Solder Free Electronics – Direct Write Electronics

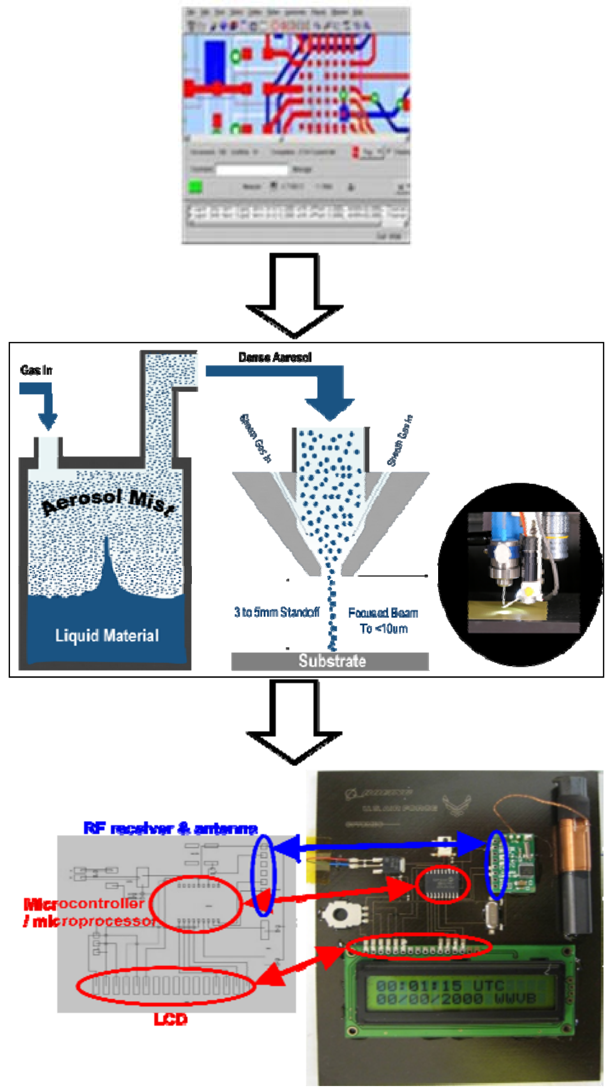
PROBLEM / OBJECTIVE

As lead-based (SnPb) solder is phased-out globally, there is a diminishing industrial base for electronic parts using leaded solder. Complicating this, DoD and many aerospace/high performance systems have unique requirements of high reliability/critical need, very long service lives, extended temperature ranges (-55°C to +125 °C), and the need for repairable systems. Furthermore, DoD acquisition programs are increasingly dependent on commercial electronic parts and assemblies. Current lead-free solder substitutions are characterized by unpredictable failures and the issues resulting from tin-whisker formations (dendritic growth). To date, no ideal SnPb-like alloy substitute has been identified. The intent of this program is to demonstrate the fabrication of functional circuits without solder via Direct Write (DW) electronics.

ACCOMPLISHMENTS / PAYOFF

Process Improvement

The DW process allows the manufacturing of electronic components and connections to create entire circuits for high-performance and customizable applications. Circuits are produced in a layer-wise fashion directly from CAD data, providing a cost-effective, flexible manufacturing method for producing high-mix, low-volume circuits. The process is flexible in terms of the types of materials that can be deposited (conductors, resistors, dielectrics, semiconductors, etc.) and feature sizes/geometries (2D as well as 3D patterns) that can be printed. Designers may quickly prototype new circuit designs, improve product reliability and performance, and manufacture these circuits using the same process. Electronics may be deposited directly onto conformal (non-planar) surfaces, making virtually all surfaces of a component act as a potential circuit board. Complex, multilayer devices can be fabricated, making the printing process simpler than the conventional electronic lithographic fabrication sequence of: mask, expose, etch, strip, and repeat.



Atomic Clock Circuit

For Open Publication, DoD Office of Security Review, 11-S-0091

The program completed a benchmark study of applicable inks (used to produce components) and substrates, designed and optimized circuits for DW fabrication, and created hybrid test articles with both Commercial-Off-The-Shelf (COTS) and DW circuitry. Additionally, it performed functional evaluations of test articles.

DW technology was applied to print complete circuits of a variety of device types (capacitors/resistors/transistors) as well as hybrid circuits, including COTS components. Ink formulation specifications have been defined to allow vendors to create inks for numerous printed electronics applications. Program efforts have enabled the identification and fabrication of numerous circuitry, including filter/inverter circuits, operational amplifier applications, and an atomic clock receiver (an example of a hybrid DW/COTS circuit).

Technology Transition

Use of the DW printing process enables designers to print complete electronic circuits directly from CAD design files, much like printing text on a piece of paper from a word processor file. The advantages of DW electronics are numerous. Chiefly, they allow totally customizable electronic circuits, use a reduced infrastructure (no hard-tooling required), enable use of small electronic packaging capabilities, require less custom circuit development time, and permit repair/rework to be performed by the same equipment. The program validated the ability to run the DW printing process for extended periods of time (> 20 hours).

Expected Benefits and Warfighter Impact

Advancements have shown promising results, with improved reliabilities and the potential for eliminating tin whiskers and their related problems. Applying the same tool for Development / Manufacturing / Maintenance / Repair / Overhaul tasks employs a reduced infrastructure to print complete circuits while eliminating solder joints, with the potential to streamline product development time by at least 70 percent, extend hardware life, and reduce part costs (independent of quantity). The shorter development cycle has the potential to allow new hardware to be rapidly deployed. Finally, the elimination of hard-tooling and process steps has the potential to improve component costs for the DoD.

PARTICIPANTS

AFRL/RXME, Ted Finnessy, 937.904.4344, ted.finnessy@wpafb.af.mil

Optomec Incorporated
Boeing Incorporated (Phantom Works)