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Automated Dispensing of Two-Component Materials in Electronics Assembly

A new paradigm on the advantages, disadvantages, and challenges of using two-component formulations in automated fluid dispensing and conformal coating.

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Abstract

Electronic devices and assemblies contain a considerable amount of fluids for structural and/or reliability enhancing purposes. Emerging expectations are challenging the capabilities of current fluids for high volume production, for example, in regard to peak temperature, thermal cycles, chemical resistance, elasticity, cost, time to final dielectric properties, and curing, or any combination of these. The solution seems to have been known for more than 50 years – two-component formulations. However, the electronics industry, which mainly uses small amounts of fluid, has been historically ambivalent to this solution, and as such, perceived two-component formulations to be reserved for large potting processes. This article, as supported by broad industry information, discusses a new paradigm on the advantages, disadvantages, and challenges of using two-component formulations in automated dispensing and conformal coating.

Introduction

It has been argued that a combination of fluid, equipment, and process aspects should be considered complementary through a holistic solution perspective (B. Perkins 2013). In extending such considerations, it seems natural to distinguish between dispensing and conformal coating fluids and their properties, the manufacturing equipment used to dispense the fluids, and the equipment's capabilities, and try to formulate a solution that will create the best manufacturing process needed for a particular application. This distinction reflects inherent design requirements to enable the fluids and equipment to achieve the technical solutions necessary while fulfilling the requirements needed for the production environment. Such division seems supported by the electronic manufacturer's factory and organizational layout.

Fluid dispensing is often a neglected topic in electronics production and technical discussions. However, fluids can literally be the "glue" which completes the component, device, or the assembly for its structural design. Fluids can also be used for thermal management, optical filtering, sealing, or protection against environmental factors, which enhance the reliability of the (final) assembly.

Typically, fluids used in the production of electronics include solder paste, thermal compounds, silver epoxy, underfill, optical bonding materials and filters, encapsulation, marking and masking, and many more. Application of these fluids is required in small volumes and is referred to as ***dispensing***. The application method uses needle technology or jetting technology, where tighter space, higher tolerances, and greater throughput are needed (Babiarz, 2006).

In addition to the fluids mentioned above, large varieties of fluids are applied to protect electronics from environmental factors such as chemicals, humidity, and particles. These fluids are referred to as ***conformal coating***. Relative to dispensing, the volume of applied fluid is large, and according to Pulido & De Sanctis (2008), is typically done with curtain, spray, or needle technologies.

Electronics production is undergoing continuous miniaturization of components and final assemblies, combined with increasing requirements for the material's performance; this is challenging the capabilities and properties of current fluid offerings for high volume production. These challenges are related, but not limited to adhesion and bonding strength, peak temperature, thermal cycles, chemical resistance, mechanical rigidity or flexibility, the desire to eliminate volatile organic compounds (VOCs), reduction curing requirements, and cost of ownership. Increasingly, this is proving to be beyond the capabilities of one-component fluid formulation offerings that are available for large-scale automated production.

As such, the industry seems headed for a deadlock situation in the short term, where fluids that comply with increasingly complex specifications may not be available. The solution, two-component formulations, have been used for years, but in most cases their application has been limited to manual or semi-automated processes.

“IT’S TIME TO BREAK THIS DEADLOCK AND FINALLY OFFER THE ELECTRONICS MARKET THE ABILITY TO DISPENSE OR APPLY CONFORMAL COATING USING TWO-COMPONENT MATERIALS ...”

Some materials currently used in the industry for large-scale production might be considered one-component, when they are, in fact, a premixed and frozen two-component formulation, e.g. most underfill and silver epoxies. Handling these fluids not only imposes great shipping costs due to the precondition of maintaining -40 degrees C, but also complex production processes in terms of in-house logistics for ensuring they are handled correctly, thawed, and consumed within the required time.

From our discussions with stakeholders in the industry, the solution appears to be a double-bind situation. Producers of electronics recognize the superior performance of two-component formulations, but the complexity associated with using them and the need to use manual

processes because automated processes aren't available, hampers them. Fluid formulators have been asked to develop innovative two-component formulations, but have not focused on this technology or followed through with these requests because there was no viable technical solution for applying them in fully automated processes for large-scale production. On the other hand, equipment manufacturers have not developed the required equipment for mixing or dispensing two-component materials since there were limited fluid formulations available.
To compound the situation, because the two-component process hasn't kept up with modern manufacturing capabilities, those who have used two-component fluids have had a negative experience and/or perception of them. The industry would greatly benefit from escaping this situation and reconsidering its historically held perceptions of two-component formulations.

Figure 1
Example of an active meter-mix system

Nordson ASYMTEK has been exploring a variety of methods to mix and dispense two-component materials. *See Figure 1.* We discussed this potential with a variety of fluid formulators, delineating the advantages, disadvantages, benefits, and possibilities for the future. It's time to break this deadlock and finally offer the electronics market the ability to dispense or apply conformal coating using two-component materials with the same small dots and fine lines, accuracy, precision, repeatability, and speed as can be done with one-component systems. These dialogues have helped us better understand how two-component materials can benefit the electronics industry and implement Perkins' concept of a holistic solution perspective.

Fluid Formulations

Fluids can be considered single-part or multi-part depending on how many components the user needs to combine at the point of use. For fine and accurate dispensing and conformal coating in the electronics industry, multi-part is considered limited to two-component formulations.

One-Component Formulations

One-component (single-part or mono-part) formulations are by far the largest majority of materials used in large-scale automated electronic production dispensing or conformal coating that require accurate and fine application. These formulations can be solvent based, which cure as the result of evaporation, or can be hardened as a result of cross-linking when exposed to heat, humidity, oxygen, or light of a specific wavelength.

The shelf-life of single-part materials is often limited to a number of weeks, and they might need refrigeration. In the formulation of these materials, chemists have to balance the material properties, shelf-life, and open time. Open time is the time the material has to be used from the time it is opened. The main advantage of a one-component formulation is in how the fluids are handled throughout the dispensing and manufacturing process, as they are easy to use so it is easy to define their use in the manufacturing process. The disadvantage is in the material's properties, which ultimately impact the functionality of the final electronic component, device, or assembly. One-component materials used for conformal coating are not as reliable as two-component in withstanding certain chemicals and environmental factors. Many one-component formulations release solvents when they are used. In addition, most one-component formulations only achieve their final dielectric properties after a few days, which has implications for testing and release of the final product for use.

Two-Component Formulations

Traditionally, two-component formulations (also called 2-component, 2K, or two-part) are based on adding a hardener to a resin, which will start the cross-linking of molecules (or the hardening process of the material). *See Figure 2*. The advantages of two-component formulations over one-component are many, but can be summarized as having superior final material properties, the dielectric properties can be achieved in a few hours whereby the final product can be put into use, and a long shelf-life.

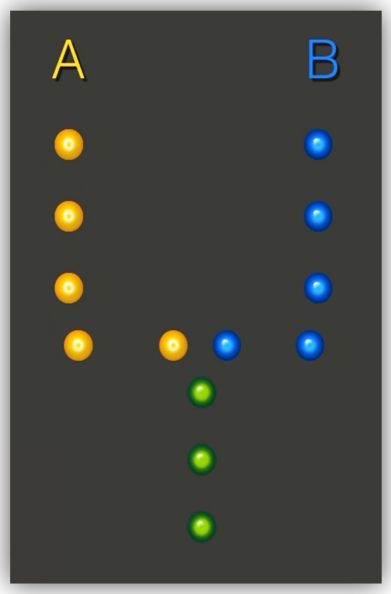

Figure 2
When the two materials are mixed together, this starts a chemical reaction that initiates a non-stop crossing linking of the chemicals.

The challenges of using two-component materials can be related to the metering, mixing, and pot life. For metering, or the ratio of each component in the final mixed fluid, a few percentage points of tolerance are usually required to ensure the final properties of the material. This not only applies to metering, but also to the need for correct and consistent mixing of the two components. Agitation of the fluid during mixing also needs to be considered.

A batch of mixed material will naturally change viscosity over time. While process control features of contemporary dispensing and conformal coating equipment can compensate for the volumetric variation this causes, the wetting properties will change. This can, for example, cause voids in the underfill due to the varying rate of flow velocity around the bumps.

The instant activation of the hardening process after mixing implies an inherent limitation in the time in which the material must be used (or hence discarded) once it is mixed.

For two-component materials, this time is often perceived as just minutes rather than hours; however, the chemist can adjust this time by using additives for either accelerating or slowing the hardening process, and often without compromising the final material performance. Users of two-component formulations need to recognize the impact of the formulation's pot-life; the longer the time available, the more robust the production environment. In large-scale production, a short pot-life might eliminate the need for curing acceleration, but it will cause many complications in production, so short pot-life will likely be restricted to applications that use a relatively large volume of fluid and large dispense patterns. It seems that in most cases, the need to accelerate curing will be required to enable use of today's dispensing applicators, especially where fine and accurate application of two-component formulation is needed.

Applying Two-Component Materials

From our discussions with fluid formulators, it has become clear that while using two-component materials grants superior performance, it also imposes challenges which need to be considered in the design of automated dispensing and conformal coating equipment that can accurately apply fine lines or dots for large-scale production. *See Figure 3*.

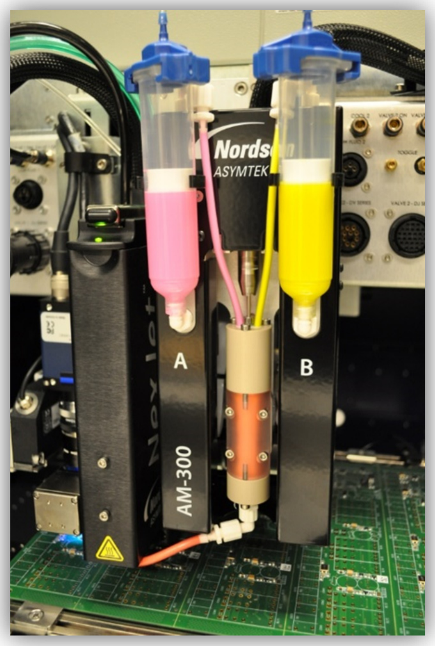

Figure 3
Using two-component materials grants superior performance; it also imposes challenges.

While the miniaturization of electronics has been driven by innovations in applying one-component formulations for small and accurate volumes as well as fast and sharp edge definition, the current offerings for two-component are limited to large volume applications. For example, one-component systems can jet fluid drops with a mass of 0.02 mg, while the smallest drops today's two-component systems can dispense are in the range of 1 mg. It seems there is a technology gap of at least a decade in the ability to apply two-component materials. This gap needs to be bridged so the high precision dispensing, jetting, and coating technologies that can be achieved with one-component materials can also be accomplished with two-component formulations. Until that happens, it will be difficult for the electronics industry to benefit from the superior material properties and advantages of using two-component formulations.

In designing a dispensing solution, consideration of technologies, process control, and robustness are key aspects. It starts with the metering and mixing of the two components where consistency and uniformity are required.

Mixing technology can be divided into two methods, though hybrids exist: static and dynamic. Static mixing consists of a mixing tube with a spiral core. While the tube is made of plastic, and thereby light, it is often long. The length depends on the metering ratio, flow rate, and symmetry in specific gravity between the two parts. The lower these parameters, the longer the tube that is needed to ensure proper mixing. In some cases it might even prove impossible to do. The advantage of static mixing is that the static mixer is a consumable, so cleaning of this part is eliminated. It supports a very short fluid pot-life, but application capabilities in terms of the fluid drop size and dispensing accuracy are consistent with rudimentary needle dispensing.

Dynamic (or active) mixing consists of an "impeller" or a "blade" that mixes the two parts within a chamber as the material is flowing by. *See Figure 4*. This ensures consistent mixing of the two parts, but also facilitates processes with low flow rate, asymmetric metering ratios, and differences in specific gravity of the two components. The design can be miniaturized, which is ideal for dispensing small volumes. The disadvantage is that this reusable mixing unit is a part which needs cleaning. The cleaning interval is dependent on the hardening time. However, in many cases this interval can be reduced by flushing the fluid path with the resin, or even with a cleaning agent.

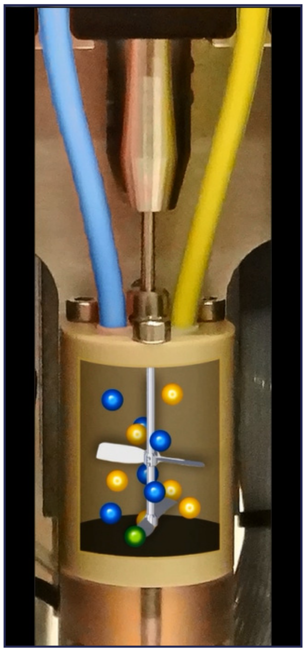

Figure 4 – Dynamic (or active) mixing consists of an "impeller" or a "blade" that mixes the two parts within a chamber as the material is flowing by.

To facilitate a short pot-life, the method and location of the metering and mixing are important considerations for applying two-component formulations. When dealing with small volume and often low flow rate, it is imperative to reduce the volume of mixed fluid. As such, the best location for metering and mixing is in the vicinity of the applicator. When using high flow rates, it can be argued that it makes little difference whether the system is located close to the applicator or farther away, as long as it provides a consistent pressure and time from mixing to application.

While in theory, the time from mixing to reaching the applicator can be calculated by simply considering the flow rate, in reality, fluid dynamics cause inconsistent cross section flows and thereby make it more complex. There are also extraneous factors that often interrupt the process, such as workshift changes, a glitch or stoppage along the production line, or something unexpected. As such, in the interest of the process window and to ensure robustness of the production environment, it is recommended to opt for materials with a minimum 2 hour pot-life, and preferably longer. Cleaning and maintenance intervals will logically correlate to the open time.

In regard to the mixing process, in-line metering and mixing of the two components is superior to batch mixing. This not only enables handling a shorter pot-life, but also a "mix on the fly" concept facilitates a rather constant time from mixing to applying the material. With a constant time, the viscosity will be consistent at any time, which results in repeatable wetting and flow.

There are many dispensing technologies and types of dispensing equipment and systems for applying single-part fluids, and these are constantly evolving. It is desirable to utilize these technologies for two-component materials in applications where those same volumes, accuracies, and edge definitions are needed.

Conclusion

Two-component formulations are selected for the superior final material properties and performance they provide as well as the shorter time it takes to achieve final dielectric properties. They are also a viable method of achieving VOC reduction.

Though two-component formulations have been neglected by the electronics industry, they already exist for various purposes, including conformal coating. Furthermore, fluid manufacturers see two-component formulations as a welcome opportunity to meet evolving needs and specifications for final material performance as well as enabling them to deal with the fluid requirements dictated by continued miniaturization of electronics.

Another driver of two-component fluid is the tremendous costs incurred from freezing, shipping on dry ice, and storing the premixed frozen single-part formulations. Shipping costs are based on the volume and weight of the product. The costs and logistics involved for the frozen formulation have gotten to be more expensive than the fluid itself.

A major limitation to two-component materials has been the lack of dispensing and coating equipment to apply the fluids in the patterns, fine lines, and small dots, and with the precision and accuracy demanded by today's technologies. That limitation is now being addressed. The stage is set for the electronics manufacturing industry to revisit, challenge, and reframe the perceptions of using two-component materials in a new paradigm that benefits from the superior properties of two-component formulations.

"A major limitation to two-component materials has been the lack of dispensing and coating equipment ... That limitation is now being addressed."

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