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Jet-Dispensed SMT Adhesives for Durable Printed Electronics

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Abstract
Polymer Thick Film (PTF)-based printed electronics (aka Printed Electronics) has improved in durability over the last few decades and is now a proven alternative to copper circuitry. This paper discusses the use of **jet-dispensed** Surface Mount Technology (SMT) adhesives for increased durability, lower component cost, and new form factor printed electronics. Jet-dispensing enables higher assembly speeds, accurate placement of multiple adhesives, smaller surface mount device (SMD) and Z-axis registration tolerance.

Introduction

The problem we have solved
PTF circuitry with improper design and materials can be fragile and subject to latent field failures, e.g. mechanical stress fracture and silver migration shorting. Jet-dispensed adhesives are quickly and accurately placed into optimized land patterns that protect the SMT joint during mechanical flexing and harsh environments.

Jet-dispensed adhesive globules travel a distance of 0.0625" (1.588mm) to 0.125" (3.175mm) to reach its destination. This greatly eliminates the need for Z-axis registration or planarity of platen and substrate as is required for stencil or needle dispensing. New form factor printed electronics that offer soft / quiet / stretchable printed electronics for medical electrodes and wearable applications can vary in surface topography so jet-dispense brings the necessary solution for SMT attachment.

PTF circuitry has become highly durable with continuous improvements in materials, process and test standards. Discrete components are routinely attached using conductive adhesive, staking compound and encapsulant (figure 1).

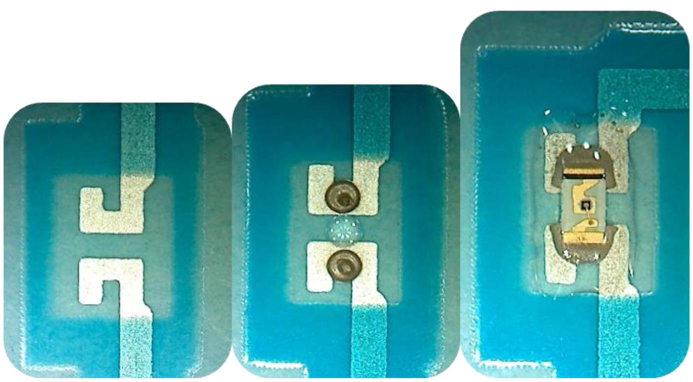

Figure 1 - SMT Stack Up: left land pattern, middle applied dots, right applied SMD and encapsulant

Durability improvements were needed for SMD attachment. Compatible materials, optimized land pattern, and placement accuracy were key. A new SMT test was adopted by IPC (ASTM F3147-15) test for mechanical durability (figure 2). A properly built SMT joint on PTF circuitry will offer mechanical durability and long-term field performance.

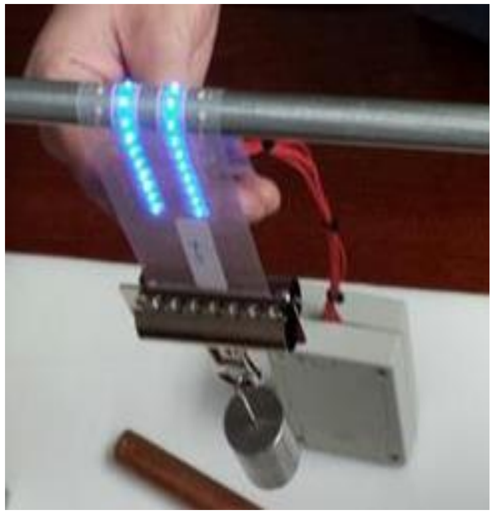

Figure 2 ASTM F3147-15 SMT Mandrel Test

Why the problem is not already solved, or other solutions are ineffective in one or more important ways
Starting with materials, a chemically and stress compatible set of materials should be used. Many PTF circuitry manufacturers use materials from various sources. Even materials from the same source can be incompatible (figure 3). Materials should be evaluated and aged for compatibility confirmation.

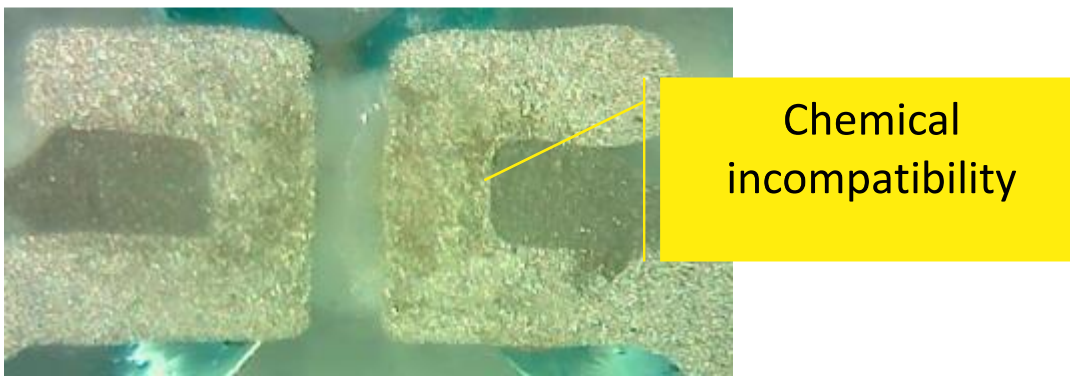

Figure 3 Material incompatibility - adhesive chemically attacks silver land

<u>Land design</u> is important for stress management. Silver adhesive bond strength is typically >1,000 psi. Many manufacturers simply place adhesive onto silver ink pad which has adhesive strength of only ~20 psi. This invites stress fracture during flex or removal. Some manufacturers will print an open area in the land pad but this does not allow for the strong bond found at end of adhesive fillet since this is over the silver ink pad. (figure 4) The suggested "hook' pattern serves to channel adhesive to the proper area and to allow the fillet end to bond direct to substrate for durability. (figure 1)

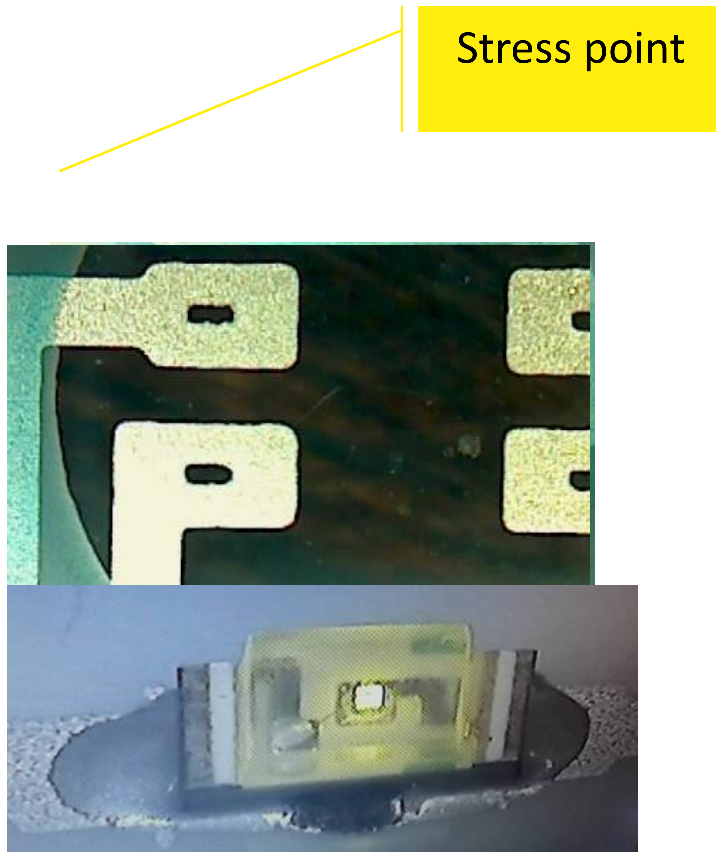

Figure 4 Ineffective Land Patterns

<u>Process methods</u> used for applying conductive adhesives include stencil printing, needle dispensing and the new jet-dispensing. **Stencil** is popular for faster process speed when numerous SMD are populated but is limited to dispense only one material; staking compound, if used, would need to be applied by needle or jet after the conductive adhesive. Also, stencil cannot be used to apply adhesives into a cavity e.g. PSA spacer cut outs. **Needle** dispensing is popular for both flat surfaces and cavities, but accurate Z-axis registration is required for fine dot application, and process speeds are slower. **Jet-dispensing** removes to large degree Z-axis registration and can apply more than one adhesive at once with fine dots in a fast and accurate manner. These advantages allow for smaller SMD which are cheaper and better for bending or flexing. Another advantage of certain jet-dispensing equipment is to apply all adhesives and place SMD in the same machine for smaller floor footprint and less registration steps.

Why a better solution is worth considering and why is it effective in some way that others are not

Jet-dispensed adhesives is a game changer for robust processing of PE circuits using a durable and compatible set of ink and adhesive materials.

Jetting of adhesives and encapsulants greatly reduces the Z-axis registration challenges seen in needle dispensing due to planarity variation of platen, substrate and applied ink layers. Jetting allows highly accurate placement of small dots of conductive adhesive and staking compound on an optimized LAND design, rapid SMD placement, and accurate encapsulant jetting. This then allows rapid placement of smaller and lower cost die, e.g. 0603.

Other efforts that exist to solve this problem and why are they less effective than our method

Test standards were historically written not to force a failure but rather to allow high yield production and customer acceptance. Hence, the relaxed standards.

Material suppliers and circuitry fabricators tend to protect good ideas as trade secrets. PTF circuit industry symposiums could do a better job to identify where PTF circuitry is winning, where it needs to improve, and how to get there…as a collaborative group.

Much production is locked into older established inks from big name suppliers since fabricators avoid material change if comfortable with production settings and the cost to change legacy specifications. Many jobs continue to adopt Bill-of-Material (BOM) specifications written many years ago and materials developed over 30 years ago.

Industry attention has been paid to leading edge technology which attracts investment but does not deliver robust circuitry.

A well-designed selection of materials and design layouts will permit sharp creasing, 85% RH/ 85°C damp heat with bias load aging, SMT mandrel flexing and other critical tests that prove and ensure robust PT circuitry fabrication.

Material improvements are available in substrate, inks, adhesives, connectors and SMD components. It is important to understand what to look for and test against when selecting your material set.

Simple techniques for stress management of the various inks and adhesives should be used to add durability.

Common practice of today's PTF circuitry industry is to prescribe careful handling procedures during installation into equipment or devices. Older SGIA/ASTM and IPC test standards specify milder environmental and performance test conditions compared to that of copper circuitry. This situation has been brought on (in the opinion of the author) by numerous designs of PTF circuitry, varied substrate composition and quality, numerous PTF inks of varied compatibility, and the ever-driving need for lower prices. Fabricators new to PTF circuitry often attract business with lower prices, not having the overhead or expertise to understand the necessary design criteria and material selection for robust circuitry.

IPC is developing state-of-the-art test standards for Printed Electronics to provide the means to identify robust circuitry. Kids gloves handling is not necessary with properly designed PTF circuitry and materials selection. Open sharing of best techniques and materials should raise the performance bar for material suppliers and fabricators alike. As more producers of PTF circuitry build to IPC test standards then the industry as a whole will grow and prosper as confidence in this technology grows.

Implementation

Many thanks to the cooperation received by General Label of Minneapolis to optimize this jet-dispensing process. GL made the investment into state-of-the-art equipment to enable faster and more accurate durable Printed Electronics. The equipment and setting are proprietary to GL but there are several suppliers of jet-dispense equipment for solder paste dispensing as used in the copper PCB industry that can be considered.

How to put this solution to work for you

For a ready-to-use engineered solution of robust materials and processes General Label can be contacted at www.general-label.com.

Evaluation

How we tested our solution

ASTM F1683-09 Standard Practice for Creasing or Bending a Membrane Switch

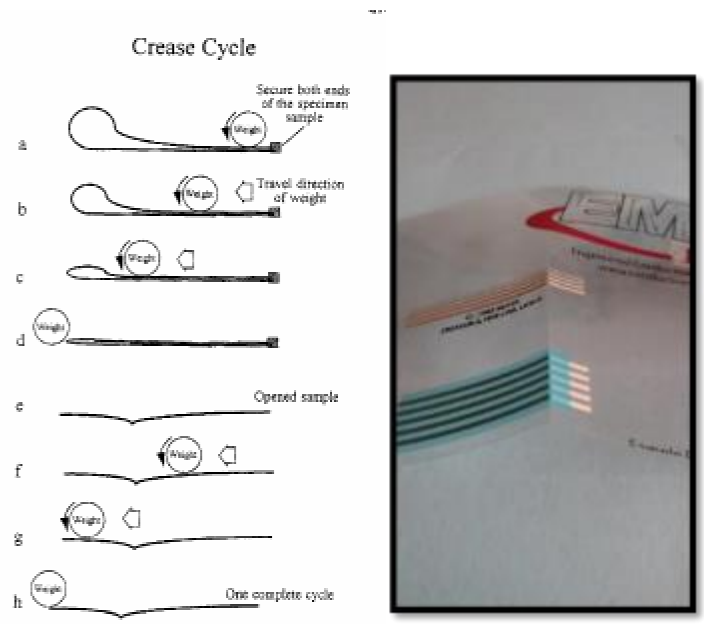

Figure 5 Crease cycle description

Best practice is a compression crease (ink on inside) followed by extension crease (ink to outside) along same crease.

ASTM F1996-14 Standard Test Method for Silver Migration for Membrane Switch Circuitry

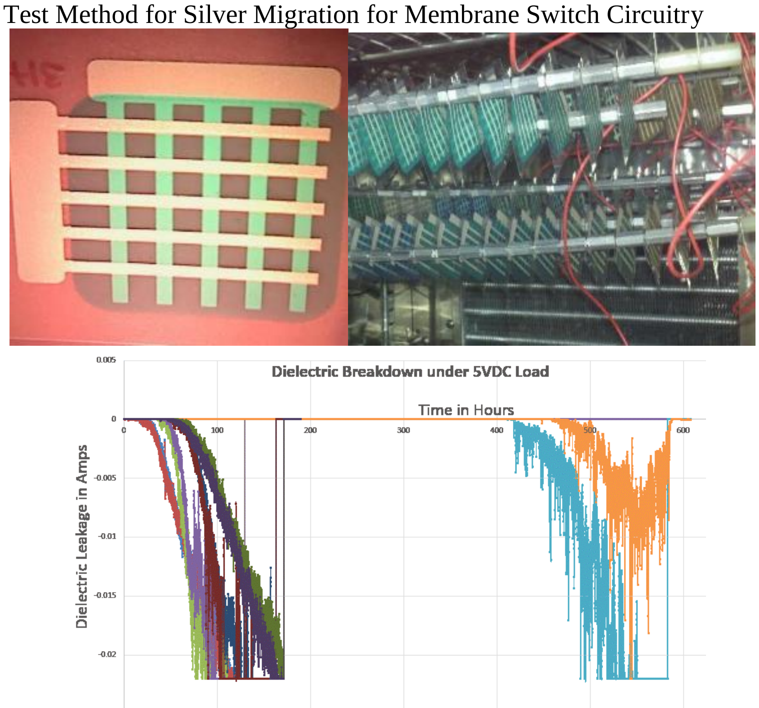

Figure 6 85%RH/85C damp heat 5VDC test description

ASTM F3147-15 Standard Test Method for Evaluating the Reliability of Surface Mounted Device (SMD) Joints on a Flexible Circuit by a Rolling Mandrel Bend

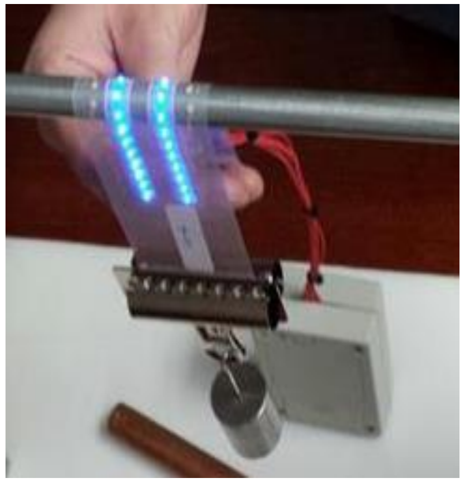

Figure 7 SMT Mandrel test description

How our solution performed, how its performance compared to that of other solutions mentioned in related work, and how these results show that our solution is effective

Many material solutions in place today do not survive the tests previously described. Many of these inks and adhesives were developed 30+ years ago and not to current standards. These materials exist and are widely used due to legacy specifications for long running projects.

More robust Printed Electronics is possible and readily available for new projects where newer materials can be specified.

What we will do next

More work is needed to develop robust processing of new form factor substrate for pliable and soft electronic circuitry and electrodes. The challenge lies with handling of the varied new substrate. But the need is popularly recognized, and many material suppliers are committed to delivering better solutions.

References

IPC Test Standards per IPC D-60 task group