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iNEMI Statement of Work (SOW)
Packaging TIG
iNEMI Holistic Modeling Process for Packaging Substrates Project

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Basic Project Information

Purpose of Project

This project will seek to establish validated processes for modeling substrate properties such as warpage, electrical, thermal, and reliability performance. Additionally, the project will provide some predictability regarding the usefulness of a new material without the need to fabricate and test a complete substrate. This will enable the industry to eliminate from further consideration all materials that are clearly not suitable for use, saving time and money.

Goals include development of material property guidelines, correlation of methodology with experimental data, and evaluation of the feasibility of developing custom modeling tools.

This project will consider and complement ongoing experimental projects wherever possible.

Scope of Work

The first phase of the project will encompass the following:

- Identification of the material properties required to enable adequate modeling of substrate based packages. This will include substrate materials, underfills, lid attaches, solder masks, mold compounds, and all other components of the various packaging systems. This information will be required in order to facilitate development of appropriate warpage, reliability, thermal, and electrical modeling.
- The test techniques and standards for measuring the properties of these materials will be identified with specific recommendations provided where necessary to ensure high accuracy and repeatability between measurement sites.

- Preferred modeling techniques will be proposed for modeling the performance characteristics of the package such as warpage, reliability, thermal, and electrical characteristics.
- Specific test techniques to be used to validate the model results and characterize the final substrate product will be recommended.

Dependency

This work is predicated on the assumption that there will be sufficient participation from the industry to make the decisions required within the scope of this project. If it is found during the course of this project that additional data is required, this Statement of Work would be modified to include any additional information. The modified SOW would be submitted to the iNEMI Technical Committee for approval prior to committing the project team to the new tasks identified.

Return on Investment

This project proposes to justify the changes to the current models by demonstrating a tangible return on investment. To this end we will present a ROI estimate using the following criteria:

Criteria:

- Impact if work is not done
  - Many material selections are made based on modeling results. When the modeling results are wrong or don't represent the real devices, the modeling can result in the wrong decisions. These in turn can slow product introduction. Some estimates have shown that being 3 to 12 months late to market can result in 25% to 90% loss in sales. In a worst case scenario, if a high volume product misses its product window, potentially $20M - $500M in direct sales can be lost, as well as lost growth opportunities and major customer relation disruptions.
  - When models can't be trusted, additional costs are accrued due to the need to test extra legs to ensure success. Additional legs on a high complexity device can easily add $100k or more per leg to a qualification. Trusted models can be used to avoid or minimize these costs.
  - When models aren't available or are not trusted, over engineering can occur, resulting in higher priced products. For example, if $1 is added per package in over engineering on a part with a market opportunity of 1M devices, $1M in profit can be lost to the supplier or $1M+ of added cost passed on to the customer.
- Benefit to industry, as well as participating companies (cost, quality, yield, efficiency gained, process or test time, quicker diagnoses of issues, other resource savings, prevention of class failures)
  - Trusted models can drive the selection of appropriate material properties, and thus the design of new materials to meet these material properties. With materials available off the shelf for new package introductions, development time can be reduced by 3 to 9 months.
  - Trial and error approaches to qualification of high complexity parts can be minimized, speeding time to market and reducing the size of the design of experiments (DOEs) which otherwise must be run.
  - Accurate models can minimize potential qualification failures which might otherwise jeopardize a product introduction.
- Basic calculation of ROI would be performed using "typical" products

Previous Related Work

Existing software modeling tools by themselves are not adequate to predict the behavior of new materials and packaging systems that are rapidly entering the marketplace. Models need as inputs accurate material properties. They also require specific analysis methodologies be applied. When a model does not provide a completely mechanistic description of a phenomenon, such as solder fatigue or interfacial delamination, modeling methodologies which correlate to the "failure" parameter are needed. Differences or errors in both material property inputs and methodologies can result in invalid modeling conclusions which are worse than useless in that they can possibly eliminate valid materials and process candidates. Although much work has been done in the measurement of materials, there is generally no set of uniformly applied standard test techniques from vendor to vendor, nor an understanding of what is needed for modeling. As such, each customer of the materials vendors must analyze the test methodologies used and judge for themselves the accuracy of the data they are receiving. Additionally, since there is not a uniform set of validated modeling methodologies and model validation techniques, any users of a model must judge for themselves the accuracy of the modeling output.

The work planned in this project will help to end (1) the unavailability of required material properties, (2) the uncertainty in the quality of the material properties measured, (3) the uncertainty of the modeling methods used, and (4) the uncertainty of the modeling results. Essentially, there has been no industry wide effort to remedy this situation.

Prospective Participants

3M (supplier)

Akrometrix (supplier)

Altera (user)

AMD (user)

Amkor (user)

ASE (user)

Atotech (supplier)

Berquist (supplier)

Chomerics (supplier)

Cisco (user)

Cookson (supplier)

Delphi (user)

Dow Electronic Materials (supplier)

Dow Corning (supplier)

Elite Materials (supplier)

Endicott Interconnect Technologies (substrate)

Freescale (user)

Henkel (supplier)

Hitachi (supplier)

HP (user)

Ibiden (substrate)

IBM (user)

Infineon (user)

Intel (user)

ITEQ (supplier)

Kyocera (substrate)

Lenovo (user)

Lord (supplier)

LSI (user)

Namics (supplier)

Nanya Plastics (supplier)

National (user)

NIST

Nitto-Denko (supplier)

NTK (substrate)

Renesas (user)

Rogers (supplier)

Shinetsu (supplier)

Shinko (substrate)

ST (user)

STATS ChipPAC (user)

TI (user)

Toppan (substrate)

TSMC (supplier)

UMC (supplier)

Phase 1 Project Plan

Task	Holistic Modeling Process Project	Quarters						
		Q1	Q2	Q3	Q4	Q5	Q6	Q7
1	**Access project resources and adjust timeline accordingly**							
2	**Identify and assess current modeling tools for applicability and identify companies to engage**							
3	**Identification of material characteristics to be evaluated. This should be one package type that has been projected to be a market need in 2-4 years.**							
4	**Identify the tests recommended for each material**							
5	**Develop a set of recommended modeling methodologies**							
6	**Specify material measurement techniques**							
7	**Recommend modeling validation techniques**							
8	**Summarize and publish results and recommendations**							

The entire project team will consist of a minimum of 2 sub-teams:
Sub-Team 1 – experts who perform modeling of substrate type packages on a regular basis
Sub-Team 2 – experts in materials characterization techniques

Phase 1 – Detailed Information

- **Task 1** – Assess Project Resources and Adjust Timeline Accordingly
    - Resources
        - This task will be addressed by the project team with background in package modeling. The team will evaluate the resources available and will pull in the scheduled if possible. The original schedule was based on the minimum resources needed to accomplish each task. If the team's assessment is that there are not enough resources available, the project could be put on hold until additional team members are added.
    - Materials and Processes
        - This portion of the project requires no funding.
    - Testing Procedures
        - Not Applicable

- **Task 2 –** Identify and assess current modeling tools for applicability
  - Resources
    - This task should be addressed by a knowledgeable team with background in package modeling. The team members should be individuals who perform modeling of substrate type packages on a regular basis, or work closely with team members that do so. (**Sub-Team 1**)
    - Roughly 0.05 man years each will be needed from this team.
  - Materials and Processes
    - This portion of the project requires no funding.
  - Testing Procedures
    - Not Applicable

- **Task 3 –** Identification of material characteristics to be evaluated for each material. This should be one package type that has been projected to be a market need in 2-4 years
  - Resources
    - This task should be addressed by a knowledgeable team with background in package modeling. The team members should be individuals who perform modeling of substrate type packages on a regular basis. (**Sub-Team 1**)
    - Roughly 0.05 man years will be needed from this team.
  - Materials and Processes
    - Material characteristics which are desirable for modeling will be specified. These techniques will relate to core, build-up, underfill, lid attach, solder mask, mold compound, and lid materials. Rationale for the technique requested will be provided to the team in written format.
  - Testing Procedures
    - Not Applicable

- **Task 4 –** Identify the tests recommended for each material
  - Resources
    - This task should be addressed by a knowledgeable team with background in package modeling and materials characterization. One set of team members should be experts who perform modeling of substrate type packages on a regular basis (**Sub-Team 1**). Another set of team members must be experts in materials characterization techniques. (**Sub-Team 2**)
    - Roughly 0.1 man years each will be needed from this team.
  - Materials and Processes
    - Test techniques for core, build-up, underfill, lid attach, solder mask, mold compound, and lid materials will be specified. As such, individuals on the team should be knowledgeable in the types of techniques which are available to generate the requested materials characteristics which come out of Task 3.

    - Any existing standards for test techniques will be evaluated, contrasted, and ranked for applicability and veracity.
  - Testing Procedures
    - Not Applicable

- **Task 5 –** Develop a set of recommended modeling methodologies
  - Resources
    - This task should be addressed by a knowledgeable team with background in package modeling. The team members should be individuals who perform modeling of substrate type packages on a regular basis. (**Sub-Team 1**)
    - Roughly 0.3 man years each will be needed from this team.
  - Materials and Processes
    - Time will be required from each member company to (1) share the methodologies they are currently using to run these types of models, (2) share what they would like to see on an industry wide basis, and (3) discuss potential options. Modeling required will be:
      - Thermal
      - Electrical
      - Thermomechanical
        - Warpage
        - Delamination
        - BLR-TC
        - Drop
        - TC
    - Round robin modeling technique development will be required to ensure that, given a set of geometries and material inputs, each company is able to reproduce similar results using their modeling tool set.
      - Should include selecting at least two specific packages which will be tested in Task 7 below.
        - One package may not be enough to capture the physics involved. Two different package constructions are recommended.
      - Will be packages readily available on the market.
      - Might be a package which some participants have already modeled.
    - When differences arise in the modeling results determined by the round robin tests, each company needs to be able to share the details of their methodologies and meshes.
    - Multiple rounds of analysis are foreseen to ensure "standardized" methodologies are developed.
    - Goodness of the methodology for new package types should be highlighted.
      - Any weaknesses in the methodology should be documented.

    - Multiple iterations with Task 5 expected.
  - Testing Procedures
    - Not Applicable

- **Task 6 –** <u>Specify material measurement techniques</u>
  - Resources
    - This task should be addressed by experts in materials characterization techniques. (**Sub-Team 2**)
    - Roughly 0.3 man years each will be required from these experts to evaluate the tests to be characterized.
  - Materials and Processes
    - Test techniques for core, build-up, underfill, lid attach, solder mask, mold compound, and lid materials will be evaluated.
    - The materials set of the package selected in Task 2 will be the highest priority.
    - Testing in dry and moisture saturated environments will be needed.
    - Samples of materials must be made available by the members.
    - Time must be allocated for testing the materials samples.
    - Some round robin testing of a single set of materials is envisioned to ensure repeatability from lab to lab.
    - Where repeatability in a test technique is not achieved, discussion will be held to determine possible causes for differences.
    - Additional round robins will be run as needed to ensure a set of repeatable test techniques.
  - Testing Procedures
    - Test will include DMA, TMA with abilities to measure X, Y, and Z characteristics
    - Moisture characteristics such as moisture swelling, moisture diffusion rates, moisture impact to CTE and modulus, etc., will be determined.
    - Adhesion test techniques will be tried and compared. Materials samples and preparation will be needed from members. Adhesion of underfill to die surfaces and to substrates will be needed.
    - Fatigue properties of Cu traces will be measured.
- **Task 7 –** <u>Recommend modeling validation techniques</u>
  - Resources
    - This task should be addressed by a knowledgeable team with background in package modeling. The team members should be individuals who perform modeling of substrate type packages on a regular basis. (**Sub-Team 1**)
    - Roughly 0.1 man years each will be needed from this team.
  - State source of funding for any components, assembly, design, and testing needs.

- Materials and Processes
  - Select the most appropriate validation techniques for each modeling output parameter:
    - Thermal
    - Electrical
    - Thermomechanical
      - Warpage
      - Delamination
      - BLR-TC
      - Drop
      - TC
  - Characterize the specified package of Task 2 according to these techniques and compare to the models of Task 2. This will require that a member company manufacture a package for the test purposes as a first step.
  - It's envisioned that the results of this task will be completed before Task 2 completes to enable a feedback loop.
- Testing Procedures
  - Digital image correlation (for warpage)
  - Shadow Moiré (for warpage)
  - Laser profilometry (for warpage)
  - Stylus profilometry (for warpage)
  - Dye and Pry, Cross-sectioning (for solder joint reliability)
  - Strain Gage measurement (for shock/drop evaluation)
  - CSAM (for delamination)
  - Theta JC, JB, JA (for thermal characterization)
  - Others

- **Task 8 –** Summarize and publish results and recommendations
  - Resources
    - One member, likely the team leader, will pull together reports from the various tasks as the final summary.
  - State source of funding for any components, assembly, design, and testing needs.
  - Materials and Processes
    - The full project team needs to review the final summary document, making corrections and addendums.
  - Testing Procedures
    - Not Applicable

Project monitoring plans

This project falls under the general category denoted as Research, i.e., given an idea or concept, research projects explore and investigate new processes. The outcome is a set of processes that could be used in a production environment if proven to be production worthy. These projects may include some preliminary reliability testing; however, the main focus is on identifying and demonstrating the feasibility of a process.

Project monitoring plans are as follows:

- Ensure open lines of communication among participants
    - Weekly conference calls
    - Meeting minutes provided through e-mail
    - Follow-up with individuals on an as-needed basis
    - Workshops and face-to-face meetings as appropriate

- Technical reviews and progress reports at regularly scheduled iNEMI meetings.

- Track and document approximate Man-Months per quarter per team member (this will require the active members of the team to provide estimates).

- Track and document approximate number of people on the project per quarter (this can be tracked through iNEMI's WebEx account).

- Project results, including Best Practices Guidelines, test conference presentations, technical papers, end-of-project webinar, etc., will be published on the iNEMI website.

Outcome of the project

- Documentation of methodology and categories needed to develop a validated set of design and simulation tools and material characterization techniques that ensure high performance of newly introduced systems.
- Distribution of the recommended methodologies to industry.
- Establishment of a set of guidelines defining what is needed from material suppliers prior to the development of appropriate models.

General and Administrative Guidelines

General and Administrative Guidelines for this project and all other iNEMI Projects are documented at http://thor.inemi.org/webdownload/join/gen_guidelines.pdf.