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iNEMI Statement of Work (SOW)
Board Assembly TIG
iNEMI Nano-Attach Project

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Project Leader: Hope Chik (Motorola)
Co-Project Leader: Name

Basic Project Information

This research project is designed to identify and demonstrate electronic assembly using only mechanical means. For example, research activity into dry adhesives has recently accelerated with the newfound understanding of the mechanisms behind the strong adhesive force generated by the gecko (i.e. biomimetic processes). To date, synthetic replication of the gecko's foot has shown promising adhesive properties. This project will first define the requirements necessary to adapt mechanical attachment schemes in electronic assembly. Current available technology will be evaluated, and new attachment schemes will be explored. Proof-of-concept material evaluation and assembled prototype vehicles will be fabricated to demonstrate the feasibility of the attachment scheme.

Scope of Work

The major goal of this research project is to provide an alternative solution to high temperature soldering processes used in today's electronic assembly. Mechanical assembly techniques have been identified as a promising solution.

The project will be divided into 3 phases, namely, the concept development, the proof-of-concept, and the prototype phase. In the concept development phase, mechanical attachment schemes will be identified and evaluated against identified performance attributes. From this, design targets will be formulated and published to the general community to attract further development in this field. The phase one deliverable will a be a White Paper summarizing the technical findings along with results from cost models analyzing the economic viability for implementing mechanical attachment schemes into the electronic assembly process. The projected timeframe for the completion of this phase is 12 months. In phase two, the proof-of-concept phase, an evaluation vehicle will be adopted and subject to identified characterization tests spanning mechanical, electrical, thermal, and reliability tests. At the end of this stage, a White Paper consisting of the test results along with a set of design guidelines for incorporating the mechanical adhesion scheme into existing components and boards will be presented. In the final phase, a prototype will be developed and put through the qualification process for electronic assembly. Development of the supply chain will also be pursued in this phase. The deliverable in this phase will be a prototype device along with a White Paper summarizing the findings of this project.

Since the nature of this project is research based, the phases will be gated with go/no-go junctions. This decision will depend on the findings of the previous phase and an evaluation of the probability of success of the subsequent phase.

Purpose of Project

Current assembly employed by the electronics industry typically follows a process flow as depicted in Fig. 1. The pre-patterned printed wiring boards (PWBs) first have solder paste, consisting of solder and flux, deposited at the desired locations during the screen print stage. Next, the majority of the components are placed onto the PWB using a rapid chip shooter. Odd components are placed using a separate component placement machine. The boards along with the components are then passed through a mass reflow oven.

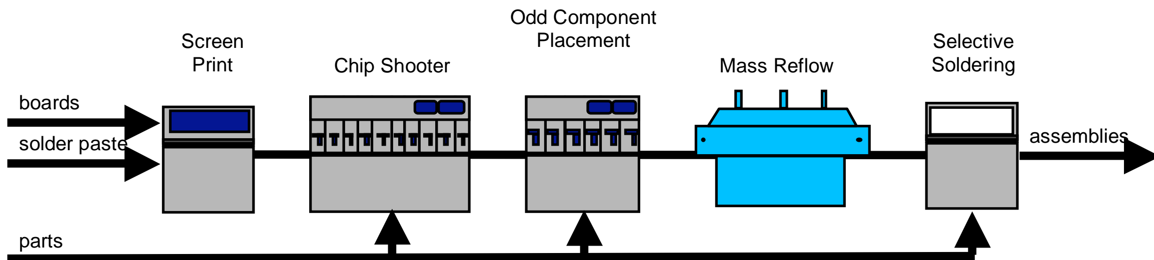

Fig. 1. Typical electronics assembly process flow

This stage involves the use of elevated temperature to bring, in this example, the solder to a liquid form where a permanent joint can be formed between the PWB and the component. Other assembly techniques such as the use of conductive adhesives also require global heating to cure the adhesive. Even laser soldering for single point implementation requires localized heating. All of these techniques introduce thermal excursions and strains increasing the reliability risk to the components and the complete board. This risk has recently been made more profound with the RoHS (Restriction of Hazardous Substances) directive driving the industry to use lead-free assembly processes. This has necessitated the use of even higher mass reflow temperatures reaching a point where thermal process tolerances are considerably tighter and reliability issues may accelerate quickly once the limits are exceeded. Already, temperature sensitive components are being assembled in lower temperature or temperature controlled attachment processes (shown in Fig. 1 by the selective soldering stage) adding to the product costs and reducing the assembly throughput.

The proposed mechanical assembly process would be performed at room temperature. Now, one can envision a more streamlined manufacturing line with the possible elimination of certain stages (i.e. the screen print and mass reflow stage). This could result in substantial cost savings and improved product reliability. New product opportunities for taking advantage of the good thermal and electrical conductivity can also be identified. To achieve that level of proficiency, many technical questions and challenges still remain such as:

- identifying materials that will meet system requirements
- understanding effective techniques to maximize contact area
- developing cost-effective assembly for mass production
- demonstrating reliability

Previous Related Work

The remarkable ability of geckos and other biological species to traverse virtually any surface has long been a fascination with researchers. Recently, a study of geckos by Autumn et al. [1] has raised our understanding of the biomimetic mechanisms behind this adhesive property.

A gecko's foot is comprised of nearly a half a million keratinous hairs called setae. A seta has dimensions of ~100 μm in length and 5 μm in diameter. The ends of each seta split into hundreds of finer hairs with a diameter of only 100 to 200 nm. It is these ends in contact with the various surfaces that are responsible for the adhesion through van der Waals forces [2]. Although van der Waals forces are weak intermolecular forces, if applied in collective unison, the average adhesion force for a gecko's foot could reach 100 N/cm^2.

Synthetic foot hairs composed of silicone [3], polyimide [4], and polypropylene [5] have been fabricated and tested for mechanical strength. Adhesive forces 200 times higher than those of a gecko have been observed at the nanoscale level with carbon nanotube surfaces [6]. Attempts have also been made to better mimic the gecko's foot by forming larger area contacts [7] and device configurations that have the ability to conform to the contours of a surface [8].

An alternative approach to mechanical assembly relying on the interconnection of nano-hooks has been proposed [9]. Results from computer modeling have shown that a 3.0 nN force is required to disengage two carbon nanotube based hooks.

Participants

Boston Scientific: Dale Lee

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Intel: Fay Hua

Motorola: Hope Chik (Project Lead), Marc Chason (Champion)

Project Plan

This section should provide all the available details for each topic.

- Resources
    - Phase 1: see Participants
    - Phase 2: TBD
    - Phase 3: TBD
- Materials and Processes
    - Phase 1: N/A
    - Phase 2: TBD
    - Phase 3: TBD
- Testing Procedures
    - Phase 1: N/A
    - Phase 2: TBD
    - Phase 3: TBD
- Schedules with milestones

			Q1			Q2			Q3			Q4	
	Phase 1: Concept Development												
1	Define requirements for automotive, consumer, enterprise, medical applications												
1.1.	attachment force												
1.2.	detachment force												
1.3.	re-attachment capability												
1.4.	electrical requirements												
1.5.	thermal requirements												
1.6.	assembly process requirements												
1.7.	environmentally friendly requirements												
2	Nanoattachment benchmarking for automotive, consumer, enterprise, medical applications												
2.1.	identify attachment mechanisms												
2.2.	identify materials and chemistry												
2.3.	synthesis/fabrication approaches												
2.4.	define critical variables												
3	Cost analysis for automotive, consumer, enterprise, medical applications												
3.1.	develop generic cost model across industries												
3.2.	delta cost effect analysis												
3.3.	perform return on investment analysis												
3.4.	identify cost-effective implementation strategy												
3.5.	opportunity analysis												
4	Deliverables												
4.1.	publish design targets for industrial development												
4.2.	refine project plan for Phase 2												
4.3.	recruit material supplier to participate in Phase 2												
4.4.	White paper presented to Technical Council												

Phase 1: Concept Development

1. Define requirements for automotive, consumer, enterprise, medical applications
   1.1. attachment force:
      – What is the maximum acceptable compressive pre-load force per unit area necessary to provide adhesion?
   1.2. detachment force:
      – What is the minimum acceptable tensile strength per unit area required to provide electronic assembly grade adhesion?
      – What is the minimum acceptable shear strength per unit area required to provide electronic assembly grade adhesion?
   1.3. re-attachment capability:
      – Define requirements for re-work, if necessary.
      – Does the tensile or shear strength change after re-attachment?
   1.4. electrical requirements:
      – What is the maximum current capacity required?
      – What is the minimum acceptable current density capacity?
      – What is the minimum acceptable breakdown voltage/current, if any?
      – What is the maximum acceptable series resistance?
   1.5. thermal requirements
      – What is the minimum acceptable thermal conductivity per unit area required?
   1.6. assembly process requirements
      – Define size of contact/bonding area required.
      – What type of contact/bonding surfaces will attachment scheme work on?
      – Are the attachment characteristics size and surface dependant?
   1.7. environmentally friendly requirements
      – Is the attachment scheme environmentally friendly?
      – Will it meet RoHS standards?

2. Nanoattachment benchmarking for automotive, consumer, enterprise, medical applications
   2.1. identify attachment mechanisms
      – What types of attachment schemes are available?
      – Do they meet the identified requirements?
   2.2. identify materials and chemistry
      – What material system is suitable for different application categories?

- Is there any prohibitive chemistry due to application/product environment?

2.3. synthesis/fabrication approaches
- What is the state-of-the-art technology?
- What technology is available that will meet our identified requirements?

2.4. define critical variables
- What are the critical parameters in a successful adhesion scheme?
- Are these parameters application specific?

3. Cost analysis for automotive, consumer, enterprise, medical applications

3.1. develop generic cost model across industries
- What parameters should be included in the cost model?
- Can a cost model be developed in a way that will be applicable across all application industries?
- If not, can the cost model be broken down into modules that can be individually included/excluded depending on the application/industry?
- How well will this technology scale?

3.2. delta cost effect analysis
- Perform cost analysis to determine whether the financial benefits outweigh the associated costs.
- Is there an economy of scale breakeven point?

3.3. perform return on investment analysis
- Will the implementation of this technology produce a positive return on investment?
- Are there implementation strategies that will generate a positive return on investment?

3.4. identify cost-effective implementation strategy
- Identify best application fit and implementation strategy.
- Where will this technology have highest chance of success?
- Can this technology be implemented into the electronic assembly process incrementally?

3.5. opportunity analysis
- Are there opportunities for implementation beyond the scope of this work (i.e. electronic assembly)?

4. Deliverables

4.1. publish design targets for industrial development
- Publish design targets derived from Phase 1 findings to generate interest from industry and attract new players to this field or accelerate development from current participants in this space, pending Phase 1 member agreement

4.2. refine project plan for Phase 2
- Refine milestone and timeline for Phase 2 based on Phase 1 findings.

4.3. recruit material supplier to participate in Phase 2
- Identify supplier to provide material used in Phase 2 evaluation vehicle

4.4. White paper presented to Technical Council
- Contains summary of findings from Phase 1 and design targets issued to industry.
- Contains go/no-go recommendation for Phase 2
- Address issue, "Is the technology mature enough to have a high probability of success in Phase 2".

Gate 1: Go / No Go
- *Decision to proceed to Phase 2 on a project level*
- *Decision to participate in Phase 2 on a company level*

Phase 2: Proof-of-Concept

5. Define evaluation vehicle(s)

5.1. down select range of opportunities based on results from Phase 1

5.2. build evaluation vehicle

6. Define materials characterization methods

6.1. mechanical tests

6.2. electrical tests

6.3. thermal tests

7. Performance characterization of evaluation vehicle

7.1. mechanical
7.2. electrical
7.3. thermal

8. Assembly development
   8.1. develop assembly strategies
   8.2. create pad/joint designs

9. Reliability characterization
   9.1. develop reliability plan
   9.2. perform failure analysis

10. Deliverables
    10.1. design guidelines
    10.2. test results
    10.3. develop project plan for Phase 3
    10.4. White Paper presented to Technical Council

Gate 2: Go / No Go

- *Decision to proceed to Phase 3 on a project level*
- *Decision to participate in Phase 3 on a company level*

Phase 3: Prototype

11. Identify test vehicle(s)
    11.1. down select based on results from Phase 2
    11.2. build prototype test vehicle

12. Qualification process
    12.1. develop qualification procedures
    12.2. develop inspection methods

13. Materials manufacturing process development
    13.1. identify raw materials sources
    13.2. process development

14. Assembly process development
    14.1. define baseline targets
    14.2. evaluate deltas to existing equipment sets
    14.3. placement equipment development
    14.4. rework equipment/process development
    14.5. process control definition
    14.6. conversion cost model
    14.7. alternative hybrid process flows

15. Supply chain development
    15.1. nanoattach supplier qualification
    15.2. identify second source

16. Deliverables
    16.1. identified supply chain
    16.2. test results
    16.3. White Paper presented to Technical Council

- Project monitoring plans
  - Planned teleconference every 2 weeks
  - Technical reviews:

        - June 2007
        - December 2007
- Outcome of the project
    - Phase 1 deliverable:
        - publish design targets for industrial development
        - refine project plan and deliverables for Phase 2
        - White Paper presented to Technical Council
    - Phase 2 deliverable:
        - material design guidelines
        - present evaluation vehicle test results
        - refine project plan and deliverables for Phase 3
        - White Paper presented to Technical Council
    - Phase 3 deliverable:
        - demonstrate prototype device
        - present prototype vehicle test results
        - supply chain identified
        - White Paper presented to Technical Council

NOTE: All changes to SOW must be approved by the TC (version control)

Targets:

	Automotive	**Consumer**	**Medical**
Assembly			
Placement speed	*Requirements will be common to all target groups*		
Placement accuracy	> 75% attachment area overlap contact area *(ANSI/J-STD-001A)*		
Attachment area	component pitch: 0.50 mm / 0.65 mm / 0.75/0.80 mm / 1.00 mm; recommended width: 0.28 mm / 0.30 mm / 0.35 mm / 0.45 mm *(JESD22-B111)*		
Coplanarity	<4.7 mil *(JEDEC MO-205)*		
Bond strength: tensile	> 147 mN for single wire-bond *(MIL-STD-883)*		
Bond strength: shear	> 49 mN x (# of bonds) *(MIL-STD-883)* 8.0 MPa for thermal adhesive *(IPC-CA-821)*		
Temperature	23°C (room temperature)		
Preload force	< 100 N		
Cleaning	*	*	*

Attachment area:

component pitch	recommended width
0.50 mm	0.28 mm
0.65 mm	0.30 mm
0.75/0.80 mm	0.35 mm
1.00 mm	0.45 mm

(JESD22-B111)

	Automotive	**Consumer**	**Medical**
Operation			
Temperature range	-40°C to +85°C (Epson USB connector)	-25°C to +55°C	37°C (body temperature)
Humidity range	0 – 100%	0 – 100%	N/A
Thermal conductivity	0.40 W/(M*C) thermal adhesive (IPC-CA-821)	0.40 W/(M*C) thermal adhesive (IPC-CA-821)	0.40 W/(M*C) thermal adhesive (IPC-CA-821)
Electrical conductivity	*	*	*
Power density	*	*	*

	Automotive	**Consumer**	**Medical**
Reliability			
Cycled temperature humidity bias life	ramp 30°C to 65°C in 4 hrs.	ramp 30°C to 65°C in 2 to 4 hrs.	*

	hold 65°C for 8 hrs. ramp 65°C to 30°C in 4 hrs. humidity at 90-98% voltage cycle 50% duty, 10 min period 63 cycles (1008 hrs.) *(JESD22-B-A100)*	hold 65°C for 4 to 8 hrs. ramp 65°C to 30°C in 2 to 4 hrs. humidity at 90-98% voltage cycle 50% duty, 10 min period 63 cycles (1008 hrs.) *(JESD22-A100-B)*	
Temperature cycling	-40°C to 125/150°C 1000 cycles *(JESD22-B-A104)*	-40°C to 125°C 1000 cycles *(JESD22-A104C)/(IPC-9701)*	-40°C to 125°C 1000 cycles *(JESD22-A104C)/ (IPC-9701)*
Power and temperature cycling	extremes: -40°C, 85°C ramp: 5 to 30 min. hold extreme: 1 hrs. power cycle 50% duty, 5 min period 63 cycles (1008 hrs) *(JESD22-B-A105)*	extremes: -40°C, 125°C ramp: 30 min. hold extreme: 10 min. power cycle 50% duty, 5 min period 1000 cycles *(JESD22-A105C)*	*
Thermal shock	5 min immersion in medium at -40°C and transferred within 10 sec. to 125°C medium 1000 cycles *(JESD22-B-A106)*	immersion in medium at 85°C and transferred within 20 sec. to -40°C medium *(JESD22-A106B)*	*
Mechanical shock	1,500g peak half-sine waveform with 0.5ms duration repeated 5 times in all orientations *(JESD22-B-B104)*	1,500g peak half-sine waveform with 0.5ms duration repeated 5 times in all orientations *(JESD22-B104C)*	500g peak half-sine waveform with 1ms duration *(Mil-Std-883,2002A, EN45502-2-2)*
Vibration	1.65 mm amplitude 20 to 2000 Hz traversed in not <4 min. legs repeated 4 times and in each orientation *(JESD22-B-B103)*	1.5 mm amplitude 20 to 2000 Hz traversed in not <4 min. legs repeated 4 times and in each orientation *(JESD22-B103-A)*	2.5g, 6 to 500 Hz, 90 min. each orientation *(EN 45502-1)*
Salt Atmosphere	exposure to salt fog at 35°C for 24 hrs. *(JESD22-B-A107)*	exposure to salt fog at 35°C for 24 hrs. *(JESD22-A107B)*	N/A
Biocompatibility	*	*	Biological Evaluation of Medical Devices Part 1 *(ISO-10993-1)*
Electromagnetic Radiation	*	*	*(ASTM-F-1119-1)*
Ionizing Radiation	*	*	*(ASTM-F-1892-04)*

Ultrasonic Radiation	*	*	2 to 5 MHz, 500 W/m^2 *(EN 45502-1)*
Cyclic Loading	*	*	*

* To be determined

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