Implementing Two-Component Conformal Coatings into Production

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Abstract

Conformal coating formulators are developing two-component solutions that improve protection, adhesion, and cure speed. Multi-component coatings are not new to the industry. Some of the oldest conformal coating formulations available are of the two-component variety. While there are some similarities between past and present, the range of possibilities these new formulations provide has not been seen in the industry prior to now. Demand for increased performance and faster cure times are driving manufacturers to revisit these chemistries. New application technologies and techniques have been developed for use in production while focusing on ease of setup, cleaning, and performance.

Along with developments in spray technology, a number of process improvements have been found. Today the majority of conformal coatings applied in high volume are done using a selective coating machine where a single wet layer of coating is applied only in desired areas of a PCB. When using traditional single part coatings there can be some challenges in developing a successful process. The properties found in some of the new coatings have provided process benefits such as: improved thickness/coverage on leads and edges, minimal underfilling of sensitive components by the coating, complete cure in shadowed areas, and offers a wide range of flexibility for target application thickness. Descriptions will follow of the benefits found with two-component coatings and how they can potentially enhance the protection of electronic circuits. Examples of applicator technology developed for these materials and the corresponding fluid delivery systems will also be described.

Introduction

Conformal coating is a protective layer or film, applied to electronic circuits that form a barrier from moisture, dust, corrosion, or foreign particles. When speaking about coatings applied in liquid form the four main types of chemistries used as defined by IPC-CC-830, are: acrylic (AR), urethane (UR), silicone (SR), and epoxy (ER). A fifth type that has become more popular in recent years is ultra-thin (UT) or also referred to as nano-coating. These coatings are often a polymer (or other) resin in a very high percent of solvent. When applied a nano-coating will dry to a film as thin as only a few microns thick. Max thickness of these types of chemistries may only get up to 10-15 micron.

When initially defining a conformal coating process the materials used can simply be categorized as either solvent based or 100% solids. Applying solvent based coatings requires the solution to be prepared at a low viscosity, typically =< 100cps, in order to be sprayed cleanly and accurately with the appropriate applicator. This either requires the coating to be provided pre-diluted from the supplier or the end user must add solvent to the batch to achieve the desired processing viscosity. This can open up the possibility for error from using the wrong dilution or inadequate mixing which can introduce air bubbles, foreign objects, or contamination. When applied properly, solvent based coatings can be applied quickly and cleanly to create a thin dry film thickness from <25um up to 75um which meets many user requirements.

100% solids coatings are just that, no solvents are used as a carrier of the resin to the substrate. When a particular wet film thickness is applied with these coatings, little to no by-products are given off during the curing step and the dry film thickness remains approximately the same as it was for the wet film. One-part, solvent-less coatings are typically applied in a thickness range of 75-200um and can offer multiple benefits in processing speed or the lack of volatile solvents but can also have limitations either in max film thickness, cure speed, or durometer/durability.

Supplying a conformal coating machine can start with a very basic fluid delivery configuration using a simple pressurized vessel feeding an air operated spray valve. Reservoirs can range in volume from a single syringe up to drums that can feed multiple applicators through many meters of tubing. More intricate systems may utilize a pump to provide consistent and bubble-free supply of the coatings along with a heating system to warm the fluid for viscosity control. To apply a 2-component formulation this has traditionally been done using a batch process where the end user might hand mix a limited quantity batch of Part A with Part B, load the batch into the fluid reservoir, run production for a set duration (typically within 1 shift), purge out the remaining coating, then flush the system with solvent. As with manually diluting a batch of solvent based coating, manually mixing a batch of a 2-component coating has a greater risk of poor results due to operator error as there are added factors to consider such as pot life, using the wrong mix ratio, or improper mixing technique.

To remedy the issues with handling and mixing 2-part formulations in production, a range of applicators combined with precise metering systems have been developed and deployed to take the user out of the fluid handling equation. For high volume manufacturing there are also multiple options available with the bulk fluid delivery systems required to handle the large quantities of fluid that must be fed to the coating system.

Two Component Coatings

While 2-component coatings are not exactly new, the latest products being developed are being targeted for not only thin film application but also for thick film encapsulation. A 2-component formulation is typically comprised of a base "resin" and "hardener" that will start to cure once mixed together. Recent products coming to market have multiple benefits for processing such as: low volatile organic compounds (VOCs), high or 100% solids composition, complete cure guaranteed in shadowed areas, and a range of viscosities. Benefits for the electronics being protected can range from having better overall component coverage, to reduced stress on components and solder joints due to thermal shock issues.

Some of these coatings are more reactive in nature where the gel time/reaction time is measured in minutes rather than hours or days. This may also be referred to as pot life or working time. A short pot life material can pose multiple challenges to traditional meter mix systems, so the fluid delivery system must be designed accordingly to facilitate a minimal volume of mixed fluid plus have a low consumable cost and provide ease of cleaning. This is enabling coating machine manufacturers to utilize modern meter-mix technology used for small volume potting and precision dispensing applications coupled with enhanced versions of their applicators.

Applicator Developments

One may think that simply adding a meter-mix machine before a spray valve can provide a solution. In theory yes, but standard meter mix equipment has a few limitations, such as achieving the low flow rates associated with the board coating process, or being able to handle quick start-stop operations without creating fluid pressure spike or loss. These can lead to variable output volumes and inconsistent pattern widths from the applicator. For example, encapsulating a PCB in a potting compound may require flow rates measured in milliliters per second delivered in a single shot at one location of the assembly that flows out to fill up a cavity. Selectively coating the same assembly may require flow rates of only a few milliliters per *minute* with the total volume of coating used being broken up into a sequence of shots applied in a specific pattern to provide the desired coverage.

Small volume metering technology has existed for quite a few years but the recent developments from coating manufacturers are enabling this technology to be adapted to suit the requirements of selective conformal coating applications. Instead of using a large, bulky, and messy mixing system confined to the rear of the machine, there now exists the equivalent of having a meter mix system right on the head of the robot with an integrated spray mechanism or coupled with an applicator of choice.

Figure 1 shows one embodiment of an all-in-one applicator that has been developed which combines the metering system with the spray head in a single device that can be mounted directly to the end effector of a robot. The compact size allows for small or large volume reservoir feed.

Figure 1 - Programmable Two-Component Spray Head

For processing at the low flow rates required, a servo controlled pump is used that has feed rates in milliliters per minute and allows for the mix ratio to be programmed, typically in any range from 1:1 to 10:1. For maintaining a consistent and tight process window, each pump must be capable of holding a volumetric output within only a few percent variation. Small volume static mixing elements are used for simplicity, ease of use, and low cost. Because of the minimal volume of fluid in process, the unit can be fed using syringes mounted directly to the pump and can be used for small batch production or process development. In high volume manufacturing, much larger reservoirs can feed the system remotely which provides for minimal changeover of the empty supply containers, in some cases providing up to 6 months or more of production before refilling the reservoirs.

This configuration has proven successful for maintaining integrity of the mixed fluid in hundreds of installations with materials that have a mixed pot life as short as 5 minutes. If there is a pause in production then the system will run an automatic purge step to flush the mixer with fresh material. If the system is to be down for extended periods of time, the user only needs to remove the mixing chamber and dispose accordingly with no additional flushing or cleaning of secondary valves or nozzles. Integrated pressure sensors can detect viscosity changes which can be used to adjust feed rates accordingly or to trigger a purge routine to flush the mixer and ensure the use of fresh coating. Other options such as flow monitors can also be used to confirm the proper mix ratio or flow rates used with a particular process.

For coating of assemblies which require the applicator to be tilted to coat tall components or underneath obstructions, the applicator can be de-coupled from the metering system and used on a robot that may have multiple axes of motion including tilt and rotate operations. Figure 2 shows a pneumatically actuated 2-part atomized spray valve that can work remotely from the metering device. The driving purpose of this particular design is the mixing happens inside the valve just before the point of application.

Figure 2 – Remote Two-Component Spray Head

Fluid Delivery Configuration

Current conformal coating machines will usually employ at least 2 applicators, one being a spray valve plus another being a needle or jet type applicator. The most basic configuration as shown in figure 3 below uses a tank or reservoir that is pressurized to feed the coating out to the valve(s). To use a reactive coating with a pot life under 10 minutes, this configuration is not feasible for any type of production.

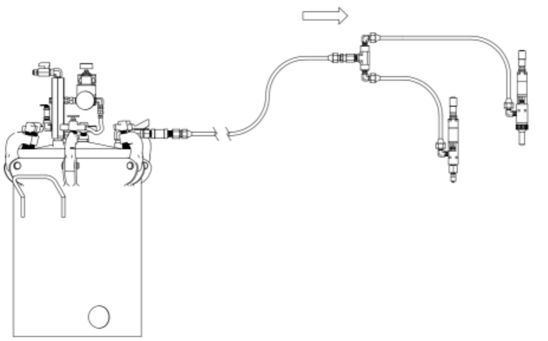

Figure 3 – Basic Fluid Delivery Configuration for 1 Part Materials

When implementing a two-part coating system each material must be supplied from its own reservoir and fed to the metering device. In the case of using an applicator as described in figure 1, this can be achieved by simply using a second reservoir as shown in figure 4 below.

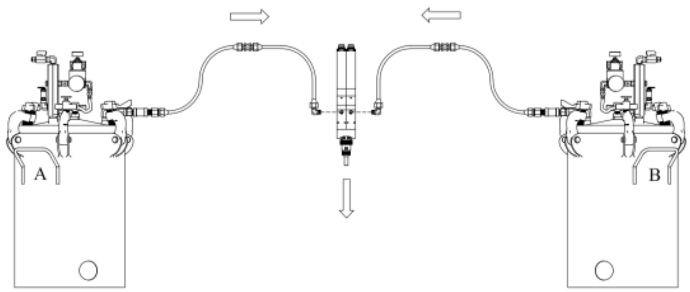

Figure 4 – Basic Bulk Feed System

Some materials may have fillers added for increased durability or enhanced flammability properties that can settle in the fluid lines when not in used. For this a circulation pump can be added to the feed system to keep the solid particles in suspension and not collect inside the hose or fittings during short down times such as between shifts or overnight. See Figure 5.

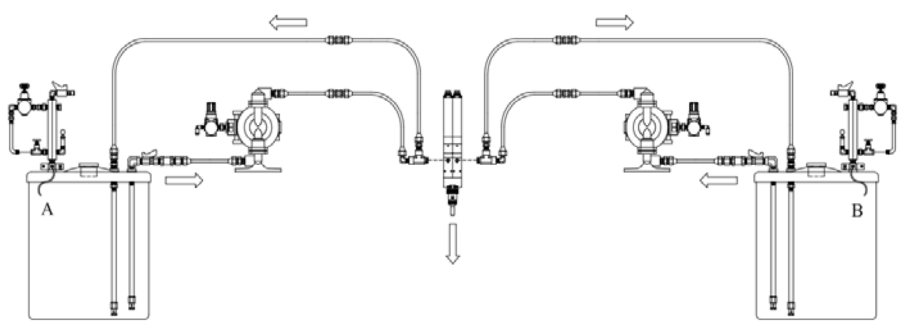

Figure 5 – Bulk Feed System with Recirculation

A common option for fluid systems is to use heat to maintain a consistent viscosity or to lower the viscosity to aid in the application. Most atomized type spray valves can handle a wide viscosity range but some airless applicators have limitations on the viscosity of the coating used to be able to achieve a consistent pattern out of the nozzle. If there are no issues with the spray valve to apply the fluid, other reasons to warm the coating may be to apply a thinner film than normally used or to help with wetting around densely populated areas on a circuit board. Figure 6 shows a sample temperature vs viscosity curve for a two-component material that starts out at just under 3000cps and will drop below 500cps with the addition of mild heat. In this case the use of heating enabled the coating to be applied in the 100 - 200micron range to satisfy a particular requirement for assembly tolerance. The same coating can also be applied at room temperature to provide much thicker films for added mechanical durability.

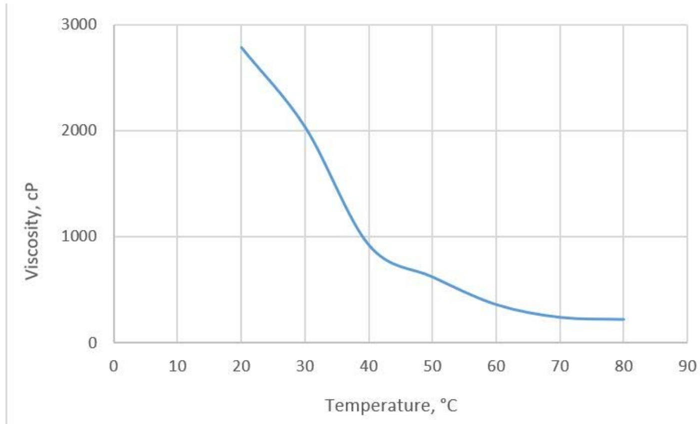

Figure 6 – Temperature versus Viscosity Example

Processing Benefits

Review any IPC document related to conformal coating or attend any coating conference and a myriad of potential quality defects will be presented. Some of the most common defects are related to the quality of coating coverage, whether it's on top of a component, around leads, on solder joints, or simply across the solder mask on the substrate. If using a low viscosity coating these conditions can be challenging to avoid simply due to the topography of a circuit board and the effect of gravity on the fluid. Figure 7 shows an example of poor coverage on component edges and on the bends of its leads.

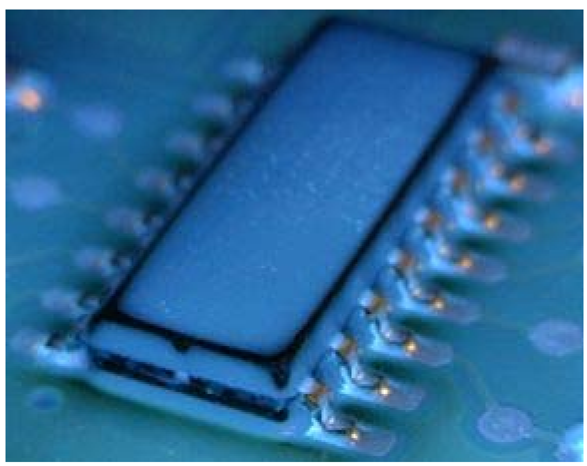

Figure 7 – Coating Thin Spots on Component Edges and Leads

If using a traditional solvent based or 100% solids coating, coverage issues may not always be solved by simply applying more coating. Other issues can arise if these coatings are applied too thick such as cracking of the coating, excess stress on components during thermal cycling, or poor curing due to trapping of solvents.

Many coating manufacturers offer secondary products that are higher viscosity or gel versions of their respective thin film coatings that can be spray or needle applied. These can be added steps in the conformal coating process, often with the same machine, and may work perfectly well for the end product. For users that do not want an additional chemistry on their bill of materials this may not always be an option.

To keep with the concept of using a single coating step, there are higher viscosity 2-component coatings that can offer a few benefits. The higher viscosity can provide the necessary protection and prevent excess flow while the reactive formula can help guarantee proper cure without creating negative stresses.

"Scavenging" is one term used to describe the effect of coating flow under components due to capillary action that draws excess coating away from surrounding areas, see figure 8. This can lead to bubble formation around leads due to elevated heat cure forcing trapped air out from under the component. In extreme cases this can also cause stress fractures in the coating or worse case cause stress cracks in solder joints due to CTE (coefficient of thermal expansion) mismatch.

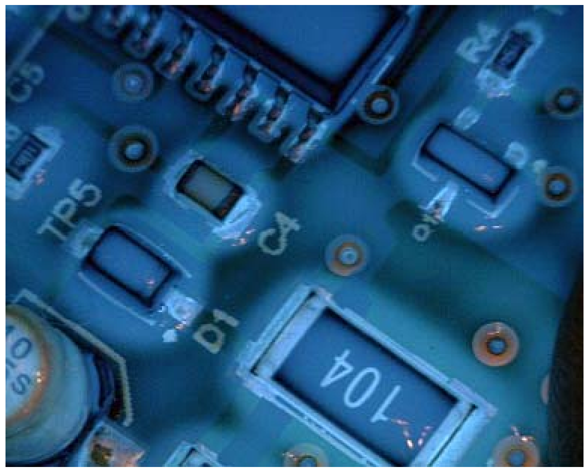

Figure 8 – Scavenging around components

Other benefit of higher viscosity coatings is there is little to no capillary effect on components. Figure 9 shows a low profile QFP removed after application of a medium viscosity two-component coating. Complete wetting was observed around leads and joints with no significant flow underneath the package.

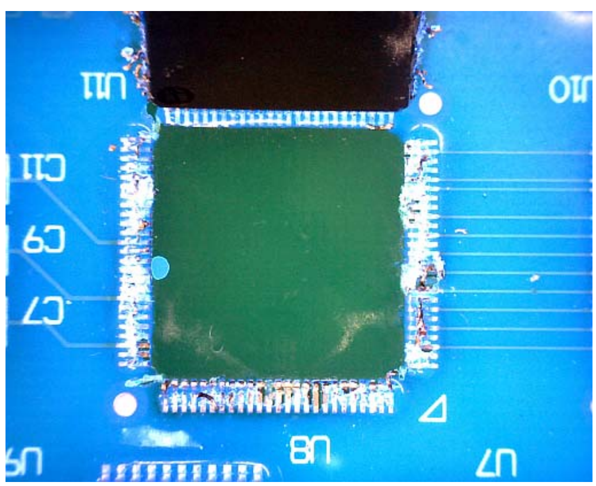

Figure 9 – No Coating Flow Under Component

For protection comparable to potting in an enclosure but without the added mass and material cost, there are two-component products available that allow for a selective encapsulation process to be used. The viscosity of these products can be prohibitive for use with traditional spray technology but can be applied with single or multi-hole nozzles depending on the target width to apply per pass. Figure 10 shows an example of a thick film encapsulant used as a replacement for a potting process.

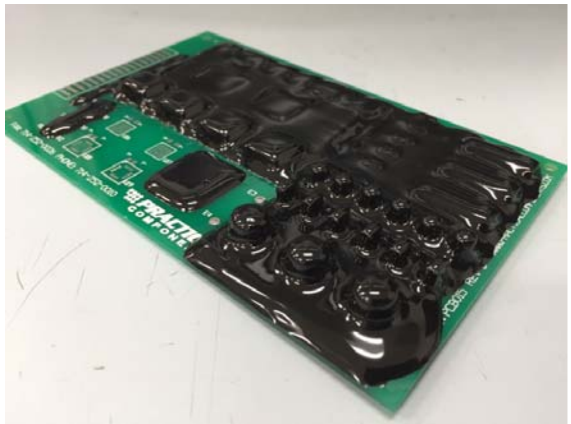

Figure 10 – 2K Urethane Encapsulant Selectively Applied

Conclusions

Conformal coating equipment OEMs and coating material suppliers must continue to innovate and explore new technologies in order to meet the challenges required to solve ongoing process issues or to help optimize their users' end products. The use of two-component materials in electronics manufacturing is becoming more popular and these materials can offer benefits for electronics protection that have often been reserved solely for potting processes. As the materials develop, the technology used to meter and apply them is evolving to allow for a wide range of processing options and techniques to suit each end user.

Implementing Two Component Conformal Coatings into Production

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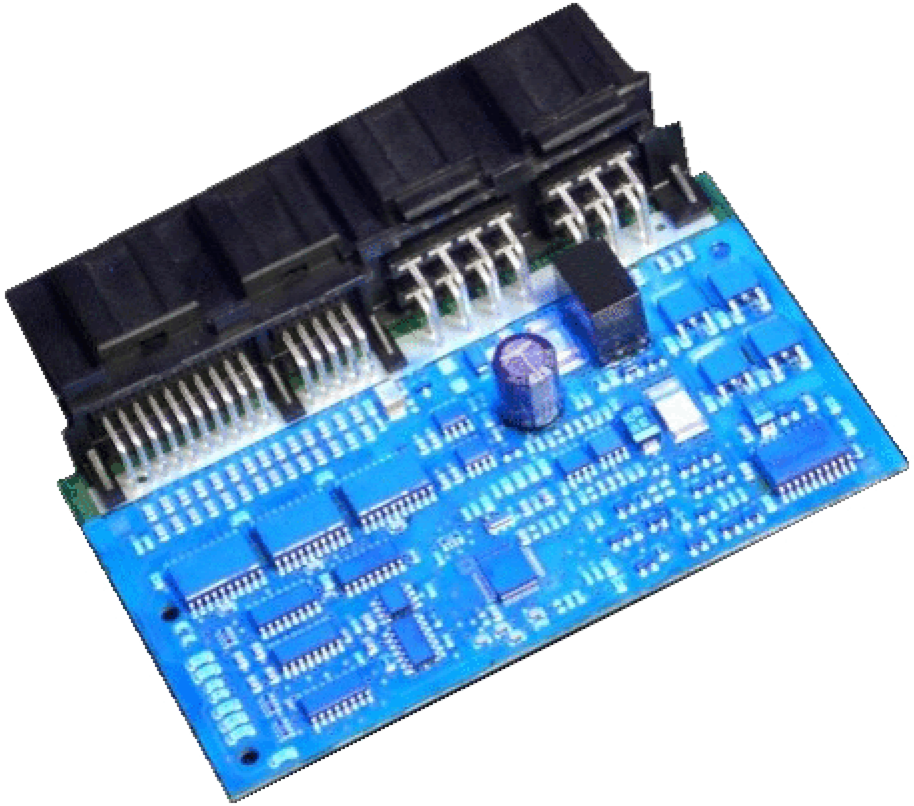
Why Use Conformal Coating?

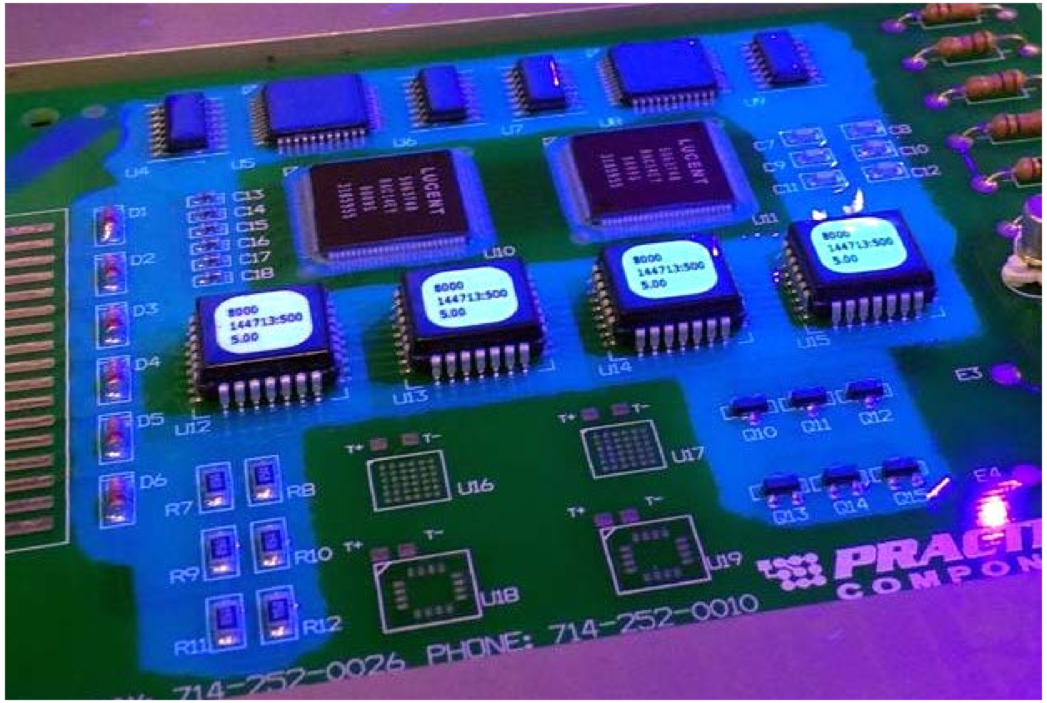
To Provide Protection From:

- Dirt, dust, foreign particles
- Moisture
- Corrosion
- Thermal Shock
- Mechanical Shock



Robotic Application

- Atomized Spray
- Airless Spray
- Needle Dispense
- Jet



Typically applied in a single wet layer only where needed

Coating Material Types*

- Acrylic (AR) - Solvent Based
- Urethane (UR) - Solvent Based
- Silicone (SR) - 100% Solids or Solvent Based
- Epoxy (ER) - 100% Solids or Solvent Based
- Synthetic Rubber (RU) – Solvent Based
- Ultra Thin (UT) - Solvent Based
- Paraxylylene (XY) – Applied in vacuum deposition chamber

* As classified in IPC-CC-830 Rev C

Coating Materials – Solvent Based

- Requires low viscosity for processing
- May require additional solvent dilution to achieve proper viscosity
- Mostly used with airless applicators
- Curing due to solvent evaporation at room temperature or can accelerate with heat
- High % of wet film thickness is lost due to solvent evaporation

Coating Materials – 100% Solids

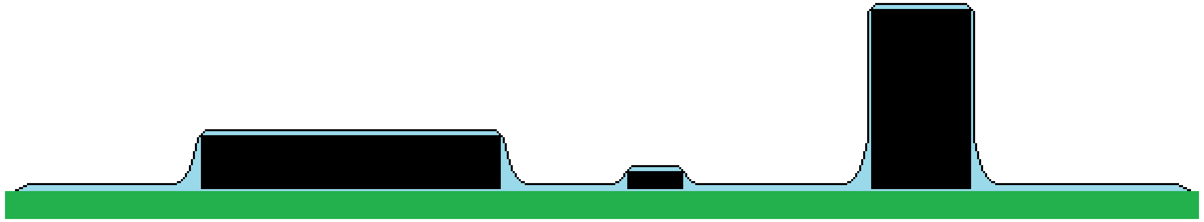
- Low to medium viscosity
- Applied “as-is”, no solvent dilution required
- Wet and dry film thickness have little or no difference
- Mostly used with atomized spray
- Cure with heat, atmospheric humidity (RTV), or ultraviolet (UV) light exposure

Two Component Coatings

NEW

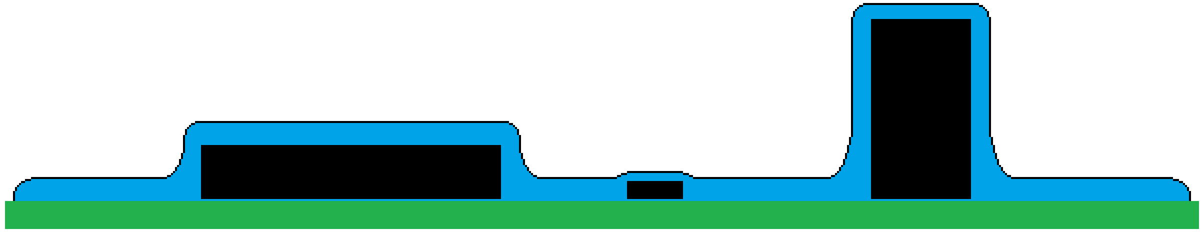
- Solvent free
- Low to medium viscosity
- Able to apply in thin film (~125µm), thick film (>300µm), and encapsulant form (3000+µm)
- No curing issues in shadow areas
- Silicone and urethane formulations are currently most popular
- Two component coatings are not new technology
- Two component coatings with all of the above features are new

Hybrid Process Application



Conformal Coating

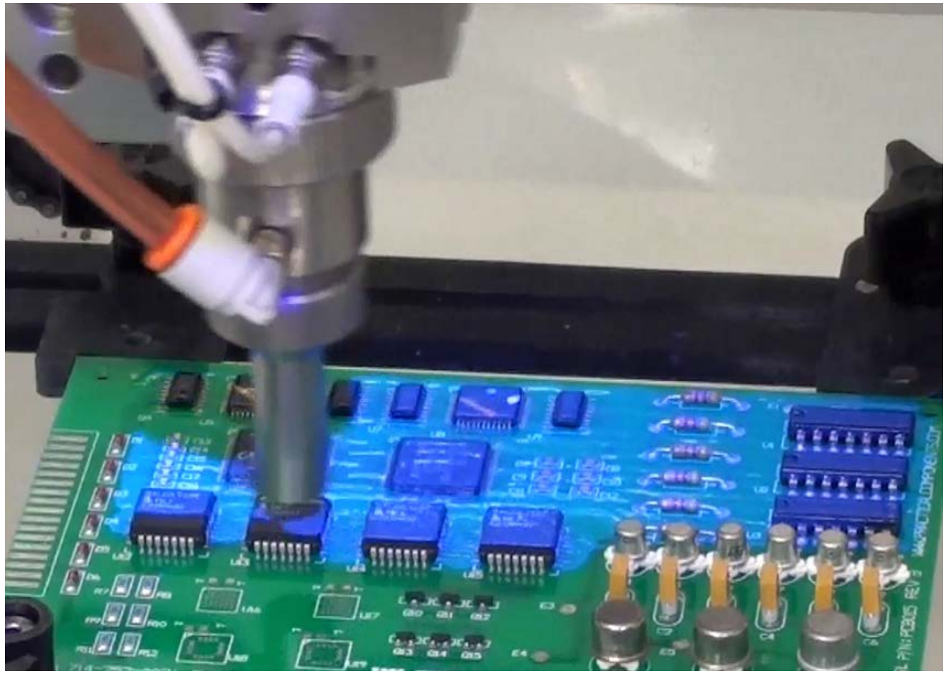
Potting



Selective Encapsulation

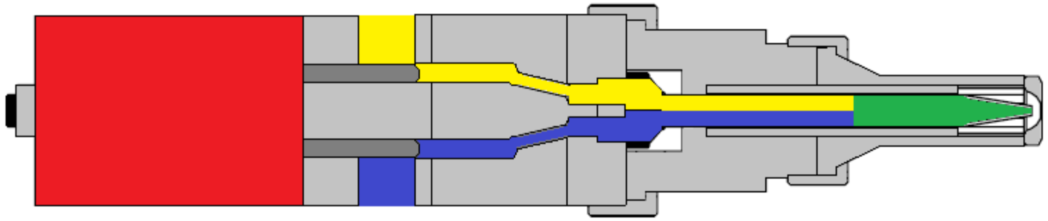
Applicator Developments

- New valve designs created to mix and spray on-the-fly
- 2 part spraying not new
- 2 part *selective* spraying is new



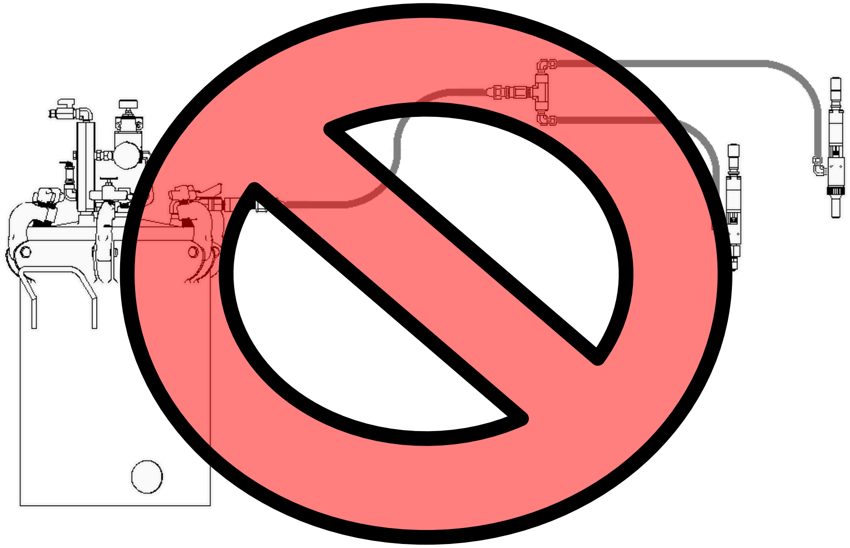
Applicator Developments

- Applicators must be able to mix prior to spray
- Spray quality must match/exceed current technology
- Minimal mixed fluid
- Easy to clean



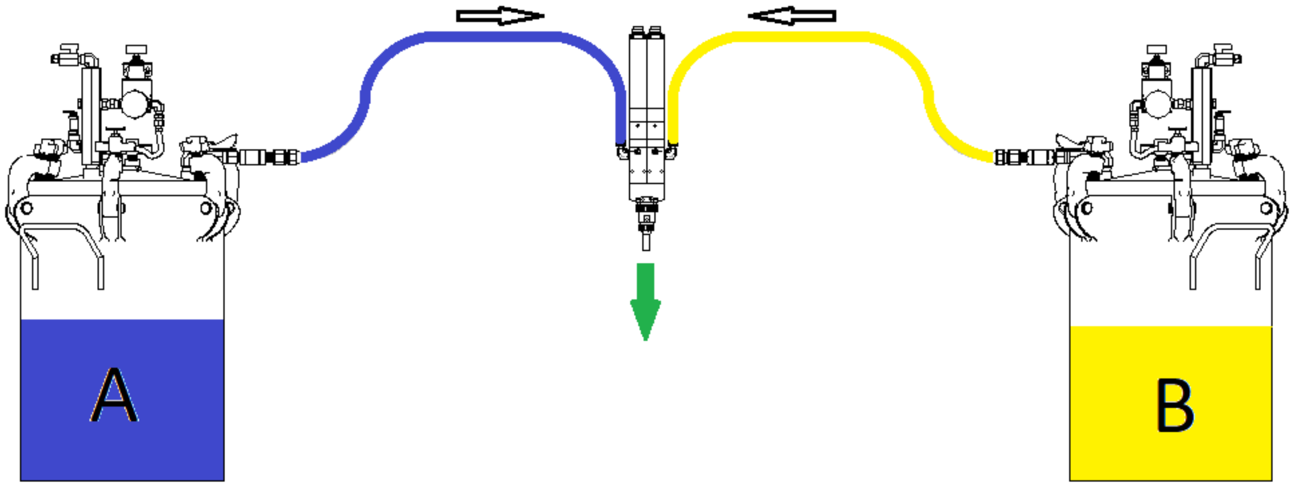
Fluid Delivery

- New coating products can have a very short pot life
- Traditional batch mixing methods will not work
- New applicator designs and equipment configurations must be used



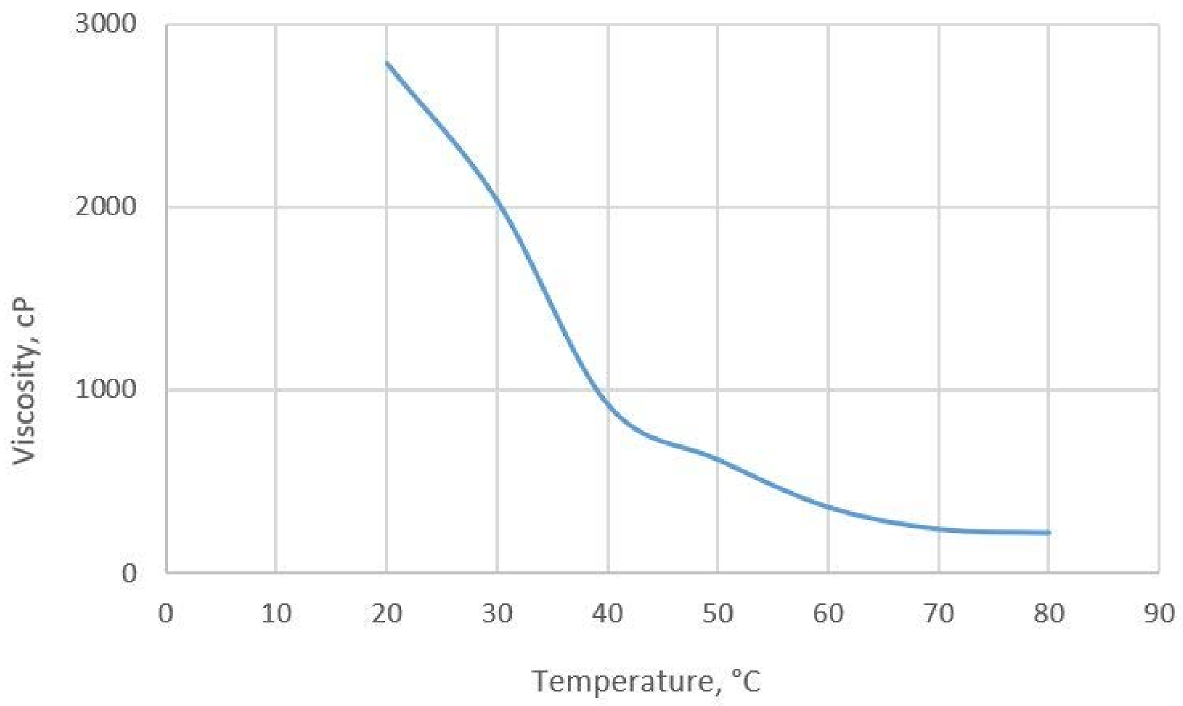
Fluid Delivery

- Each fluid component must be supplied separately
- Both parts fed into metering system
- Each part stays separate prior to mixing portion
- Metering pumps can be remote or integrated into spray head



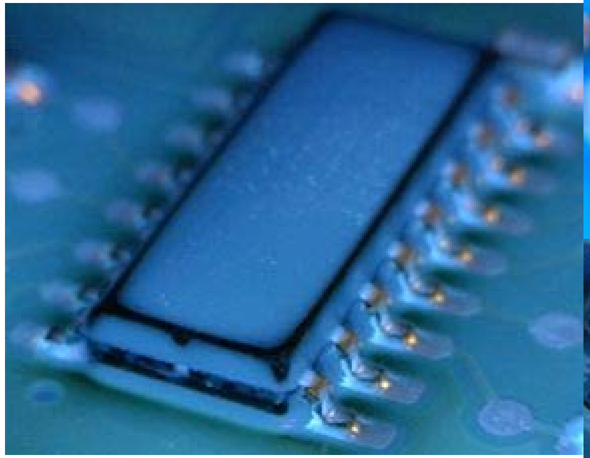
Fluid Heating

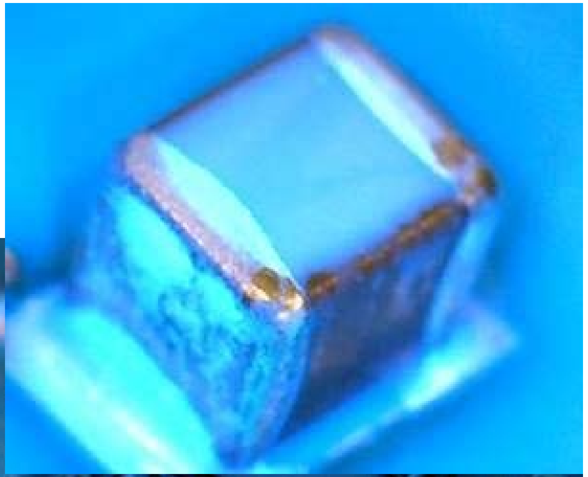
- Addition of heat can help with processing
- Lowering viscosity = thinner film
- Higher viscosity = thicker film

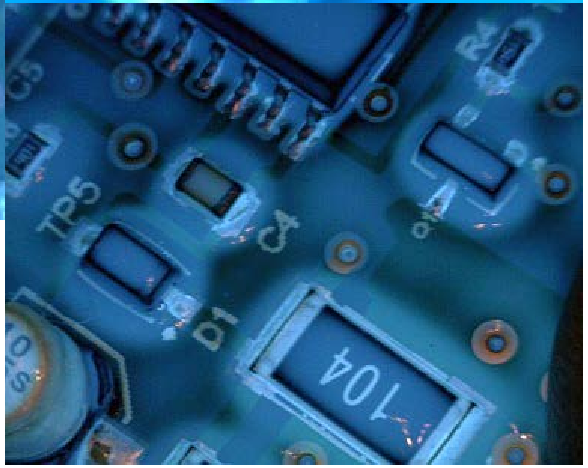


Common Conformal Coating Issues

- Dewet
- Scavenging
- Underfilling of components







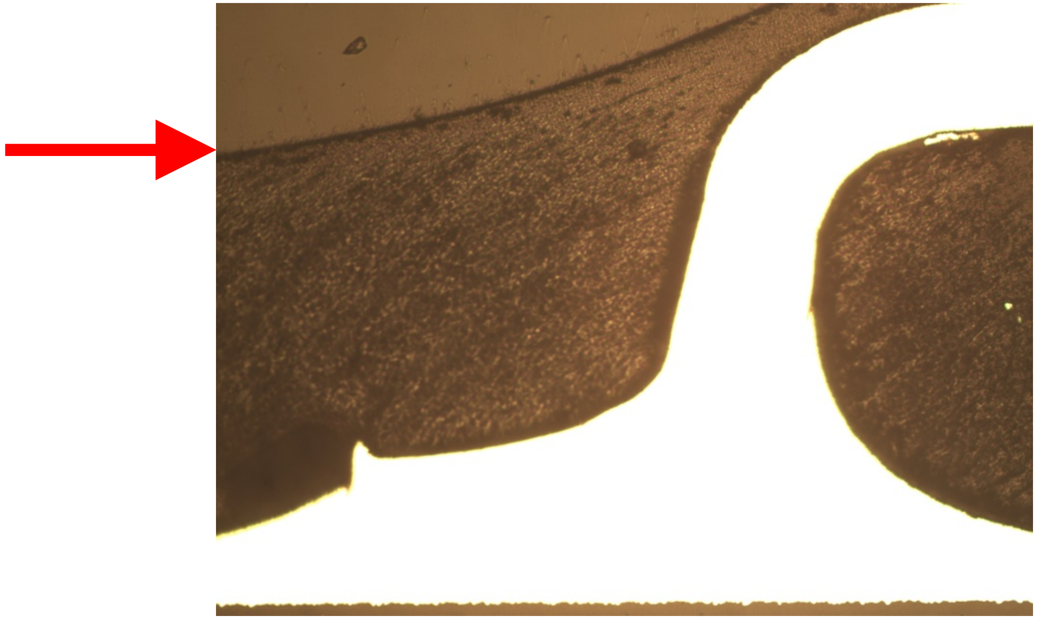
Typically using low viscosity coatings < 800cps

Benefits – Improved Lead Coverage

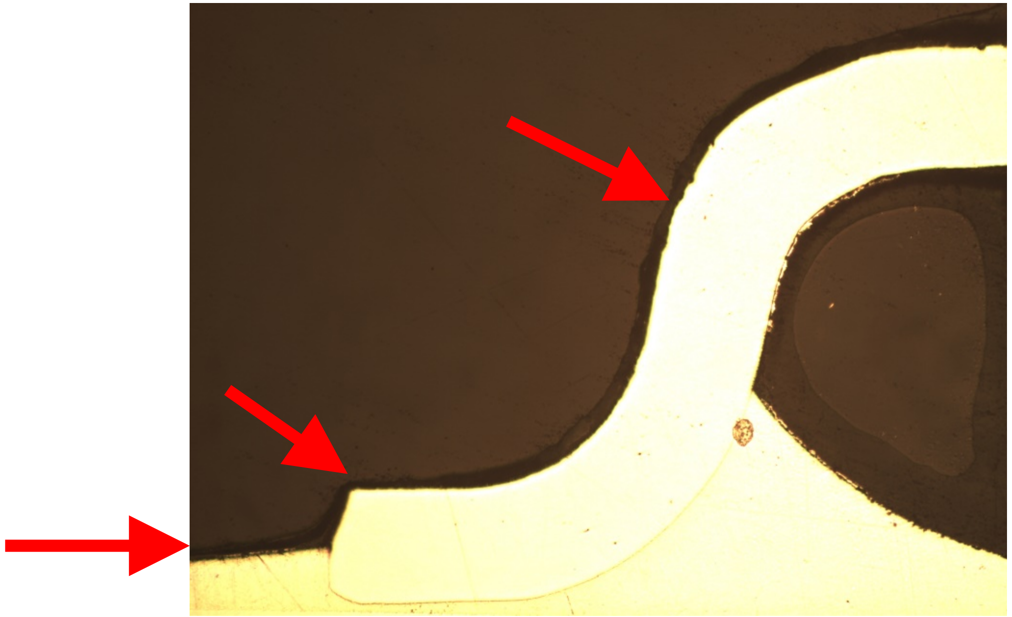
If using a medium-high viscosity product…

- Little or no flow down leads due to gravity
- Increased or consistent thickness along all surfaces
- No thin spots

Benefits – Improved Lead Coverage

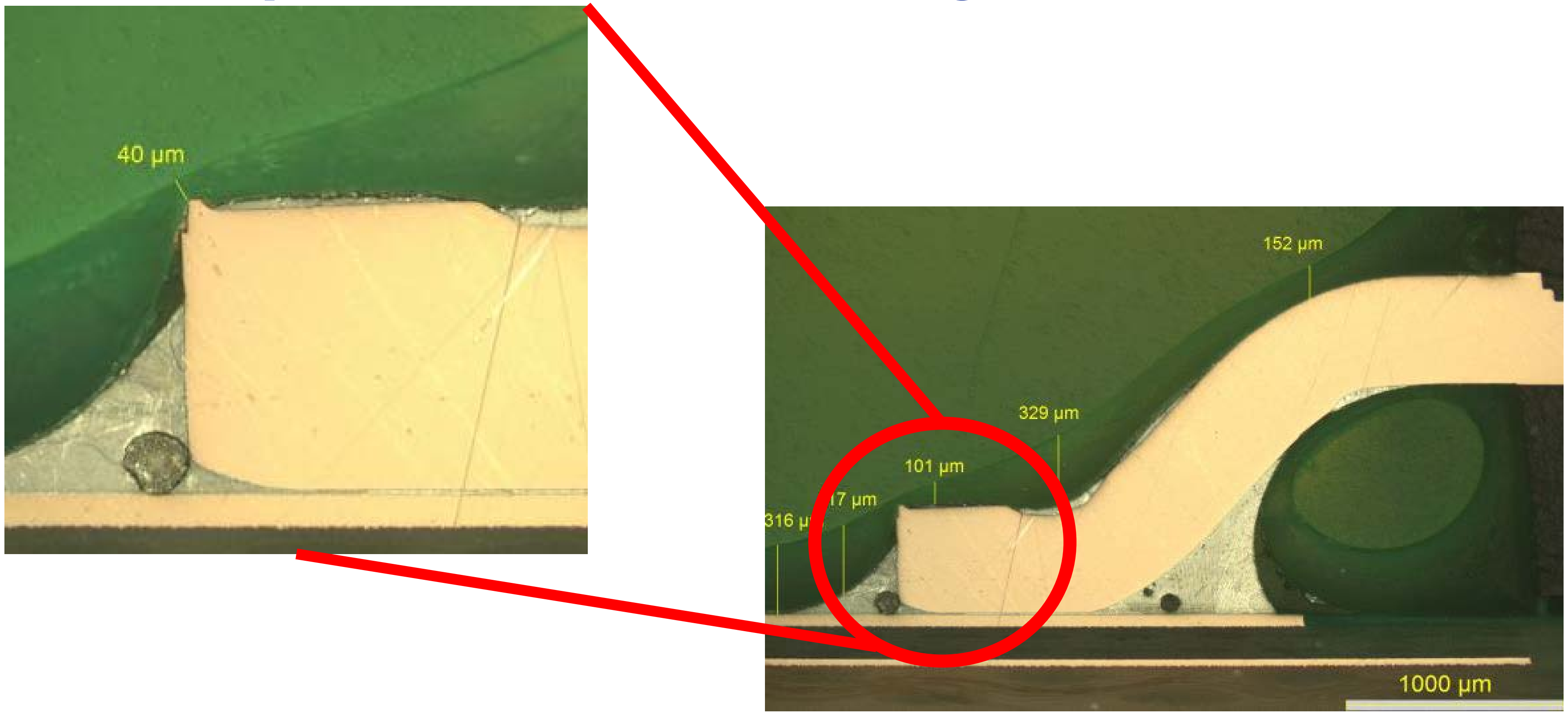


2 Part Med Viscosity Urethane -
>125 µm at knee



1-Part Solvent Based Acrylic -
<25µm

Benefits – Improved Lead Coverage

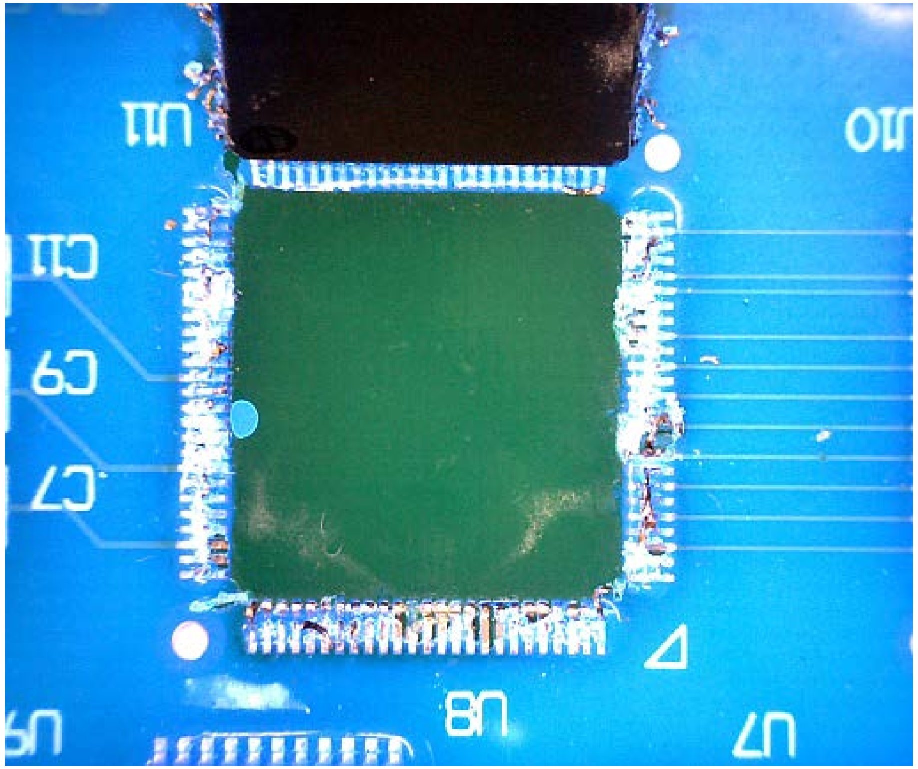


Acceptable thickness on sharp corners with nominal thickness ~200µm applied to assembly

Benefits – Controlled Flow

If using a medium-high viscosity product…

- No flow under component
- No trapped air
- No stress during thermal cycling

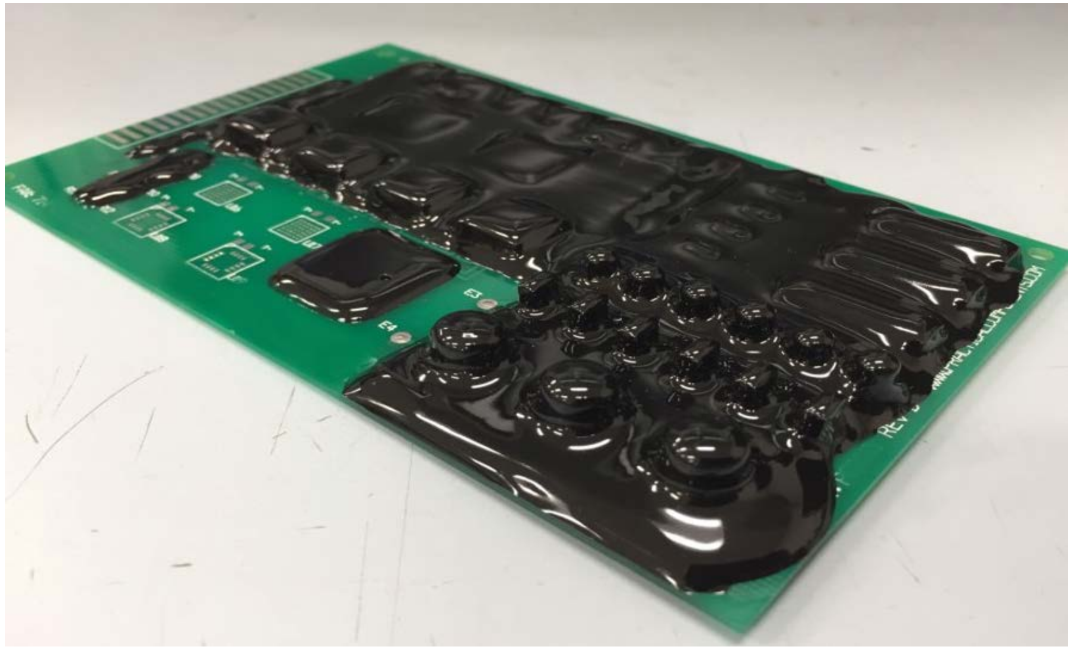


Spray applied urethane @ 300µm

Benefits – Possible to Encapsulate

If using a medium-high viscosity product…

- Can create greater film thickness
- Increased moisture resistance
- Increased chemical resistance
- Increased mechanical protection
- Increased thermal dissipation



Example – Urethane >10000cps, 2-4mm thickness, 5-7min gel time after mix

Conclusions

- New fluid technologies providing options for increased ruggedization
- Thin, thick, and encapsulation possible using selective methods
- Potential to solve low thickness issues on corners/edges
- No curing issues due to thickness or shadows

Acknowledgements

- Phil Kinner - phil.kinner@electrolube.com
- Jim Stockhausen – jim.Stockhausen@altana.com
- Peter Coate – peter.coate@altana.com
- Rick Jordan – rick.Jordan@altana.com
- Matt Eveline – meveline@chasecorp.com

Thank you