Current State of Research and Development for Electronic System Integration

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1. Introduction
Higher performance of electronic system operation has been demanded day by day. However, electronics packaging is now the bottleneck to extract the full performance of high CPU operation. The following new project of "the Ultra High-Density Electronic System Integration (E-SI)" of ASET are started from April 1999 with 18 companies' researcher.

This 5-year Project activity is mainly sponsored by MITI and through the New Energy Development Organization (NEDO). There are many activities outside of Japan for the basic technology leadership in the next industrial and academic research area of electronics System Integration. For the future electronics industry it's quite important to understand the future products needs, the technology trend and the social dynamic changing such a seamless information exchanging by light weight and easy handling, portable, clear and vivid visual panel, easy voice controlling, low power consumption, low price, safety security etc. Because the world has been highly intellectualized, safeguarded and politically stabilized, people feel significance of information technology. At the same time high-speed processing accuracy, reliability and saving energy are required to protect the global environment. And it creates the new seamless telecommunication value added society and multi media communication. For these system needs the future system circuit and controlling architecture should be divided and reconstructed into the most optimum subsystem.

Then the suitable subsystem circuit will appear with the maximum performance. This situation should be clear for the future Electronics System Integration by the top down designing. The right and optimum consideration for combining the electronics and electro-magnetic circuit, optic and electro-optics, actual mechanical production engineering and other system controlling technology will support those technology installation with the total designing. This paper is the first FY activity report of E-SI contained the main target items and the E-SI technology trend researching.

2. The system technology trend and needs for E-SI
Technology trend
- Minimizing and the lightest weight.
- High performance with low power consumption.
- Digital processing and networking by smooth communication connection.
- Huge information memory data and its data processing and ultra high speed instruction/transfer.
- Electronics and opto-electronics technology development.
- Total system designing and packaging under the high quality production.
- Minimum energy consumption, EMI/EMC consideration.
- Easy testing, easy repairing and maintenance.

E-SI Project Target Item (Needs for E-SI)
The national project for this Ultra High-Density Electronic System Integration basic technology researching target are the followings.

1. Super-high-density three-dimensional LSI chip Integration technology: (High density 3D stacked Integration)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>① Super High-Dens. 3D Chip Integration Tech.</td>
<td>LSI Chip Stack Forming Process Technology</td>
<td>Stacking, Bonding, Test Basic Tech.</td>
<td>Try &amp; evaluation by through-process</td>
<td></td>
<td></td>
</tr>
<tr>
<td>③ Optimum Circuit &amp; Structure Design</td>
<td>EMI evaluation System Develop. &amp; Test</td>
<td>EMI generator LSI Design &amp; Analyzing</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>④ Market &amp; Tech. Trend</td>
<td>Technology trend &amp; New Market Survey</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
- Stacked LSIs chips with through Holes (less than 10um diameter and 50um depth) in Si substrate.
- The LSI chip will be connected with micro-bumps on the each chip (DRAM & CPU).

2. Opto-electronics hybrid integration technology:
- LSIs with LEDs on the board (mother and daughter-board) with the optical interconnection instead of metal.
- Higher performance of chip to chip will be realized by optical and electronic interconnection technology.

3. Optimum circuit design technology for 3-D and opto-electronics interconnection:
- Solution providing especially Electro Magnetic Compatibility(EMC) problem for 3-D and opto-electronics interconnection

**Relationship between Subjects**

- Opto-Electronic Multi Chip Module of 100 G bits throughout
- 3D Stacked LSIs
- 3D Structured Optical PCBs of 1 T bits throughout with Opto-Electronic MCMs

**Fig. I** Ultra High-Density E-SI project target

3. Current situation of the E-SI project

**High density 3D stacked Integration**

- Through Via: Research and trial of technology candidates showed the possibilities for through hole electrode formation.
- Chip Thinning: Grinding damage characterization and dry etching test showed damage-free possibilities.
- Chip Stacking: High accuracy bonding for 20um-pitch, comparison of bonding method (metallurgical, non-metallurgical), 3-5um gap encapsulation were tested.

**Fig. II** Through Hole Formation by RIE

- Inspection & Test: CSAM and X-ray inspection was tested 40um-pitch probing with Si-whisker was tested.
- Design: Thermal analysis revealed bump / encapsulation / substrate effects for heat dissipation. Structural analysis indicated small stress value but specific concentration in bump areas.

**Fig. III** Hole: 10um Sq. 25 Depth

**Fig. IV** Stress reduction by Dry Etching

- Chip Stacking: High accuracy bonding for 20um-pitch, comparison of bonding method (metallurgical, non-metallurgical), 3-5um gap encapsulation were tested.

**Stacking and Testing**
- Flip-chip Bonding:
  HAB: Micro-bump joint was achieved in 20mm pitch.
  UFB, CBB: Fundamental metallurgical bondability was confirmed in 100mm pitch
- Encapsulation:
  No Metallurgical: Anisotropic interconnections are hard to apply to 20mm pitch, and NCP is selected as one of the main encapsulation process.
  Underfill: Low viscosity resin with no filler realized the encapsulation of the narrow gap between the die and the interposer in 20mm pitch.
- Structure Design:
  Thermal: TH electrodes were not so effective compared with the thermal bumps, while the interposer thermal conductivity was the dominant factor.
  Electrical: TH electrodes are excellent for high frequency module, although TH dielectric thickness effects capacitance.
Thermal: In case of the thin device, the die stress is concentrated above bump. At any other point, no distinct stress was observed especially for Si Interposer.

-Probing & Inspections:
Probing: Silicone whisker probe was selected, and the required overdrive was confirmed from the stand point of the contact resistance to the gold plating.
Internal Inspections: IR, SAM, and X-ray were evaluated detecting the defects on the bump and the underfill resin in 20mm pitch, which were necessary to be optimized.

Opto-Electronic Packaging Technology
Large OE-MCM board:
- Fundamental research is the main activity for the optical parts, materials, sub-assembly and clarify the R&D items by 3D optical Packaging trial model as this project target.
- Fluorinated polyamide multi-channel optical waveguides with low-loss down to 0.3 dB/cm
- Film-lamination method for economic and simplified fabrication for MCM
- Photo-bleaching technology for further cost-reduced and simplified manufacturing of MCM
- High-precision 40 channel optical alignment-free assembly using multi-chip batch self-alignment
- Right-angled coupling between Optical devices and waveguides using Si “Pyramidal mirrors”

Large size and low loss OE-Board: (Size: ~600mm, Loss: <0.05dB/cm, Throughput: ~ 500Gbit/s)
- Interconnect with Opto Connectors, and Opto Devices by two way of optical fiber and polymer waveguide.
- Bending waveguide connector and Crank optical path connector has been also investigated.
- Bookshell structure optical Bus for Tbits troughput and Skew generation mechanism and dominant factors have been studied.

Optimum circuit design technology
EMI/EMC matter:
Fundamental technology development has been investigated for solving EMC problems of 3D-LSI chip and Opto-electronic packaging
- Development of EMI probing technology with 10 μm space resolution and high-frequency response.
- Development of EMI reduction technology to satisfy VCCI standard class B without shield box.
- LSI design has been studied for programmable noise generation by CMOS gate array of 0.35 μm process with separated power supply system of core from that of I/O and noise generating circuits by core and I/O circuits.

4. Conclusion
- Though this E-SI project research has started only 1 year ago, there found a lot of new possibility in the 3D stacked LSI chip technology, opto-electronics device packaging and interconnecting technology and the optimum circuit design and analyzing EMI/EMC technology for the new seamless information network society.
This activity has been expected to a huge contribution to creating a big new value added market and new mobile wearable electronics and optics combined system in near future. As this project will have the middle range check and evaluation by the NEDO in 1.5 year, the researcher will make their all efforts for installing the foundamental technology progress in this E-SI field.

Acknowledgments

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Reference


