Heterogeneous Integration Roadmap

Highlights from M&S

• State of the art
  • High Fidelity Models: FEA, CFD, FDTD
  • Lower Fidelity Models: Compact models...
  • Point analysis tools

• Example of Challenges
  • Electrical – SI/PI die-die coupling, parasitics.
  • Thermal & Mechanical – Hot spots, Warpage..
  • Multi-physics – Mobility shifts, Migration
  • System-Level models – fast/accurate models
  • Reliability – Physics of Failure
  • Materials – Stochastic behavior
Heterogeneous Integration Roadmap

Modelling and Simulation Techniques

- Electrical analysis
- Thermal & thermomechanical
- Mechanics & multiphysics modeling
- Multi-scale modeling
- Machine learning/AI
- System-level modeling
- Material characterization
Heterogeneous Integration Roadmap
Moving towards a New Paradigm

TODAY
- Chip Design Flow
- Package Design Flow
- System Design Flow

Future
- Chip Design
- Package Design
- System Design

Co-Design
- Electrical Analysis
- Thermal Analysis
- Mechanical Analysis

Modelling & Simulation
Multi-Physics
Moving towards chiplets

• Multi-domain/co-simulation requirements
• Large design space for multi-objective optimization
### Heterogeneous Integration Roadmap

#### Modeling & Simulation

<table>
<thead>
<tr>
<th>Scale:</th>
<th>Devices (nm)</th>
<th>Packages (um-mm)</th>
<th>Boards (mm-cm)</th>
<th>Systems (cm-m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data:</strong></td>
<td></td>
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<tr>
<td>Materials</td>
<td>Manufacturing Characterization; Mission Profiles, etc</td>
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<tr>
<td><strong>Electro-thermal interactions:</strong></td>
<td></td>
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<tr>
<td><strong>Thermal:</strong></td>
<td>• Joule Heating</td>
<td>• Passive/Active cooling</td>
<td>• Hot spots</td>
<td>• Thermal resistance</td>
</tr>
<tr>
<td><strong>Electrical &amp; Optical:</strong></td>
<td>• Signal/Power Integrity</td>
<td>• EMI/Crosstalk</td>
<td>• Parasitics/Signal delays</td>
<td>• Optical attenuation</td>
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<tr>
<td><strong>Electro-mechanical/chemical interactions:</strong></td>
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<tr>
<td><strong>Mechanical:</strong></td>
<td>• Stresses</td>
<td>• Fatigue</td>
<td>• Warpage</td>
<td>• Metal-migration</td>
</tr>
</tbody>
</table>

**Design for Manufacture, Performance, Reliability & Robustness**

**Thermo-mechanical interactions**

**Model Fidelity:** Analytical, Circuit/Network, Compact/Response Surface, MOR, MD/FEA/CFD

**Model based Optimization; Big Data Analytics; Physics of Failure Models; Prognostics; etc.**
Heterogeneous Integration Roadmap

Potential Solutions

Advanced solvers (CPU, CPU-GPU, Cloud AWS, and DSA).

Multi-scale modeling

AI/ML applications

Advanced multi-scale material characterization.
EDA suppliers are enabling multiphysics and system co-design solutions through on-going developments:

- No single tool can do it all.
- Modular architecture to 3rd party simulation tools
- Open access data formats
- 3D-ADK’s
• Chip-package-board interactions
  • Floor planning, Shielding
  • TxV locations
  • Design of cooling structures
  • Chip-package interactions
  • Package Board interactions

• Multi-physics aware design
  • Electro-thermal
  • Thermo-mechanical
  • Physics of Failure

• AI enhanced design space exploration

T. Brandtner et-al, "Chip/Package/Board Co-Design Methodology Applied to Full-Custom Heterogeneous Integration," ECTC, 2020
Heterogeneous Integration Roadmap

Applications

MEMS

Reliability

Manufacturing Process

Composite Materials

Digital Twin
Digital Twin

- Digital Twin is the ultimate aim of product design, reliability and lifetime management.
- Modeling and Simulation plays a vital role in digital twin realization.
Heterogeneous Integration Roadmap

Plans for next edition

• Plans for next edition
  • Expand/revise current sections
  • Strong theme for Chiplets
  • New section on photonics
  • New Section on Process Modelling

• Current linkages with TWG’s
  • Co-Design (Need for fast analysis)
  • Single and Multi-Chip
  • Automotive
  • Mems and Sensors
  • Reliability
  • Thermal
  • Supply Chains
Ensuring Roadmaps Align

Chapter 14: Modeling and Simulation

For updates, visit http://eps.ieee.org/hir
TWG Members & Contributors

- Chris Bailey (University of Greenwich)
- Dale Becker (IBM)
- Xuejun Fan (Lamar University)
- Dhruv Singh (Apple Inc)
- Rajen Murugan (Texas Instruments)
- Nancy Iwamoto (Honeywell)
- Willem van Driel (Signify & TU Delft)
- Przemyslaw Jakub Gromala (Bosch)
- Sven Rzepka (Fraunhofer ENAS)
- Kuoning Chiang (National Tsinghua University)
- Abhijit Dasgupta (Univ Maryland)
- Manuel Smeu (Univ. Binghamton)
- Dhruv Singh (Apple Inc)
- Satish Kumar (Georgia Tech)
- Robert Rao (Microchip)
- William Chen (ASE)
- Kouchi Zhang (TU Delft)

We welcome new participants

Contact:
- Przemek Gromala: przemyslawjakub.gromala@de.bosch.com
- Chris Bailey: Christopher.j.bailey@asu.edu
- Xuejun Fan: xfan@lamar.edu

Visit our M&S Panel at EuroSime

https://www.eurosime.org/