iNEMI New Package/ Material Qualification Methodology Project

Survey Results Webinar
July 9, 2019

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iNEMI Overview

iNEMI®

Advancing manufacturing technology

What is iNEMI?

The International Electronics Manufacturing Initiative (iNEMI) is

- a not-for-profit,
- industry-led,
- highly efficient

R&D consortium of approximately 90 leading electronics manufacturers, suppliers, associations, government agencies and universities.

iNEMI

- roadmaps the future technology requirements of the global electronics industry,
- identifies and prioritizes technology and infrastructure gaps, and
- helps eliminate those gaps through timely, high-impact collaborative projects.

Who is iNEMI?

iNEMI Mission

Forecast and Accelerate improvements in the Electronics Manufacturing Industry for a Sustainable Future via Collaborative Innovation

Roadmap	• Anticipate technology requirements • Identify gaps • Focus R&D priorities
Collaborative Projects	• Eliminate gaps • Deliver learning & critical data • Leverage efforts & participants' resources
Forums & Workshops	• Share solutions & best practices • Prioritize key challenges • Network with customers & suppliers

iNEMI Roadmap:

- Full electronics manufacturing design/supply chain scope
- 10 year outlook
  - Update every other year
- Broad global, cross-industry participation
  - > 500 participants
  - > 350 companies/organizations
- 2019 Roadmap
  - Release beginning July 2019

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Collaborative Projects

14 Currently Active iNEMI Projects

Project Name
New Package Technology Qualification methodology
Warpage Characteristics of Organic Packages, Phase 4
QFN Package Board Level Reliability
Impact of Low CTE Mold Compound on Second Level Board Reliability, Phase 2
PCBA Cleanliness
W/PLP Flowability & Warpage
Wafer/Panel Level Substrate Fine Pitch Inspection/Metrology
PCB Warpage Characterization And Minimization
Characterization of Pb-Free Alloy Alternatives
PCBA Materials for Harsh Environments, Phase 2
Conformal Coating Evaluation for Improved Environmental Protection
Development of Cleanliness Specification for Expanded Beam Connectors, Phase 3
Eco-Impact Estimator Update, Phase 3
BiSn Based Low Temperature Soldering Process and Reliability

Project plans, results and presentations available at: https://community.inemi.org/projects_all

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New Packaging Technology Qualification Methodology

Background

- New package technologies are qualified using procedures and test conditions based on past experience with the most similar technology previously qualified.
  - While previous experience is important to consider, it cannot be the only criterion.
  - Relying too much on experience may result in overlooking new failure modes and/or new wear out mechanisms.
  - Current test standards may not capture the reliability risk in the new package or may overstress the technology in the new package.
- Lack of understanding of the assembly processes, application environments, and use conditions of all potential end-users (vs targeted end-users) poses challenges when developing the appropriate reliability test plan for new package/materials.
  - Test plan only focuses on standard test methodology or complies with the requirements of a few key customers.
  - For new technologies field knowledge (failures, issues, etc.) cannot be fed back into the test plan.
  - For new materials/package development, test plan completeness is always questionable.
  - Proceeding quickly to device qualification in the new package may delay determination of root cause for technology issues for the new package.
  - Little effort by industry to come out with a new test standard for new packaging technologies.

Purpose of Project

- The purpose of this project is to develop a methodology for qualifying new packaging technology to address the gaps resulting from:
  - Lack of understanding of assembly processes.
  - Lack of understanding of the interactions of the materials and components within the new package.
  - Lack of understanding of the application environment.
  - Lack of understanding of the use conditions of all potential end-users.
  - Lack of understanding how variations of the packaging and manufacturing process could affect product quality and reliability.

Project Leaders

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iNEMI New Package/ Material Qualification Methodology Project

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July 9, 2019

Presenter:
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Curtis Grosskopf - IBM

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Contents

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Introduction

- During iNEMI's 2016 Substrate & Package Technology Workshop in Singapore, the following was identified as a major gap in the packaging industry
  - Lack of understanding of the assembly processes and application environments of all potential end-users (vs targeted end-users) affects development of effective reliability test methodologies for new package/materials development
    - Test plans only focus on standard test methodology and comply to customer requirements
    - Current test standards may not capture the reliability risk in the new package, or may over-stress the new package
    - Data about field failures are not captured in a way that provides feedback to the test plan
    - For new materials/package development, test plan completeness is always questionable
    - Little industry effort to develop new test standards

Introduction

- Past issues with standard test plans when qualifying new technology
  - Variability of bondpad structure and strength for qualification of Cu wire bonding
  - New failure mechanism and unique manufacturing controls for embedded IC packages
  - Are we sure the standard test plan is able to detect and characterize all weak points in a new technology?

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Introduction

- iNEMI officially started the industry project "Methodology for Qualifying New Packaging Technology" in July 2017 to address the gap identified

- The purpose of this project is to develop a methodology for defining qualification plans for new packaging technology to address the gaps resulting from:
  - Lack of understanding of the assembly processes
  - Lack of understanding of the interactions of the materials and components within the new package
  - Lack of understanding of the application environment
  - Lack of understanding of the use conditions of all potential end-users
  - Lack of understanding about how variations of the manufacturing process could affect product quality and reliability

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Introduction

- Project timeline
  - Review of current industry qualification standards - October 2017
  - Completed the generation of the questions for the first survey - March 2018
  - Conducted the first survey – March to June 2018
  - Results and analysis of the first survey presented at IEMT2018 conference in September 2018 in Malaysia
  - Conducted the follow-up survey – Dec 2018 to Jan. 2019
  - Presented summary at ICEP2019 Conference in April in Japan

Current Industry Standards Overview

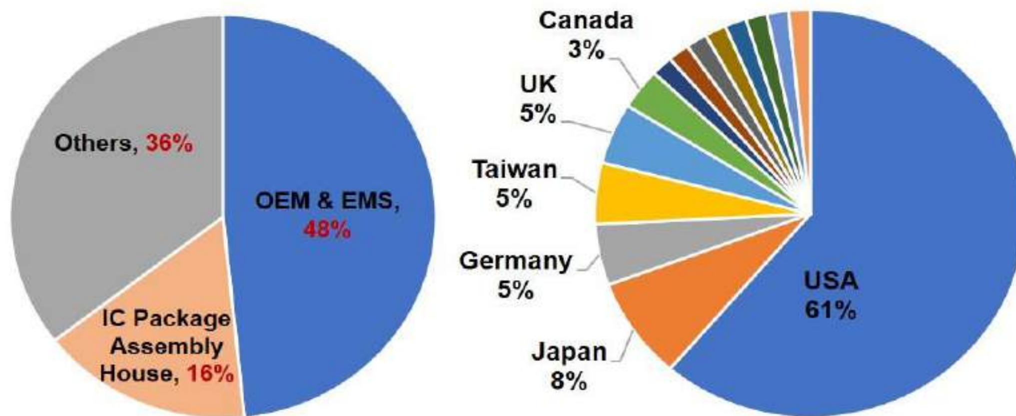
- Several industry standards commonly used to qualify new electronic packages (qualification plans, tests methods, and pass/fail requirements) are shown below
- None of these industry standards addresses
  - The entire process for qualifying a new package technology/material
  - Which industry best practices should be used, e.g.,
    - How to identify best material set
    - Initiate Failure Mode and Effects Analysis (FMEA)
    - Assess all possible customer assembly and field conditions

Standard Number	Standard Title
JESD47	Stress-Test-Driven Qualification of Integrated Circuits
JESD94	Application Specific Qualification Using Knowledge Based Test Methodology
JEP150	Stress-Driven Qualification of & Failure Mechanisms Associated with Assembled Solid State Surface-Mount Components
AEC Q100	Stress Test Qualification for Integrated Circuits
IEC-60749-43	Guidelines for IC reliability qualification plans
Mil-Std-883	Test Method Standard for Microcircuits
Mil-Std-750	Test Methods for Semiconductor Devices

Survey Scope and Respondents

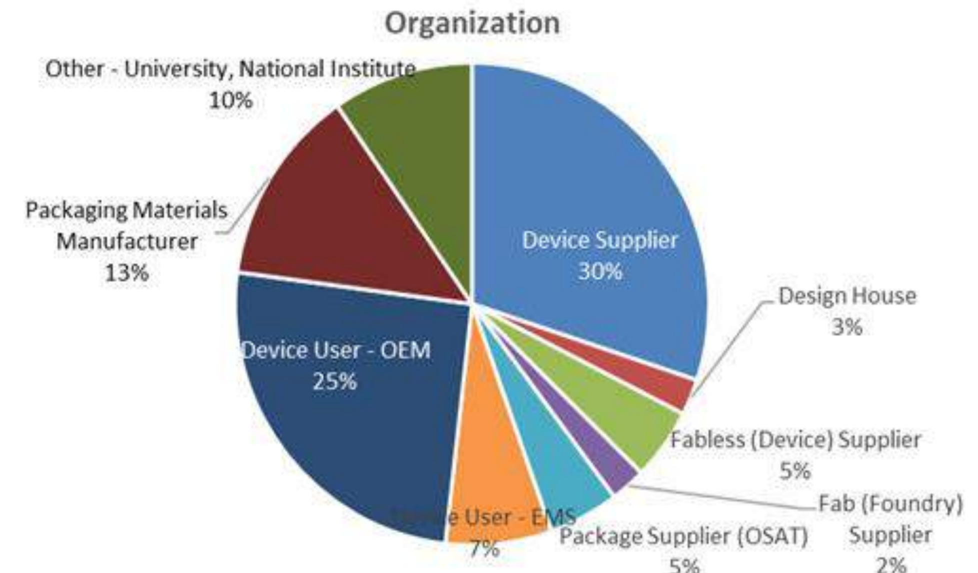
The First Survey

- The first survey consisted of 7 sections covering the qualification requirements and methodologies used to develop and qualify new package technologies and new materials
- A total of 62 responses were received for the first survey



The Follow-up Survey

- The follow-up survey attempted to obtain detailed information in a few key areas, specifically new package technologies and application spaces
- A total of 92 responses were received for the follow-up survey



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First Survey Results

A) Current Methodology to Develop New Packages/Materials

Group by total usage (the % value on the x-axis)

- >75%: Ensure qualification plan including customer's requirement, technical assessment prior to product qualification, and FMEA
- 50%~75%: Computer simulation, FEM, and Test to failure
- <50%: Test ICs

Comparison by group of respondents

- Each group's usage of a specific practice is noted by the % value in each group's color in each bar
- IC packaging houses stated that they used all six of the listed practices at a rate of 75% or higher
- OEMs only had use rates of 75% or higher for three practices
- Only 20% of OEMs use specially designed test ICs instead of product ICs and only 44% perform computer simulation

- These differences may be due to the fact that many OEMs are not involved at the beginning of evaluating new package technologies and materials

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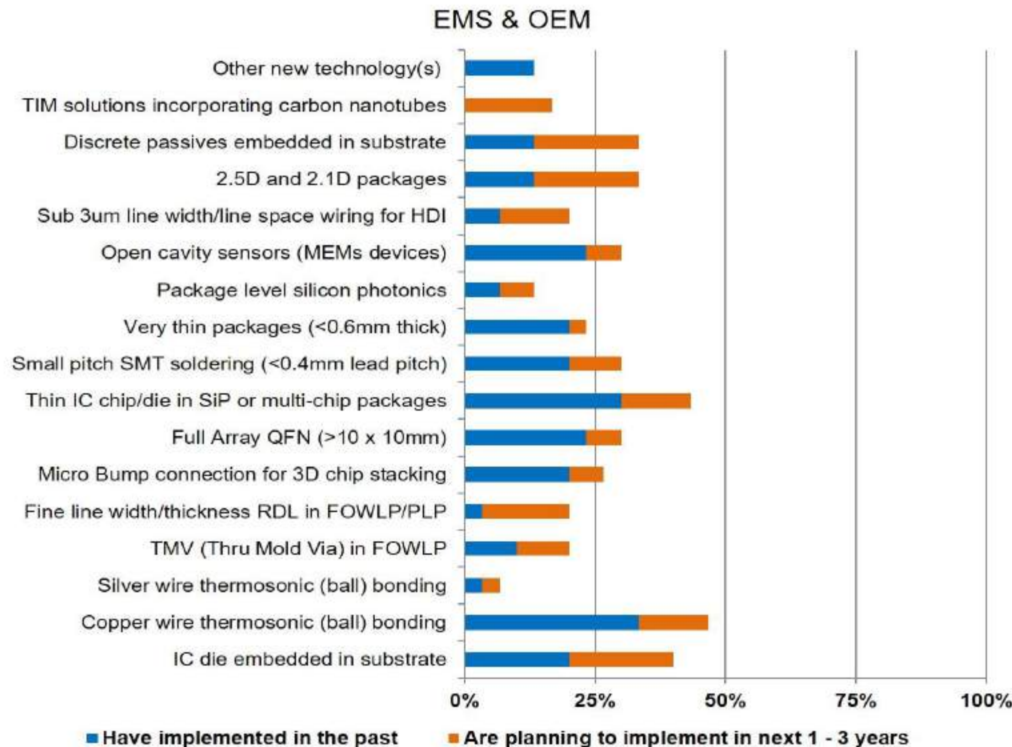
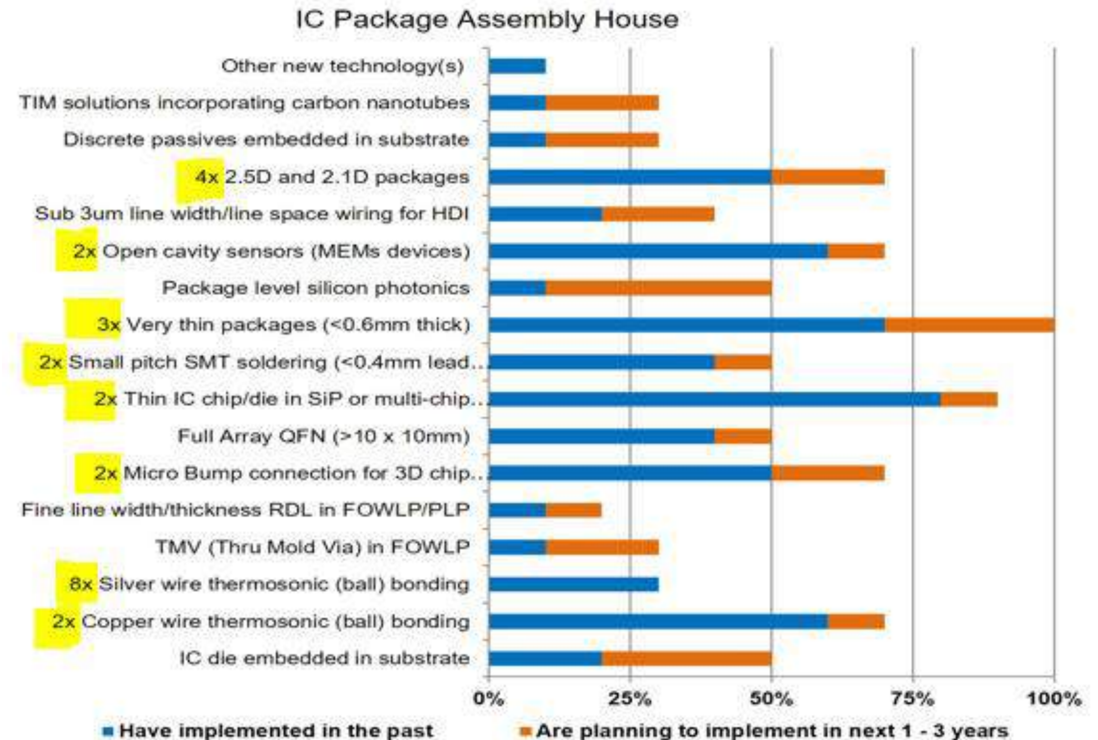
First Survey Results

B) Types of New Technologies/Materials





Discrepancies were also observed between OEMs and IC packaging houses with respect to which new technologies have been implemented or are planned to be implemented

- IC packaging houses reported much higher implementation rates of new technologies
- This difference in implementation rates may be due to OEMs not being aware of the new technologies within the devices they procure
- Another possible reason for the discrepancy could be that some new technologies are only used in niche markets outside of the OEM’s product set

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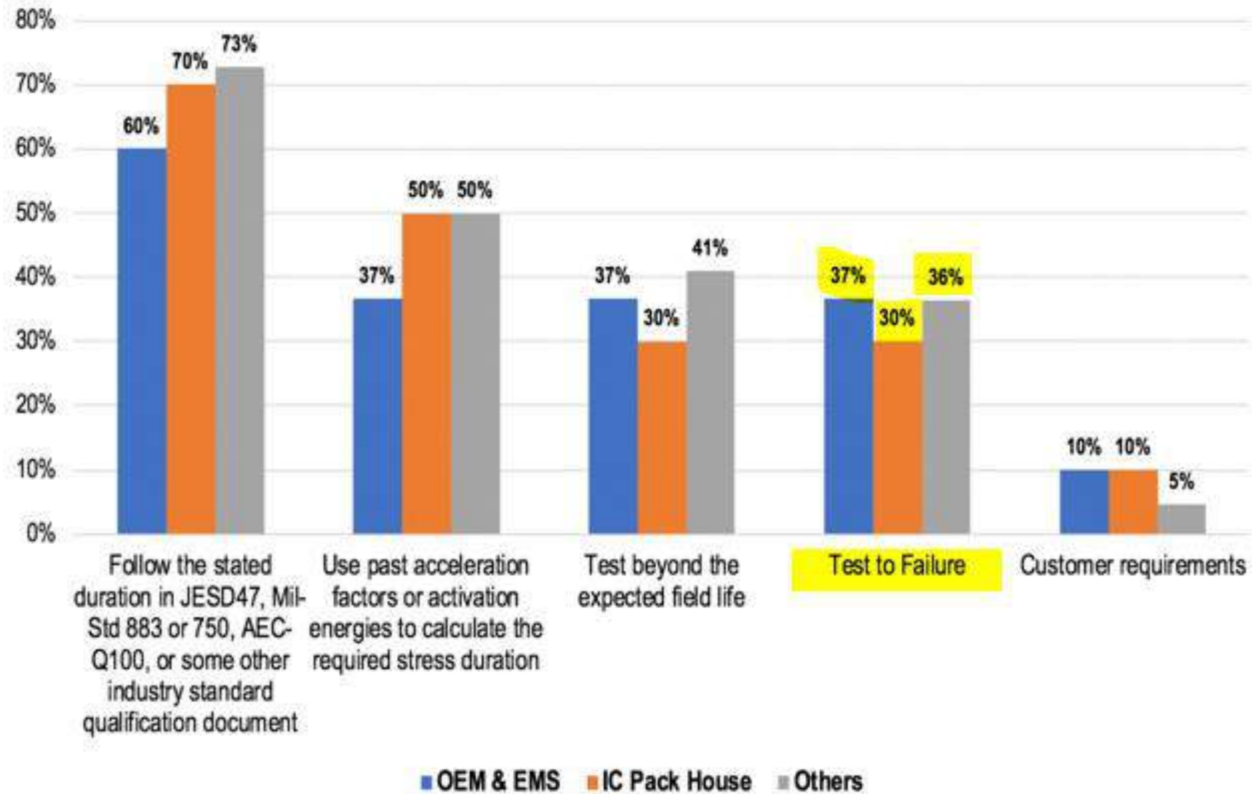
First Survey Results

C) Practices to Determine the Duration of Stress Test



Approximately 1/3 of the respondents from each of the three sectors responded that they test beyond the expected field life and that they test to failure when qualifying new technologies

- This is a significant recognition by the industry that new technologies may require new acceleration models compared to previous technologies
- However, it also implies that a need exists for the remaining 2/3 to possibly reconsider their current practices when qualifying new technologies

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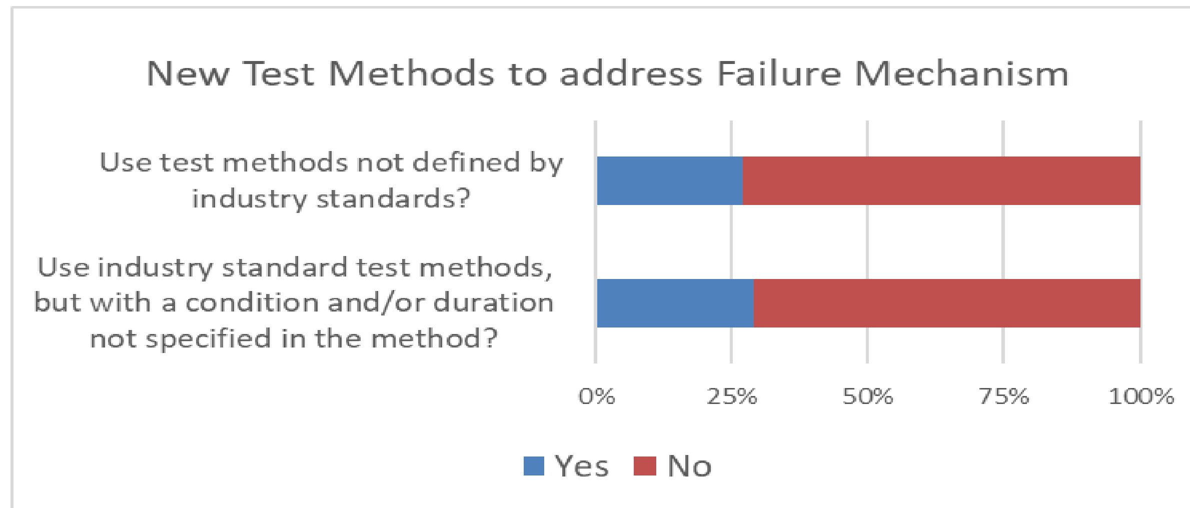
First Survey Results

D) New Test Methods to Develop to Better Address Relevant Failure Mechanisms



- When reviewing the other responses in the survey for the roughly 70% of respondents who answered “No” to both questions
  - 36% stated that the application space requirements of their product exceeded those stated in the corresponding qualification standard
  - 61% saw a need for the industry to develop new test methods to better address relevant failure mechanisms

- This suggests that the industry is aware of issues and opportunities exist to better align qualification methodologies with application requirements

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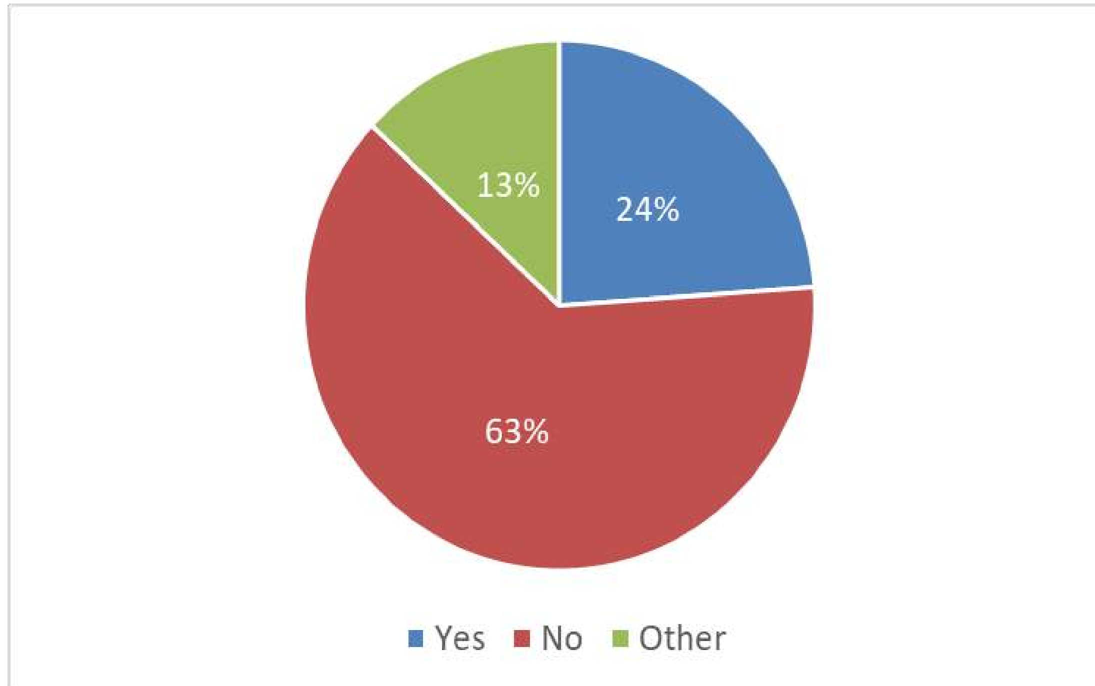
First Survey Results

E) Qualification Report from Suppliers



- This figure shows the responses on whether suppliers provide all the necessary information in their qualification report to their customers (OEMs)
  - Only 24% of the respondents stated they did;
  - 63% stated they did not; and the remaining
  - 13% included responses of "occasionally", "sometimes", and "varies from supplier to supplier"
- This represents a major disconnect between what is provided and what is required with respect to qualification reports.

First Survey Results

F) Qualification Plan Given by Business Partner

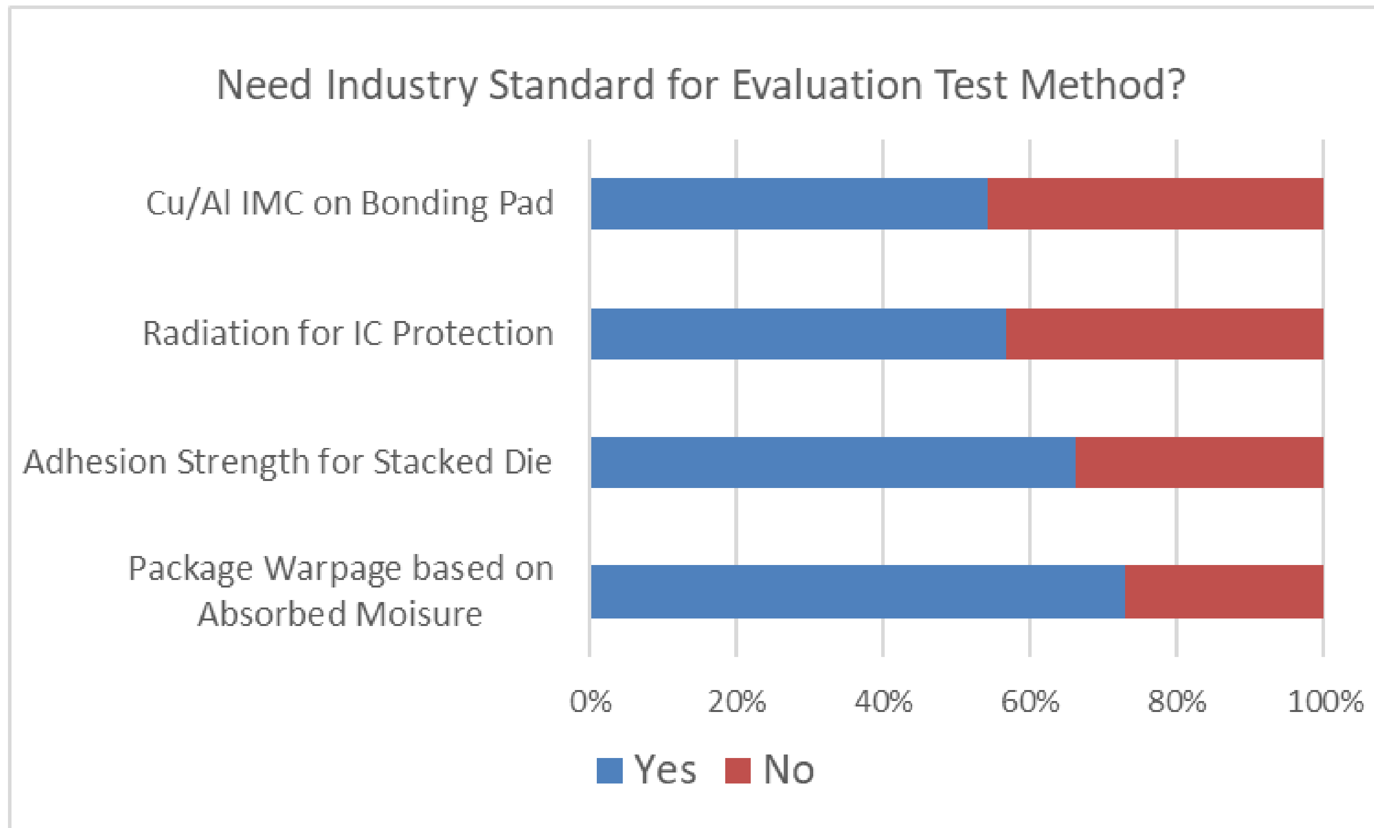
- The last part of the survey attempted to gather information on how qualification plans were generated
- We attempted to understand if customer requirements were incorporated and if the qualification plan included input from customers
- Unfortunately, there were not enough responses for any of the groups (device users (OEM and EMS), device suppliers, fabless device suppliers, OSATs, foundries, and design houses) to be able to make any comparisons or conclusions

Follow-up Survey

- While the survey results provided key insights into current industry practices and validated the gap identified by the iNEMI workshop, a few "surprising" and even "contradicting" observations were made in analyzing the survey responses:
  - The lack of qualification reports
  - The difference in opinion between packaging houses versus OEMs on rate of implementation of new package technologies and materials
  - For the questions that covered application use conditions, several recommendations were made, but it was not clear how widely held those recommendations were within the industry
- Therefore, the project decided to conduct a follow-up survey
- The follow-up survey attempted to address the deficiencies and gaps identified by the previous survey, thus it focused on verifying responses and gathering detailed information in these five areas:
  - A) test methods
  - B) qualification standards
  - C) application temperatures (both use and junction)
  - D) new application spaces
  - E) package qualification methodology tools and best practices

Follow-up Survey Results

A) Needs Identified with Test Method

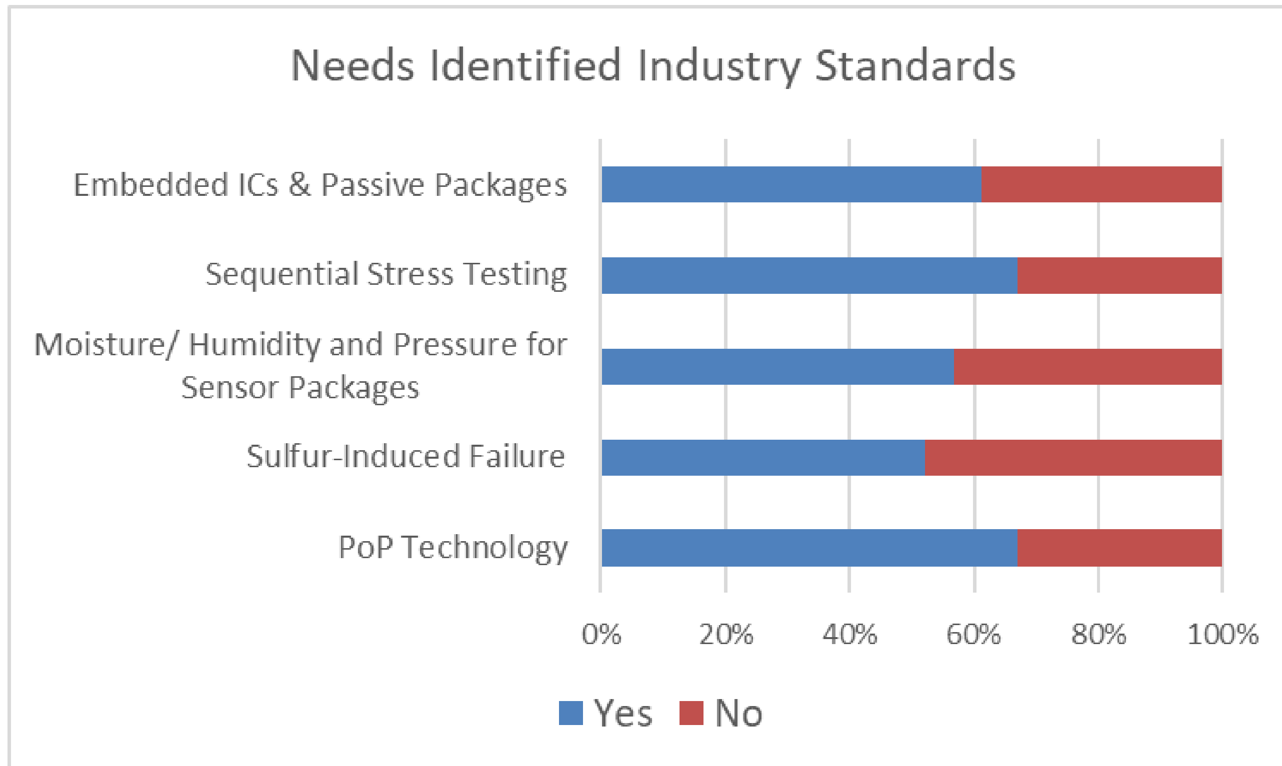


The first set of questions in the follow-up survey asked respondents whether they agreed with recommendations from the first survey that the industry should generate four new test methods.

As all four test methods were supported by more than 50% of the respondents, this project will recommend to the appropriate standards bodies that all four topics warrant consideration for new test methods.

Follow-up Survey Results

B) Needs Identified Qualification Standards



The second set of questions in the follow-up survey asked respondents whether they supported the generation of five new qualification standards.

As all five qualification standards were supported by more than 50% of the respondents, this project will recommend to the appropriate standards bodies that all five topics warrant consideration for new qualification standards.

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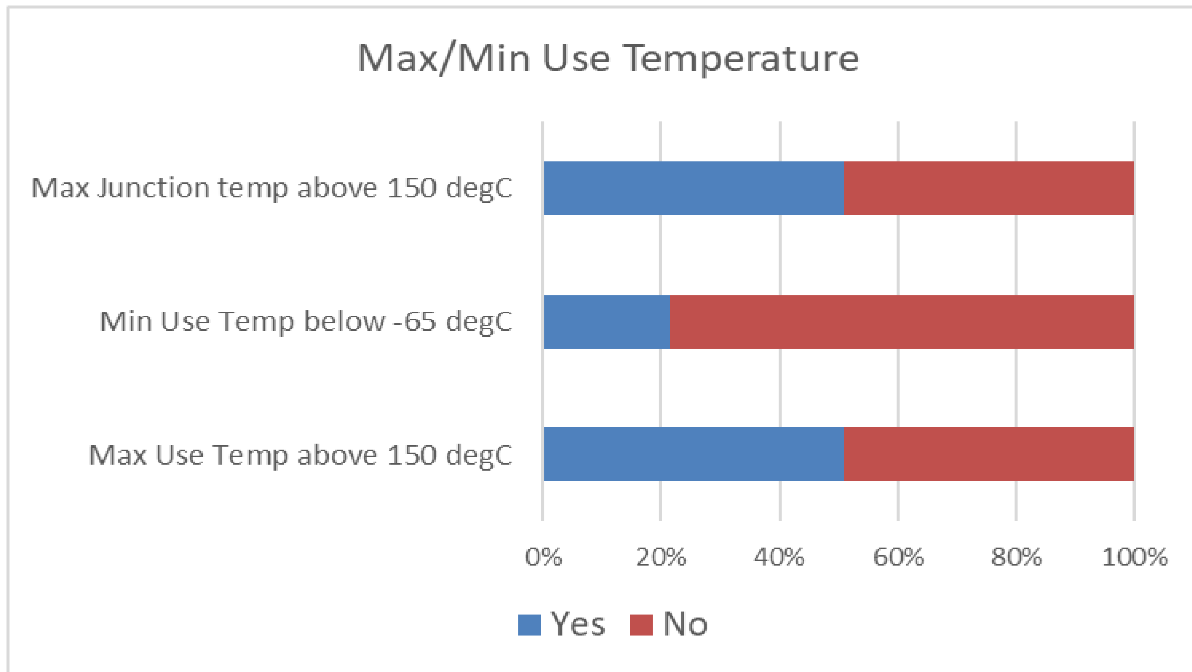
Follow-up Survey Results

C) Application Temperatures



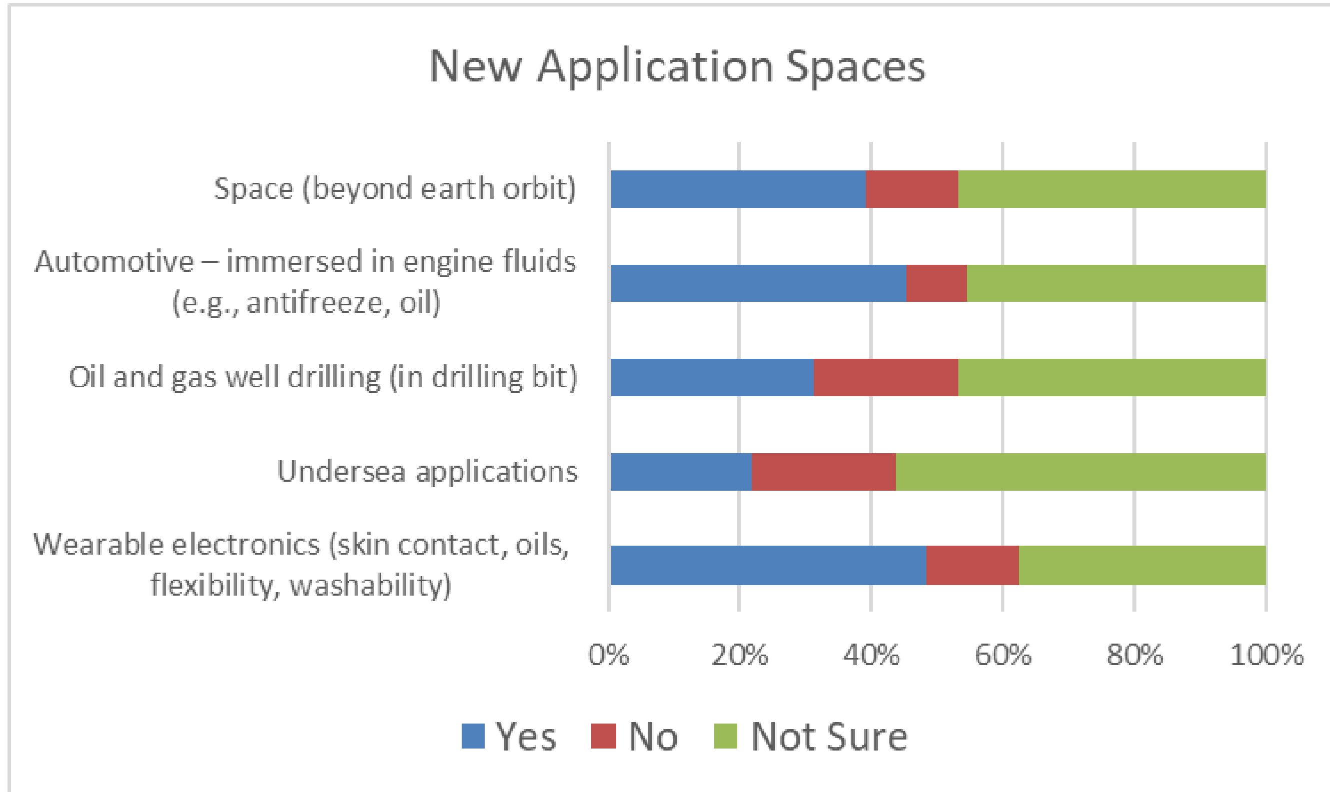
There were a few responses to the first survey that stated that there were applications for electronics that were at temperatures below -65°C or above 150°C (both junction and use), but very few details were provided.

Details gathered by follow-up survey:

- 50% of the respondents confirmed that applications existed where the maximum junction temperature may go above 150°C and/or use temperatures are above 150°C.
- Only 20% stated they were aware of applications in which the use temperature went below -65°C, these included space, Mars, Antarctica, and computers at cryogenic temperatures (e.g., quantum computers).

Follow-up Survey Results

D) New Application Spaces



The follow-up survey assessed the industry's support for these five new application spaces; wearable electronics, undersea, down hole (in well) drilling, automotive – immersed in engine fluids, and space – beyond earth orbit.

Even though the level of support was below 50% for all five questions, the level of non-support was even lower.

- This project will recommend to the appropriate standards bodies or industry organizations that most of these new application spaces warrant their consideration to be added to their qualification documents.

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Follow-up Survey Results

E) New Qualification Tools and Best Practices

- The respondents were asked if they used any other qualification methods, tools or best practices as part of the assessment of new package technologies and materials.
  - Two responses of note were:
    - digital imaging correlation and
    - highly accelerated stress testing to expedite development.

- Though many comments were submitted, most of the recommendations were test methods, not necessarily additional best practices or novel ways to analyze the new technology or material.

- However, the list of comments when assessed as a group, suggested that when developing qualification plans for new technologies or materials, all possible interactions and use applications must be considered and addressed.

Summary

- The results of the two surveys highlighted that there is a discrepancy between supplier and customer knowledge on the use of new technologies and materials
  - This discrepancy highlights the need for greater sharing of information between companies, from end use conditions to qualification results.
  - The awareness of what failure mechanisms could occur with new package technology and how best to test for those mechanisms, can be improved, and would greatly benefit from the generation of an industry guideline of best practices.
  - This difference in understanding and use of qualification methods confirms the need for an industry guideline of best practices.

Summary

- The survey also highlights differences between field use conditions and the qualification stress conditions required to support the use conditions.
  - Respondents highlighted that application use temperatures are rising, with some going higher than the current 150°C upper limits
  - A few going below the -65°C lower limits
  - The fact that survey respondents have extended their test durations indicates an awareness that improvements are needed to industry test methods and the requirements in qualification standards
- Device users pointed out a large discrepancy in what information was provided in a qualification report
  - This highlights the need for better communication across all members of the supply chain from end users back to package development teams.

Next Steps

- Project team to complete its analysis of the responses from the second survey
- Continue to work on the generation of a package qualification methodology (white paper) for new technologies and materials, referencing industry test methods, qualification standards, and industry best practices
  - Plan to assess the completeness of the qualification methodology by reviewing the issues raised in the first survey for industry adoption of copper wirebonding and lead-free soldering and determine how well the methodology would have identified all of these issues if all of the practices described in the methodology had been used
  - Targeting end of 2019 to complete methodology
  - Working group is still accepting anyone willing to help generate the white paper, specifically individuals with detailed knowledge of specific best practices (see next page for partial list)
- It is the project group's intent that this white paper be taken over by an industry standards body, so that it can be published and then maintained and improved over time

Next Steps

- Best Practices or “Tools”:
  - Computer simulation including FEM (Finite Element Modeling) for thermal, electrical, and stress/strain evaluation and for material selection
  - FMEA (Fail Mode and Effects Analysis)
  - Detailed DOEs (Design of Experiments) to assess materials and assembly process parameters
  - 3-step approach: technology assessment, technology qualification, product qualification
  - Specially designed “stress test” ICs (that are more sensitive to know silicon and CPI failure modes) are used for package qualification instead of product ICs
  - Detailed construction analysis, on virgin product and after reliability stress testing
  - Multiple stress cells run at different stress conditions to verify defect modes and calculate acceleration factor
  - “Test to failure” to identify potentially new failure modes and expected life
  - X-ray diffraction imaging for strain/warpage of package and chip/package interaction

Acknowledgement

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