PRESENTATION OUTLINE
Technology & Market Trends for Advanced Packaging

• About Yole Intelligence

• Advanced Packaging: Technology Trends & Drivers

• Advanced Packaging: Supply Chain

• Advanced Packaging: Market Trends

• Conclusions
Advanced Packaging: Technology Trends & Drivers
TECHNOLOGY ROADMAP: FROM NANO-SCALE TO MICRO SCALE

<table>
<thead>
<tr>
<th>Year</th>
<th>Advanced Nodes</th>
<th>Advanced Packaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>2015</td>
<td>22nm</td>
<td>16/14nm</td>
</tr>
<tr>
<td>2017</td>
<td>14nm</td>
<td>10nm</td>
</tr>
<tr>
<td>2019</td>
<td>10nm</td>
<td>7nm</td>
</tr>
<tr>
<td>2021</td>
<td>7nm</td>
<td>5nm</td>
</tr>
<tr>
<td>2023</td>
<td>5nm</td>
<td>3nm</td>
</tr>
<tr>
<td>2025</td>
<td>3nm</td>
<td>2nm</td>
</tr>
<tr>
<td>2027</td>
<td>2nm</td>
<td>1.5nm</td>
</tr>
</tbody>
</table>

Assumed Moore's Law

- 16/14nm
- 10nm
- 7nm
- 5nm
- 3nm
- 2nm
- 1.5nm

Stacked Die µBump Pitch (µm)

- 95 to 48 µm
- 44 to 20 µm
- 20 to 10 µm (w/ hybrid bonding < 10 µm)

Die to Substrate FC Bump Pitch (µm)

- 200 to 150 µm
- 80 to 40 µm
- 50 to 30 µm

Substrate to Board BGA Ball Pitch (µm)

- 400/350 µm
- 300 µm

Industry is looking into the growing importance of functional roadmap

Advanced Packaging is essential to bridge the scale-gap between die and PCB

Average trends based on technology and industry expectation

*Minimum dimension

NEW TRENDS & DRIVERS: OPPORTUNITY FOR ADVANCED PACKAGING

System requirement
- More computing power
- More bandwidth
- Lower latency
- Lower power consumption
- More functionality
- System integration
- More memory
- Lower cost
- Lower form-factor

Opportunity for various devices
- CPUs, GPUs, SoCs, APUs, FPGAs
- ASICs, DSPs, MCUs
- MEMS/Sensors
- Power ICs/discretes
- Memory
- Optoelectronics

Opportunity for advanced packaging
- CIS, 3D SoC, Embedded silicon bridge, Active/Passive silicon interposers, 3DS, HBM, 3D NAND

Main applications (non-exhaustive)
- Fan-Out Packaging: RF, PMIC, Audio, Connectivity, APU, (x)PU, ASIC, FPGA
- WLCSP Fan-In Packaging: RF, PMIC, Audio, Connectivity, Driver IC, DC/DC converter
- System-in-Package (SiP): AiP/mmW FEM, FEM, PA module, Wi-Fi/BT module
- FCBGA Packaging: (x)PU, networking ASIC, FPGA, automotive & infotainment modules
- FCCSP Packaging: APU, RF, Baseband, PMIC, memory
- 2.5D/3D Stacked Packaging: (x)PU, ASIC, FPGA, 3D NAND, HBM, CIS
SEMICONDUCTOR PACKAGING ROADMAP

Combined Timeline of 3D Interconnect Density & Technology Node

3D Interconnect Density Data adopted from TSMC

Technology Node here refers to front-end node and is based on the expected average value within the industry.

3D ID = (No. of lines per mm) * (No. of vertical interconnects per mm²)

Timeline


0.003µm 0.007µm 0.028µm 0.090µm 1.0µm 3.0µm 10.0µm
CHIPLET AND HETEROGENEOUS INTEGRATION ADOPTION

01 Partitioned die
  ➢ more dies per wafer

02 Higher yield
  ➢ Optimized cost

03 Finer bump or pad pitch
  ➢ Higher density

04 Optimization node per chiplet

05 Faster time-to-market
2021-2022 CAPEX HIGHLIGHTS FOR PACKAGING PLAYERS

Estimated 2022 CapEx spending by top players [$M]

- **Intel**: 28%
- **TSMC**: 25%
- **Samsung**: 14%
- **ASE**: 12%
- **Amkor**: 6%
- **JCET**: 5%
- **PTI**: 4%
- **Tongfu**: 3%
- **Tianshui Huatian**: 3%

Packaging CapEx from top players was growing last 2 years

### 2021

- **$11.9B**

### 2022

- **$14.5B**

*IDM and foundry business models
Intel, Samsung, and TSMC are leaders in the high-end performance packaging market space and key innovators in the field. With 2.5D and 3D technologies, these big players are now offering their products and services in the market for high-end performance applications.
Advanced Packaging: Supply Chain
GLOBAL MAPPING OF THE ADVANCED PACKAGING SUPPLY CHAIN (HQ)

- Non-exhaustive list of players
- Equipment providers are missing
**FOCUS ON HIGH-END PACKAGING**

Mapping of players based on technology

- **Non-exhaustive List of Players**

  - **Si Interposer suppliers**
    - TSMC, Samsung, and Intel are the main players for the higher-end technologies, for which they strongly compete.

  - **Hybrid Bonding: Bump-less**
    - Development
    - TSMC, Samsung, and Intel are the main players for the higher-end technologies, for which they strongly compete.

  - **3D Stacked Memory: TSV, Micro-bumps**
    - In low to mid-end advanced packaging, OSATs are the main players involved.
Advanced Packaging: Market Trends
Advanced Packaging revenue is swiftly catching up to that of the traditional packaging market.

In 2021, Advanced Packaging accounted for 44% of the total packaging market. This will increase to ~53% in 2027 at about $65B.
ADVANCED PACKAGING MARKET DYNAMICS – UNITS

Advanced Packaging Shipment Volume (Munits)

CAGR 2021-2027 ~ 5%

SiP
FCCSP
FCBGA
2.5D/3D 13% CAGR
WLCSP
FO
ADVANCED PACKAGING MARKET DYNAMICS – REVENUE

Advanced Packaging Market Revenue ($M)

- SiP
- FCCSP
- FCBGA
- 2.5D/3D 18% CAGR
- WLCSP
- FO

CAGR 2021-2017 ~ 11%

Revenue ($B)

2021

2022

2023

2024

2025

2026

2027

CAGR

$0.0B

$10.0B

$20.0B

$30.0B

$40.0B

$50.0B

$60.0B

$70.0B

$34B

$62B

$0.0B

$70.0B

$60.0B

$50.0B

$40.0B

$30.0B

$20.0B

$10.0B

$0.0B

2021

2022

2023

2024

2025

2026

2027

CAGR
OSATs accounted for 65% of the AP wafers in 2021. Foundry is taking AP business from OSATs.
Conclusion
CONCLUSION

• Advanced Packaging has become the essential solution to compensate increasing front-end node costs and to sustain more than moore trend

• A key trend driving Advanced Packaging is the adoption of a chiplet approach to attain heterogeneous integration

• Advanced packaging demand is still increasing, and the market growth is mainly propelled by automotive, 5G and HPC related applications

• Advanced packaging is becoming more complex and is catching-up the traditional packaging from revenue point of view

• The Advanced Packaging market total revenue reached $34B in 2021 and is expected to record an 11% CAGR reaching $62B in 2027.
Thank you!

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FIELDS OF EXPERTISE COVERING THE SEMICONDUCTOR INDUSTRY

• Semiconductor Packaging
• Semiconductor Manufacturing
• Memory
• Computing and Software

• Photonics & Lighting
• Imaging
• Sensing & Actuating
• Display

• Radio Frequency
• Compound Semiconductors
• Power Electronics
• Batteries

• Electronic Systems
• Emerging Technologies
## A COMPLETE SET OF PRODUCTS & SERVICES TO ANSWER YOUR NEEDS

### REPORTS

**Insight**
- Yearly reports
- Market, technology and strategy analysis
- Supply chain changes analysis
- Reverse costing and reverse engineering

**Format**
- PDF files with analyses
- Excel files with graphics and data

**Topics**
- Photonics, Imaging & Sensing
- Lighting & Displays
- Power Electronics & Battery
- Compound Semiconductors
- Semiconductor Manufacturing and Packaging
- Computing & Memory

115+ reports per year

### MONITORS

**Insight**
- Quarterly updated market data and technology trends in units, value and wafer
- Direct access to the analyst

**Format**
- Excel files with data
- PDF files with analyses graphs and key facts
- Web access (to be available soon)

**Topics**
- Advanced Packaging
- Application Processor
- DRAM & NAND
- Compound Semiconductor
- CMOS Image Sensors
- Micro-controller
- Semiconductor Test Equipment

7 different monitors quarterly updated

### TRACKS

**Insight**
- Teardowns of phones, smart home, wearables and automotive modules and systems
- Bill-of-Materials
- Block diagrams

**Format**
- Web access
- PDF and Excel files
- High-resolution photos

**Topics**
- Consumer: Smartphones, smart home, wearables
- Automotive: Infotainment, ADAS, Telematics

205+ teardowns per year

### CUSTOM SERVICES

**Insight**
- Specific and dedicated projects
- Strategic, financial, technical, supply chain, market and other semiconductor-related fields
- Reverse costing and reverse engineering

**Format**
- PDF files with analyses
- Excel files with graphics and data

**Topics**
- Photonics, Imaging & Sensing
- Lighting & Displays
- Power Electronics & Battery
- Compound Semiconductors
- Computing & Memory

190 custom projects per year

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YOLE GROUP'S MAJOR ACTIVITIES PER ENTITY

- Market, technology, and strategy consulting
- M&A and evaluation of companies
- Direct access to the analysts
- Technology, process & cost analysis
- Teardown and reverse engineering
- Comparative analysis
- Characterization of electro-optical performances and risks
- Specification, design and industrialization of systems
A WORLDWIDE PRESENCE

180+ collaborators in 9 different countries
A WIDE RANGE OF INFORMATION SOURCES

Our unique position allows us to obtain detailed and accurate information to meet your needs.

- 5,000 players' interviews per year
- 120+ annual conferences
- 1250+ teardown tracks available
- 6,800+ companies’ news relayed
- 100+ analysts worldwide

20+ years in the semiconductor industry

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A UNIQUE AND PROVEN METHODOLOGY

MARKETING EXCELLENCE AND BEST-IN-CLASS NETWORK

• Market segmentation
  ➢ Per application
  ➢ Per technical needs
  ➢ Per technology adoption and supply chain’s tendencies

• Primary research and direct interviews with key players

“Thanks to its unique semiconductor market intimacy, its understanding of the industrial environment and its vision on future technologies adoption, Yole Group supports its customers at every stage of their growth”

BOTTOM-UP, TOP-DOWN AND INDUSTRIAL EXPERTISE

• Top-down
  ➢ End market demand analysis
  ➢ Market forecasts at system and component levels down to wafer and equipment

• Bottom-up
  ➢ Ecosystem analysis
  ➢ Consolidate industrial players’ revenue at component, module and system levels

• Industrial experts in all our fields of investigation

STATE-OF-THE-ART TECHNOLOGY AWARENESS

• Technology analysis
  ➢ Competitive landscape and technology comparison
  ➢ Reverse costing
  ➢ Reverse engineering

• Technology life cycle
  ➢ Development cycles
  ➢ Supply chain adoption
  ➢ HV manufacturing and evolutions

• Performance testing and analysis
OUR NETWORK IS THE ENTIRE SUPPLY CHAIN ACROSS 6 MARKETS

6 KEY MARKETS

Mobile & Consumer
Automotive & Mobility
Telecom & Infrastructure
Medical
Defense & Aerospace
Industrial

Academic/research
Design & engineering
Material & equipment
Front-end manufacturing
Back-end manufacturing
OEMs & system integrator
Consulting & finance
REPORTS, MONITORS & TRACKS

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