Advancing Microelectronics

Inside the Multichip Module, Hybrid, Electronic Packaging and Surface Mount Industries

iMAPS

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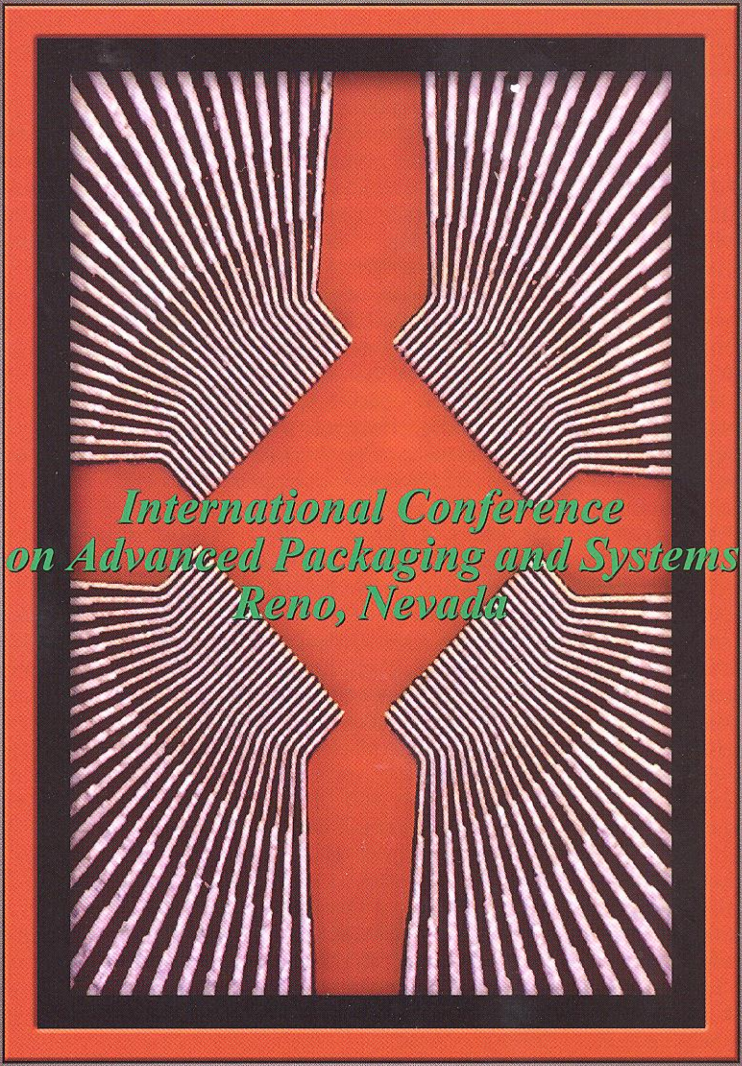
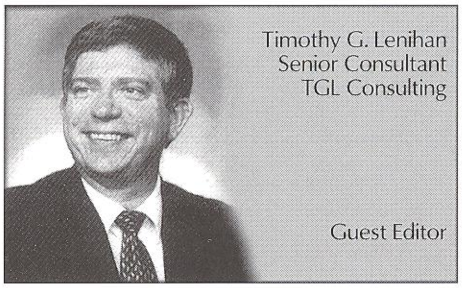


ICAPS '02

March 10-13, 2002

IMAPS ICAPS '02



Welcome to this issue of *Advancing Microelectronics* describing the program for the International Conference on Advanced Packaging and Systems (ICAPS '02)! This new conference is primarily focused on advanced electronic systems and the advanced electronic packaging used in these systems. Our goal is to make this the premier conference for systems developers and electronic packaging suppliers while keeping the conference small enough for meaningful interaction amongst the attendees. The main objective of ICAPS is to get the systems and packaging developers together in one conference. This will enable the participants to learn about the latest industry advances in systems and packaging technologies as presented by industry leaders. Attendees will also be able to interact, with industry experts, to exchange information and find solutions for their needs. The second objective of ICAPS is to bring together the industry leaders in advanced systems and packaging to exhibit the latest technologies under one roof. The third objective is to offer Personal Development Courses by industry experts to expose our industry practitioners to new areas and increase their skills.

Topics to be covered in the conference are System Applications, 3D Packaging, Design and Test, High Density Packaging Materials, Thermal Management, High Density Packaging, Reliability, MEMS Packaging, Advanced Substrates and Lids, and Power Packaging. In addition, there will be a Plenary Session on Folded Flex and Thinned Silicon Multi-Chip Packaging with six papers over two days.

The choice of Reno, Nevada, provides a cost effective location with entertainment for all attendees and spouses. It's a short distance from Silicon Valley allowing participants to save money and still be able to conduct business if needed.

This issue of *Advancing Microelectronics* contains two papers that would be typical of the papers presented at the ICAPS conference. The first paper by Zhenwei Hou (et al.) is the Best Paper from last year's HD International Conference that also had an Advanced Systems and Packaging content. This paper focuses on the current environmental need to remove Pb in electronic assembly processes and using Sn-Ag-Cu. While no "drop-in" solder alloy has been found for eutectic Sn-Pb, this paper does examine an alternative and the issues associated with this choice of materials including reliability.

The second paper, by David Liu (et al.), examines using Laser Direct-Write Technology for the rapid fabrication of a broad range of micro devices and circuits at lower temperatures and cost. This technology is capable of producing mesoscale (2 to 100 um) features using an "all-in-one" laser tool. The laser tool is capable of multiple material depositions, sintering, and micromachining without moving the substrate from the system. The processing temperatures are low (200-300C) and the laser head speeds are of the order of 1m/sec. Multilayer structures can be made in the same tool and design changes are quickly done by editing the software design files. The ability to create Integrated Passives and trim circuits for performance using this technology may be very useful for wireless and RF applications where quick turn around times have been a barrier to development and implementation.

I think you will find these papers educational and stimulating. Today's economic challenges require us all to be motivated to find the best ways to satisfy our customer's needs. ICAPS '02 provides a forum to examine the best in Advanced Systems and Packaging technologies and find the right solutions. As the General Chair, let me ask you to please join us ICAPS '02 in Reno, Nevada, for this industry event!

Timothy G. Lenihan is a Senior Consultant at TGL Consulting in Rochester, New York. He received his Ph.D. in Electrical Engineering from the University of Arkansas in 1996. During his career he has worked at IBM in the East Fishkill Technology Park where he held managerial positions in the semiconductor and packaging development areas. Dr. Lenihan held the position of Director of Technology and Director of Sales and Marketing for Sheldahl, Inc. in Longmont, Colorado. More recently, he was the CTO and Senior Vice-President of Engineering and Quality for Zecal Technologies Incorporated. Currently, he is consulting in the areas of Electronic Packaging and Integrated Passives.

Dr. Lenihan is a Senior Member of the IEEE, member of IMAPS, and a member of the New Academy of Sciences. He is also an Adjunct Professor in the Department of Electrical Engineering and the High Density Electronics Center at the University of Arkansas.

Laser Direct-Write Technology and Its Low Processing Temperature Low Cost Applications

David Liu, Scott Mathews, Chengping Zhang, and Michael Duignan, Potomac Photonics, Inc., 4445 Nicole Drive Lanham, MD 20706, Ph.: (301) 459-3031, FAX: (301) 459-3034, E-mail: dliu@potomac-laser.com

Introduction

Laser direct-write is a new processing technology that allows the rapid fabrication of micro devices and circuits. These micro devices and circuits find applications in a variety of areas such as microelectronics, photonics, MEMS, and MOEMS. This technology utilizes low temperature processing (200-350°C) and does not require the use of masks, screens, molds, or stamps. It also avoids the use of photoresists and complex chemistries with associated costs and potential environmental consequences. Laser direct-write technology is able to produce features as small as a few microns in dimension [1].

Today, there are two dominant processing technologies in the microelectronics industry: thick-film and thin-film. Thick-film technology utilizes imaged screens to print materials on a substrate followed by firing at high temperature, typically between 800-1200°C. Successive screen-printing and firing process steps are used to build the circuit. Thick-film technology has been used to fabricate Multi-Chip Modules (MCMs) and 3-D circuitry via a Low Temperature (~850°C) Co-fired Ceramic (LTCC) process. Thick-film technology cannot easily produce lines and spaces smaller than ~100 µm (0.004") wide.

Thin-film technology, on the other hand, utilizes vacuum deposition equipment and processes to produce thin (typically sub-micron) layers of materials. Circuitry and complicated 3-D devices with sub-micron features are then fabricated using photomasks and lithography to pattern the previously deposited materials. Integrated circuits (ICs) are fabricated using thin-film technology.

DARPA MICE Program

Thick-film technology is generally low-cost while thin-film technology needs a Clean Room manufacturing environment and is expensive to implement. When devices and components with mesoscale (2- to 100-µm features) conductors, resistors, capacitors, or inductors are required, thin-film technology has typically been used. However, its inherent processing complexity and high cost have been obstacles to widespread implementation. The demand for a competitive processing technology that can fill the "mesoscale gap" was recognized by the U.S. Defense Advanced Research Projects Agency (DARPA), which launched the multi-million dollar Mesoscopic Integrated Conformal Electronics (MICE) program in 1999 [2].

Laser Direct-Write Technology

Potomac Photonics, Inc., teaming with the U.S. Naval Research Laboratory and Superior MicroPowders, Inc., is developing a laser direct-write workstation to deposit conformal mesoscale passive electronic components, interconnects, microelectrodes, and sensor elements. This tool combines, for the first time in a single machine, the ability to both deposit (additive) and remove (subtractive) material with micron resolution and write speeds that approach 1 m/s.

The laser forward transfer deposition process is suitable for an exceptionally broad range of materials from traditional thick-film pastes to organic and inorganic powders and extending even to living cells.

The DARPA MICE program focus has been applied to creating materials compatible with low processing temperatures (200-350°C), so that inexpensive polymer substrates can be used in ways that are not now feasible. Figure 1 illustrates a typical setup of a laser direct-write forward transfer workstation. A thin layer of the material to be deposited is applied to a laser-transparent backing. The result is called a "ribbon" because it is analogous to a typewriter ribbon. Irradiated from behind by a pulsed laser directed by a computer, the material is driven forward to a receiving substrate. By moving the substrate and the ribbon (or the beam and the ribbon) simultaneously, materials can be directly patterned onto the substrate. Design changes can be implemented simply by changing the CAD file that drives the laser. Thicker layers can be achieved by repeating the processing steps. By changing the ribbon material, the constituent parts of virtually any kind of material can be deposited. When multiple circuit layers are fabricated during one set-up, tighter design rules can be employed than is cus-

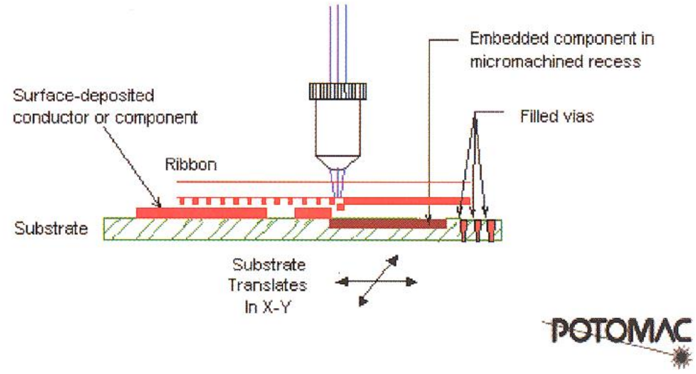
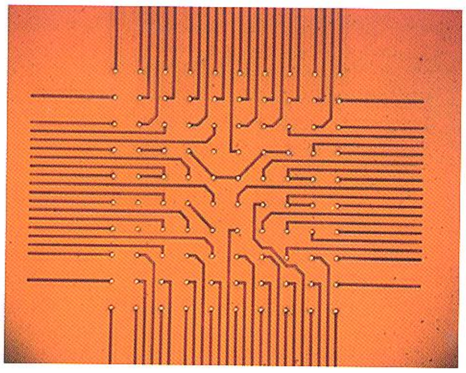


Figure 1. Illustration of laser direct-write forward transfer and laser micromachining techniques.



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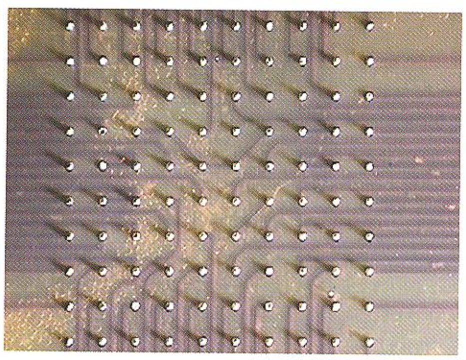
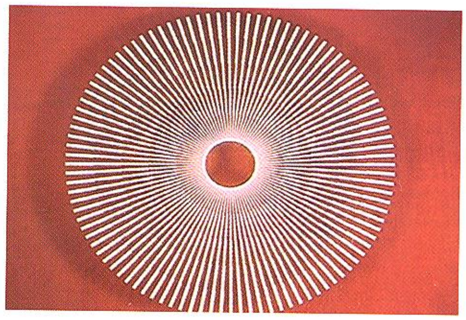


(B)

Figure 2. A completed signal layer for die package development on polyimide using laser direct-write technology: (A) 50-um wide micromachined interconnect grooves and through-vias; (B) interconnect grooves and through-vias filled with silver conductive paste.



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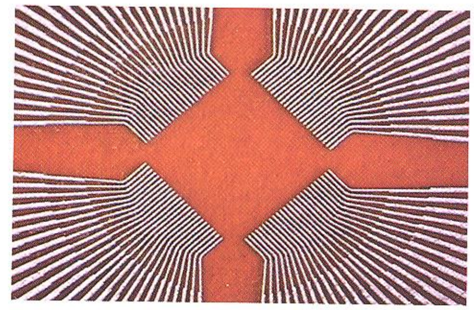


(B)

Figure 3. Laser direct-write and micromachined conductor fanout patterns on polyimide: (A) radial fanout with 60-µm inner pitch, 32-µm wide lines, and 28-µm minimum spacing. (B) stepped fanout with 60-µm inner pitch and 250-µm outer pitch.

tomary because no physical re-alignments are required between layers. CAD file adjustments can accommodate the need for making differential shrinks or stretches of deposition layers.

Low-Temperature Laser Sintering

In the fabrication of passive components, heating is generally required to achieve the final product after deposition. This can be done by using post-deposition oven curing/firing, or by using direct laser sintering. The workstation includes an infrared laser for direct in-situ laser sintering (not shown in Fig. 1), which localizes the highest temperatures to small material volumes near the surface of the layer. The main advantage of laser sintering is that it permits the use of flexible low-cost polymer substrates that are otherwise not suitable for high temperature firing.

Laser Micromachining

Finally, a powerful feature of this tool is that the same laser direct-write/direct-sintering system is also a laser micromachining workstation. The laser can ablate blind or through vias, mill recesses, and trim deposited components to specified dimensions and values with high precision. Vias and recesses can be filled with directly deposited materials to create planarized embedded components. After fabrication, the machining laser can also be used to dice or excise the micro device or circuit from the array in which it was manufactured.

Applications

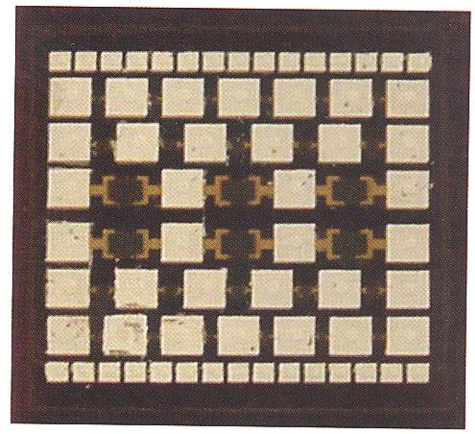
To demonstrate these capabilities, some application examples are presented.

Mill and Fill

The first several examples involve the "Mill & Fill" technique. Figure 2 shows the fabrication of a signal layer for die package development. 50 um-wide signal lines and through-vias were created using laser micromachining. The vias and lines were filled with low-temperature curing silver paste to form an integrated conductor and bump array.

Figure 3 shows conductor patterns on polyimide for probe card applications. The radial fanout (Fig. 3A) has a 60-µm inner pitch converted to a 350-µm outer pitch. Corresponding line widths increase from 32-µm to 120-µm with 28-µm minimum spacing. The 100-trace square pattern (Fig. 3B) has a 60-µm inner pitch and a 250-µm outer pitch with gradually widening conductor lines to minimize trace resistance. All these patterns can be fabricated in minutes using laser direct-write technology.

Figure 4 shows examples of passive components fabricated using laser direct-write deposition on polyimide. A test vehicle resis-



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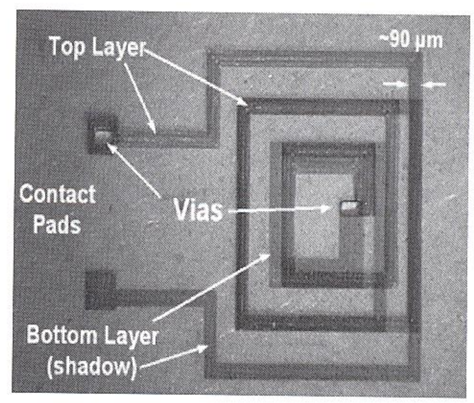
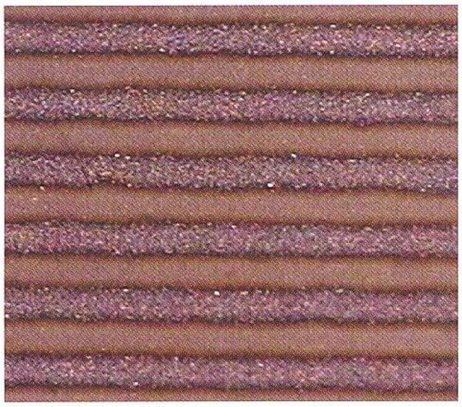
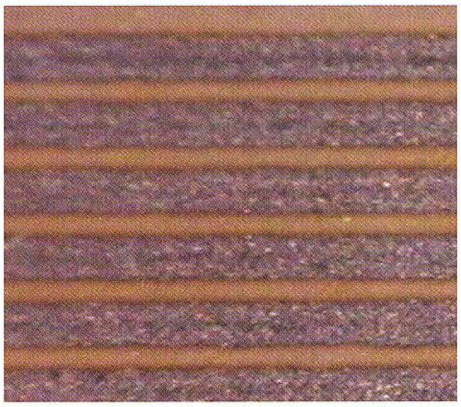


(B)

Figure 4. Embedded passive components on polyimide using laser micromachining, direct-writing, and sintering techniques: (A) a completed encapsulated resistor array test structure with a variety of size and aspect ratio resistors. Total array size is 1-inch square. (B) a double-sided micromachined spiral inductor with through-vias ready for filling.

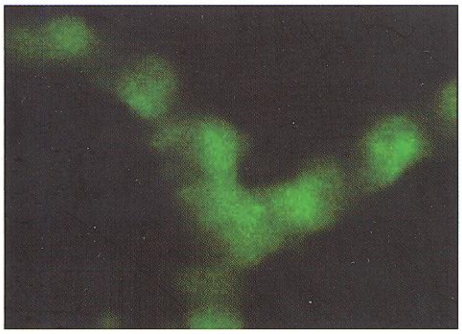


(A)

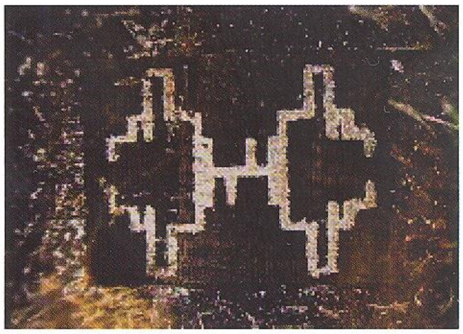


(B)

Figure 5. Laser direct-write forward transferred silver conductor lines on unfired ceramic tape. The lines have been laser sintered and are conductive: (A) 2-mil wide lines with 2-mil wide spaces. (B) 4-mil wide lines with 1-mil wide spaces.



(A)



(B)

Figure 6. Laser direct-write technique for very low-temperature applications: (A) transfer of live E-Coli bacteria. The picture was imaged with UV light where only transferred live cells fluoresce. (B) a fractal pattern antenna deposited on the back of a honeybee using the laser direct-write technique.

tor array (Fig. 4A) was deposited directly on polyimide. The resistors were then directly laser sintered. Finally, the array was encapsulated using another layer of polyimide to exclude humidity and contamination. Electrical contact pads were created using laser micromachining and filled with silver conductive paste for electrical characterization. A spiral inductor (Fig. 4B) was also fabricated by micromachining and filling both sides of a polyimide substrate. Two vias were created and filled to make the electrical interconnections.

Forward Transfer

Figure 5 shows conductive silver lines on unfired ceramic tape deposited using laser direct-write forward transfer and sintering techniques. Wet or dry materials on tape can be transferred. Dry materials on tape can be transferred in either the contact or off-contact modes. Two-mil wide (and narrower), dense, smooth conductive lines (Fig. 5A) can be readily deposited using the laser direct-write forward transfer technique. Compared to the lines deposited on unfired ceramic tape using conventional thick-film printing, the laser direct-write technique can provide narrower lines. The laser direct-write tool can also micromachine grooves and vias in unfired ceramic tape and fill the structures with conductive material using one machine.

LTCC Rework

Printed but unfired ceramic tape sheets often contain serious defects (shorts or opens or both) that must be reworked before the sheets can be processed further. The current most popular rework technique (a microprobe, "wet" or "dry") is difficult to manually manipulate and can easily damage the sheet being reworked, rendering it useless. However, the laser direct-write technique can be used to fill opens and open shorts during unfired ceramic tape inspection. The resulting rework is accurate, repeatable, and quickly performed.

Very Low Temperature Applications

Figure 6 demonstrates the use of the laser direct-write technique for very low temperature depositions by the U.S. Naval Research Laboratory [3]. Live bacteria can be transferred (Fig. 6A). The picture, showing the transfer of live E-Coli bacteria, was imaged using UV light (only transferred live cells fluoresce). The fluorescence of the transferred bacteria continued for over five days, indicating that the transferred bacteria were still living for that length of time. Direct-write circuitry can be deposited onto organisms such as insects (Fig. 6B). A fractal pattern antenna was deposited on the back of a honeybee using the laser direct-write technique. Such a capability makes it possible for laser direct-write technology to find a variety of applications in microfluidics, Micro Electro-Mechanical Systems (MEMS), and Micro Optical ElectroMechanical Systems (MOEMS).

Conclusions

In conclusion, a new laser direct-write deposition process has been developed specifically to produce mesoscale (2- to 100-um features) devices and circuits. This "all-in-one" laser tool combines multiple processing capabilities such as laser deposition, in-situ laser sintering, and laser micromachining. The processing technology is aimed at low processing temperatures (200-350°C) and higher write speeds (1 m/s), which allows the writing of many kinds of materials on many kinds of surfaces at low cost.

Reference:

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2. DARPA DSO Mesoscopic Integrated Conformal Electronics (MICE) program, Dr. Valerie Browning, Program Manager.
3. B.R. Ringeison, D.B. Chrisey, A. Pique, H.D. Young, R. Modi, M. Bucaro, J. Jones-Meehan, and B.J. Spargo, "Generation of Mesoscopic Patterns of Viable Escherichia Coli by Ambient Laser Transfer," to be published in Vol. 23 [2], Biomaterials, 2002.