Packaging: The Core of Competitive Advantage

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ASE Manufacturing Sites
Assembly, Materials & Test
ASE Worldwide Locations
Packaging & Us

- What is changing?
- What has not changed?
- How should we invest our time and energy to evolve with our changing world?

Outline

- The Big Picture
- Changes: Business, Market, Technology
- Situation Analysis
- Packaging DNA- Re-inventions & Innovations
- Smart Product Business Opportunities
- CPMT Professionals
- Wrap-Up
The CPMT Profession

“The transition from agriculture to manufacturing is still the route to higher productivity and rising living standard for developing economies. In advanced economies, manufactured goods stand as the tangible expression of innovation and competitiveness. We see that a new era of innovation and opportunities promises to inspire a new generation of manufacturing professionals”

Manufacturing the Future: The next era of global growth & innovation
McKinsey Report November 2012

Electronics Market Evolution (10+ X Multiplier)

<table>
<thead>
<tr>
<th>Era of Ubiquitous Electronics</th>
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<tr>
<td>Era of Smart Products &amp; Big Data Systems</td>
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<tr>
<td>Smart Computing (PMP) 108+ Units</td>
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<td>Ambient Intelligence (PMMP) 100B+ Units</td>
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<tr>
<td>Era of Smart Products &amp; Big Data Systems</td>
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<td>We are here</td>
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<td>TSMC 1987</td>
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<td>ASE 1984</td>
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<td>Birth of Fabless Model</td>
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<tr>
<td>Birth of IC/Electronic Industries</td>
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<td>Invention of Transistor 1947</td>
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<td>Invention of Integrated Circuits 1958</td>
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PC (PM) 350M+ Units

Cell Phone (PP) 1.4B+ Units

Mainframe Millions Units

Military Thousands Units

We are here

1970s 1980s 1990s 2000s 2010s
A HISTORY AND FORECAST OF THE ELECTRONICS INDUSTRY

HISTORY AND FORECAST OF THE ELECTRONICS INDUSTRY

Military/Aero
Industrial/Medical
Automotive
Consumer
Communications
Computer

Commodity Inflation/ASP Erosion Pinch Bottom Line

Return to Growth 5.6% - 5.9% CAAGR

$1.6
$1.8
$2.0

Consumer-Driven Economic Expansion 5.5% CAAGR

Dot Com Hangover

World GDP Growth

4.8% 2.3% 2.9% 3.6% 4.9% 4.6% 5.2% 2.8% -0.6% 4.8% 4.2% 4.5% 4.6% 4.6%

Dot Com Hangover

Dot Com

Consumer

$311.239rd-elec

Semiconductor

Global Recession

Financial Crisis

Commodity Inflation/ASP Erosion Pinch Bottom Line

Military/Aero

Industrial/Medical

Automotive

Consumer

Communications

Computer

Global Recession Financial Crisis

Return to Growth 5.6% - 5.9% CAAGR

$0.8

$1.0

$1.2

$1.4

$0.6

$0.4

$0.2

$0.0

World GDP Growth

4.8% 2.3% 2.9% 3.6% 4.9% 4.6% 5.2% 2.8% -0.6% 4.8% 4.2% 4.5% 4.6% 4.6%

Semi industry outlook: Growth in 2013

Billions of Dollars and Revenue Growth

3Q12 $255 -5.3% $229 -10.4% $301 31.8% $307 1.8% $307 -3.0% $298 4.5% $311 9.9% $342 3.6% $354 6.1% $376 6.1%

4Q12 Forecast

3Q12 Forecast

Source: Prismark, Nov 2012

Source: Gartner, January 2013

www.cpmt.org/scv/
Changes

Business
Market
Technology
SEMI: A Cyclical Business

Source: SEMI 2013 + Gartner, January 2013

Semi Market vs. Global GDP

Source: IMF & Gartner, January 2013
Smart phones at play!

MOBILE PHONE UNIT SHIPMENTS

Source: Prismark, March 2013
SMARTPHONE SHIPMENTS

![Bar chart showing smartphone shipments from 2010 to 2012.]

- Samsung and Apple Dominate
  - Samsung with many models, Apple with just one
- Huawei and ZTE are Growing Rapidly
- Other Chinese (Yulong, Lenovo, etc.) also very aggressive
- Smartphone pioneers are in critical situation
- Sony, HTC, LG, Motorola Battling in Second Tier
- All focused on smartphones

Source: Primark, March 2013

Moore’s Paper

“Cramming more components onto integrated circuits”

Gordon Moore  Electronics, Volume 38, Number 8 April 19, 1965

“The future of integrated circuits is the future of electronics itself. The advantages of integration will bring about a proliferation of electronics, pushing this science into many new areas.”

“Reduced cost is one of the big attractions of integrated electronics, and the cost advantage continues to increase as the technology evolves towards the production of larger and larger circuit functions on a single semiconductor substrate.”

Moore’s Law
Scaling
Performance
Lowering Cost
Electronics product proliferation
**Flattening Cost Curve**

Source: IBS, 2012

**More Moore and More than Moore**

- Beyond CMOS
- More Moore: Scaling
- More than Moore: Functional Diversification
- Interacting with people and environment
- Non-digital content
- System-in-Package (SiP)

Moore's Law

Combined SoC & SiP - High Value System
Situation Analysis

- **Business - Growth aligning with global GDP**
  - Slow semi growth + escalating capex + extreme technology driving consolidation
  - Dynamic consumer business = two players dominating across landscape
  - Electronics in every business: Consumer, aerospace, industry, home, health
  - Full product technology integration co-exists with delineated supply chain

- **Market - Fast Changes**
  - Consumers want more & more functionality - MEMs, Sensors, & more.
  - Product cost expectations are given
  - Smart Phone/Tablet superseded PC as the Market Driver
  - Big Data driving data center & network systems

- **Technologies - Inflection Point**
  - More Moore scaling continues. CPI at 14 nm FinFET in 2014 ?
  - Scaling is stalling in power, in bandwidth, & in cost per gate
  - More than Moore integration with 2.5D and more?

- **Future has arrived**
  - Customization in Mass Production
  - Heterogeneous Integration - nodes, technology, function, business, region

Packaging DNA

**History**
- For 40+ years, semi industry has lowered cost 9 orders of magnitude through scaling & Moore’s Law
- Packaging has been a crucial technology enabler without the Moore’s Law scaling advantage

**Present**
- With the burgeoning mobile and smart phone era, the packaging industry is experiencing a flowering of new package innovations and reinvention of traditional packages.
- Packaging is leading the charge for ‘More than Moore’ integration
Packaging DNA 2013

- For 40 years, our Packaging DNA was:
  - Wire bond with Au wire
  - Flip Chip solder bump

- In last couple of years, we have introduced new DNA:
  - Au & Cu Wire bond
  - Flip Chip Cu Pillar
  - Wafer level Packaging: WLCSP + WL fanout
  - Embedded technologies
  - 2.5 D Interposer - TSV
  - 3D Packaging
  - Packaging for MEMs, Sensor, and Power
  - Heterogeneous integration

- And more on the way......

Gold vs. Copper Wire:
Copper is ~30% of the market in 2012

Source: SEMI, Global Semiconductor Packaging Materials Outlook, November 2011
Image sources Sumitomo Metal Mining and Tanaka Denshi Kogyo
ASE Total Production Unit Shipment

ASE Group Total Shipment: > 10 Billion units up-to-date

Units: Equivalent to LQFP 144L

ASE Cu Wire Bonder Quantity

Cu Wire Bonder
Cu Wire Bonder %
And billions of $$ saved!

FC Cu Pillar

- Superior electro-migration & thermal performance for high current carrying capacity device application
- Low cost substrate design (Non solder mask/Slot design) and reducing substrate layers. Smaller Cu pillar diameter allows more traces in a layer.

Feature:
1. Cu pillar bump
2. MUF only
3. BOL (bump on lead)
4. Non solder mask
Cu Pillar Applications

**FC-CSP**
- Cost Effective
  - Au stud -> Cu pillar
- Fine Pitch
  - Bond on Lead (BOL)
  - MUF
  - Reflow & Thermal Compression
  - CUF & NCP/NCF
  - Non-circular bump
  - Substrate innovation

**FC-BGA**
- Cost Effective
  - UBM size shrinkage for better substrate routability
  - Build-up layers reduction or Build-up 1/2/1 -> Laminate
- System Performance
  - Thermal/ EM (high current density)

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WLCSP growth driven by Mobility

WLCSP unit forecast by end application area (Munits)

![WLCSP unit forecast graph](image_url)

Intel, 2007 ECTC

**CAGR** = 14%
Value Engineering

- Low Cost WLCSP
- Improved Reliability/Large WLCSP
- High Power WLCSP
- Thin WLCSP
- WLCSP for Embedding
  - WLCSP for MEMS/TSVs

WLP Plus - TSV, MEMS & Stacking

- WLCSP Innovation Examples
  - Die on die, thin die mounted on face of WLCSP, between perimeter solder balls
  - Used for WLCSP and WLCSP MEMS
  - TSVs for Backside connectivity for Power packages, including High Frequency Analog Amplifiers
  - WL IPDS
  - WL MEMS

Diplexer

MEMS PKG

ASIC

MEMS

MEMS PKG
Evolutionary Paths for FOWLP

- Single Die FOWLP
- Multi Die 2D FOWLP
- Multi Die with Passives FOWLP
- Double sided 3D FOWLP
- Double sided 3D FOWLP Module Assembly
- Package on Package (FOPOP)

3D aWLP Stacked POP

- 3D aWLP Bottom 490µm
- 3D aWLP Top
- 3D aWLP Stacked POP
Why Embedded?

- Miniaturization, Miniaturization, Miniaturization
- Performance: electrical, thermal
- 3D packaging

Embedded Component Technology

- Ultimate Objective
  - Miniaturization of SIP

Intel - Bumpless Build-Up Layer
Casio - Embedded WLP
Imbera - Integrated Module Board
GE - Chips First Build-Up™
Fraunhofer IZM - Chip in Polymer
Heterogeneous Integration: 3D + 2.5D evolution

Collaborative Design 2013

Co-design and simulation for Chip-Package-System are essential for co-creativity for the Market Place

Transition Needed in Design and Simulation Flows

1. Design
2. Fab
3. Thermal
4. Mechanical
5. Optical
6. Electrical
7. Simulation
8. EOSAT
9. 3D IC integration
10. Heterogeneous integration
11. Reliability Test
12. Productivity improvement

2010

2013+
Roles in Collaborative Engineering

- **Product Architect & Packaging Architect**
  - Product integration Architecture & Design - Performance, Cost & schedule
  - Source multi diverse die devices for package integration

- **Device Designer in Fabless and/or Fablite IDMs**
  - Supply multi die device products
  - Co-design ecosystem

- **Assembly & Packaging Engineer**
  - Co-design ecosystem model - heterogeneous and multi foundry products
  - Assembly materials & processes

- **Interposer foundry & substrate supplier**
  - Co design and co-processing participation

- **Material & Equipment Supplier Partnership**
  - Optimal materials and equipment for HVM

Collaborative Business Model

Optimizing Core Competency

- Chip Architecture Design
- Semiconductor Manufacturing
- Packaging Assembly Test

IDM | Fabless Foundry | Virtual IDM - An evolving Business Collaboration Model

www.cpmt.org/scv/
2.5D IC Ecosystem Models

- Foundry IC → Interposer foundry → OSAT MEOL
- Foundry IC → Interposer foundry → OSAT ASSY
- Foundry IC + Interposer → OSAT MEOL+ASSY
- Foundry IC + Interposer w/MEOL → OSAT ASSY
- IDM / Foundry Captive Turnkey
- Most models will likely be employed

Electronic Business

The BIG Picture
Smart Product Business Opportunities

Smart Products Zone
New markets creation with new products and new applications

- Extreme cost
- Scalable flexibility
- Human capital
- Extreme technology
- Holistic design & Ease-of-use
- Supply chain ecosystem

Infrastructure
- Evolving standard by economies of scale

System
- Evolving standard by branding premium

Towards Ubiquitous Electronics

Market Drivers
- Mobile Devices & Network Systems
- Cloud
- Ubiquitous Electronics

Integrated Network Growing

Desktop Computer
Laptop Computer
Ipod / MPG Player
Cell Phone
GPS
Blackberry
Tablet

Data Center Backbone
Network Router
Game Consoles
Hand Held Games
Generation Mobile: The Personal Nerve Center

Mobile computing: Enabling a multi-tasking generation
Game-changing wearable electronics
Motion & Sensor

Smart pants
Smart pajamas
Smart shoes
Smart shirt
Smart tattoos

Real-time health in 2013

Vital signs
Glucose meters
Blood pressure monitors
Smart inhalers
Detecting & medicating
Healing
The Smart Home: gaining control

- Energy
- Network
- Security
- Entertainment
- Appliance

Transportation:

- Automotive
- Air
- Rail
- Sea
Automotive:

- Chassis: braking systems, electronic power steering, active suspension
- Body Electronics: controlling, body, seat, door, window, HVAC, lighting + remote
- Safety: Airbags, electronic stability, collision detection
- Networking & Communications: CAN, LIN, BLUETOOTH, Ethernet, 4G, social media partnerships

Source: Freescale 2012

Robotics:

- Medicine
- Therapeutic
- Avatar
- Education
- Domestic
- Manufacturing

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Re-inventing the CPMT Engineer

- Understand business & market directions, and technology implications
- Mastering core packaging DNA
  - WB, FC, WLP, 2.5D & 3D, embedded, ...........
- Global Network
  - CPMT - Connecting Peers & Mentoring Talent
- Ecosystem Collaboration
  - Design & simulation tools, Materials & HVM equipment
- Practice engineering with both sides of our brain

Co-Engineering with both sides of brain

EXPERIENCE = USABILITY/ANALYTIC + DESIGN/CREATIVE

Left-Brain Functions
- Analytic thought
- Logic
- Language
- Science and math

Right-Brain Functions
- Holistic thought
- Intuition
- Creativity
- Art and music
Is collaboration a natural instinct?
For organizations? For individuals?

“With consolidation, competitive advantage shifted to those best at collaboration.”

Dan Hutcheson, Jan 2013

“I want to put a Ding in the Universe”

Steve Jobs

Together we shall put our Dings in the Universe
Summary

- The challenge for the electronics business lies firmly in the areas of technology complexity, business model, and market diversity.
- Packaging technology becomes a crucial enabler and gate. Innovation and re-invention are critical for success.
- CPMT professional stand at the front line of destructive market and technology inflection point.
- The need to reach out & engage in collaborative engineering is becoming paramount.

Acknowledgement

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