Electronic Infrastructure and Packaging for Mesoscale Systems

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Mesoscale systems are built by connecting a group of miniature devices – for example, MEMS sensors, electronic or optoelectronic chips, miniature power sources – and enclosing them in a suitable package. To accomplish its function, a mesoscale sensing system must have 5 essential features: (1) a source of power, (2) a means of communication with the outside world, (3) a means of processing signals, (4) a sensing or actuating element, and (5) a package to protect it in its intended environment. Often, the sensing or actuating device is a MEMS component. In this case, the other essential elements, items (1) – (3) and (5), together can be thought of as infrastructure that supports operation of the MEMS component and interfaces it with the outside world. In the macro world we recognize that office buildings provide similar infrastructure – power (electricity), communications (internet/phone), data processing (computers) and protection from the environment (walls and roof) – to support the working elements (people) inside. In this larger world, standard, but adaptable, construction technology has evolved to provide this infrastructure. However, “mesoscale” infrastructure concepts are at an early phase of their evolution, and much work remains to be done.

A new group at Potomac Photonics, Inc. under the leadership of Dr. Paul Christensen is developing next generation techniques for fabrication of mesoscale system infrastructure – power, signal processing/communication, and packaging. Just as a macro-scale building can be constructed in different shapes and sizes with different materials and internal structure, there is a need for infrastructure platforms to be adaptable to the many constraints presented by the wide range of mesoscale system applications. Building upon work conducted from 1998 to 2002 under the DARPA Mesoscale Conformal Electronics (MICE) program, the company will combine precision laser fabrication techniques, nanomaterials, and advanced battery and energy scavenging technology to produce an integrated approach to mesoscale system infrastructure. The result of these innovations will substantially simplify implementation of new system concepts and have the potential to reduce size, cost and maintenance requirements of many mesosystems currently on the market.

It’s a grand vision and a big job, but Potomac has released some of the examples shown here as a study of this work in progress. Initial work used alumina substrates on which miniature interconnect circuits were fabricated by silver paste filling of laser-milled channels and pads. Attaching miniature IC’s and 0201 and 0402 passives resulted in a working circuit, shown in Fig. 1, with dimensions of only a few millimeters. This fabrication technique allows use of very narrow conductors that are embedded below the substrate surface, and allows routing of traces between pads to minimize the need for multilayer circuitry. For example, with more conventional interconnect technology the single-layer circuit shown in Fig. 1 would require two conductor layers for realization. Laser milling followed by paste filling minimizes the need for photolithographic masks, plating tanks, photoresist and the entire associated chemical effluent stream. As a consequence, the fabrication processes are relatively environmentally friendly as well as being well suited to the short design cycles and moderate batch sizes that are often associated with new mesoscale systems.

Although ceramic substrates are useful in some specialized applications, a larger market need exists for infrastructure based on organic materials. Through use of new electronic nanomaterials that allow high quality conductors to be deposited from paste and sintered at temperatures compatible with organic substrates, the embedded conductor approach can be extended to packaging based on polyimide, liquid crystal polymer, ABF (Ajinomoto Buildup Film), and RCC (resin-coated copper)

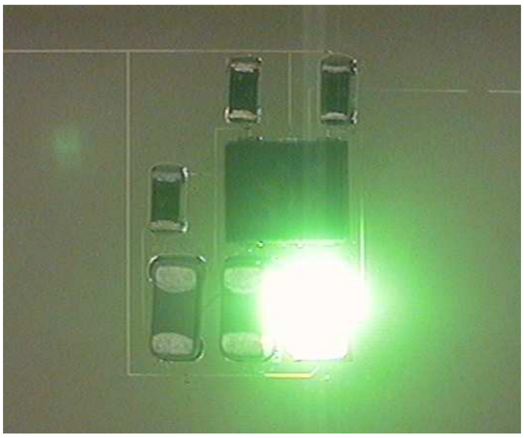

Fig. 1. Potomac LED control circuit using embedded conductors on a polished alumina substrate. Width of the circuit is 3 mm. The LED is show in its “on” state.

Figure 2 shows an example of construction of the circuit shown in Fig. 1 on a polyimide substrate. In this example the circuit is mounted on a small, rechargeable Li battery only 7 mm in diameter.

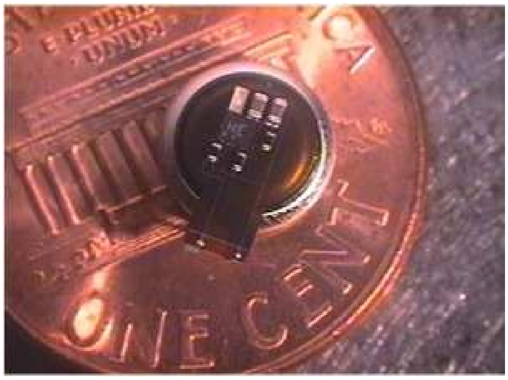

Fig. 2. LED control circuit fabricated on a polyimide substrate and mounted on a small Li battery

The embedded conductor approach reduces the number of conductor layers required for routing of many circuits, but multi-layer approaches will still be needed for more complex devices. In addition, this relatively new technology must be shown to be environmentally robust and amenable to high production yields. As a first step toward addressing these issues, Potomac is now constructing and testing multilayer daisy chain configurations like that shown in Fig. 3. These incorporate hundreds of conductor links and vias and will be used to investigate production yields associated with fabrication of these elements as well as provide a platform for testing the effects of thermal cycling and flexing.

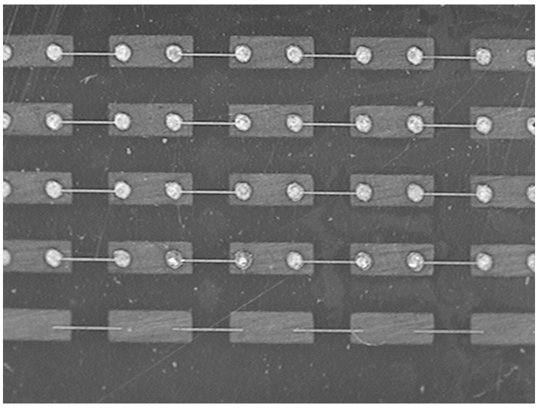

Fig. 3. Two layer daisy chain test circuit. Top layer is polyimide with 10 micron silver traces. Bottom layer is FR4 with 100 micron copper conductor pattern.

In the longer term, Potomac has its eye on application of this technology to wireless sensors, medical devices, security systems, and similar areas where miniaturization and flexibility in physical form factor are important. Two (2) initial applications are being pursued: (1.) Strain gauges for aerospace and infrastructure (i.e. bridges); and (2.) Implantable glucose sensors for a large Defense constractor and the #5 medical device company respectively. Figure 4 shows a wireless sensor packaging concept that extends the approach to incorporate an unspecified MEMS sensing component with commercially-available active and passive electronic components providing onboard signal processing, wireless communication and thin-film battery power. Figure 5 compares the overall size and possible form factors available with this approach with the most compact devices currently available on the commercial market. With further evolution to incorporate embedded passives and energy harvesting components Potomac expects to provide a cost-effective, easily manufactured product that will create a major paradigm shift in packaging of miniature wireless sensing systems.

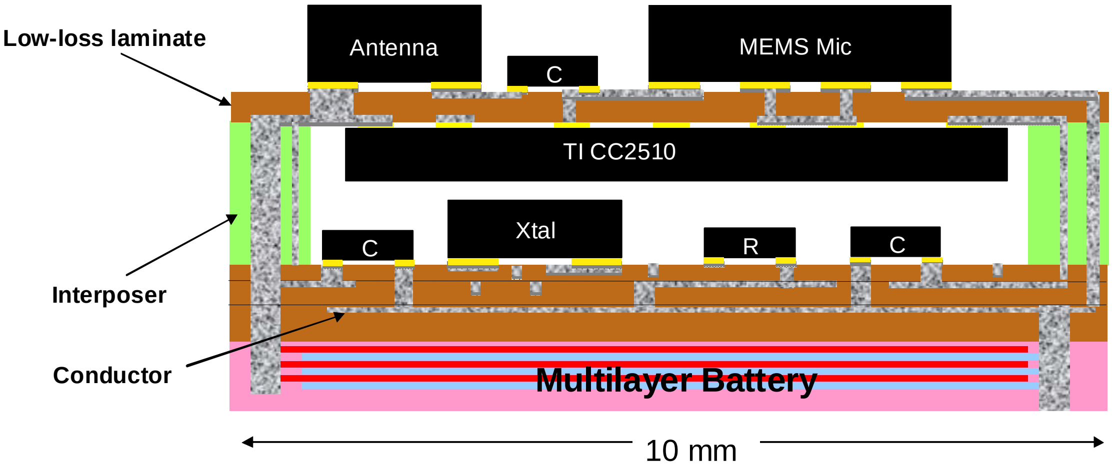

Fig .4. System concept for a wireless sensor based on currently-available active and passive components.

Potomac will provide continuing updates on its R&D work at www.potomacmeso.com. The company is actively seeking collaborators and end users with an interest in this technical area. Inquiries and comments are always welcome including suggestions on specific applications.. Contact Paul Christensen (pchristensen@potomac-laser.com) or Lori Beer (loribeer@aol.com)

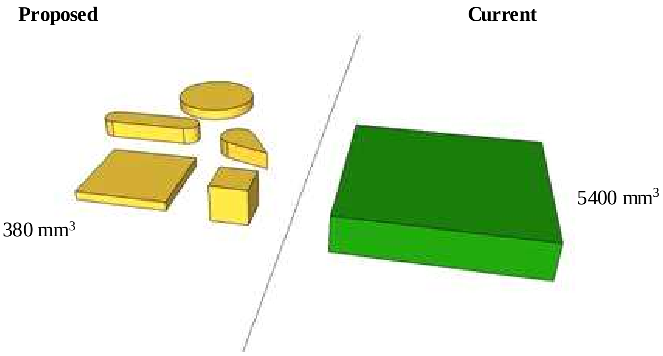

Fig. 5 Relative sizes and possible shapes of Potomac wireless sensor packaging (light colored shapes) compared with typical current products (dark color).