Utilizing Printed Electronics Methods for the Fabrication of Multi-layer PC Boards

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As a demonstration of printed electronics capabilities, an aerosol-jet printer was used to fabricate multi-layer pc boards. The aerosol-jet printer was equipped with a stationary nozzle through which an ink stream could flow and an x-y stage onto which a substrate could be mounted. During printing, the ink stream was shuttered open or closed while the substrate was moved in the x-y plane to trace out a desired feature. The first pc board example was a 2-layer power supply board designed to output 3 regulated voltages of 2.5 volts, 1.8 volts and 1.5 volts given a 5 volt input voltage and a 1 amp input current. The second pc board example was a 4-layer digital interface board designed to route signals around to different places on the board. For both boards, each metal layer was initially designed using a standard pc board development software application. The resulting layouts for each metal layer were imported into AutoCAD and modified for aerosol-jet printing. Such modifications typically involved breaking the layouts into rectangular shapes only where traces were needed and defining serpentine fill patterns in order to print connected, solid features. Since aerosol-jet printing is an additive manufacturing fabrication method, dielectric material was printed only where electrical isolation between metal layers was needed. For a given metal layer, the overlap of that layer with all other metal layers to be previously printed was defined. The dielectric layer was then created by removing features from the overlap in areas where interconnects between layers (typically referred to as vias when using standard fabrication methods) were required.

Polyimide coated thermally oxidized Silicon wafer pieces (spin coated to approximately 5 um thickness and thermally cured at a temperature up to 255 C for at least 90 min) were used as the substrate material. Cabot CSD-32 Silver nanoparticle (AgNP) ink was used as received for the metal layers. HD Microsystems polyimide (PI) thinned with N-methyl-2-pyrrolidone (NMP) (approximately 2:1 by volume) was used for the dielectric layer. Each metal dielectric layer was printed using the AgNP ink to a targeted thickness of 5 um and each dielectric layer was printed using the PI ink to a targeted thickness of 10 um. Once printed, each layer was thermally sintered/cured at a temperature up to 255 C for at least 90 minutes prior to printing subsequent layers. An Optical image of a fully printed 2-layer board is shown in Figure 1a and of a 4-layer board in Figure 1c. 2-layer circuit boards were populated by standard pick-and-place techniques with a conductive adhesive to attach components in place. Built up boards (Figure 1b) were tested for functionality at room temperature, thermally cycled from 10 to 80 C for 63 cycles and subjected to high temperature operational life testing at 70 C for 96 hours. Design criteria, fabrication methods and test results will be presented in detail.

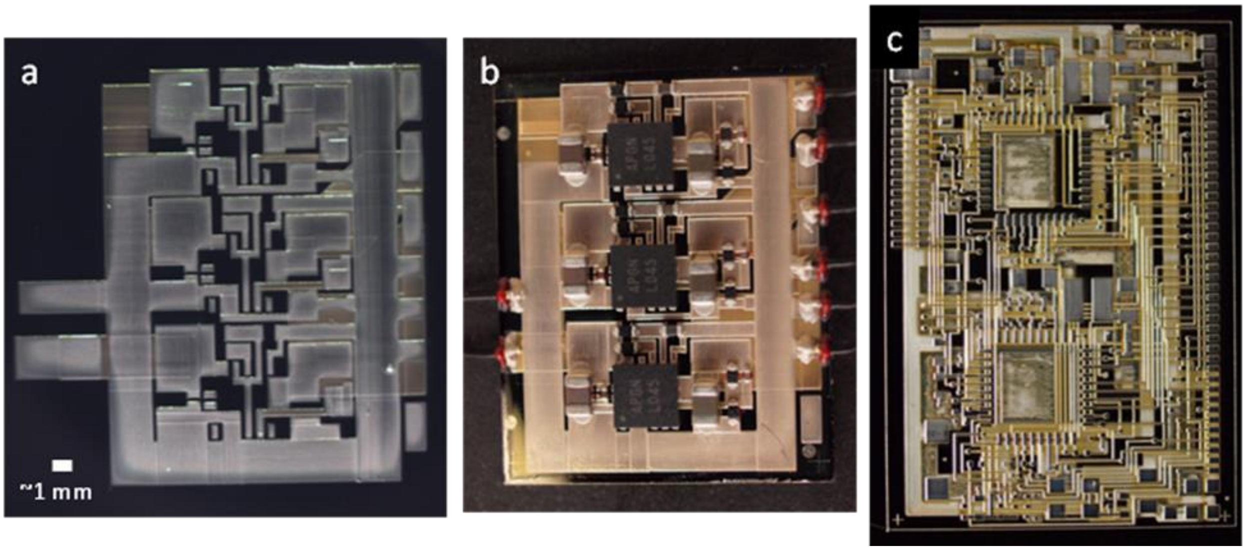

Figure 1. Optical images of (a) a fully printed and (b) a populated 2-layer power supply boards along with (c) a fully printed 4-layer digital interface board.