An Emerging Heterogeneous Integration Era
— Global and Taiwan’s IC Technology and Business Development Trends

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Etron Technology, Inc.
Outline

- Paradigm Shifts in Electronic System (ES) and Integrated Circuits (IC) Industries
  - From 70s through 90s; Global versus Taiwan
- Emerging Technology and Business Development Trends into 21st Century
  - From monolithic integrated circuits to Heterogeneous Integrated system chips
  - From Fabless/Foundry to CVVI (Clustered Virtual Vertical Integration) business model
  - Taiwan outlook: Growth thrust towards innovation based on manufacturing, clustered with global partners
- Conclusions
Paradigms in ’70s to Mid-’80s

- **Driving Forces and Keys for Success**
  - Major Technology Innovations, e.g. Intel’s CPU
  - Closed Systems for **Single** Applications, e.g. Computer (IBM’s Mainframes) or Telephone (AT&T’s Switching Systems)

- **Characteristics and Models**
  
  Vertical Integration (Electronic System)

  |----------------|-----------|-------------|-------------|

  IDM (Integrated Device Manufacturer) (IC)

  Application & Subsystem Design
  - Chip Design
  - Wafer Fab
  - Packaging & Testing

  Specialty Knowledge Domains
Taiwan IC Industry in ’70s to Mid-’80s

- A Small Player in the Worldwide IC Business

### Key Events:
- **1970**: Started Few Design Companies
- **1975**: Transferred CMOS from RCA to ITRI
- **1980**: UMC Spin-off from ITRI
- **1985**: Hsinchu Science Park Started

### Vertical Integrated Organization
- Consumer ICs by ITRI
- Computer ICs by ITRI
- Product + Manufacturing Company (IDM)

### Revenue Data:
- Revenues ~0.6% of Worldwide Sales

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*ITRI: Industrial Technology Research Institute (A Mixed National and Industrial Laboratory)
Paradigms in Mid-'80s through '90s

- **Driving Forces and Keys for Success**
  - *Open Systems with Standards* for ICs, e.g. PC/Notebook with CPUs and DRAMs
  - *Capital Intensive Manufacturing to Design/Foundry Synergy*, e.g. Taiwan pioneered foundry model by TSMC

- **Characteristics and Models**

  **Horizontal Segmentation**
  (Electronic System)

  1. Channel/Application
  2. System/Service
  3. Software
  4. IC

  **IDM/Fabless/Foundry/Vendors**
  (IC)

  - Application & Subsystem Design
  - Chip Design
  - Wafer Fab
  - Packaging & Testing

  **IP/EDA**

  - Design Foundry
  - Wafer Foundry
  - Packaging & Testing
Taiwan IC Industry in Mid-’80s through ’90s

- Fast Growth Thanks to the Innovative Foundry & Fabless Model plus Advanced Technology Development Success

- Revenues > 11% of Worldwide Sales

- Success in 8” Wafer Manufacturing Attracted US$16B Investment

- National Submicron Project by ITRI: 8” Wafer & 0.5-micron Tech Development

- TSMC Founded

- Vertical Integrated Organization

- Product + Manufacturing Company (IDM)

- Consumer ICs by ITRI

- Computer ICs by ITRI

- Memory ICs

- Fabless

- Wafer Mfg.

- Foundry

- ASICs

- Fabless; Design House

- Testing & Packaging Service

- Fast Growth Thanksto the Innovative Foundry & Fabless Model plus Advanced Technology Development Success
Paradigms into 21st Century – Personal Application Revolution

- **Driving Force**
  - Application-Driven: Consumer-Centric with 4C Integration (Computer + Communication + Consumer + Content)
  - Integrated Systems with Mixed Closed and Open Standards

- **Emergence of Mobile Intelligence Appliances (MIAs)**
  - Cell phones: 500M units in 2003 (3X of PCs),
  - Digital Cameras,
  - Digital Audio/Video Players,
  - PDAs, iPods,
  - Wireless/Bluetooth/Home Connectivity,
  - Automobile Entertainment Units, etc
Personal Application Revolution Demands & Nourishes System Chips

- **4C Functionality in a Single MIA**

- **Small Formfactor, Limited Footprint, Low Cost, Reduced Power: Absolutely Required**

- **Various Circuit Families Integrated into One Single-Package/Module IC**
  - Digital, analog, memory, RF, power-related, etc.
  - **Single Die or Multiple Dies: A Key Decision**
New System Chip Architecture: MDSC

- Multi-dimensional Die integration System Chips
MDSC Analogy

- Metropolitan-like Die-Society Cluster
  - Conceptualized as land development and building construction

  e.g. SFO Union Square or Taipei World Trade Center versus one-story house at Wyoming
MDSC Realization in Cell-Phone Cameras – SEM

After T.H. Tong (ASE Corp.)
New Measurements into System-Chip Era

- **Moore’s Law**
  - More *transistors* in a 2D die area
  - **Monolithic Integration (MI)** by using planar technologies in a single die
  - 2X in 12 to 24 months
  - Progress will continue for 4 decades (G. Moore, Electronics 1965 & ISSCC 2003)

- **MDSC – Lu’s Metrics**
  - More functions per unit volume in a smaller footprint
  - **Heterogeneous Integration (HI)** by using multi-dimensional stacked-die technologies
  - ??X every year
  - Emerging as Application-driven, starting in the 21st century (N. Lu, ISSCC 2004)
Emerging Business Models for System-Chip Companies

- System Chips, Especially MDSCs, Need Clustered Virtual Vertical Integration (CVVI) Business Models

- Key: Co-Development and Profit-Sharing
System-Chip Olympics – Global Business CVVIs and Flagships

- Samsung
- JSMs
- PAN-PACIFIC
- TSMC
- UMC
- Silicon Valley
- IBM
- PAN-ATLANTIC
- ESMs
- Silicon Valley
Business CVVI Example I: IBM

- IDM from ’70s to mid-’90s
- Diversified in mid-’90s: Contract Manufacturing
  - Providing standard cells, IPs, foundry service to selected partners
  - Co-developing technologies in multiple alliances
- In 2002: Technology and Engineering Service
  - Providing skills in various specialty segments to customers with valuable application channels
  - Allowing partners to use IBM knowledge and resources to co-develop products for win-win results

*Communication with J. Kelly and T.C. Chen (IBM)*
Business CVVI Example II: TSMC

● Developed a New Foundry Model since 1986
  – No product but manufacturing only in order to avoid conflicts of interest with customers
  – Provided best in-house technology – not most advanced at beginning but well-positioned business model made it successful

● More Co-Development of Technologies and Business with Customers and Suppliers
  – e.g. Co-developing flip-chip packaging technology with assembly vendors, but complete assembly production business will belong to those vendors
  – Invested in a sensor assembly company to support CMOS sensor customers

*Communication with G. Hu and M. Chang (TSMC)
Business CVVI Example III: JSMs

- Japanese Semiconductor Manufacturers Changed into Two Major Business Structures
  - One DRAM-focused manufacturer, clustered with emerging fabs in Taiwan and China
  - IDMs focused on SoC, SiP, flash memory, Combo, IP, etc.

- Entering MDSC Era by Open IDM Model
  - e.g. Toshiba’s SoC-centric Open IDM model provides a technology/automation platform to facilitate partners’ product development and foundry integration
  - e.g. NEC forming cooperative relationships with fabless companies by providing strong technology platforms

*Silicon Sea Belt Summit, Fukuoka, 2003; Communication with Kohyama (Toshiba) and Tosaka (NEC)
Business CVVI Example IV: Samsung

● An Electronic System House with IDM Semiconductor Division
  – Recent successes with ICs, displays, cellular phones, home appliances, games, etc.

● Migrating Towards Vertical Integration
  – Developing knowledge in all four system segments, especially for MIA products
  – Smartly mixing “owned and closed” technologies with “the best imported from the outside”
  – Promoting a vision of Collaborative Alliances, thus actually implementing CVVI strategies

Silicon Sea Belt Summit, Fukuoka, 2003; Communication with Y.W. Lee (Samsung)
Paradigm Shifts in Electronic System (ES) and Integrated Circuits (IC) Industries
  - From 70s through 90s; Global versus Taiwan
Emerging Technology and Business Development Trends into 21st Century
  - From monolithic integrated circuits to Heterogeneous Integrated system chips
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  ➡️ Taiwan outlook: Growth thrust towards innovation based based on manufacturing, clustered with global partners

Conclusions
Paradigm Shift: Regional Force Change

- **IDM**
  - US
  - Japan
  - Europe

- **Fabless**
  - US
  - Taiwan

- **Foundry**
  - Taiwan
  - Singapore
  - Korea
  - China
  - Malaysia

- **New Paradigm**

- **Pan Pacific IC Circle**

- **P²IC²**
Taiwan’s New Directions for IC Growth

- Leader in IT System and Display Manufacturing
  - Fulfilling customer demands and setting product directions
  - Headquarters in Taiwan, cost-effective manufacturing in China, efficient global logistics for worldwide customers

- Leader in Foundry Technology and DRAM Manufacturing
  - Heavyweights supporting R&D; Best practice in global alliances

- #2 in IC Design Industry Scale, Next to Silicon Valley
  - Best CVVI Infrastructure to enhance product variations in the heterogeneous integration era, with partners coming worldwide

- More Emphasis on Value-added Growth than Revenue Growth – An Industry Consensus
  - Pushing for innovation and competitiveness
  - Respect IP; value intellectual power; focus on quality
Effective Fabless Plays a Pivotal Role

IC-created Knowledge Economy

Fabless

IP Libraries
Technology Know-how
System Know-how
Design Excellence

Foundries

System Co's
Technology CVVI Example 1: A Common Platform for System Chips

- Design Foundry + Wafer Foundry + System Houses
- A Reconfigurable DAV Platform to Derive SoCs
  - Rapid implementation with pre-defined technologies
  - Accumulated learning and reuse for faster product introduction

After Y.R. Lin, K.C. Shih, J. Lai, and N.C.C. Lu (Global Unichip Corp.)
Tech-CVVI Example II: MDSC Packaging Technologies

- Packaging Houses + Design Houses + Wafer Foundries
- Stacked-die and Flip-chip Turnkey Capabilities
  - Wafer thinning, bonding or bumping, bumped-wafer probing, assembly, final tests, etc.

After H.M. Tong (ASE Corp.)

- 0.3mm Mold Cap
- 1.0mm Overhang for 3mil Die

Die to die

Wire Bond

Reverse Bonding

Stagger/ Tri-Tier Bonding

Molding

After H.M. Tong (ASE Corp.)
Technology CVVI Example III:
Handset Platform for Telecom & Multimedia

- System Houses + IC Companies + Package Vendors
- Multiple **Processors** + Variable **Memories** Architecture
  - IC contents determine functionality for different end-user needs
  - Identical footprints manufactured for multi-purpose applications

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**Phone-Centric**

- **RF**
- **Telecom CPU**
- **Multi-Media CPU**
- **RAM**
- **Flash**

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**Entertainment-Centric**

- **RF**
- **Telecom CPU**
- **Multi-Media CPU**
- **RAM**
- **Flash**

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**Wireless**

- **Controller**
- **Interface**

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**After Huang, Lee (Inventec), Hu (UMC), Lu**
Fabless Revenue Growth: Taiwan vs. Worldwide

Source: IEK/ITRI-TSIA Project (Nov. 2004)
## A Race with Obstacles

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<th>Description</th>
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<tr>
<td>2004</td>
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<tr>
<td>1</td>
<td>Finland</td>
<td>Strong planning</td>
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<tr>
<td>2</td>
<td>U.S.</td>
<td>Tech supremacy</td>
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<tr>
<td>3</td>
<td>Sweden</td>
<td>Squeaky clean</td>
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<tr>
<td>4</td>
<td>Taiwan</td>
<td>Strong innovator</td>
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<tr>
<td>7</td>
<td>Singapore</td>
<td>Superefficient</td>
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<td>9</td>
<td>Japan</td>
<td>Top in R. and D.</td>
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<td>Hong Kong</td>
<td>Good institutions</td>
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<td>South Korea</td>
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<td>91</td>
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<td>Poor credit rating</td>
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<td>102</td>
<td>Bangladesh</td>
<td>Worst corruption</td>
</tr>
</tbody>
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*TIME Magazine, Oct. 25, 2004*
Conclusions

- **Paradigm Shifts in Both ES and IC Industries:**
  - From closed Mainframe to open PC to integrated MIA
  - From Office computation to Personal 4C
  - From monolithic ICs to heterogeneous integrated chips

- **Heterogeneous Integration (HI) Transforming IC Industry on Four Aspects:**
  - Synergistic growth of technologies for smart products
  - Emerging CVVI business model
  - Knowledge consolidation from system, IC to manufacturing
  - Mix-and-Match in culture from West to East and B to C

- **Taiwan’s New IC Thrust in the HI Era**
  - Add innovation value and continue manufacturing growth
  - Play a pivotal role in Pan-Pacific IC business and technology growth