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Materials Development for Direct Write Technologies

Editors: Douglas B. Chrisey, Daniel R. Gamota, Henry Helvajian and David Paul Taylor
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SYMPOSIUM PROCEEDINGS VOLUME 624**

Materials Development for Direct Write Technologies

Symposium held April 24–26, 2000, San Francisco, California, U.S.A.

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PREFACE

The goal of Symposium V, "Materials Development for Direct Write Technologies," held April 24–26 at the 2000 MRS Spring Meeting in San Francisco, California, was to identify and develop new materials approaches based on the direct write technique (transfer method) and to demonstrate the required electronic or other device performance (chem/bio sensors, phosphor display, FET, etc.). Many different CAD/CAM approaches exist to direct write or transfer material patterns and each technique has its own merits and shortcomings. Many approaches were presented including plasma spray, laser particle guidance, MAPLE DW, laser CVD, micropen, inkjet, e-beam, focused ion beam, and several novel liquid or droplet microdispensing approaches. One common theme to all techniques is their dependence on high-quality starting materials, typically with specially tailored chemistries and/or rheological properties (viscosity, density and surface tension).

Typical starting materials, sometimes termed "pastes" or "inks", can include combinations of powders, nanopowders, flakes, organic precursors, binders, vehicles, solvents, dispersants, surfactants, etc. This wide variety of materials with applications as conductors, resistors, and dielectrics are being developed especially for low-temperature deposition ($< 300\text{--}400^\circ\text{C}$). This will allow fabrication of passive electronic components and RF devices with the performance of conventional thick film materials, but on low-temperature flexible substrates, e.g., plastics, paper, fabrics, etc. Examples include silver, gold, palladium, and copper conductors, polymer thick film and ruthenium oxide-based resistors and metal titanate-based dielectrics. Fabricating high-quality crystalline materials at these temperatures is nearly impossible. One strategy is to form a high density packed powder combined with chemical precursors that form low melting point nanoparticles *in situ* to chemically weld the powder together. The chemistries used are wide ranging, but include various thermal, photochemical and vapor, liquid, and/or gas coreactants. The chemistries are careful to avoid carbon and hydroxide incorporation that will cause high losses at microwave frequencies or chemistries that are incompatible with other fabrication line processing steps.

To further improve the electronic properties for low-temperature processing, especially of the oxide ceramics, laser surface sintering is used to enhance particle-particle bonding. In most cases, individual direct write techniques make trade-offs between particle bonding chemistries that are amenable with the transfer process and direct write properties such as resolution or speed. The resolution of direct write lines can be on the micron scale, speeds can be greater than 100 mm/sec, and the electronic material properties are comparable to conventional screen-printed materials. Optimized materials for direct write technologies result in: deposition of finer features, minimal process variation, lower prototyping and production costs, higher manufacturing yields, decreased prototyping and production times, greater manufacturing flexibility, and reduced capital investments.

Douglas B. Chrisey
Daniel R. Gamota
Henry Helvajian
David Paul Taylor

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INTRODUCTION AND NOTES ON THE PROCEEDINGS

So far, direct write processing techniques have been relegated to niche applications. One reason for this is that these techniques are serial in nature. Another reason is that the cost of these techniques is tied to their acceptance in the marketplace. Presently, the specialty applications that use direct write processing techniques are important enough to justify this symposium. In the future, I believe that direct write processing will become more important—and possibly much more important.

In assembling these proceedings, I have used the paper of Ken Church et. al. to provide an overview. The breadth of these proceedings indicates only part of the range of applications for direct write processing. "Editing" of silicon integrated circuits, surface texturing hard drive surfaces and the drilling of via holes in printed circuit boards are important applications of laser direct write processing techniques in mature markets. Dan Ehrlich's paper on "Real World Applications" was moved to near the front because it provides another perspective on the current level of acceptance of direct write processing. A significant market already exists for these applications of direct write technology. However, these more mature direct write processing technologies were not emphasized in this symposium. Instead, the emphasis of this symposium was novel direct write processing technologies.

A significant fraction of the papers involve use of direct write processing to achieve the integration of board level electronic circuit elements. It is necessary to write conductors and other materials for wiring, capacitors and resistors. Many applications require more specialized components, so it is necessary to write structures to be used as batteries, antennas and other devices. The dream driving this research involves fabricating future electronic circuit boards—fully populated with components—by some turn-key direct write processing machine. Such a machine might be realized through a new kind of inkjet printing, a laser printer technology, or a micro-pen approach. Alternatively, the new technology to build such a turn-key direct write machine might arise from a very different area, such as the one of the new laser or particle beam techniques. Some of this effort has been influenced by the Mesoscopic Integrated Conformal Electronics (MICE) research initiative sponsored by DARPA under the direction of William Warren. These new technologies should bring about a revolution in the rapid prototyping of new designs.

Other papers of the symposium explore direct write processing technologies more consistent with MEMS (MicroElectroMechanical Systems) applications. The ability to handle non-silicon materials and to assemble different components into an integrated device are important factors in successfully creating a variety of MEMS devices. These MEMS devices are already built into inkjet printer heads, optical scanners, accelerometers for airbag deployment, and they are becoming even more ubiquitous. It is interesting to consider the future of micro-instrumentation ranging from biomolecular sequencers on a chip to pico-satellites the size of a hockey puck. I have become convinced that one of the key benefits of using direct write techniques for these applications is the ability to fabricate true three-dimensional structures.

Another group of papers in this symposium explores the possibility of using direct write techniques to process material on the nanometer scale. A variety of ion beam or electron beam milling techniques can be used to fabricate devices on this scale. Lasers might also be used to create nanometer scale structures, either by using vacuum ultraviolet wavelengths or using other tricks. The papers of this symposium use a contact printing scheme in combination with ion milling of the stamps to produce nanometer scale structures.

There is considerable overlap in categorizing the papers of this symposium. The papers have been roughly grouped by processing technique and area of major interest. Is laser printing with a variant of electrostatic ink properly grouped with laser techniques or with particle

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transfer methods? Does contact printing of liquids with a stamp belong in the same category as a micropen method involving painting a slurry of suspended particles onto a surface? The choices I have made in organizing the papers are rather arbitrary. With low temperature processing, there is often a need for post-processing or sintering which varies with the direct write materials chosen and the survivability of the substrate. It rapidly becomes clear that the ultimate success of most of these approaches to direct write technology depends on the nature and quality of the materials as much as the processing technique.

The Materials Development for Direct Write Technologies symposium contains papers that emphasize both processing techniques and materials. I can only hope that the printed version of the proceedings papers conveys some of the interest and cross-disciplinary character of the symposium itself.

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