ECE/MSE/ME 6776: Microelectronics Systems Packaging
Spring 2024

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Office Hours: Thursday 3:30-4:30 PM
TA: Shane Oh (shaneoh@gatech.edu)
Class time: TH 2-3:15 PM
Class Location: Klaus 1447

Text Book:
- Will supplement the course with journals and conference proceedings

Course Overview:
Course overview: Monolithic silicon integrated circuits (ICs) have progressed at an unprecedented rate of innovation in the past 60 years through Moore’s Law. During much of these 60-years, electronic packaging played a ‘secondary-role’ – the package was there to enable simple space transformation and routing of interconnects off-chip. This, however, has changed. Today, advanced packaging and heterogeneous integration have evolved to be critical enablers to the next phase of Moore’s Law. It is widely accepted that classical monolithic integration can no longer simultaneously meet performance, power, and cost needs of future electronics, and thus, giving rise to the ever more critical fields of “advanced packaging” and “heterogeneous integration.” In this class, we explore traditional packaging technologies and emerging new heterogeneous integration architectures based on 2.5D and 3D integrated circuits. This class will explore these important new integration technologies along with understanding some of the electrical, thermal, and thermo-mechanical design considerations. The course material is both very timely and exciting given the revolutionary changes happening today in IC design and technology.

Grading:
Homework: 10% (graded based on effort)
Exams: Two in class exams each 22.5% (45% total)
Project: Written proposal: 30%
Proposal class presentation: 15%

Exams: There will be two exams during the semester. All exams are closed book and closed notes. You may bring one US letter page (8.5 by 11 inches, one side) of handwritten notes and formulas to each of the two exams (along with a scientific calculator).
Project: **Written Proposal**

The course project is designed to educational, useful, and fun; the objective is to write a research proposal! The goal of the proposal is for you to pick a topic that most interests you in the field of packaging and to write a mock NSF research proposal on it (instead of NSF 15-page limit, we will do 5-page proposals – excluding executive summary; references not included in page limit). Think of this as your opportunity to propose a topic of research for your MS/PhD degree to a potential thesis advisor and/or funding agency (including fellowship applications). We will strictly follow NSF proposal writing guidelines. The written proposal grading will be split into three parts:

**Part 1:** (5% of written proposal grade)
- Topic selection: Short paragraph on the topic of choice and why

**Part 2:** (25% of written proposal grade):
- 1-Page executive summary of intellectual merit and broader impact of your proposed research

**Part 3:** (70% of written proposal grade):
- The relevant prior work in your chosen area (2-pages)
- The broader impact of your research (1 page)
- The intellectual merit of the proposed research (2 pages)

**Proposal Class Presentation**

You will make an in-class presentation addressing intellectual merit and broader impact of your proposed research. The presentation length will be based on class size. This will be determined during the semester.

Course Topics Include:
- Traditional interconnection approaches: wirebonds and flip-chip
  - Traditional packaging
  - Discuss technology and pros/cons
  - Electrical and thermal design considerations
  - Material attributes
  - Fabrication and processes
- Package substrates
  - Organic
  - Ceramic
  - Glass
  - Silicon
  - Polymer (flexible electronics)
- Emerging 2.5D and 3D IC Technologies
- Discussion of technology options
- State of the art (products and research)
- Fabrication and technology considerations
  - TSVs
  - Polymer bonding
  - Oxide bonding
  - Cu-Cu
  - Hybrid bonding
- Fan-out wafer-level packaging
- Electrical modeling
  - Parasitics
  - S-parameters; [RLCG] extraction
  - HFSS overview and modeling
  - Various interconnect technology modeling and benchmarking
  - High bandwidth density digital signaling design considerations
  - Power delivery design considerations
- Thermal challenges and opportunities
  - Thermal modeling
  - Impact of temperature on electronics
  - Overview of cooling technologies (conductive and convective) and benchmarking
  - State of the art demonstrations/products (Google TPU, Microsoft immersion cooling, etc)
- RF/mm-wave and photonic packaging
  - Unique challenges
  - Design considerations
  - Material properties
  - Examples of state of the art
- Thermomechanical design considerations
  - Materials, stresses, warpage in 2.5D and 3D IC technologies
Projected course schedule is shown below.

<table>
<thead>
<tr>
<th>Week</th>
<th>Topic</th>
<th>Notes</th>
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<tbody>
<tr>
<td>8-Jan</td>
<td>Welcome and Introduction to Field</td>
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<tr>
<td>15-Jan</td>
<td>Packaging Technology Evolution: Wirebonds, Surface-mount, flip-chip</td>
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<tr>
<td>22-Jan</td>
<td>PCBs, Packages, and Interposers: Technologies and Design Considerations [HFSS Demo]</td>
<td>Project: Topic Selection [Thursday]</td>
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<tr>
<td>29-Jan</td>
<td>PCBs, Packages, and Interposers: Technologies and Design Considerations [HFSS Demo]</td>
<td>Project: Proposal 1-Page executive summary due [Thursday]</td>
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<tr>
<td>5-Feb</td>
<td>PCBs, Packages, and Interposers: Technologies and Design Considerations</td>
<td>Project: Proposal 1-Page executive summary due [Thursday]</td>
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<td>12-Feb</td>
<td>3D ICs: Technologies, processes, design considerations</td>
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<tr>
<td>19-Feb</td>
<td>EXAM 1 on Tuesday</td>
<td>Exam 1 on Tuesday Feb 20th</td>
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<tr>
<td>26-Feb</td>
<td>3D ICs: Technologies, processes, design considerations</td>
<td>Thermal design and cooling technologies for electronics</td>
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<td>4-Mar</td>
<td>Thermal design and cooling technologies for electronics</td>
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<tr>
<td>11-Mar</td>
<td>Design for Thermomechanical Reliability</td>
<td>March 13 Withdraw deadline</td>
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<td>18-Mar</td>
<td>[No classes]</td>
<td>Spring Break</td>
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<td>25-Mar</td>
<td>Fan-Out Wafer Level Packaging</td>
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<td>1-Apr</td>
<td>Exam 2 on Tuesday</td>
<td>Exam 2 on Tuesday April 2nd</td>
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<tr>
<td>8-Apr</td>
<td>Class presentations</td>
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<tr>
<td>15-Apr</td>
<td>Class presentations</td>
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<tr>
<td>22-Apr</td>
<td>Class presentations</td>
<td>Final Instructional Class Days April 22 23</td>
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<tr>
<td>25-Apr</td>
<td>[No Final Exam; project due latest by final exam day]</td>
<td>Written proposal latest date by 5:30 PM on Thu Apr 25</td>
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