Semiconductor Packaging and Test
A supply chain challenge

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ASE Group

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Session 3: Impact of new markets on test and the supply chain
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Keywords throughout this presentation

The next big thing?

Supply chain

Value chain

Industry branch, sector

System in Package

Semiconductor packaging

System on board

Test
Outline

1. ASE Group introduction
2. IoT, the next big thing?
3. SiPs or Modules?
4. SiP packaging roadmap
5. Test innovations and challenges
6. Conclusion
ASE Group Introduction
ASE Group: Business Units

Chairman
Jason Chang
Richard Chang

ASE ATM

COO
Tien Wu

2013 revenues: $4.8B

USI

CEO
Tien Wu

$2.7B

Real Estate
# ASE Group Synergies

<table>
<thead>
<tr>
<th></th>
<th>ASE</th>
<th>USI</th>
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</thead>
<tbody>
<tr>
<td><strong>Main operations</strong></td>
<td>IC assembly and test (A&amp;T) services</td>
<td>Module/System Design and Manufacturing Services (DMS)</td>
</tr>
<tr>
<td><strong>Main technologies</strong></td>
<td>die attach, wire bonding, bumping, flip chip, moulding, IC test, Wafer level packaging</td>
<td>Compartment Shielding, Conformal Shielding, Hi-Density SMT, and Embedded Technologies.</td>
</tr>
<tr>
<td><strong>Accuracy range</strong></td>
<td>1µm - 50µm</td>
<td>20µm-100µm</td>
</tr>
<tr>
<td><strong>Business models</strong></td>
<td>- Outsourced IC assembly and test services.</td>
<td>- Module/System design and manufacture including Supply chain and Services.</td>
</tr>
<tr>
<td></td>
<td>ASE is a service company</td>
<td>USI is a service company</td>
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</tbody>
</table>
ASE’s Role in the Manufacturing Value Chain

Unique assets for an OSAT

- Material
- Assembly
- Wafer Bumping / Probing
- Foundry
- Engineering Test
- Integrated Circuit Design

Module, Board Assembly & Test (DMS)
Final Test
Services Offered by ASE Group
ASE Group Value

**ASE + USI → Leadership**

- **System integration**
  * OSAT & EMS expertise and customers
  * Assembly & Test + System Design
  * Total Service & Manufacturing Solution

- **Market share gain**
  * Strategic investment
  * Technology leadership

**New Driver**

**Organic Growth**
ASE Broad Portfolio: A&T

• Full Turnkey Service
  • Assembly
  • Test
  • Substrate
  • EMS

• Lowering Cost/Creating Value
  • Cu Wire Bond
  • High Density Matrix
  • Low Pin & Discrete
  • Economies of Scale

Networks, Servers, Desktops
  • MPU/GPU
  • Network Processors
  • ELK, CPI
  • Si Interposers/IPD

Mobility, Communication, Entertainment
  • System in Package
  • Package on Package
  • Heterogeneous Integration
  • TSV Stacking
  • Mobile Devices
  • FC CSP
  • Multi row QFN

Industrial, Homes, Automotive
  • Analog Packaging
  • WLCSP
  • Fanout WLP
  • Micro Form Factor
  • MEMS
ASE Worldwide Locations
IC Assembly & Test

Suzhou, China (ASEN)

ASE Weihai, China

Shanghai, China (Material)
Paju, Korea

Shanghai, China (A&T)
Takahata, Japan

Kunshan, China

ISE Labs
Fremont, California
Austin, Texas

Penang, Malaysia

Singapore

- Sales and Representative Offices
- IC Service
- System Service
USI Businesses & Positions: DMS

Diversified & Balanced Businesses with Leading Market Positions

Segment
2013 Revenue

Wireless Networking
40%

Storage & Computers
25%

Industrial Products
15%

Visual Products
10%

Car Electronics
10%

Products & Market Positions

Wi-Fi SiP
WW No.2 for Smart Phone & Tablet

SSD & NAS
WW No.1 for Enterprise & SMB

POS
WW No.2 for Hospitality & Retail Market

LCD X-Y Board
WW No.2 for TV, NB, Monitor

Regulator
No.1 for China OE Charging System

M2M Module
For Home Appliance

X-86 M/B
No. 2 for Customers in DT and Server

SHD
WW No.1 for Logistics & Warehousing

LED Back Light
For TV, NB, Monitor

LED Lighting
WW No.2 for Lighting System

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USI Worldwide Locations

- Kunshan, CN
- Shanghai, CN
- Shenzhen, CN
- Nantou, TW
- Hsinchu, TW
- Taipei, TW
- Yokohama, JP
- Sunnyvale, CA
- Long Island, New York, US
- RTP, NC, US
- Guadalajara, MX
- Paris, FR
- Shenzhen, CN
- Kunshan, CN
- Shanghai, CN ZJ
- Shanghai, CN JQ
- Nantou, TW
- Guadalajara, MX

- R/D
- Manufacturing
- Global Sales
- RMA & Logistics
The “Internet of Things”
*The next big thing in the industry?*
Volume Paradigm: 10X in 10Y, accelerating

- **Aerospace**: Thousands Units
- **Mainframe**: Millions Units
- **PC (PM)**: 350M+ Units
- **Cell Phone (PP)**: 1.8B+ Units
- **Smart Computing (PMP)**: 10B+ Units
- **Internet of Things (IOT) (PMMP)**: 100B+ Units
  - Exponential Connectivity & Big Data

Long Tail

1970s 1980s 1990s 2000s 2010s 2020s

We are here
IoT is not a market, it's a tech trend.
IoT is a not a market, it’s a tech trend

Home Heating Automation

Home Smart Lighting

Connected Car
Low power wireless module vendors

Which RF comm standard will prevail for IoT Applications?
Home Heating Automation: Technology & Architecture (Option 1)
Home Heating Automation: Technology & Architecture (Option 2)
Home Heating Automation: Technology & Architecture (Option 3)
Home Heating Automation: Supply Chain

- Thermostat
- Energy Provider
- Heating System
- Electrician
- Internet Service Provider
- Telecom Service Provider
- Mobile Phone
- OS
- British Gas
- Kelag
- RWE

...
Do you remember how and when mobile telephony soared?

1982-1987
EU agreements develop and deploy a common cellular telephone system across Europe, GSM to become a mandatory standard

1987-1990
“Groupe Spécial Mobile” is placed under ETSI (European Telecommunications Standards Institute). First specification is released. Extension from 900MHz to 1800MHz.

1990-1995
Networks are deployed by main telecommunication companies in Europe. GSM becomes “Global System for Mobile communications”

1995
Commercial launch subscription business model

1995-2000
Strong growth of the European electronics industry
System integration packaging challenges for “smart lighting”
The connected car opportunities

The Intelligent Car
(Almost) as Smart as You

The Internet of Things (IoT) is spurring the development of innovative technologies that are delivering new ways for cars to inform, entertain and assist drivers in a safe and comfortable way. Here’s a look at how technology is changing daily commutes, both now and in the future.

Today
Car owners and buyers want the latest technologies in their vehicles, and safety is key.

- 60% of roadway collisions could be avoided with half a second’s warning
- 90% of collisions could be avoided with a full second’s warning

Intelligent Maintenance

Local analytics could be applied to thousands of on-board sensors to flag abnormal events and take corrective action. The data may then be sent to automakers for deeper insight into trends across entire vehicle fleets.

Smart Traffic Environments

Smarter traffic management could reduce vehicle wait time by 40%, and travel time by 26%. Think smart street lights and roads that better manage traffic flow efficiency, and street signs that display relevant location-based data.

Tomorrow
Car buyers will have new demands too!

- 69% said they would like to use a semi-autonomous lane-keeping system
- 63% would like to use car-to-car communications
- 63% would welcome a fatigue warning device in their vehicles

Data, Data Everywhere

152 million connected cars will be on the road by 2020, generating 11 petabytes of data annually. Intelligent cars could collect and analyze data from each other, the cloud and the transportation infrastructure to provide the right information, at the right time, and in the right way to keep drivers safe.

Vehicle-to-Vehicle Communication

Intelligent cars have the potential to reduce 79% of crashes by exchanging information about location, speed and direction. As a result, cars could then take proactive measures to keep traffic moving efficiently and safely.
SiPs or Modules?

or SiPs in Modules?
What is an SiP Module?

SiP module is a package that contains an **electronic system or sub-system** and is **miniaturized** through **IC assembly technologies**.

- Miniaturized Module Package
- Electronic System Functionality
- IC Assembly Technology
SiP Module Technologies

Conformal Shielding
- RF EMI Shielding

Compartment Shielding
- Pkg. Internal RF EMI Shielding

IPD and Embedded SBS
- Integrated Passive Devices
  - EDS & EPS

WLP
- Bare die package
- SMT

AoP (Antenna on Package)
- Antenna Integration for 2.4G/5G/60GHz

Thermal Enhancement
Irregular Cu-Pillar
- Thermal Dissipation

Stacked Die / Pkg
- Flip Chip & Wire Bond

SMT
- Passives
  - Connectors
  - Rigid or Flex
SoC to SiP/SiM Evolution

Technology complexity vs. system complexity
# SiP / Module Comparison

<table>
<thead>
<tr>
<th>Technology definition</th>
<th>SiP</th>
<th>Module</th>
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<tbody>
<tr>
<td>Use of either W/B or flip chip or IC embedding. “one package solution”</td>
<td>SMT soldering</td>
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<table>
<thead>
<tr>
<th>Business model definition</th>
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<th>Module</th>
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</thead>
<tbody>
<tr>
<td>Service assembly and test</td>
<td>Service assembly and test or branded products</td>
<td></td>
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<table>
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<tr>
<th>Components are</th>
<th>Consigned by customer</th>
<th>Purchased by module assembler</th>
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<tr>
<th>Supply chain &amp; product liability</th>
<th>Lower</th>
<th>higher</th>
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## Issues
- Test liability and the known good die issue
- System liability and test of the system

Why not reinvent SiP so as to use SiP technologies following the Modules business model? Or any combination of the 2?

Will only be possible with standardization (catalog products)

Will be low cost when high volumes

New ways are possible
ASE Group’s agile business models

Consignment
Customer consigns most components to ASE

Buy & Sell
USI buys all components and owns the module

System Value
- lower
- higher

Supply chain management complexity (for customer)
- higher
- lower

ASE Group System liability
- lower
- higher

System in Package
Module
SiP value mapping

higher flexibility

shorter time to market

less development cost

better performance

less power consumption

smaller size

Above chart from Sony Tsugio Makimoto and Infineon Grit Sommer (2005)

In many cases, systems are made of a weighted mix of SoC, SiP and SoB
Where (for which App) does SiP make sense?

→ SiP not a ubiquitous solution for IoT

### IoT main segments

<table>
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<tr>
<th></th>
<th>vehicles</th>
<th>buildings</th>
<th>wearable</th>
<th>industrial</th>
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<tr>
<td><strong>cars</strong></td>
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<tr>
<td><strong>trucks</strong></td>
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<tr>
<td><strong>trains, ships</strong></td>
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<tr>
<td><strong>homes</strong></td>
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<td><strong>commercial</strong></td>
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<tr>
<td><strong>public buildings (airports, hospitals)</strong></td>
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<tr>
<td><strong>watches</strong></td>
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<tr>
<td><strong>glasses</strong></td>
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<td><strong>infrastructure</strong></td>
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<tr>
<td><strong>utilities</strong></td>
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<tr>
<td><strong>equipment</strong></td>
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#### Need for miniaturization
- **cars**, **trucks**
- **watches**, **glasses**
- **infrastructure**, **utilities**
- **equipment**

#### Need for low power for autonomy (connected or not to the grid)
- **vehicles**, **buildings**, **wearable**, **industrial**

#### High volumes (scaling effect for lower cost)
- **vehicles**, **buildings**, **wearable**, **industrial**

#### ASiP value add
- **vehicles**, **buildings**, **wearable**, **industrial**
Miniaturisation does not matter for smart home?

- tailor-made furniture object ... $$$
- cost of a router that does not spoil the look ... ?
The upstream supply chain
From components to hardware
Can a single company make it all?

Technology

- Modularization
- Standardization
- Partnerships

→ Test and packaging
Trend of Modularized Subsystems

Flexible
- Eco-mobius by ZTE

Scalable
- Project Ara by Google

cost & security
- puzzlephone by puzzlephone

Time-to-market
- Concept by Phonebloks
ASE SiP packaging roadmap
SiP Module Roadmap for miniaturization

**Embedded**
- Embedded Passive Substrate
- a-EASI* (Lead Frame, 1L/3L for Active)
- Embedded Substrate (PI Tape, for Active & Passive)
- SESUB** (Laminate 2L/4L, for Active & Passive)
- SESUB** (Cavity & Laminate 2L/4L/6L, for Active & Passive)

**WLP/FO-WLP**
- 8" aWLP* (Single Die)
- Wafer Level MEMS
- 12" FO-WLP (Single/Multi die)
- Wafer Level Capping

**2.5D/3D Stacking**
- aMAP* PoP
- Exposed-die PoP
- MoM / Double Side (Frame Board)
- Double Side (Molding)
- Molding Embedded Package
- HB-PoP
- 2.5D Organic Interposer
- 2.5D Silicon Interposer

**Past**
- 2014 1H
- 2014 2H
- 2015
- 2016

**Note:**
- * ASE Trademark
- ** ASE/TDK Joint Venture Trademark

**Connectivity** | **BB / AP** | **Cellular Radio** | **Power / Audio** | **Sensor**
SiP Module Roadmap *advanced process*

160um Passive Clearance

120um Passive Clearance

100um Passive Clearance

Irregular Cu Pillar Assy.

Cu Pillar (CuBOL 50/100um pitch, ETS 150um w/ 2 traces pass)

Max. Loop Height 65um w/ 0.8mil wire / fwd bond

Cu Pillar (CuBOL 30/60um pitch, ETS 120um w/ 2 traces pass)

Max. Loop Height 60um w/ 0.8mil wire / fwd bond

MUF w/ 0.17mm Thin SBS / Coreless SBS

Exposed Die Molding

Exposed Passive Molding

--- | --- | --- | --- | ---
Connectivity | BB / AP | Cellular Radio | Power / Audio | Sensor
Test innovation and challenges
Test challenges

- Systems require system functional testing of the system
  - Is self testing (BIST) the solution?
  - Why not use the radio stages of the system under test to perform RF testing?
    - Less contacts are needed to the external world
    - Invent the SUT concept (System Under Test) as opposed to DUT (Device Under test)

- If sensors, specific handlers are needed

- Multiple sensors in a system is becoming the norm
  - Complete environmental handlers are needed
    - For example Pressure, temperature, humidity, CO, CO2 sensors in a single device

- Test cost to enable scaling
Bringing down testing costs (multi-row) QFN strip testing

- Strip/panel testing consists in performing final test in parallel on all the devices on a strip or panel before final singulation
- Needed Investments: strip handlers and testers
- Some additional process steps, but the throughput benefits offset the amortization costs
A specific flow

- Molding
- Post-mold cure
- Singulation
- marking
- Final test
- FVI

Pre-cut to isolate fingers

Test output mapping for laser marking

- Pre-cut path
- Tie bar Removed
- Package line
- Lead frame
- Compound area
Conclusion
Conclusion

- IoT is not a market. It is a tech trend, in many different industrial sectors, each one with a specific supply chain. To make these segments boom does not depend on us. This will primarily require political will, industry standardization efforts, and determined leaders:
  
  **IoT = many opportunities for the European industry!**

  - But European companies should partner, not compete against one another
  - Application software, services and usability are key

- SiP will offer value for some of these opportunities only, and will only be cost-effective for high volumes (tens of millions annual units)
  
  - Modularization of the systems will contribute to the scaling effect reaching the billions units order of magnitude

- Most Packaging and Test Technologies are here (hardware is ready, unless software!). But we can prepare ourselves to “the big hit”
  
  - Standardization of package interfaces for modularization
  - Battery integration
  - Just like packaging, test should be brought cost-effectively up to the system-level
Thank You

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