Challenges of Next Generation Microelectronic Assemblies for Sensors

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WIRELESS CONNECTIVITY, THE INTERNET, and the cloud significantly influence the new products that are developed today. This "connected" infrastructure for sharing information creates new opportunities for collecting information using sensors. As product application areas expand into niche markets, next generation sensors will have challenges that need to be addressed. Novel materials, custom processes, and size reduction are some of the key performance enablers for new applications. These requirements need to be carefully considered for the microelectronic assembly. When these challenges are properly addressed, new products can be successfully developed at the lowest cost and development time.

Challenge #1

Novel materials—used to functionalize next generation sensors—need to be integrated with semiconductor and microelectronic manufacturing processes. These materials can have chemical, biological, or magnetic properties which are designed to be reactive in application-specific environments. Traditional adhesive cure manufacturing processes, such as heat cure and UV cure for die attach, can render functionalized sensors inoperable. Microelectronic assembly processes need to accommodate these unique requirements with a robust process window that does not sacrifice product design function. Low-temperature cure adhesive, ambient moisture-cure adhesive, and adhesive tape may be used to eliminate the damage from heat and UV during the die attach process.

Using the ***Test Early, Test Often*** approach, and a concurrent engineering model, a study was conducted to compare two room temperature curable adhesives for attachment of a sensitive die that measured 3.35mm square. The design requirement for the die attach was a minimum of 10 kgf shear force (>90% ultimate shear strength). The process requirement for die attach at volume production was to meet the minimum design shear force requirement in less than eight hours to avoid excessive work-in-progress (WIP). Adhesive A and Adhesive B were tested in a side-by-side die attach and cure study. The test data confirmed that Adhesive B was a more suitable die attach solution, and provided the required data for developing an effective and efficient process window for production. (See Figure 1) The next step will be a coarse screening life test of sample parts bonded with Adhesive B to ensure the success of design objectives of fit, form, and function.

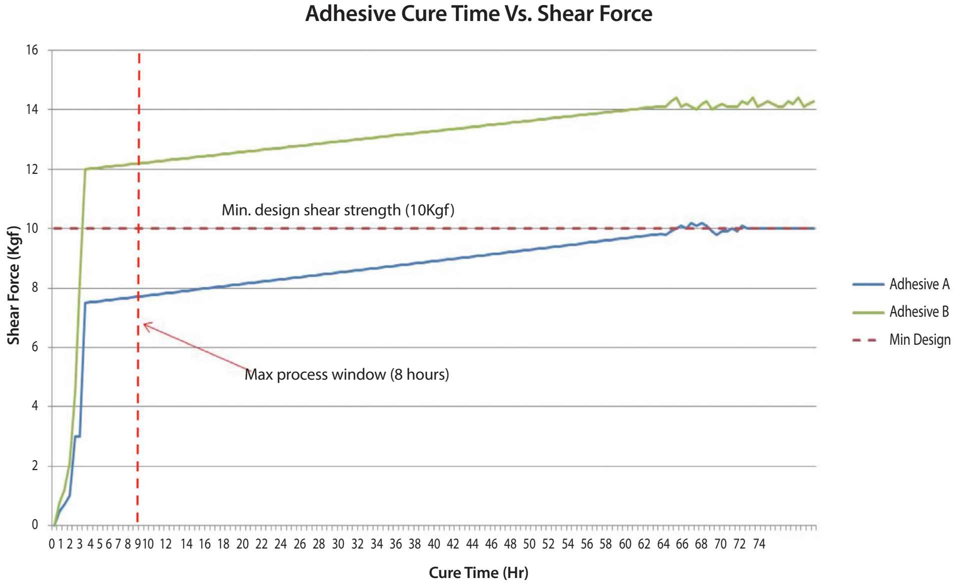

Figure 1. Adhesive die shear results.

Challenge #2

Wire bonding is a commonly used process to create low-cost and reliable electrical interconnects between sensor die and mechanical package assemblies. There are many factors that can affect the quality of the wire bonding process, like bond pad quality and cleanliness. This is not trivial, especially when high temperature (>300°C) manufacturing processes are required for assembling the mechanical package prior to the wire bond operation. Early collaboration between the design and process teams is necessary to converge on solutions that result in a manufacturable product that meets or exceeds the design requirements for the life of the product.

Destructive wire bond shear testing is the best method for quantifying the strength of the wire bond weld because it measures not only the shear strength, but also the weld quality. Table 1 shows a common method for evaluating the wire bond weld quality. The bond quality is rated using a 1-4 quality scale based on how much of the weld interface remains after shear testing. This interface between the wire and substrate is referred to as the "nugget". Figure 2 shows an example of two nuggets, each with a nugget rating of 4. In new product development, shear testing is used as a design of experiment input to develop a robust wire bond process, and in production, this method is used as a statistical process control tool to monitor the process and maintain product yield >99%.

Nugget Rating	Percentage of Nugget Remaining After Shear
1	0-24%
2	25-49%
3	50-74%
4	75-100%

Table 1. Wire Bond Shear Test.

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Figure 2. Sheared wire bonds.

Challenge #3

Empirical data is always needed to validate any theoretical model, and sensor devices are no exception. The function, scale, and form factor of sensors continues to evolve. As the functionalities are expanding, the scale and form factors are shrinking. The continual miniaturization creates competing requirements for microelectronic assembly design and process development, which make it more challenging to collect empirical test data. This presents a unique challenge for testing, where cutting edge, state-of-the-art test capabilities are increasingly essential to the development process.

A capacitive MEMS pressure sensor with a diaphragm that is only 150 μm wide and 950 μm long is shown in Figure 3. Interferometry was used to collect real time deflection data of the diaphragm over various pressure ranges. (See Figure 4) A change in mechanical deflection, of 0.1 μm in the Z direction, was measured. The diaphragm deflection data was correlated with the electrical output signal of the MEMS pressure sensor. This empirical data was used to optimize the design of the MEMS sensor diaphragm structure. The data was also used to effectively characterize the sensor response curve.

As new, connectivity-based products emerge, their value will be derived from real-time information that is provided by sensors. The demand for these products will continue to increase along with new requirements for their market segments. Design and manufacturing challenges related to the microelectronic assembly of next generation sensors can be accommodated without sacrificing product design function. Whether it is a novel material, a custom process, or a unique test, the microelectronic assembly is the critical path for a sensor solution that gets your product to the market.

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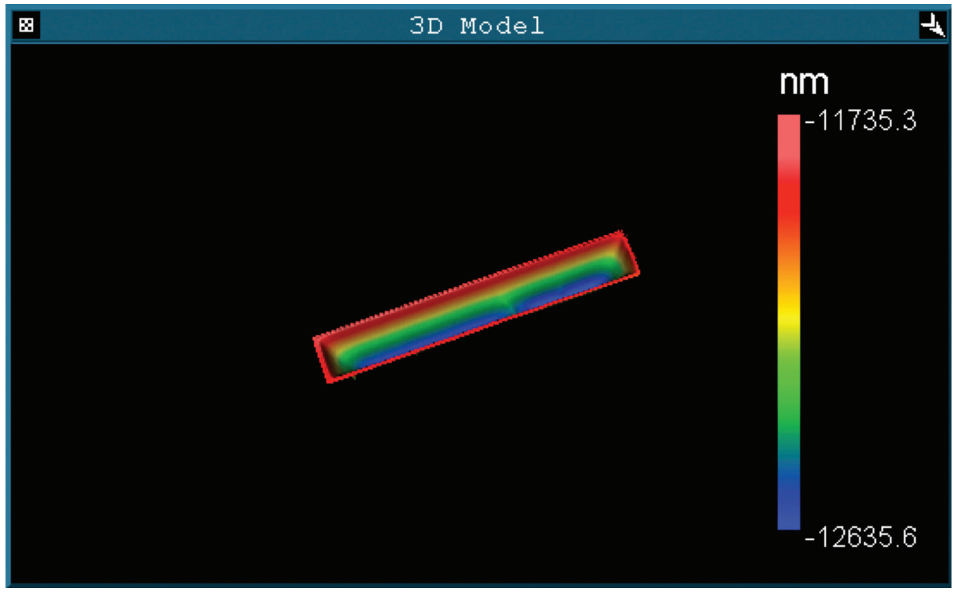

Figure 3. 3D model of MEMS diaphragm.

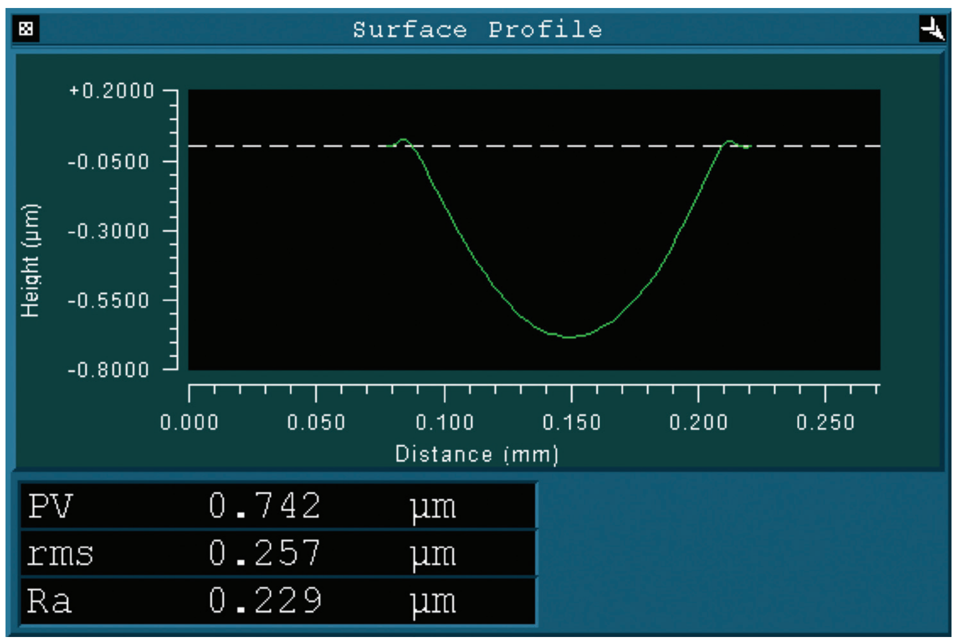

Figure 4. Cross-sectional view of deflection depth.

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