Packaging Materials Market Trends, Issues and Opportunities

Dan Tracy
Sr. Director Industry Research
SEMI
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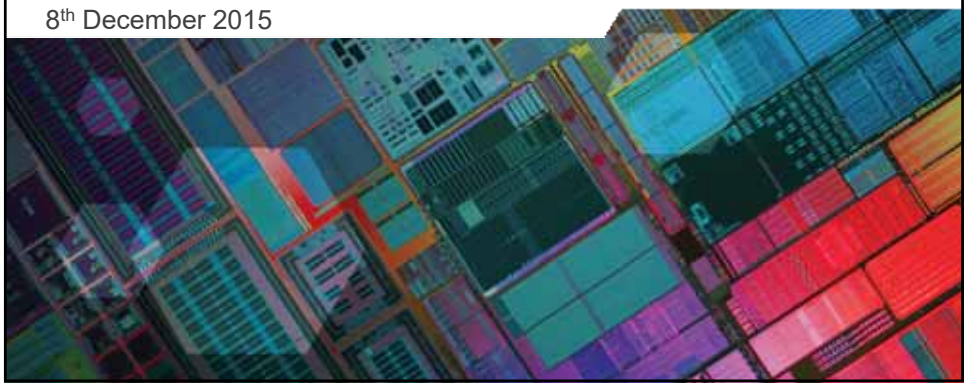
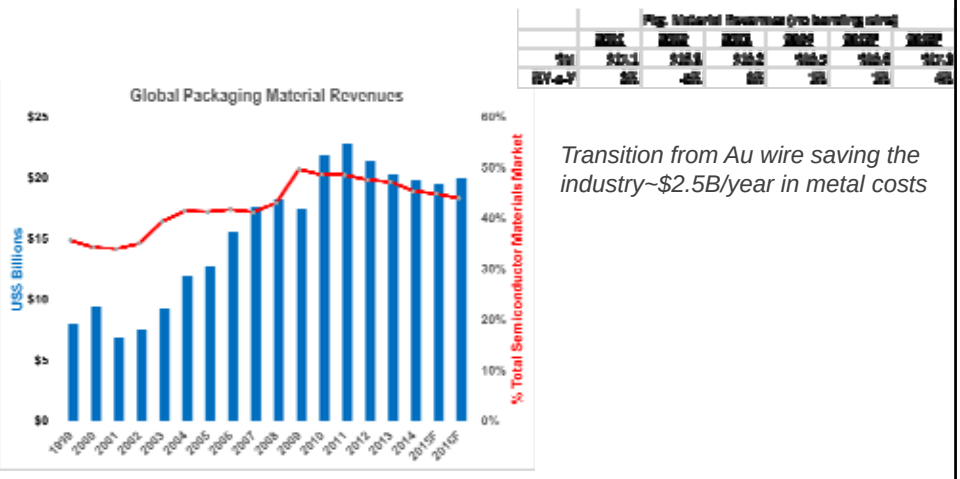


Outline

- Market Size
- Industry Trends
- Material Segment Trends
- China
- Summary

Packaging Materials-
~45% to 50% of the total material spend



Transition from Au wire saving the industry~$2.5B/year in metal costs

Source: SEMI November 2015

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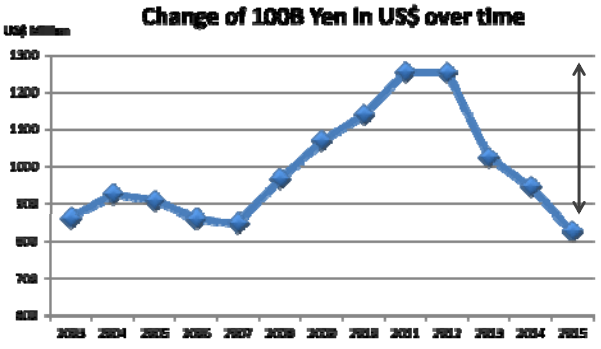
Economic Trends

- Weakening Currency, especially Yen & Euro, will dampen 2015 industry figures when report in US$.
- With no currency impact, the semiconductor equipment market would be up +5% to +6% in 2015 vs. 2014 instead of the -1% decline



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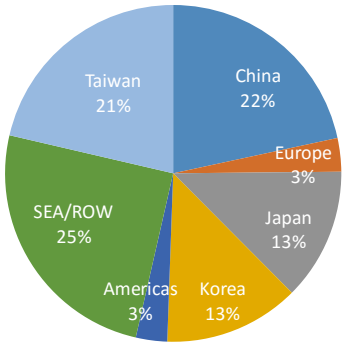
Regional Packaging Materials Markets



Region	2015F $US B	2016F $US B	% Change
China	$4.23	$4.41	4%
Europe	0.63	0.65	3%
Japan	2.48	2.48	0%
Korea	2.55	2.57	1%
Americas	0.59	0.59	0%
Taiwan	4.18	4.29	3%
SEA/ROW	4.90	5.01	2%
Total	**$19.6**	**$20.0**	**2%**

Totals may not add due to rounding

2015F = $19.6 billion

Source: SEMI November 2015

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Industry Trends

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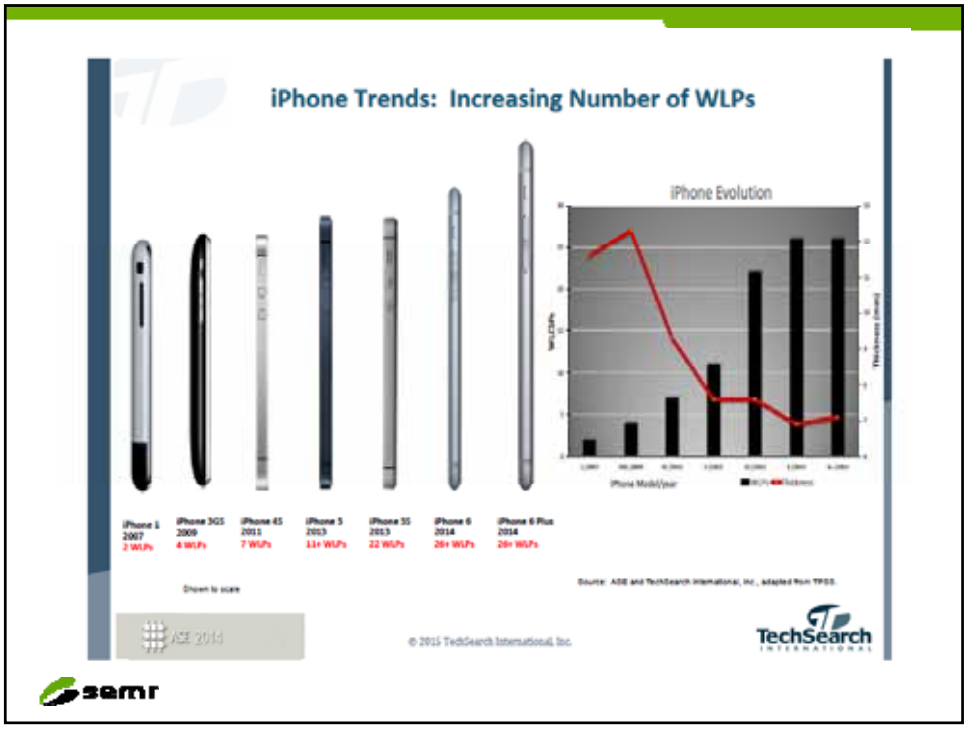
iPhone Trends: Increasing Number of WLPs
iPhone Evolution
iPhone 1
2007
2 WLPs
iPhone 3GS
2009
4 WLPs
iPhone 4S
2011
7 WLPs
iPhone 5
2013
11+ WLPs
iPhone 5S
2013
22 WLPs
iPhone 6
2014
20+ WLPs
iPhone 6 Plus
2014
20+ WLPs
Shown to scale
ASE 2014
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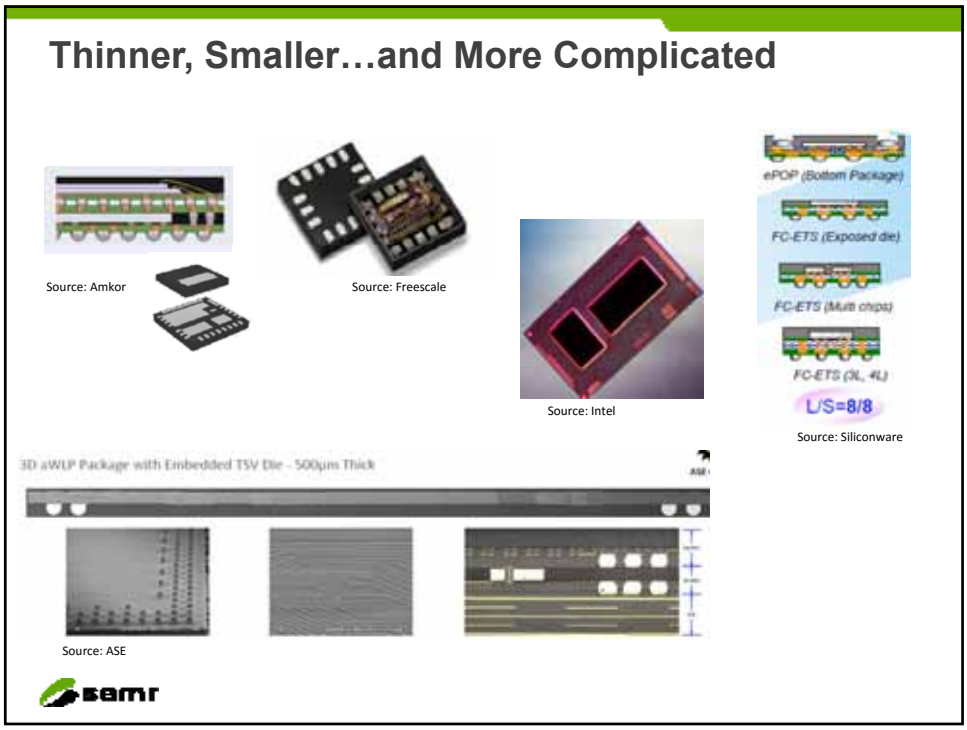
Thinner, Smaller…and More Complicated
Source: Amkor
Source: Freescale
Source: Intel
ePOP (Bottom Package)
FC-ETS (Exposed die)
FC-ETS (Multi chips)
FC-ETS (3L, 4L)
L/S=8/8
Source: Siliconware
3D aWLP Package with Embedded TSV Die - 500µm Thick
Source: ASE
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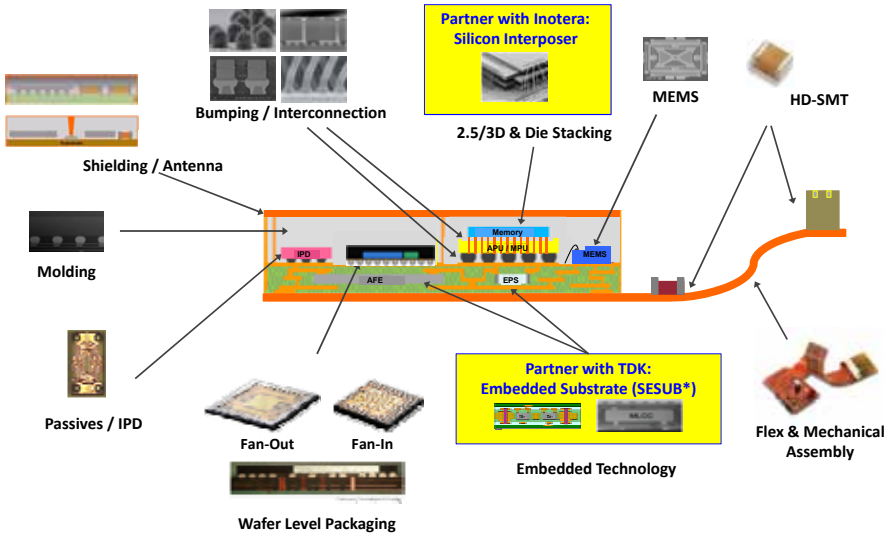
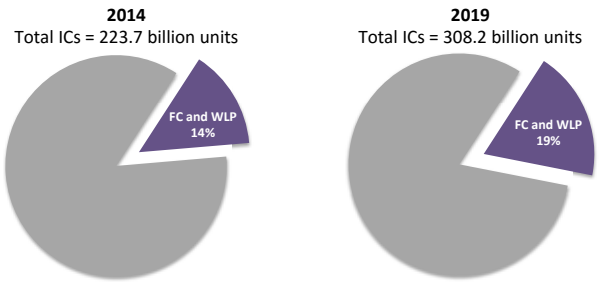
Adding Differentiation to System-in-Package (SiP) Toolbox



* SESUB is a trademark or registered trademark of TDK Corporation.

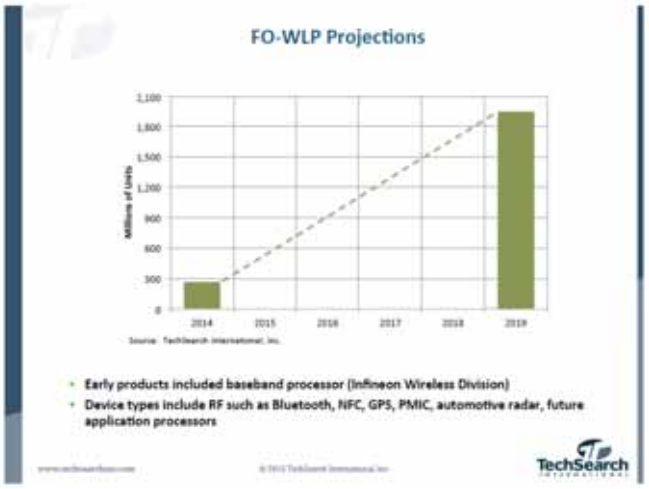
FC and WLP Growth Driven by Mobile Products



Includes only integrated circuits as defined by IC Insights. Excluded are devices such as image sensors, MOSFETs, IPDs, and filters.
Source: TechSearch International, Inc. and IC Insights.

- **Flip chip (solder, gold, and Cu pillar) and wafer level packages (WLPs)**
  - Growth in WLP market driven by mobile products (smartphones and tablets)
  - Expansion in flip chip market driven by modules in smartphones
- **CAPEX expansion**
  - Continued spending by OSATs and Foundries on advanced packaging
  - Capacity for 300mm bumping (especially Cu pillar) and wafer level packaging

Fan-Out Wafer Level Packaging



- Maintain same WLP size with die shrink
- Increase I/O
- Thinner than flip chip pkg
- Heterogeneous integration/SiP
- Fine L/S (10/10µm), w/ roadmaps for (≤5/5µm)

Emergence of Outsource Packaging

Today:
- ~51% of packaging revenues
- Leading new packaging development…Cu pillar, FO-WLP, SiP, and more…

2005:
- ~40% of packaging revenues
- Fabless companies grow; IDMs shift to outsourcing

1995:
- ~18% of packaging revenues
- Emergence of leading Taiwanese and Korean OSAT companies

1985:
- ~5% of packaging revenues
- Manufacturing focus in the Philippines
- PDIP & Transistors

Source: Gartner

Source: ASE

Source: Siliconware

Material Segment Trends

TSMC to expand IC-packaging efforts (EE Times 2011)

GLOBALFOUNDRIES Demonstrates Collaborative Model for Next-Generation Chip Packaging Technologies (2013)

SMIC and JCET Establish a Joint Venture to Build China's Local IC Manufacturing Supply Chain (PRNewswire 2014)

TSMC Has A New Growth Driver, In Packaging: Morgan Stanley (2015)

TSMC will enter FanOut Business (Yole Developpement (2015)

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Packaging Material Market Trends

- CSP laminate substrates, CSP leadframes, and WLP are driven by mobile computing and communications
- Flip chip and copper pillar continue to expand the market for underfill materials.
- Need more development for WLP dielectrics used in multi-layer structures
- Mold compounds- warpage control/package reliability (MSL1); withstand high flexing for wearable applications
- QFN- cost optimization through design (including strip size) and reduced plating area (also improves MSL); higher lead counts (routable); improved power dissipation

Source: SEMI and TechSearch International- *Global Semiconductor Packaging Materials Outlook*

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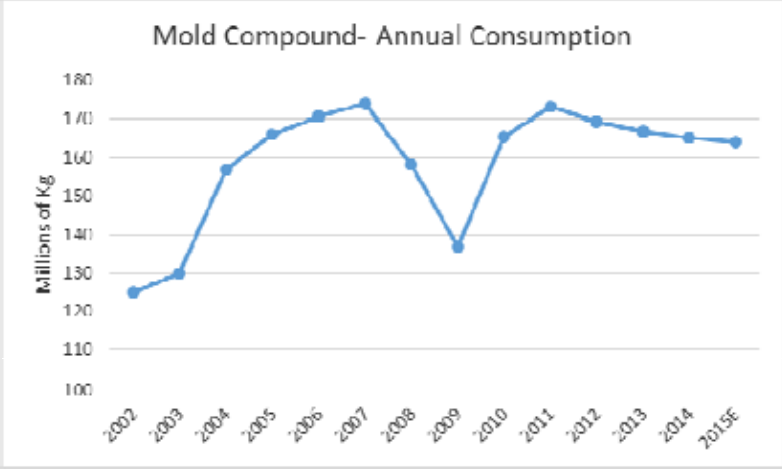
Challenge with Smaller and Thinner…



Source: SEMI and TechSearch International- *Global Semiconductor Packaging Materials Outlook*

Laminate Substrates

- ~$8B market
- Stable supply base
- Good demand/supply balance in recent years
- Flip chip substrate suppliers
  - Bump pitch trends drive finer features and higher substrate prices
  - Previously, focused on MPU and graphics applications
  - Now, the focus is on mobile applications- *growth market but more cost sensitive and shorter development cycles*
  - Laminate CSP could be impacted by growth in FO-WLP

Source: SEMI and TechSearch International- *Global Semiconductor Packaging Materials Outlook*

Wafer Level Dielectrics

- ~$100M market currently
- Requirements for new materials include:
  - Low moisture absorption (reduced outgassing at elevated temperatures)
  - Low stress (to match the CTE of the chip) and/or low modulus (for less wafer bow)
  - Low temperature cure (200 to 250°C)
  - Lower/no outgassing
  - Lower dielectric constant
  - Higher resolution at thicker layers
  - Wide process windows
  - Enhanced board-level reliability performance
  - Desire for “standard” material for multi-layer applications

Source: SEMI and TechSearch International- *Global Semiconductor Packaging Materials Outlook*

Underfill Market

- Global market of $220M in 2014
- Many suppliers (as many as 30+)
  - Continued consolidation likely, still new players entering market
- No-flow
  - Applied prior to chip placement, either on the wafer or substrate
  - Film-based and Wafer applied
- Interest in the use of mold compounds as underfill
- Increased use of board-level underfill or edge underfill for CSP/BGA parts and some WLPs
  - Apple underfills almost everything above a certain size
  - Micromax in India and many handset makers in China have almost no underfill

Source: SEMI and TechSearch International- *Global Semiconductor Packaging Materials Outlook*

Mold Compounds

- ~$1.2B market size
- Stable supply base, very strong position maintained by Japanese suppliers
- Focus on warpage control, CTE properties, low moisture absorption, and low Cl^-
- Molded Underfill (MUF) for thin Cu pillar flip chip packages
- High thermal conductive and high voltage applications emerging
- Need for flexible mold compound for wearable applications
- Supplier/material often defined by customer so OSAT can't switch

Source: SEMI and TechSearch International- *Global Semiconductor Packaging Materials Outlook*

Leadframes

- ~$3B market
  - Flat to declining revenues going forward
  - Low to moderate unit growth overall
    - *QFN growing at ~12% CAGR (2014-2019)*
    - *Other IC leadframes at -1% CAGR*
- 30+ suppliers worldwide (with varying capabilities for stamping, etching, and plating)
  - Some consolidation and re-structuring of the supplier base
  - Still a significant number of companies with a regional focus (e.g. Korea and China)
- Need suppliers with capability for pre-plated leadframes etching and surface treatments for adhesion promotion

Source: SEMI and TechSearch International- *Global Semiconductor Packaging Materials Outlook*

On-Going Leadframe Advancements

- "Routable" QFN Type
  - Wirebond, flip chip, exposed pad (thermal), *higher* lead counts
  - Employ etch back of copper strip to increase number of rows and I/O in a QFN-type leadframe
  - Use leadframe and mold compound to create a low cost package
  - Can provide lower cost package vs. laminate or WLP
- MIS (JCET, QDOS), HDL (QPL), others…
- Routable QFN type supply chain is developing at the moment as process improvements continue for HVM

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China: Industry Targets

	2015	2020
Total Revenue	>350 Billion RMB	>870 Billion RMB (CAGR > 20%)
IC Manufacture	**32/28nm mass production**	**16/14nm mass production**
IC Design	Part of key area technologies approach international first class level (e.g. mobile smart terminal, network communication)	Key area technologies achieve international leading edge. (e.g. mobile smart terminal, network communication, cloud computing, IOT, big data, etc)
Packaging & Test	**Mid- to high-end revenue > 30% revenue**	**Technology to achieve international leading edge**
Material	12 inch silicon wafer into production line.	Enter global supply chain
Equipment	65-45nm key equipment into production line.	Enter global supply chain

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Packaging in China

- 110+ companies with 150 or more A&P plants
  - 7 of top 10 IDMs (per IC Insight 2014 ranking)
  - 9 of top 10 OSATS (per Gartner 2014 ranking)
- China has ~27% of worldwide assembly & test manufacturing floor space, ranking first in global share (PwC)
- Gartner 2014 OSAT Ranking
  - #7 Jiangsu Changjiang Electronics Technology (JCET)
  - #12 Tianshui Huatian Microelectronics
  - #14 Nantong Fujitsu Microelectronics
- JCET acquired #4 STATS ChipPAC
- Tianshui Huatian acquired Flipchip Technologies
- Nantong Fujitsu and AMD JV

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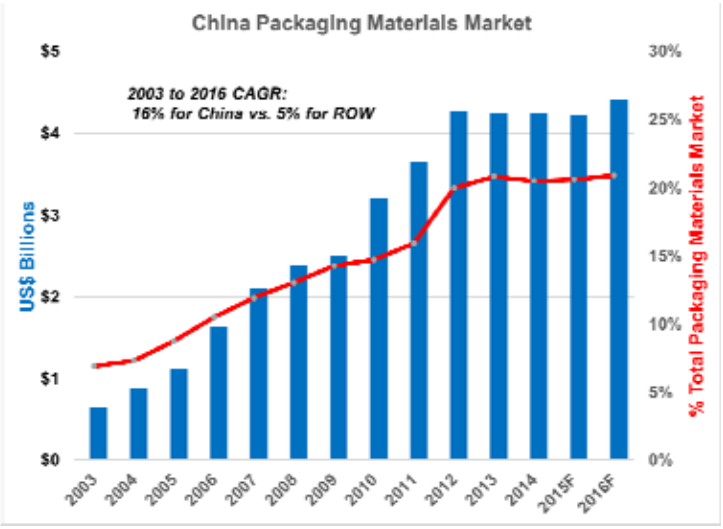
China Packaging Materials Market



Source: SEMI

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China Supplier Share of Packaging Materials

Segment	2009	2010	2011	2012	2013	2014
Leadframes ($M)	~$150	~$180	~$230	~$280	~$290	~$340
% Share of World Total	5%	5%	7%	9%	9%	11%
Bonding Wire (B m)	0.3	0.4	0.6	0.9	1.2	1.6
% Share of World Total	<2%	2%	3%	5%	7%	8%
Mold Compounds ($M)	~$16	~$25	~$29	~$35	~$40	$40-$45
% Share of World Total	<2%	2%	2%	<3%	3%	4%

- Small share currently on a global scale
- Current volume geared towards traditional/legacy type packaging in China
- New(er) suppliers in plating chemicals and liquid encapsulant (mainly for LED)

Source: SEMI and TechSearch International- *Global Semiconductor Packaging Materials Outlook*

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Summary

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Summary

- Packaging materials $20B market (45% to 50% of the total semiconductor materials market)
- Mobile applications driving packaging development
  - *New package form factors… smaller, thinner, and more complex*
  - *Different cycle time and cost considerations compared to the past PC-driven era*
- Advanced packaging
  - *Strongest unit growth*
  - *OSATS prominent and leading role in package development*
  - *Need for new materials*
  - *FO-WLP will prove disruptive for laminate substrate suppliers*
- China has fast emerged as a key market for A&P
  - *Fast developing infrastructure including local material suppliers*

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