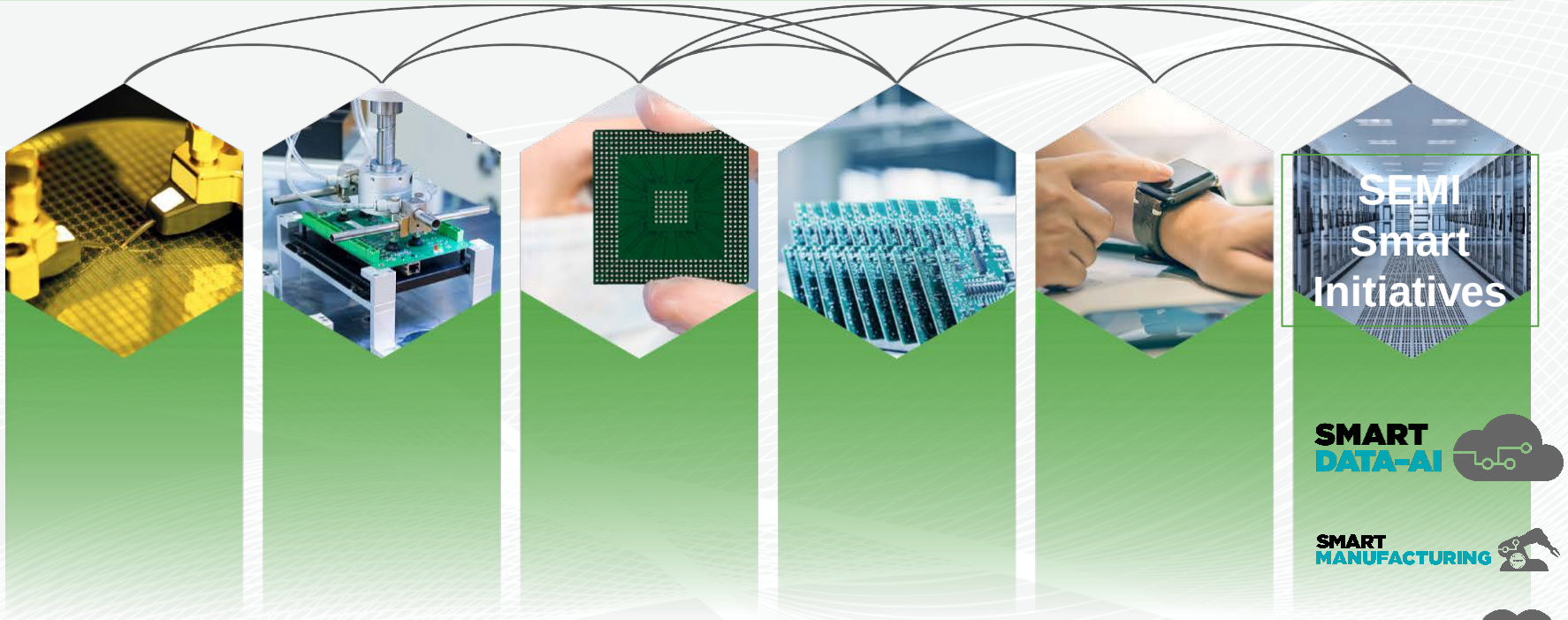
Electronic System Design Alliance

FOA fab owners alliance

FlexTech

MEMS & SENSORS INDUSTRY GROUP®

SOI industry consortium



Substrates
Materials
Components
Subassemblies

Equipment

IP
Design
Fabless

Device
Manufacturing
Packaging Test

System Integration

Applications

SMART DATA-AI

SMART MANUFACTURING

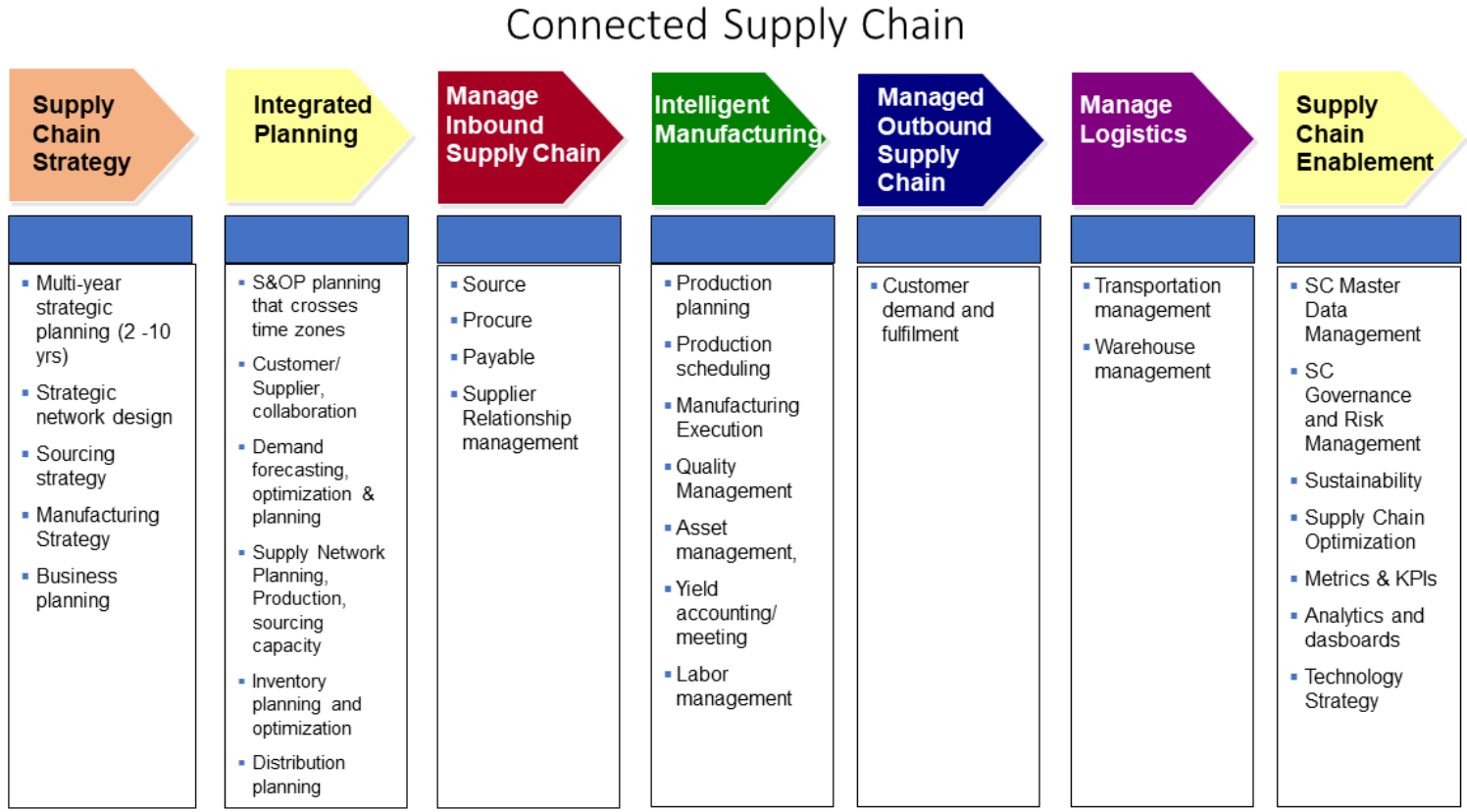
SMART MEDTECH

SMART MOBILITY

Smart E2E Supply Chain Management, Control and Risk Mitigation

HETEROGENEOUS INTEGRATION ROADMAP

"Smart Supply Chain" – Importance of SC Control Tower



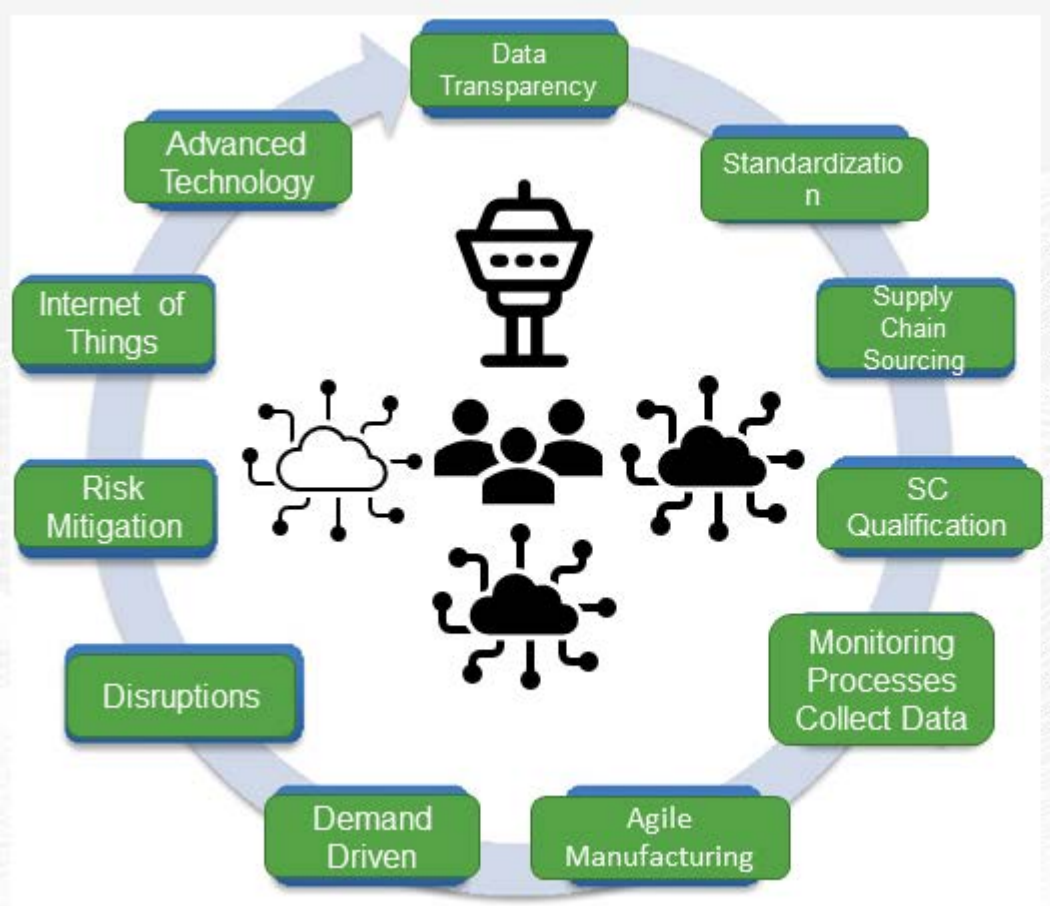
Supply Chain Management – Component Business Model

Szakal, A. and K. Pearsall. "Open industry standards for mitigating risks to global supply chains", *IBM Journal of Research and Development* 58(1):11-113

Business Control Management via SC Tower

- ✓ SC control tower defined as a connected, personalized look at the ecosystem for a given product
- ✓ Personalized dashboard of data, key business metrics and events across the supply chain
- ✓ A SC control tower enables organizations to more fully understand, prioritize and resolve critical issues in real time

SC Control Towers are moving towards SC Cognitive Decision Towers. Per KPMG "the effectiveness of a SC ultimately comes down to … efficient processes and effective decision making. This is a cross functional view of the entire SC Ecosystem." [8]



*This is a typical component and electronic packaging Supply Chain (SC) Ecosystem, but not all inclusive (such as distribution, customer, etc.

Mapping the Supply Chain

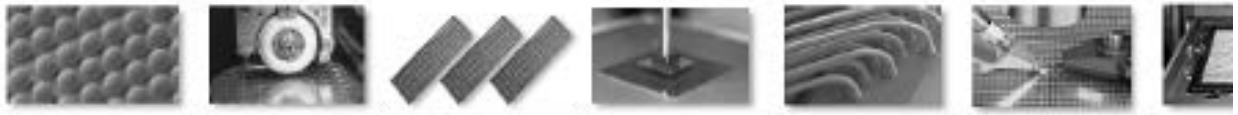
HETEROGENEOUS INTEGRATION ROADMAP

Close look at equipment & materials per type per process

Supply Chain Map for Complete Packages

These are finished packages and the next step will be SMT assembly

Key: Red = Materials
Blue = Equipment



Package Type	RDL and Bump	Wafer Singulate	Carrier Systems	Die or Flip Chip Attach	Wire Bond	In-Line Metrology	Und Ove
Wirebond Leadframe	n/a	Carrier Tape Wafer Saw	Leadframe	Solder Chemicals Mounter or TCB	Au or Cu Wire Wire Bonder	Optical Inspect'n	Resin Dispen
Wirebond Substrate	n/a	Carrier Tape Wafer Saw	Leadframe	Solder Chemicals Mounter or TCB	Au or Cu Wire Wire Bonder	Optical Inspect'n	Resin Dispen
Flip Chip Substrate	Litho & Plate Litho, Plate, Insp	Carrier Tape Wafer Saw	Substrate	Solder Chemicals Mounter or TCB	n/a	X-ray Inspect'n	Resin Dispen
2.5D Substrate	Litho & Plate Litho, Plate, Insp	Carrier Tape Wafer Saw	Substrate & Interposer	Solder Chemicals Mounter or TCB	n/a	X-ray Inspect'n	Resin Dispen

Summary

- Succinctly distilled a strategic path forward for this new TWG
- Included inputs from the automotive, aerospace, power, high performance computing and other teams
- Considered the packaging advancements such as TSV, HBM, chiplets, etc.
- Look forward to cross-collaboration with other TWGs and, indeed, the industry-at-large
  - Consider combining supply chain control towers beginning with die, chip, package, PCB, and other assemblies
- Future direction for the SC Chapter is to broaden it to include Smart Manufacturing and the Smart Factory. “This enables all information about manufacturing process to be available when and where it is needed across entire manufacturing supply chains and component product lifecycles.”

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[4] “ What will 5G bring to end-users?”, URL What will 5G bring to end-users? | MediaTek (en) , Feb 16, 2017

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[7] Ann Steffora. “Data Centers On Wheels”, Systems and Design. URL Data Centers On Wheels (semiengineering.com) , June 28, 2021

[8] Mark Levy, Chris Foster, and Kirk Hull. “Cognitive decision centers”. KPMG, November 2019.

[9] K.J Pearsall and A. Szakal. “Open industry standards for mitigating risks to global supply chains”, IBM Journal of Research and Development, Vol. 58, No.1, January/February 2014.

•[10] Kitty Pearsall, B.J. Steele, and Paul Zulpa. “A Smarter Supply Chain – End to End Quality Management”, 18th European Microelectronics and Packaging Conference, September 2011.

Backup

Electronic Packaging Supply Chain Landscape Today

The supply chain for electronic packaging has also changed [1]

- “Global supply chain market size value is $15.85 billion (2019).”
- Global supply chain market is expected to experience a CAGR of 11.2% from 2020 to 2027. This results in an increase to $37.41 billion in 2027.” (ResearchAndMarkets 2021)
- 62% of companies have limited visibility of their supply chain and 15% only have visibility on production. Six % report full visibility, and only 17% say they have extended supply chain visibility. Supply chain visibility is among the top strategic priorities of companies worldwide. (Zippia)
- “Only 22% of companies have a proactive supply chain. (Logistics Bureau, 2020)”
- 43% of small businesses don’t track their inventory. “67.4% of supply chain managers use Excel spreadsheets as a management tool.”
- “21% report that they don’t have inventory.”
- “38.8% of US small businesses experienced supply chain delays due to Covid.”

Evolving OSAT Landscape Brings Challenges

1. **Global Advanced IC Packaging Market size was estimated at USD 35.11 billion in 2020, It is projected to grow at a CAGR of 8.22% to reach USD 61.1 billion by 2027. [13]**
2. Rising demands for chip packages and multiple package types from OSATs leading to shortages in manufacturing capacity and limited package type from a given supplier anticipated
3. Growing need for low-cost packaging alternatives
4. Number of OSATs decreasing as OSATs consolidate, merge or invest more dollars in other OSATs
5. OSATs need to introduce advanced package offerings to maintain competitive edge
6. Foundries and Non-traditional foundries required to meet demand, offer turn-key advance packages (competing with OSATs)

Global OSAT Market Segment Overview

- OSAT market revenue is valued at 37.95 B$ in 2021, and is projected to reach $60.19 B$ by 2027 (Modor Intelligence) [10]
- ASE is the top ranked revenue contributor to the OSAT market and posted 1.86 B$ in 2021 revenue with a 35% YoY growth (Trendsource)
- North America was the highest revenue contributor at 13.87 B$ or a little over 40% of the market share (Allied Market Research) in 2020
- Top 8 OSAT's revenue reached 7.37 B$ in 2021 [11]

Ranking *	OSAT	2019 M$	2020 M$	2021 M$	2019/2020 YOY	2020/2021 YoY
1	ASE	1160	1379	1863	18.9	35.1
2	Amkor	895	1173	1407	31.1	20
3	JCET	679	879	1099	29.5	25
4	SPIL	678	910	931	34.2	2.3
5	PTI	479	649	742	35.5	14.3
6	TFME	283	351	591	24	68.4
7	TSHT	312	284	467	9.7	64.4
8	KYEC	193	256	274	32.6	7
TOTAL M$		4679	5881	7374		

Global Foundry Market Segment Overview

"The global semiconductor foundry market reached a value of 72.8 B$ in 2021." [12]

- Even with chip shortages and foundry capacity shortages, the top 10 foundries delivered 2Q 2021 revenue of 24.4 B$ with a YoY of 29%.
- TSMC is the number 1 ranked foundry. In 2Q 2021 it posted 13.3 B$ revenue and a 31.6 % YoY growth. This accounted for greater than 50% of the market
- Some foundries (TSMC, GlobalFoundries, UMC and Samsung) are directly competing with the OSATs
- Foundries have deep pockets, own IP, offer a variety of packages including strategic advance package types
- Foundry infrastructure enables OSAT sharing and collaboration as well as a competitor
- 1Q22 foundry output value up 8.2% QoQ, says TrendForce

Ranking	Foundry	2Q 2019 M$	2Q 2020 M$	2Q 2021 M$	2019/2020 % Growth	2020/2021 % Growth
1	TSMC	7,750	10,105	13,300	30.4	31.6
2	Samsung	3,180	3,678	4,334	15.7	17.8
3	Global Foundry	1,358	1,452	1,522	6.9	4.8
4	UMC	1,162	1,440	1,819	24.0	6.3
5	SMIC	791	941	1,344	19.0	42.8
6	Power Jazz	306	310	362	1.3	16.8
7	Power Chip	174	298	459	59.8	65.1
8	VIS	223	265	363	18.8	37.0
9	Hua Hong Semi	230	220	658		2.0
10	Dongbu HiTek	185	193	245	4.3	26.9
	Top 10 Total	15,359	18,902	24,406		29.1

Supply Chain Disruptions

HETEROGENEOUS INTEGRATION ROADMAP

Supply Chain Constraints
Raw Material Shortages *(e.g., ABF)*
Political/Personnel Unrest Disruptions (strikes, geo-political) and pandemics: *(e.g., U.S.-China Trade War; Japan-Korea Trade War [materials], Ukrainian unrest)*
Regulatory and EHS *(e.g., Waste management issues)*
Industry Standard Parts Disruption *(e.g., Dual+ sourcing, proximity)*
Natural Disasters *(e.g., Earthquakes, flooding, disease outbreak)*

Supply Chain Development
Equipment Capabilities
Materials Design

Environmental
Transactional / Business Models
Innovation Pipeline

https://www2.deloitte.com/us/en/blog/health-care-blog/2021/semiconductor-chip-shortage-hits-medtech-strategies-to-build-resilient-supply-chains.html

IEEE IEEE photonics Society semi IEEE ELECTRONICS PACKAGING SOCIETY ASME ELECTRON DEVICES SOCIETY

Questions?

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