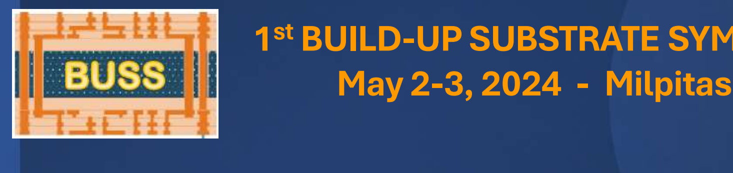
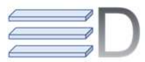


US Landscape for Substrate Manufacturing

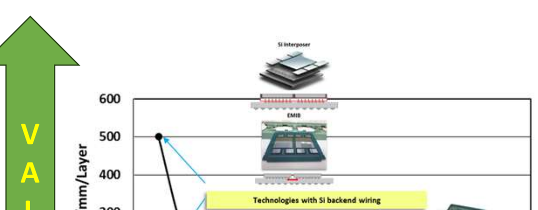
Venky Sundaram

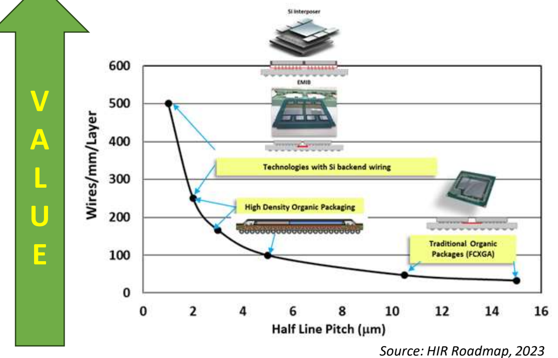
Founder & President, 3D System Scaling LLC

May 3, 2024



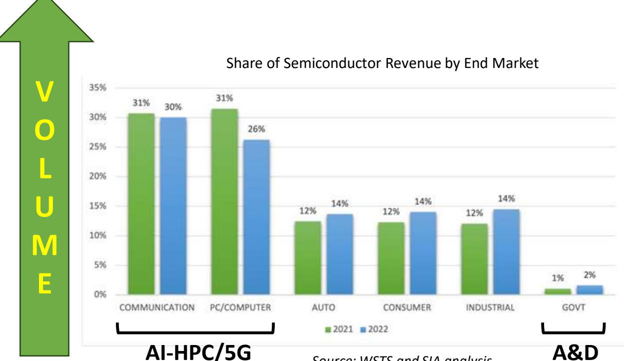
Package Substrate Scaling & Market Segmentation



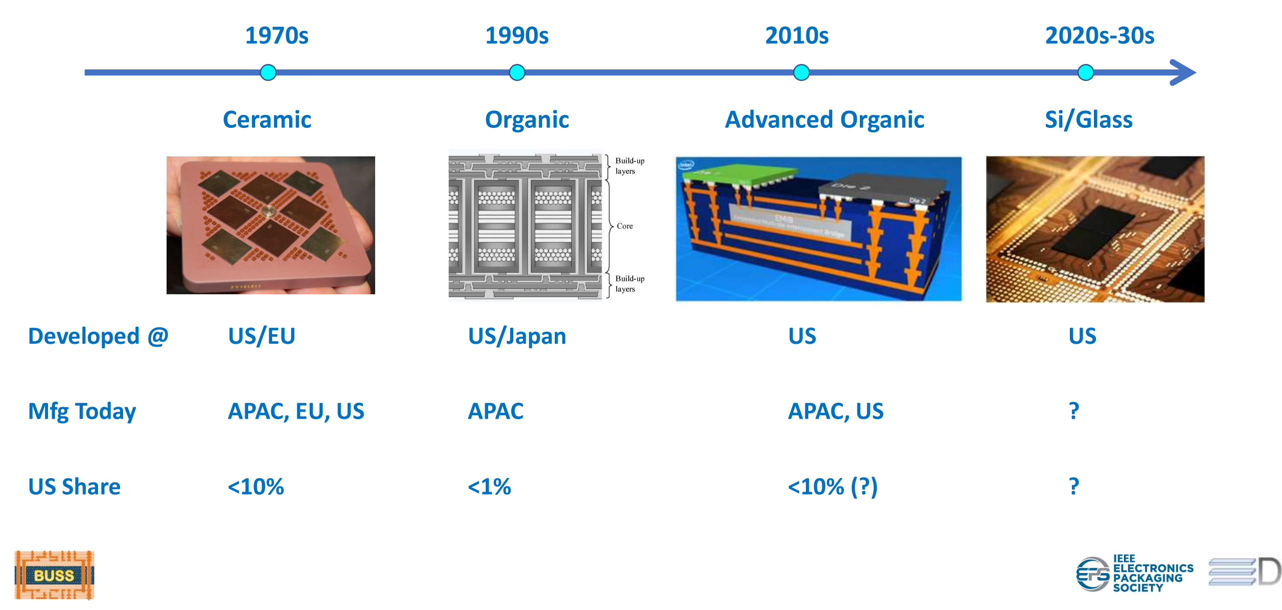


Source: HIR Roadmap, 2023

Granularity in Market Segmentation is Important



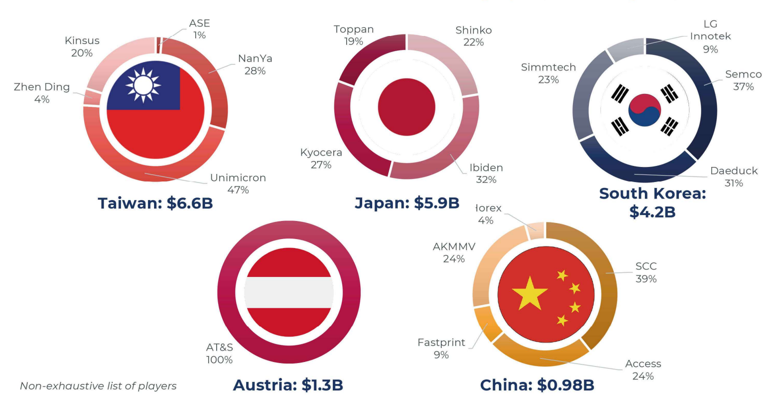
Source: WSTS and SIA analysis

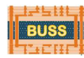


Non-US Landscape for Substrate Manufacturing

ADVANCED IC SUBSTRATE INDUSTRY – 2022 MARKET SHARES BY LOCATION

Source: Status of the Advanced IC Substrate Industry report, Yole Intelligence, 2023

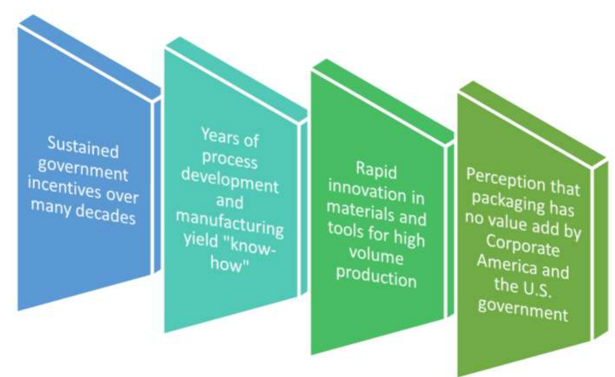




www.yolegroup.com | ©Yole Intelligence 2023

Where did Substrate Manufacturing Go and Why?

- Off-shore manufacturing (Japan, Taiwan, Korea, China) dominates the space driving supply chain resiliency concerns
- Migration happened when pitches were coarse and substrate sizes were smaller – **emphasis on cost rather than value**
- Substrates Today - Designed in the US (mostly!), manufactured in Asia - high value-add portions remain in the US (system architecture, EDA)
- Low cost of production offshore is not solely due to low labor costs - decades of knowhow and yield learning
- Customers trust Suppliers, not their Countries



Source: NIST Funded MRHIEP Report
Courtesy: Vineeth Harish, GoMacTech 2024

Are Chip-Package Co-Design and New Technology Inflections Opportunities to Re-shore Substrate Manufacturing?

Building Substrate Supply Chain Resilience

Extracted from the NIST Funded MRHIEP Report

- Building resilience in organic substrates and PCBs is challenging due to existing supply chains and manufacturing capacity offshore
- **Recommendation:** U.S. should leapfrog existing technologies and focus development and manufacturing investments into emerging system substrates

Technology	On Shore Capability		Offshore Sources	Global Status
	Captive (IDM/Foundry)	Non-Captive		
Organic Substrate	Specialty	Specialty	Taiwan, South Korea, Japan, China	**Asia**: HVM **US**: LVM
Glass Substrate	Pilot Production	Pilot Production	China, Taiwan, Japan, South Korea	**Asia:** In Development for IC Substrates **U.S:** In Development for IC Substrates
Silicon Interposer	In Production	Limited Production	Taiwan, South Korea, China	**Asia:** HVM in IDMs and OSATs **US:** HVM in IDMs
Silicon Substrate	-	-	-	**US and Asia:** R&D only

Simplified by: Vineeth Harish, GoMacTech 2024

A View from IPC (Courtesy: Matt Kelly)

> Issues

- No capability/capacity within US, 20yrs behind
- **High switching costs, low margins**, weak domestic demand signals, how to achieve sustainable business model?

> Groups

1 – US-based PCB fabricators

- Working to advance into substrate production
- TTM, Sanmina, Calumet, Green Source, start-ups
- There are no US-based substrate producers

2 – Int-based substrate fabricators

- Market leaders not racing to US to establish new production
- Unimicron, Ibiden, SEMCO, Nan Ya, Shinko, Kyocera, AT&S
- With leadership positions, limited interest in collaborating

> Technology Requirements

State of Practice (SOP) – catch-up (9/12LS, 65mm, 8-20 layers)

- ABF + alt build-up films, cores, yields, processes, qualification
- **Market leaders deployed BUT US-fabricator learning curve**

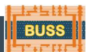
State of Art (SOA) – NextGen (5/5>2/2LS, 100mm+, >20 layers)

- Wafer-based processes, embedded actives/passives, thermals
- **New materials, designs, equipment, processes, qualification, reliability – glass, RDL, wafer-based substrates, SiC, etc**

> Needs

- IC-substrate technology priorities and roadmap
- Catch up (SOP) – standards and WFD/education for SAP, mSAP
- **R&D (SOA) – new workgroups w/ new learning (IP vs stds)**
  - > Standards – R&D first, new knowledge > IP protection + standardization
  - > Skills / Workforce – very little know-how in US

BUILD ELECTRONICS **BETTER**



Voice of Supply Chain (Overseas Materials, Equipment, Substrates)

Extracted from the NIST Funded MRHIEP Report

- **Substrate Manufacturing**
  - Investing in current production capacity expansion will put downward pressure on pricing and not incentivize onshoring
  - Skill gaps in a trained manufacturing workforce is a significant barrier, needs focused and sustained investment
  - Incentivizing global manufacturers to initiate or expand footprint in the US
- **Materials & Chemicals Supply Chain**
  - Lack of onshore demand from immediate customers (substrate makers) is a major investment barrier
  - Develop cost-competitive and leading-edge raw material supply chain in US to motivate material suppliers
  - Expand scientific centers of excellence to support future roadmaps
  - Integral involvement of US end users
- **Equipment Supply Chain**
  - Existing capacity in overseas manufacturing and demo centers is a barrier to US expansion
- **Innovation Hubs**
  - Keys for customer collaboration and development, precede manufacturing investments at same geographies
  - Significant overseas supply chain with innovation hubs at home HQs

Opportunities to Increase Onshore Substrate Manufacturing

Extracted from the NIST Funded MRHIEP Report

Onshoring Approaches

1. Incentivize overseas suppliers to expand capacity in the US (preferred by commercial customers)
2. Enable existing US suppliers to upgrade capabilities (e.g. PCB to Package Substrate)
3. Incentivize new startup businesses onshore - requires new technology adoption

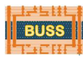
Additional Onshoring Focus

1. Supply chain (materials/chemistry/equipment) onshoring strategies
2. Innovation hubs for US and overseas suppliers, substrate manufacturers and end users

Simplified HPC Manufacturing Roadmap Targets

Extracted from the NIST Funded MRHIEP Report

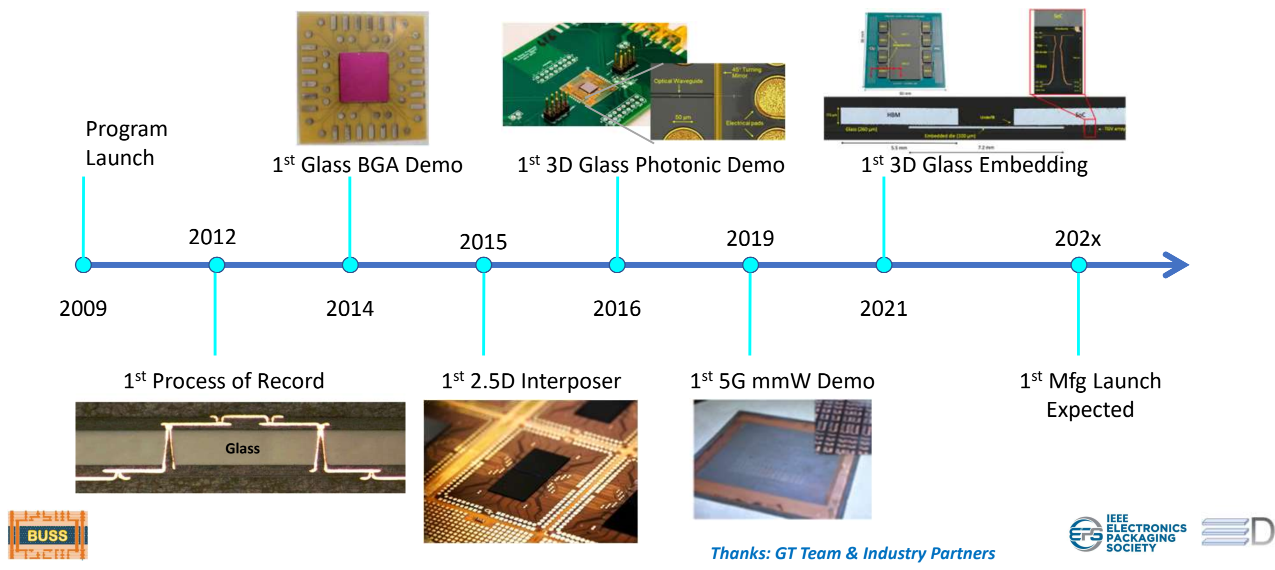
Parameter	Unit	2025	2027	2029
Silicon Node	nm	3nm	2nm	1nm
I/O Bandwidth (Logic-HBM)	Gbps	1024 x 2.4	2048 x 3.6	4096 x 6.4
I/O per mm per layer (shoreline)	#	250	500	1000
I/O lines and spaces (and vias)	micron	2/2/2	1/1/1	0.5/0.5/0.5
Package to Board I/O BW	Gbps	64 per I/O	112 per I/O	256 per I/O
Package to Board Pin Count	#	9600	11200	12800
Power Density	W/mm^2	1	1.05	1.1
Package Dimension (Minimum)	mm	95	103	120



Next Generation Needs Create Opportunities for New Manufacturing Sites
Pitch Scaling, Form Factor, Power Efficiency, Thermals, Cycle Time Reduction

Glass Substrates - An Opportunity to Increase US Share of Mfg?

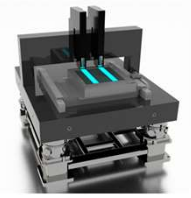
R&D Investments in Georgia Tech Consortium exceed $100M; Multiple Companies Investing in Manufacturing



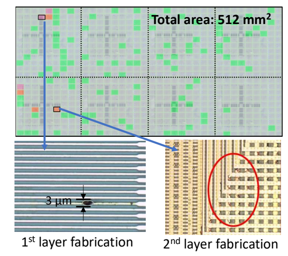
Thanks: GT Team & Industry Partners

Materials & Equipment Supply Chain as Leverage

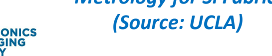
- Identify Key Gaps in Future Roadmap needs for Advanced Substrates
  - Panel Lithography Tools & Scaling
  - Metrology, Inspection & Electrical Test
  - Planarization
- Incentivize US Supply Chain Expansion in Critical Materials & Equipment
- Leverage US superiority in AI and ML - e.g. AI based defect detection and yield management
- Combination of US based Design, US based Supply Chain & Innovation Ecosystem - likely to provide time-to-market competitive advantage for US advanced substrate manufacturing



Digital Lithography (Source: Applied Materials Inc.)



Metrology for Si Fabric (Source: UCLA)



Summary

- Current substrate manufacturing landscape heavily biased towards offshore
- US should focus on what the US is good at
  - Continuous Innovation
  - Customer value creation
  - AI enabled advanced manufacturing
- System architecture and design customer proximity is a major US competitive advantage
- Time-to-market is a major customer cost factor - can the US take advantage?
- Expand materials and equipment supply chain capability as a lever
- University/Innovation Ecosystem and attracting global talent are US Core Competencies

Download NIST MRHIEP Final Report: *https://drive.google.com/file/d/1L4UihJf0lqvTzzLk8xaQwhpFIYnMBzV_/view*