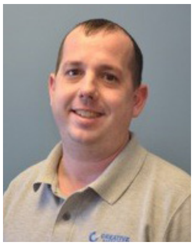
GUEST EDITORIAL



Next-generation wafer-level processing through customized materials

By Jonathan Knotts, Joseph Morano [Creative Materials]

The trend to move manufacturing processes from single-unit processing to wafer-level processing (WLP) has grown over the last several years. The implementation of WLP, while advantageous from the perspectives of overall cost containment and efficiency, can also present a variety of challenges, and customized solutions may be required in order to achieve successful implementation of this technology. Wafer-level processing involves delaying singulation of the devices being produced until as many steps as possible of the manufacturing processes are complete.

Many companies that have successfully implemented WLP are realizing huge increases in throughput, reduced energy costs, and lower labor costs. Other companies have struggled with new difficulties in controlling yield rates, failure mechanisms and limited materials and experience upon which to draw. Many thermal management, die attach and advanced composite materials are designed for manufacturing processes that are 10, 20, or even 30 years old and do not offer the resolution, uniformity and reliability required to successfully implement WLP. The need for customized products that are unique to the product, process and population of the wafer has become quite apparent to both end users and suppliers. When building an array of parts rather than a discrete part, the challenges fall outside of the normal scope dealt with by back-end manufacturing groups. These new challenges often require expertise from a variety of backgrounds and industries that need to be included in both understanding and engineering the solution to a successful WLP implementation. This article will discuss how these challenges can be successfully managed to develop engineered solutions through the use of highly customized materials.

Reducing the occurrence of defects

Many potential part defects can be introduced in WLP implementation. These can cause poor yields and are often challenging to overcome. Difficulties in moving to WLP include but are not limited to, voids, contamination, shorts, opens, warpage, and compatibility with downstream laser marking or vision systems. Further problems are created when adjusting processing parameters to improve yields. As the process is fine-tuned in order to reduce or eliminate one type of defect, another problem is created. Some examples may include: 1) Applying a thicker layer of conductive adhesive to eliminate opens, which can then create warpage or shorts; 2) Using high-temperature curing to increase shear strength can create cracking and warping (see Figure 1); and 3) Increasing shear conditions during application to reduce viscosity can improve wetting, but can also impart air, which creates one type of void, while eliminating another; 4) Adding fillers to improve thermal heat transfer which in turn increases the viscosity will increase occurrences of voiding (see Figure 2). The many potential failure mechanisms do not allow for easy process control or adjustment.

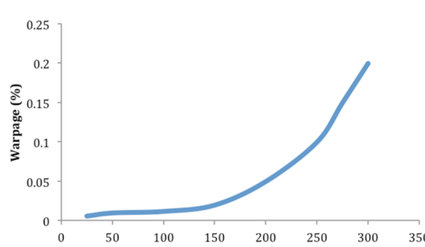


Figure 1: Degree of warpage vs. curing temperature.

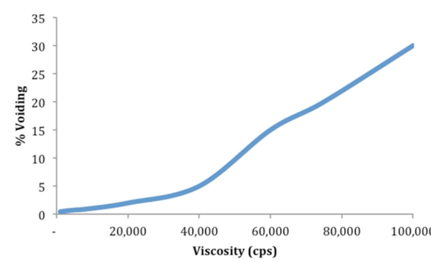


Figure 2: Percentage voiding vs. material viscosity.

A material designed uniquely for the narrow performance window allows for creation of a robust process within a narrow window.

Most of the existing functional materials used in back-end manufacturing have been on the market for decades and often are not RoHS compliant, contain high ionic levels particularly hydrolysable chloride, and use outdated materials technology. These materials are repurposed into WLP applications, as they are readily available and familiar from use in older discrete device processes. The lack of available information or vendor responsiveness has caused many manufacturers to find themselves in a bind when the bill of materials includes polymer-based composites that do not meet chip-level requirements. Coarse particles, wide particle distributions, and undesirable modifiers, such as heavy metals or silicone oils, are common in older products. Most of these products were designed for general use bonding and encapsulation and did not rely on the high standards and requirements that guide today's formulators.

With sluggish support from composite manufacturers, especially regarding new uses of older product lines, many fabricators reach out to custom formulators, consultants, and equipment manufacturers looking for guidance. This situation can be taken as an opportunity for the consultant: rather than addressing only the specific problem encountered by the manufacturing team, a new solution can be devised by deconstructing all of the concerns, requirements and processing challenges, resulting in the development of a specialized formulation that resolves the problem. It is essential to include all downstream processing and device requirements in a new materials property set. This prospective planning approach to the material design is essential to ensuring reliability of the devices over the expected lifespan and operating conditions.

Many of the challenges simply come from the basic differences in geometries in scale when moving to a WLP. The long expanses or trenches, innumerable sharp intersections, variations of geometries within populations, and lack of hoop stresses take normal back-end processing principles out of the scope of WLP problem solving. Thermal expansion, shrinkage, and many other properties, which are based on an inch-per-inch basis, become centralized across the wafer. This magnifies the stresses, creating warping, cracking and exothermic events. Hoop stresses cause materials to shrink radially inward, promoting strong bonds and intimate contact between layers when coated on the surface of a part. In addition to the advantage of hoop stress, the discrete part manufacturer also has fewer challenges due to smaller masses of composites used simultaneously, thereby avoiding defects associated with exothermic reactions. The natural behavior of shrinking onto the part or around the part in the case of hoop stress is a benefit often taken for granted in discrete component manufacture. When filling polymeric materials between multiple substrate surfaces, the multi-faceted wetting during the curing process can cause delamination, cracking, or dimpling. Heat dissipation, shrinkage, and stresses are all challenges that become more difficult to manage with these changes in size and geometry. With the continual reduction in the size of devices, the wafer's own dimensional stability is diminished and contributes less and less to the mitigation of these challenges.

Application principles utilized on larger scale products using composite technologies are typically foreign to device manufacturers that are specialized in microscale concepts and problem solving. The combination of macro- and micro-scale backgrounds is needed to ensure good part performance and proper wafer performance and handling prior to singulation. During the customizing, process information is shared both ways. The end user provides requirements and processing capabilities and the custom formulator provides insight into the polymer behaviors, root causes for failures and the many ways to control or mitigate the defects.

Custom formulations create new products with properties that span both micro- and macro-scale concerns, push tolerances and minimum feature sizes down, and also widen processing windows. The integration of customer needs and processing requirements into the design of the product allow the formulator to fit the product into the WLP goals as a tailor would fit a suit to his client.

Many challenges exist with respect to implementation of WLP that involve the technical aspects of materials and processing, but these tend to be a secondary set of problems. The primary barrier to success tends to be a lack of information sharing. Material suppliers are wary of providing trade secrets or proprietary compositions. Fabricators, needing to protect new products and processes, create a tense and tight-lipped dialogue. This hesitancy to communicate full disclosure of product capabilities and limitations by material suppliers and a bare list of requirements from the fabricator often provide misguided and poor results during initial trials, thus preventing many programs from ever getting off the ground. The much-needed intimacy of efforts on both sides requires a great deal of trust that can be difficult to cultivate. To address this set of challenges, we offer a hands-on approach with on-site support for training and real-time material modification that has the end effects of a closely matched material and process.

With shorter sales cycles for new device ratings and intense competition in most device markets, the speed at which these iterative developments must happen requires significant dedication of resources from both sides. When resources are devoted and a broad base of knowledge is utilized, WLP is both successfully implemented and highly optimized.

Biographies

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