"Quality in, quality out"

A capability study conducted by GM Nameplate, Chromaline and Engineered Material Systems has returned a newly designed PET substrate for screen printing in flexible printed electronics

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In computer science, the saying goes "garbage in, garbage out" referring to a logical process wherein poor quality input can only produce poor quality results. One can relate to this fact in screen printing: Processing a job using even one poor-quality intermediate (e.g. a jagged film positive, or a homemade exposure unit, or expired ink) cannot be expected to produce ideal finished results; regardless of whether all other intermediate hardware and consumables are of the highest calibre.

Professionals in flexible printed electronics realise this dilemma and are willing to invest in high-performance materials and equipment in order to yield high-quality screen printed circuitry. Beginning with an engineer-designed digital CAD rendering, a high-resolution film positive is processed from an US$80 000 plotter. That photo tool image must be replicated with a high-quality polymer stencil by means of a finely tuned and focused $10 000 exposure system. This photopolymer stencil layer is supported by a high-strength, low-elongation, metal alloy mesh; perhaps stretched trampoline-style by one of a handful of capable individuals; with a completed cost of about $200 per square-foot.

In spite of all best efforts, knowledge and experience, inevitably the press operator must still 'beat it into submission'. There are a multitude of variables to control on the press alone – off contact, down stop, squeegee hardness, angle, pressure and speed – to name the primaries. And it seems, even repeating the same job under the same setup never produces exactly the same results without some demanding fine-tuning tasks. In many cases, the original artwork must be modified and the process starts over, delaying the time of delivery to the customer and creating wasted time and material.

The most accurate conductive line possible

A year-long study by a small group of printed electronics professionals on these issues included a flexible circuit fabricator (GM Nameplate from Seattle (WA), USA), a photo stencil manufacturer (Chromaline from Duluth (MN), USA) and a conductive ink manufacturer (Engineered Materials Systems from Delaware (OH), USA). The goal was to screen print the narrowest, most accurate conductive line possible in a typical production environment using commercially available, cost-conscience materials.

In spite of using a precision photo tool (25 000dpi), a capillary film capable of copying that image on high open area mesh (400tpi, 0.0007in diameter stainless), a rheology-optimised silver paste and a master press operator, it was the interfacial compatibility between the silver paste and the substrate material that made the most significant impact on the final print quality. Beginning with a photo plot of alternating 100µm (+/-2µm) lines and spaces, using an industry standard print treated polyester produced an average printed line width of 179µm (range of 163-189µm) as seen in Figure 1. The silver paste flowed as designed, to transfer from squeegee side to substrate, during the print stroke; however, the surface tension of the substrate was unable to assist in retaining the ink flow to within the intended print width.

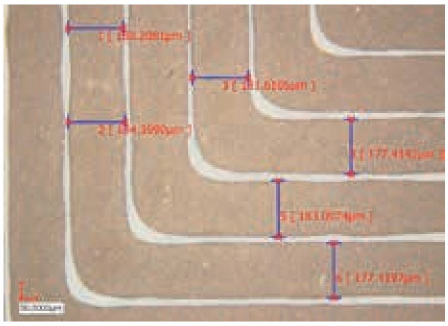

Figure 1 – 100µm Ag lines/spaces on standard treated PET, 89% max. spread

Reducing the line and space widths down to 50µm produced complete shorting (Figure 2). All printed lines spread at least 100%, revealing the limitations of line and space fineness on standard treated PET. Typically with these results, artwork must be adjusted, screens remade/reordered and the job re-run.

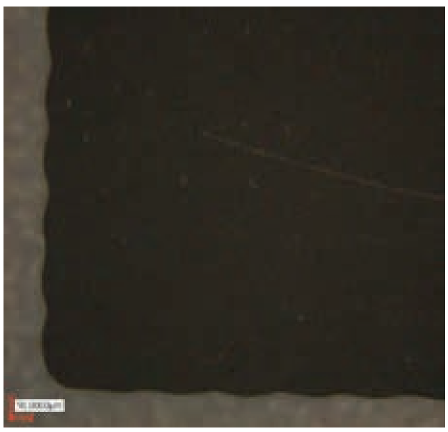

Figure 2 – 50µm Ag lines/spaces on standard treated PET (complete shorting)

Considering that the trend in many electronic devices is to either make them smaller and/or equip them with a higher density of functionalities in the same space, forward-thinking manufacturers may begrudgingly be forced to move to more expensive, less productive processes in lieu of screen printing. But still, those doing today's work may strive towards continuous improvement – to produce higher quality flexible circuitry with lower rejection rates.

A redesigned substrate

Slightly refined printed line quality was found when substituting in an "etched" PET with increased surface roughness. However, to significantly improve the quality of the printed trace, a new flexible substrate was engineered to provide interfacial compatibility as well as to inhibit paste spread. Utilising a pre-stabilised polyester carrier, a surface coating was formulated to receive the silver particles while absorbing the paste's solvents, preventing lateral spreading along the surface.

Substituting this newly-created coated substrate for the standard PET while maintaining all other variables unchanged, produced dramatically improved results. The American expert team reprinted the 100µm lines and spaces, thus achieving a maximum spread of only 9% (range of 96-109µm) from the original artwork dimension (Figure 3).

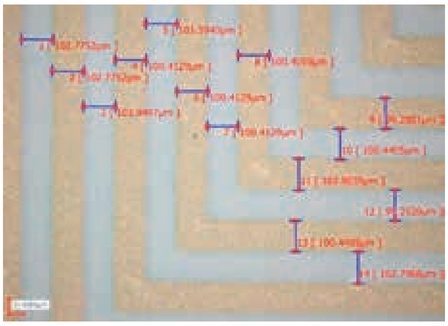

Figure 3 – 100µm Ag lines/spaces on coated PET, 9% max. spread

This substrate's ability to restrict paste flow allowed a further reduction in printed line width while maintaining accuracy and conductance. Comparing the same 50µm line and space features as before, this coated PET now permits higher density of trace features without shorting (Figure 4). Calculations over several prints yielded an average trace width of 49.1µm (44-54µm range).

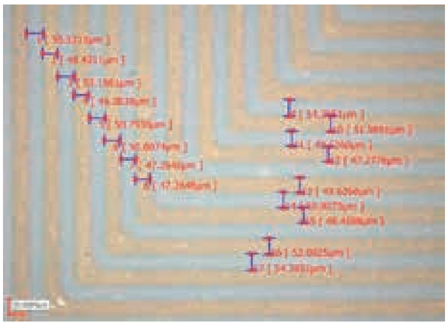

Figure 4 – 50µm Ag lines/spaces on coated PET, 8% max. spread

"This study answered our initial goal – using non-exotic, commercially available equipment and materials, alternating 30µm line and space features could be screen printed with reasonable accuracy and consistency," commented Marty Medvetz, alpha product specialist at Chromaline Screen Print Products. "Utilising the coated PET substrate, the final print produced an average line width of 30.8µm with a range of 26-37µm (Figure 5). We used the same ink and stencil for all printed results in this study."

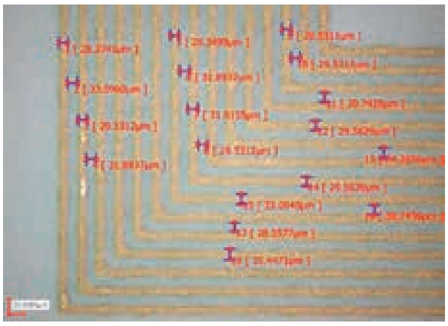

Figure 5 – 30µm Ag lines/spaces on coated PET, < 7µm spread

He added: "Whether it's qualifying capabilities for next-generation flexible circuitry, or achieving greater throughput and latitude for the press operator, a single variable introduced into the process can either create opportunities or obstacles. In our study, despite investing in high-quality stencil materials, ink and equipment, plus an experienced press operator, choosing a low-cost substrate caused press setup difficulties and prevented intended results. The development of a new type of flexible polyester-based media enabled us to greatly improve printed line accuracy when all other aspects were optimised. Thus, our motto should read 'quality in, quality out'."