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Embedded Component 3D Packaging

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Several types of embedded component, high-density packages have been suggested by various groups over the past few years [1-4]. Recently, the drive to increasing miniaturization has brought the topic to the forefront, and efforts have intensified to identify those embedded component packaging concepts that are best suited to various market niches. Our work on miniaturized embedded conductor interconnect circuits has served as a natural foundation for development of novel 3D packaging concepts. We placed strong on the benefits of process simplicity, low capital equipment costs, and adaptability to a wide range of electrical and mechanical design requirements. The basic process concept is summarized in Figure 1.

Module fabrication

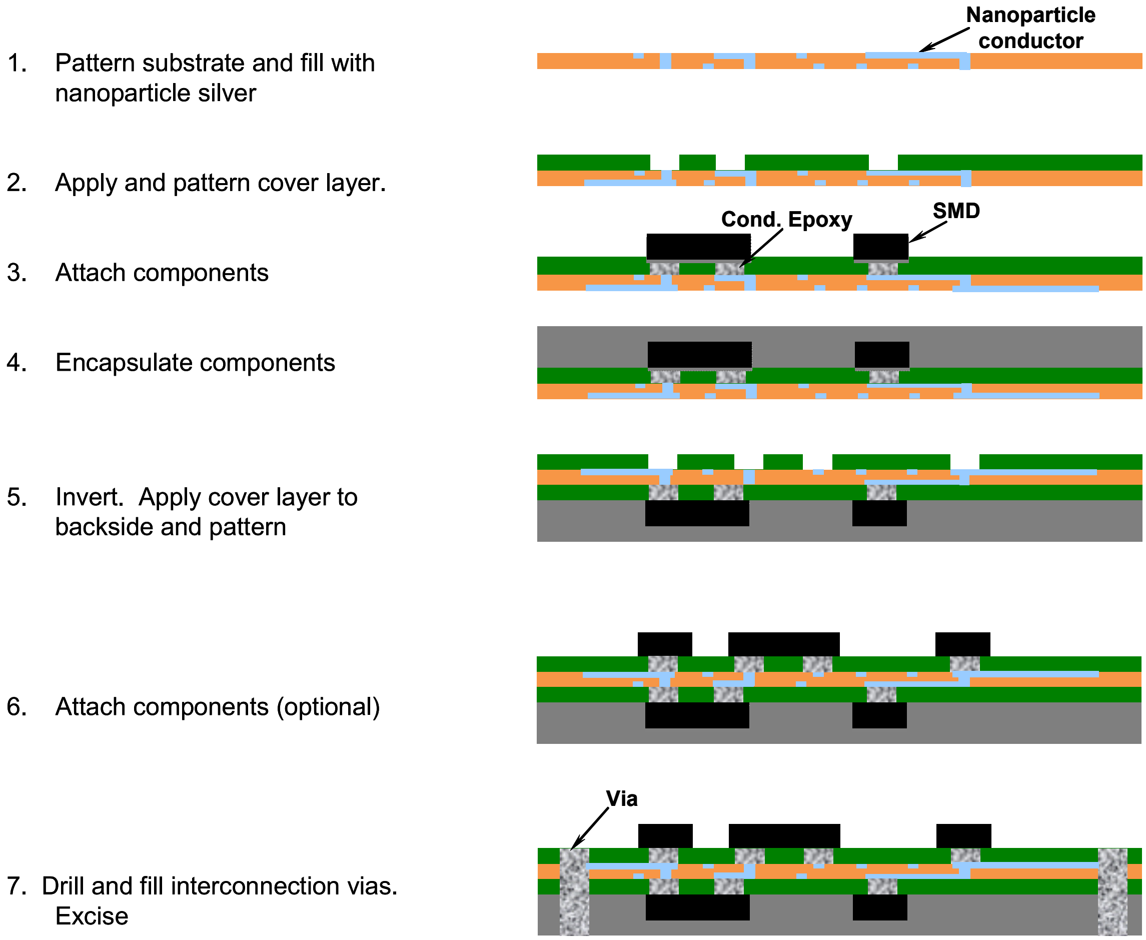

Fig. 1. Fabrication of an embedded component assembly.

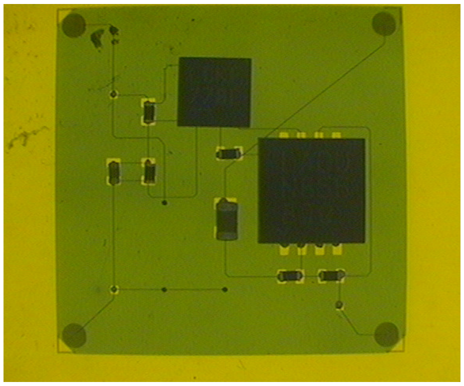

Fig. 2. Frontside of an amplifier circuit after mounting of components. Dimensions of the green coverlay area are 10 mm x 10 mm.

Fabrication of an embedded component module begins with construction of a double-sided interconnect circuit on a thin substrate using laser-embedded nanoparticle conductors. Conductor fabrication steps are discussed in a companion whitepaper[5]. After deposition and patterning of a cover layer, the circuit is populated with surface mount components. Conductive epoxy is used for electrical connection of the components to the conductor pads. Figure 2 shows a dual op amp circuit with mounted components.

The circuit is then encapsulated with thermally conductive epoxy similar to that used for silicon chip encapsulation. A molding assembly is used to assure flatness and parallelism of the top and bottom surfaces. Since the thin substrate is quite compliant, the two encapsulation materials are nearly identical, and there is strong adhesion between the substrate, the coverlay, and the encapsulant, thermal stresses due to CTE mismatchs are minimized. Curing of the encapsulant results in a rigid module with thickness (typically 1 to 1.5 mm) that is only slightly greater than that of the largest component.

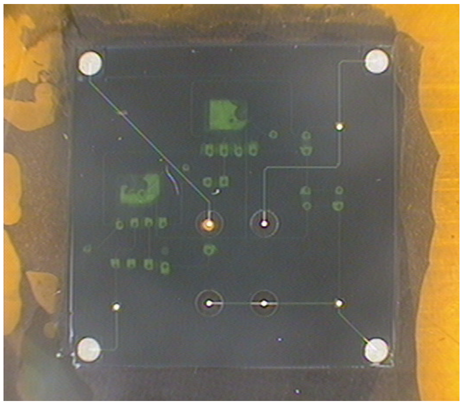

Fig. 3. Backside of the circuit of Fig. 2 after encapsulation and application of cover layer. Molding flash on the frontside is visible around the edges.

Conductive traces on the backside of the substrate can be used for interconnection of components and connection to vias used for interconnection of modules (formed in the final process step). Components that require access to the ambient environment such as sensors or antennae also can be placed on the backside. A patterned cover layer is again used on the backside to protect and isolate the nanoparticle conductor pattern. Figure 3 shows the backside of the circuit of Fig. 2 after encapsulation. Photodefined windows in the coverlay expose nanoparticle silver pads. Visible in Fig. 3 are four large pads at the corners of the pattern. Vias will be drilled through the entire module at these points for module-to-module interconnection.

After patterning the backside coverlay and attaching any desired components, the module interconnection vias are drilled and filled, and the module is excised. Figure 4 shows two amplifier modules like that of Fig. 3 after drilling and excision. One of these modules has a MEMS microphone attached to the backside.

Although the amplifier circuit of Fig. 4 is not characterized by high component density, it is important to note that much higher component densities are clearly achievable. Similarly, the shape of the module footprint need not be square. Since laser processes are used for pattern generation, via drilling, and excision, module footprints of almost any shape can be produced.

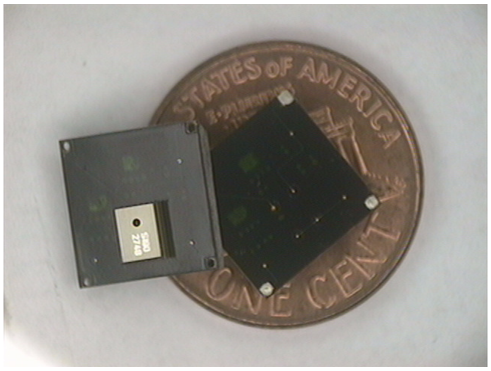

Fig. 4. Two amplifier modules like that of Fig. 3. The top module has a MEMS microphone attached.

Modules like that of Fig. 4 are a type of SiP (system-in-package) assembly that has several benefits:

1. A very high degree of miniaturization is potentially achievable. Component densities can approach the maximum achievable for packaged components.

2. The assembly is mechanically robust, and allows good isolation of components and conductor structures from the environment.

3. Capital equipment requirements are minimized. Highly miniaturized circuits can be built using only a laser scanner, adhesive dispenser, oven, and pick-and-place machine.

4. All processes are low temperature, lead-free, and generate very little waste stream.

Module stacking

Modules like that in Fig. 4 can be stacked and interconnected using the vias that extend through the module, as suggested by Fig. 5. Precision stacking can be accomplished with the same pick-and-place tool used for component placement. If desired, a low-viscosity epoxy, similar to that used for chip underfill on printed circuit boards, may be used for further enhancement of the mechanical and environmental robustness of the assembly.

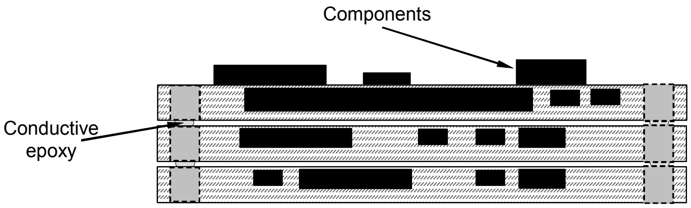

Fig. 5. Stacking of modules to construct 3D assemblies.

The two-module stack shown in Fig. 6 contains all of the electronic components needed to make a wireless microphone. Embedded in the top module are a Texas Instruments cc2530 wireless chip that provides the wireless communication link as well as A/D conversion and a microprocessor. Embedded in the lower module are the preamplifier components shown in Fig. 2. On the top of the stack are mounted the MEMS microphone, a chip antenna with balun, and the crystal used by the wireless chip. The overall dimensions of the two-module system are 10 x 10 x 4 mm^3.

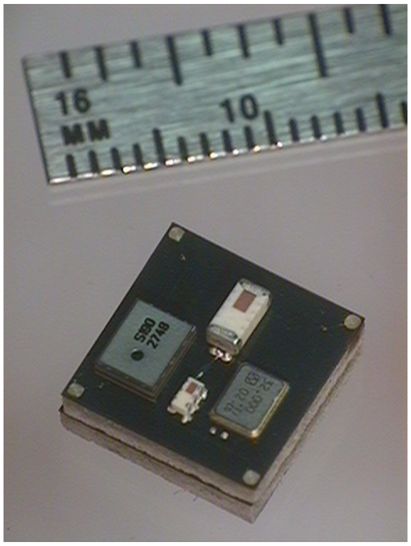

Fig. 6. Two amplifier modules like that of Fig. 3. The top module has a MEMS microphone attached.

Miniature electronic systems like those of Fig. 6 exhibit the same high component density, freedom of form factor and simplicity of manufacturing process associated with their individual modules. The modular assembly approach also provides opportunities for testing and quality control of the individual modules before stacking. This has obvious benefits for cost and yield.

Since software-controlled machine processes are used throughout, this technique is well-suited to prototyping and small-batch manufacturing. However, the advent of fast, high-power laser systems, rapid component placement machines and advanced dispensing equipment allows the approach to address high-volume applications as well.

Electronic systems like the ones described in this article represent a route to miniaturization that can realistically be pursued in-house by companies of all sizes. This new route provides cost-effective manufacturing, improved control over the supply chain, quick response to customer design, and accelerated time to market.

References:

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