Project Call for Participation: PLP Fine Pitch Substrate Inspection/Metrology, Phase 4

January 20-21, 2022

Feng Xue, IBM
Joe Zhihua Zou, Intel
Charles Reynolds, IBM

Listen to the recorded webinar

YouTube: https://youtu.be/N2GLkoOaipw
Other video: http://thor.inemi.org/webdownload/2022/Projects/PLP_fine_pitch_inspect-4_cfp.mp4

iNEMI Project Manager: Masahiro Tsuriya
Agenda

• Introduction of Project Chairs
• iNEMI Project Development Process
• Project Briefing
  • Background
  • Objectives
  • Scope
  • Timeline
  • Resource
• How to Join
• Q&A

Note: All phones will be on mute until the end of the presentation
Introduction of Project Chairs

Feng Xue (IBM)
Job title: Senior Technical Staff Member
Experience:
• 17 years experiences in semiconductor technology, quality management and supply chain operation
• Current role as Chief Architect for Supply Chain Quality System & i4.0 Solutions
• Member of IBM Academy of Technology

Joe Zhihua Zou (Intel)
Job title: Principle Engineer, Ph.D.
Experience:
• 19 years experience in semiconductor technology of R&D on substrate manufacturing, metrology, inspections and testing, quality control, 3D packaging as well as supplier chain management
• Currently program manager as 3D packaging R&D and next generation metrology on advanced substrates

Charles Reynolds (IBM)
Job title: Senior Technical Staff Member
Experience:
• More than 30 years experience in packaging design and development
• Currently focuses on CSP development
iNEMI Project Development Process

1. CONCEPT
2. DEFINITION
3. PLANNING
   - iNEMI Technical Committee (TC) Approve SoW & PS
4. LAUNCH
5. EXECUTION
6. CLOSURE

“Initiative”
Open for Industry input

“Project”
Limited to committed Members
iNEMI Project Management Policy

• Two governing documents for projects
  • SOW (statement of work): sets out project scope, background, purpose, benefits, and outlines required resources, materials, processes, project schedule, etc.
  • Project Statement (PS): signed by participating companies to secure commitment on resource and time contributions.

• iNEMI Project requires iNEMI membership
  • Signed membership agreement
  • Commitment to follow iNEMI By-laws and IP policy
Project Briefing
Project Background

- Heterogeneous SiP packages are popular as an electronic packaging solution. In addition, circuit boards are incorporating high-dense circuit patches and layers to support increased signal requirements. This technology requires finer circuitry patterns and designs. However, it is difficult to validate and measure the designed line width and spaces, and to detect defective features.

- Measurement capability on fine line (<10um) and space (<10um) on panel sized substrates/interposer impacts both yield and performance capability. Fine line and space capabilities provide high density interconnects which supports the advanced package technologies for multiple components integration.

- iNEMI initiated the project Fine Pitch Circuit Pattern Inspection Metrology in 2016. In Phase 1 of the project, the team conducted an industry-wide survey to assess the readiness of measurement and inspection capability for fine circuit pattern substrates. The survey was completed in February 2017.

- Phase 2 was started in March 2017, in which an inspection capability study on a glass-based test vehicle and a silicon wafer-based test vehicle was conducted. The test vehicles (TV) were designed with fine pitch pattern trace widths from 10um nominal down to 1um nominal, and associated defect designs such as excess copper and missing copper. The defect sizes are varied from 10%, 30%, 40%, 60%, and 80% from the nominal values. The phase 2 project was completed in February 2020.

- phase 3 was started in March 2020, in which a similar test vehicle design used in Phase 2 was used for fabricating an organic substrate TV for measurement capability study. The Phase 3 project was completed in September 2021.

- Team continues to work on this project as Phase 4 to update the readiness of measurement and inspection capability for fine pitch pattern substrate. Phase 4 will also include the planning of fabricating 5um, 3um, 2um and 1.5um design rule for TV sample as part of recommended next step from Phase 3.
Key Element for AOI Measurement

- **Optics:**
  - High Resolution/ Selectable Magnification is needed

- **Light source:**
  - Adjustable light source / angle / color filter(s) to enhance contrast

- **Alignment:**
  - Perform comparison from AOI product image to design requirements to validate results and avoid defect false alarms

- **Inspection policy:**
  - Assess different algorithms to fit different materials and design

- **Filter:**
  - In order to separate the defects, auto filtering is needed to categorize the defects into predefined groups.

- **Type of Analyses:**
  - Inspection: Detection of any variation based on given requirement.
    - Comparing against Reference (CAD or Golden Reference Image)
    - Comparing against Fixed Values (Absolute Reflection Values)
    - Comparing against Neighborhood
  - Metrology: Measuring of defined Objects
    - Absolute Measuring (Measuring the dimension of a defined Object)
    - Overlay Measuring (Position of defined Objects to each other or Reference Point)
  - Post Processing:
    - Analyzing data based on given Models (coplanarity for Bumps)
    - Process Control based on feedback of variations over Lots/Time
    - Generating Maps and Reports
Sample of Phase 3 Results

<table>
<thead>
<tr>
<th>Unit-Top</th>
<th>A</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>J</th>
</tr>
</thead>
<tbody>
<tr>
<td>10um</td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>8um</td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>6um</td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>4um</td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
</tr>
<tr>
<td>3um</td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
<td><img src="#" alt="Image" /></td>
</tr>
</tbody>
</table>
Sample of Phase 3 Results
Project Objective

Motivation:
- With the deployment of finer pitch substrate features in advanced packaging (SiP, 2.5D etc), there is a need to identify and characterize the capabilities of inspection technologies that can enable faster process development and higher yield in volume production.
- Continue from phase 3 to expand the study for 1.5um to 5um designed organic TV.

Objective:
- There are two steps for this project.
- Step 1 is to conduct the industry survey to understand what are changed form previous survey results conducted in 2016.
- Step 2 is to evaluate current inspection & measurement capabilities for fine pitch substrates that will be needed over the next 5 years.
  - AOI measurement and inspection studies includes the various defects types and also the narrow trace widths.
- Assess the AI assisted AOI inspection system and readiness for finer trace patterning.

Strategy/Approach:
- Identify the potential fabricator who could make phase 4 test vehicle sample with below 5um line space design.
- Design and Fabricate Test Vehicle on organic substrate (using Phase 3 TV design as the base reference). Design for TV contains trace width nominal of 5um, 3um, 2um and 1.5um with various defects levels for mouse-bite and protrusion.
- Understand and quantify the automatic optical inspection (AOI) capability limitations for the fine pitch patterns and defects on TVs
- Compare with AOI metrologies and identify the different capability results among the AOI systems.

Longer term:
- Analyze the measurement data and compare the data with AOI equipment type and other metrologies and TV substrate types.
### Project IS/IS Not

<table>
<thead>
<tr>
<th>This Project <strong>IS:</strong></th>
<th>This Project <strong>IS NOT:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project Phase 4</strong></td>
<td></td>
</tr>
<tr>
<td>Evaluate defects at intermediate level (in build at organic laminate material)</td>
<td>Develop new inspection and measuring equipment machine/systems</td>
</tr>
<tr>
<td>Review the measurement capabilities by different equipment and test vehicle.</td>
<td>Conduct the qualification efforts on specific metrologies at a specific company</td>
</tr>
<tr>
<td>Provide the technology readiness for fine pattern circuit boards</td>
<td>Develop a specific standard(s)</td>
</tr>
<tr>
<td>Create recommendation for the metrology</td>
<td>Repeat prior or existing work</td>
</tr>
<tr>
<td></td>
<td>Biased towards specific suppliers, geographies, or market segments</td>
</tr>
<tr>
<td></td>
<td>Involve any devices/assembly process and not involve any reliability test</td>
</tr>
</tbody>
</table>
Proposed experiment plan for phase 4

Design the test vehicle
- Nominal dimension: 5um, 3um, 2um, 1.5um
- Establish test nets for E-test

Test vehicle fabrication
- Use organic or polyimide base material (glass?)

Test vehicle verification:
- Verify the fabricated TV sample quality (trace widths, defects shape and sizes) with high resolution metrologies
- CMM/SEM/X-section for dimension verification
- Warpage measurement

Inspection Companies:
- Invite the contributors from phase 3
- E-test correlation

Note:
The TV design would be updated per the project members.
Timeline starts from the project sign-up when the participating team members are confirmed.

### Task 0 Kick-off

#### Step 1: Study Industry Survey:
- Task 1-1 Set up new survey questionnaire
- Task 1-2 Conduct the survey
- Task 1-3 Analyze and summarize survey results

#### Step 2: Design the test vehicle
- Task 2-1 Design the test vehicle
- Task 2-2 Evaluate the test vehicle fabrication capability

#### Step 3: Conduct the AOI Inspection Study:
- Task 3-1 Test vehicle fabrication
- Task 3-2 Test vehicle verification
- Task 3-3 Inspection & Measurement of Test vehicle
- Task 3-4 – Publish the Project Summary

<table>
<thead>
<tr>
<th></th>
<th>Q1</th>
<th>Q2</th>
<th>Q3</th>
<th>Q4</th>
<th>Q5</th>
<th>Q6</th>
<th>Q7</th>
<th>Q8</th>
<th>Q9</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Step 0</strong></td>
<td>x</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Step 1:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 1-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
</tr>
<tr>
<td>Task 1-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Task 1-3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Step 2:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 2-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Task 2-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td><strong>Step 3:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Task 3-1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Task 3-2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Task 3-3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Task 3-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>
Resources and Risks

**Present Participants:**
- IBM, Intel, Unimicron, AT&S, Ibiden

**Potential Participants:**
- Inspection Contributors: equipment manufactures from phase 3

**Risks:**
- TV design restriction risk is low
- Inspection resource restriction risk is low
- Challenges to fabricate the TV samples
  - *Should the test vehicle fabrication capability for 2um/1.5um be determined as "not ready", the project would be put on-hold. Assessment will be done every 6 months till a capable fabricator is confirmed*
How to Join
Sign-Up Due on **February 25, 2022**

- iNEMI membership is required to join the project
- Download SOW and PS from iNEMI web:
  - [https://www.inemi.org/content.asp?admin=Y&contentid=733](https://www.inemi.org/content.asp?admin=Y&contentid=733)
- Sign the PS
  - Signature of representative of participants
  - Signature of manager approval
  - Send scanned PS to [m.tsuriya@inemi.org](mailto:m.tsuriya@inemi.org)
  - iNEMI Vice President of Technical & Project Operations will sign and approve your participation and send you back the completed PS with acceptance
- Join iNEMI membership, or questions, contact Masahiro Tsuriya ([m.tsuriya@inemi.org](mailto:m.tsuriya@inemi.org))
Q&A