MASTERBOND®
CASE STUDY

Flexible EP37-3FLF Adhesive Excels in E-Textile Packaging Study

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Electronic textile (e-textile) technology, in which microelectronics is embedded into fabrics, has spawned an exciting new class of products that can be used in the fashion, medical, military, and other industries. Examples of applications under research are real-time gas detection in wearable systems, electronic mats that melt ice on roofs, and physiological monitoring garments that measure heart rate, respiration, and temperature. To ensure these smart textiles maintain the look and feel of traditional fabrics as much as possible, they typically employ flexible electronic circuits. In real-world use, wearable e-textiles will be subject to motion, bending, and the jarring effects of washing. Such activity will impose shear and bending forces on the embedded electronic circuits, potentially threatening reliability and performance.

The challenge for e-textile packaging engineers is to maximize the reliability of the embedded circuits while keeping the package as thin and flexible as possible. The flexibility of an electronic circuit depends on the materials used for the substrate, components, and interconnections that make up the circuit, as well as the dimensions and configuration of these materials. Many e-textile circuits use adhesives to attach electronic die to substrates or to serve as stress-reducing underfills in flip chip assemblies. It is critically important that the adhesives used in e-textiles offer sufficient flexibility and bond strength in order to ensure reliability under conditions of bending and other movement.

Master Bond EP37-3FLF

Master Bond EP37-3FLF is an exceptionally flexible epoxy compound that forms high strength bonds that stand up well to physical impact and severe thermal cycling and shock, making it ideal for e-textile applications. Because it is flexible and produces a lower exotherm — heat released during the polymerization process — than conventional epoxy systems, EP37-3FLF lessens the stress on sensitive electronic components during cure. Reducing stress during cure is essential for protecting fragile die and other components in ultrathin, flexible electronic packages.

EP37-3FLF bonds well to a variety of substrates, including metals, composites, glass, ceramics, rubber, and many plastics. It offers superior electrical insulation properties, outstanding light transmission, especially in the 350- to 2000-nm range, and is serviceable at temperatures from 4K to 250°F. EP37-3FLF can be cured in 2-3 days at room temperature or in 2-3 hours at 200°F. Optimal properties are achieved by curing overnight at room temperature followed by an additional 1-2 hours at 200°F.

Master Bond EP37-3FLF was selected as one of six adhesives tested in a study of flexible electronic packaging for e-textiles conducted at the University of Southampton.[1]

Application

The goal of the University of Southampton study was to investigate the influence of material selection and component dimensions on the reliability of an e-textile packaging approach under development. The packaging structure uses flip-chip technology to attach multiple ultrathin die to a flexible plastic substrate. Patterned interconnects and bond pads on the plastic strip serve to link the individual die, with solder used to make the electrical connections between the die and the interconnects and underfill adhesive applied to reduce the stress on each die. The resulting long, thin circuit can be surrounded by packing and covering fibers to form the e-textile.

Key Parameters and Requirements

The key measures of reliability investigated in this study were the shear load and bending stresses of the adhesive and substrate layers of the flexible package. For the purpose of experimentally validating simulation techniques the research group was using to optimize the flex packaging, the researchers developed a simplified version of the packaging, consisting of a single electronic die mounted to a plastic substrate using an adhesive. This electronic die on package (EDOP) served as a test vehicle for assessing the reliability of the packaging method as a function of various materials, dimensions, and configurations of the die, substrate, and adhesive. Experimental results could then be compared to simulated results to determine whether the simulation technique could be used to tweak the design of the more complex package.

Results

Shear load and bending tests

In the first part of the study, the researchers focused on the performance of the adhesive layer of the EDOP package, testing six different adhesives, including Master Bond EP37-3FLF. They conducted shear load and bending experiments on a number of EDOP samples, each of which consisted of a Kapton substrate, a silicon die, and one of the six adhesives under test. Multiple EDOP samples were created for each adhesive tested, varying the adhesive thickness of each sample by controlling the amount of adhesive dispensed.

An experimental apparatus was set up to facilitate the shear load and three-point bending tests. For the shear load tests, a force was applied and transferred through the test apparatus to one end of the silicon die (refer to Figure 1). The force was increased until failure occurred. For the bending tests, the substrate was clamped at either end and a force was applied and transferred to the underside of the substrate (refer to Figure 2). Again, the force was increased until failure occurred. For each test, the force that caused failure was recorded for each adhesive type and thickness.

For both the shear load and bending tests, Master Bond EP37-3FLF exhibited the best performance. The external forces required to cause failure in the EDOP samples that used EP373-3FLF were significantly greater than the forces required to break all the other samples across the entire range of thicknesses. For the EP37-3FLF samples, the optimal thickness — the thickness at which the external force required to break the sample was the highest — was 0.048-0.05 mm.

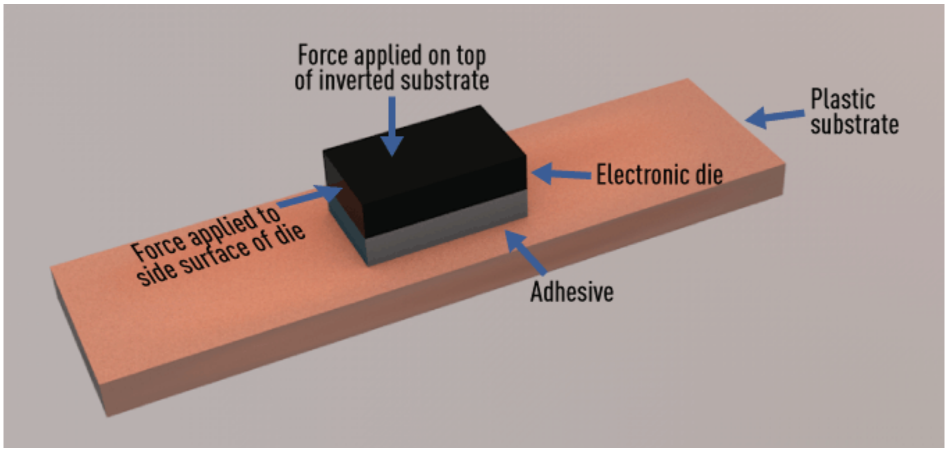

Figure 1: In this model of the shear load experiment, an external force is applied to the left edge of the electronic die while the substrate is fixed in place.

Validation of simulation

The experimental results of the shear load and three-point bending tests were then compared with the results of simulations that were based on a finite element model of the EDOP package (refer to Figures 1 and 2). The simulation results consisted of the maximum simulated shear stress in the adhesive layer as a function of adhesive thickness. The thickness at which stress in the adhesive is minimized represents the optimum thickness predicted by the simulation. For each of the six adhesives under investigation, the optimum thickness predicted by the simulation mirrored the optimum thickness revealed by the experimental results. Thus, the simulation was validated, enabling the researchers to use the simulation to perform additional reliability tests on the overall EDOP package design.

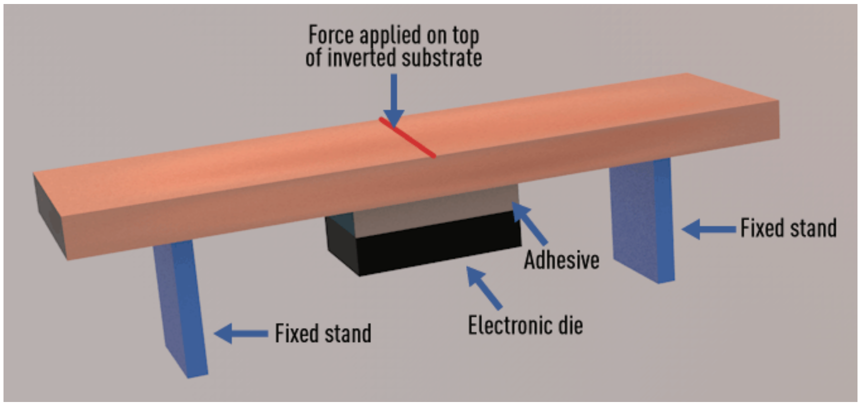

Figure 2: In the three-point bending model, an external force is applied to the center of the substrate on the opposite side of the electronic die.

Adhesive strength

Next, the researchers used the simulation to identify the practical shear strength of each adhesive. For each adhesive, they applied the adhesive thickness and failure force at that thickness, as revealed in the shear load experiments, to the simulation. The simulation assumed a silicon die and Kapton substrate, each of fixed dimensions, in addition to the adhesive. In each case, the simulation result represents the stress in the adhesive at the point each sample failed. By averaging the simulated failure shear stresses from all the samples of a particular adhesive, they determined the practical shear strength of the adhesive when bonding silicon to Kapton. The simulation results indicated that Master Bond EP37-3FLF had the highest practical shear strength of the six adhesives examined.

Optimum materials combination

In the final part of the study, the researchers ran simulations to identify the optimum combination of adhesive and substrate materials as well as the optimum thickness of the substrate.

To determine the best material combination, the researchers simulated the maximum shear and bending (Von-Mises) stresses in both the adhesive and substrate levels of various EDOP models when an external force of 20 N is applied. The EDOP models simulated a silicon die and all possible combinations of the six adhesives and three different substrates (Kapton, Mylar, and PEEK), with fixed dimensions for all components. Simulation results showed that both the shear and bending stresses in the adhesive layer were the lowest for the EP37-3FLF adhesive, while the stresses in the substrate layer did not vary significantly for each adhesive. Because the lowest stresses occurred for the combination of EP37-3FLF adhesive and the Kapton substrate, this was determined to be the best material pairing.

To assess the optimum thickness of the Kapton substrate, the researchers conducted further shear load and bending simulations on an EDOP model subjected to an external force of 20 N. The EDOP package was modeled as a silicon die of fixed dimensions with a 0.05mm-thick EP37-3FLF adhesive layer and a Kapton substrate of various thicknesses. The simulation indicated that the optimum thickness of the Kapton substrate was between 0.048 and 0.052 mm.

Conclusion

Master Bond EP37-3FLF epoxy adhesive was singled out for its outstanding ability to withstand shear and bending forces in a flexible electronic packaging structure under investigation as part of an e-textile development effort. The combination of a silicon die, a 0.048-0.052-mm thick Kapton substrate, and a 0.05mm-thick layer of EP37-3FLF adhesive exhibited the best performance of all the materials and dimensions tested.

This study demonstrated that EP37-3FLF adhesive bonds are capable of withstanding substantial shear and bending loads, making EP37-3FLF well suited for e-textile applications that involve movement, bending, and washing. Because EP37-3FLF is optically clear, its use may be extended to flexible displays, optoelectronics, and other applications that require both flexibility and optical transmission.

Research and development organizations can rely on Master Bond EP37-3FLF to help maximize reliability while keeping electronic packaging as thin and flexible as possible.

References

[1] Li, Menglong, et. al., Stress Analysis and Optimization of a Flip Chip on Flex Electronic Packaging Method for Functional Electronic Textiles, IEEE Transactions on Components, Packaging and Manufacturing Technology, Vol. 8, No. 2, February 2018, pp. 186-194.