Polymeric Material Solutions for Jetable Fluid Delivery Assembly and Harsh Environment Protection

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Abstract

Jetable fluid delivery and other MEMS devices are being exposed to more extreme environments. These packages rely on polymeric materials as structural adhesives for various substrates. The materials also provide protection from mechanical shock; extreme thermal cycles, and can withstand long exposure to harsh chemical environments. This paper will discuss the advantages and limitations of thermoset polymeric solutions, their properties as well as the necessary selection criteria to maximize adhesion and environmental resistance. In addition, the choice of lab test methods and test design conditions are critical in the optimization, reliability and performance of the products used in the application.

Introduction

The manufacture of jettable fluid delivery and other MEMS devices requires the assembly of a variety of components. The substrates often consist of multi-layer silicon die, thin and thick wall engineered plastics, noble metals, and flexible substrates. The components can be assembled through the use of molding materials, mechanical fasteners, or structural adhesives. Structural polymeric adhesives are most often the ideal choice because they mate the substrates to form a continuous surface. They then become the barrier holding fluids within the device and also prevent the outside environmental contaminates from entering the device.

A typical device will use a number of adhesives. For example, the electrical connections from the flexible circuitry connected to the silicon jetting device have to be protected from the chemical inks within the device and from external contaminates. A uniform bead of a polymeric adhesive may be dispensed to surround these sensitive wires and encapsulate them. In addition to protecting the contacts from corrosion, the adhesive also cushions these wires from mechanical damage caused by equipment contact or dropping. This same material may also be used to fill the spaces or gaps created in the part design. Dielectric, thermally conductive or electrically conductive die attach adhesives fixture the silicon MEMS device in place orienting openings for fluid pathways from the ink reservoirs. Only adhesives are able to flow around and under components filling the area with low expansion material that will compensate for the differences in the expansion rates of the various components. Adhesive selection is dependent on many variables, but will primarily depend upon the substrates, production process options, and desired final finished product properties. There are some applications where the substrate can not withstand high temperatures. In these cases, adhesives have additional selection criteria. In addition, there is a driving force to reduce size and increase performance.

Physical Properties

The physical properties of the polymeric adhesives will depend upon the application requirements. Adhesives product ingredients selection criteria are based on the most critical design requirements. These requirements may be:

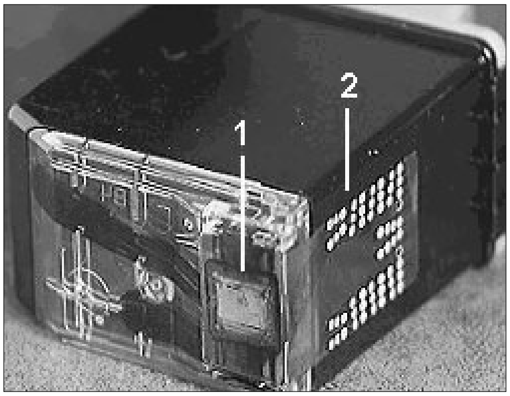
Low Ionic Species

Adhesives with low ionic species such as halides may be desirable for wire bonds or lead encapsulation. Water from the ink media along with bias current during operation can extract anions such as chloride from low purity adhesive components. If the polymeric material, in conjunction with water, contacts the wire bond, corrosion will occur. Over time, the wire bond may fail and cause a short making the device fail. Raw material selection for the adhesive can control the level of extractable species and extend device life. This the adhesive design, raw materials would be specially selected to have a low level of contaminates.

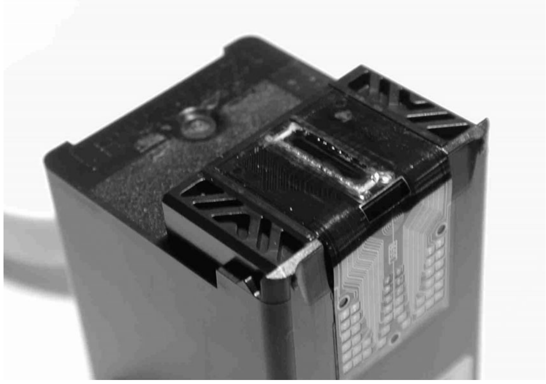
Coefficient of Thermal Expansion

If an assembly is thermal cycled, the various device substrates will expand and contract at different rates. The moving substrates can cause small fractures that may cause premature failure. Low coefficient of thermal expansion (CTE) adhesives can match the movements of the different substrates reducing component fatigue. Adhesives compounded with fillers will reduce the CTE mismatch over a wide temperature range. The filler will reduce the effect of the organic polymer movement over a wide temperature range. High filler concentration levels are needed to minimize CTE changes.

Side view:



1 is the print head with die. 2 is the reservoir. [1]



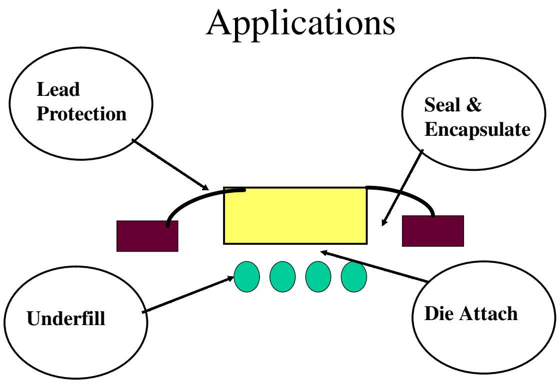
Top view

Modulus

Some assembly applications such as die attach and lead encapsulation require high modulus, or stiff support adhesives, for high strength. The adhesive must be hard and stiff to resist impact damage. Conversely, a low modulus, flexible, rubber adhesive is used for potting and gap filling. The lower modulus, allows the adhesive to move with the substrates. The adhesive absorbs and dissipates the stress so the assembly stays intact.

Thermal and Electrical Conductivity

Noble metals, such as silver, are compounded into adhesives to make an electrical connection between the die and the wire bonds. These metals are also thermally conductive and will, therefore, dissipate heat. Non-electrically conductive fillers such as boron nitride will simply conduct heat.

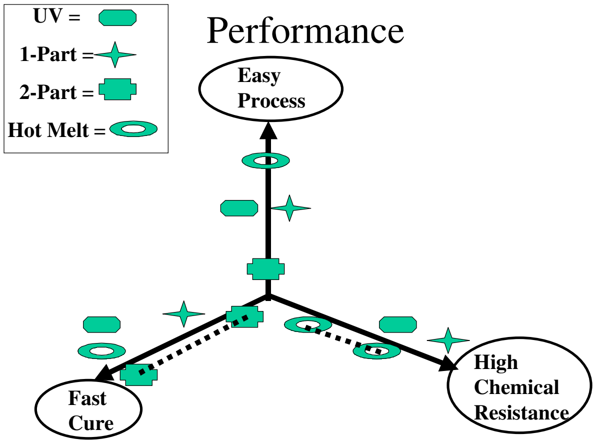


Processing

The application method selected for processing is influenced by the application. If the adhesive must self-level, fill a gap, or flow under another section of the part, it must be a lower viscosity fluid with no sag resistance. Most often this type of material will be applied by syringe. Syringe, stencil and screen applications require the adhesive to have body or thixotropic structuring. This type of rheology will help the adhesive hold its shape once it is on the substrate prior to cure. A balance must be established between applicator ease and control of the material once it is on the substrate. Stencil and screen printing are ideal for large smooth surface areas and provide the most uniform adhesive thickness.

Adhesion

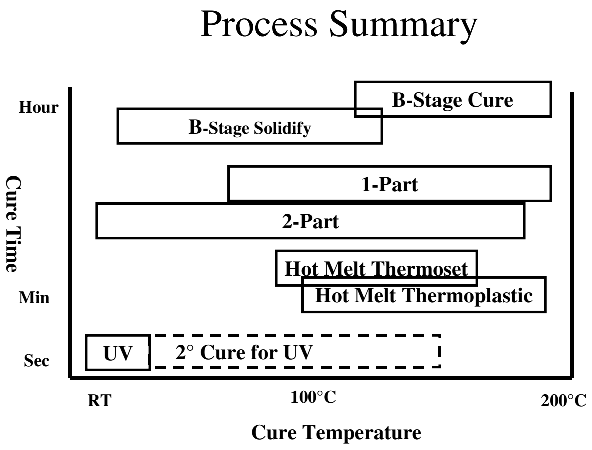
Adhesion tests often must be developed for a specific part design. Some standard tests can be used for screening various adhesives. One such test is an Instron tensile lap shear test, which can be developed for a specific grade of plastic or metal. The overlapped part can be tested at various temperatures or before and after exposure to the harsh chemical environment.. If dissimilar substrates are to be bonded, a component shear strength test could be developed. In this test, a shear force is applied to an edge of a substrate, such as a die, and then pushed off of the surface it is bonded to. Often times the best test is to actually assemble a “real” part and observe performance over the anticipated useful life, while exposing the part to expected environmental hazards. Upon failure, it is important that the failure mode be determined. Distinguishing failure mode requires identification of what failed (the bond or the substrate). In addition, the mode of failure may be related to the chemical environment, mechanical or thermal stress, incomplete cure, or improper surface preparation.



Curing

Adhesives may be thermoset or thermoplastic. Once a thermoset is cured it can not be reversed or easily re-worked. A thermoplastic can be applied from solvent or melted into place with a heated applicator. Typically, it is warmed until it is fluid and then poured into a casting. The higher the melt temperature, the viscosity is lower. The material can be applied to the substrate at room temperature or the substrate may be pre-heated to extend flow and open time until it is mated with another substrate. This process can be completed in seconds with the part attaining its full strength. Re-applying heat will soften and re-melt this adhesive for repair or re-positioning. Careful adhesive selection is required to assure the adhesive does not soften during normal device operating temperatures. An alternative to thermoplastics is thermosetting hot melt adhesives. Once applied, a secondary moisture post cure crosslinks the material to an irreversible solid.

Another type of fast, low temperature curing thermoset is acrylates. UV curable adhesives are cured very close to room temperature with a high intensity UV lamp. This type of adhesive requires a line of site exposure to the UV lamp. Some UV curable compounds contain additional curative to crosslink areas shielded from the UV source. These “shadowed areas” require a second curing step consisting of either heat or moisture. Most often UV curable materials are used in open areas and are applied as coatings, encapsulants and gap fillers.



One and 2-part thermoset adhesives provide controlled curing options. In the case of a 2-part chemistry, the cure is initiated with mixing. Work life can vary from minutes to days with these products. Materials with limited work life require quick assembly, but can be handled immediately. Full properties can be reached faster with an elevated temperature post-cure. One-part thermosets have a long open time and require a high temperature cure (typically above 100^{o}C) to achieve maximum properties.

Hot melts and UV curable adhesives are the fastest curing at the lowest temperatures.

Reliability Testing

Adhesives may be evaluated by: analytical test methodology, mechanical tests on the assembly substrate, environmental testing in the chemical media at ambient or operating temperature. Most often a combination of tests are required to match the adhesive with the application. The ideal is to build a complete part and monitor performance over time.

Decision Tree

Requirements										
Components	1-Part	2-Part	1-Part	1-Part	1-Part	1-Part		1-Part	2-Part
Repairable	No	No	No	No	Yes	No	No	No	No
Chemical Resistance	Hi	Lo to Hi	Med to Hi	Hi	Lo to Med	Med to Hi	Med	Med to Hi	Med to Hi
Adhesion	Hi	Hi	Substrate dependent - Med	Substrate dependent - Med to HI	Med to Hi	Med to Hi	Med to Hi	Substrate dependent - Med	Substrate dependent Med
Primary Cure	Oven cure-Med or Hi	RT or Oven (Lo-Med-Hi)	UV very fast	UV mod. fast	High temp melt	Med temp melt	Med temp melt	Oven - Med or Hi	RT - oven
Secondary Cure	NA	Step Cure	Heat or Moisture	Heat	NA	Moisture	UV	NA	Moisture
Uncured Use Life (Pot Life)	Med - Long	Short	Long	Long	Long	Med	Med - Long	Med	Med - Long
Chemistry	Epoxy		UV - Epoxy	UV - Acrylate	Thermoplastic Hot melt	Thermoset Hot Melt		Silicone	

Conclusion

Narrowing adhesive selection to a manageable few for reliability testing requires that the key property be defined. Each key property has a minimum and maximum level of importance. This range will help deciding where property compromise will be made. If for example, the manufacturing process must have an opportunity to repair an adhesive bond, products could be selected on ease of repair.

Reference

1. Microscopy UK, January 1999 Micscape Magazine, http://www.microscopy-uk.org.uk