

Resins For Potting And Encapsulation In Electronics

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In the early days of potting and encapsulation epoxy resins were the materials of choice. Epoxy resin technology has tended to mature over recent years and most of the exciting developments in resin technology are now taking place in polyurethane chemistry. This is leading to polyurethane resins becoming more and more dominant, and taking market share from epoxies to an increasing extent.



Figure 1 - Mixed resin pack being dispensed

Resins used for these applications can be of various chemical types. Epoxy resins have been widely used for many years – they are generally hard and tough and exhibit low shrinkage on cure. They are characterised by an excellent level of mechanical properties, good high temperature performance and good adhesion to a wide variety of substrates – chemical resistance is also good. The cross-linking or curing process generally takes place slowly especially where small volumes of resin are involved. Fast cure hardeners can be used but these generate a lot of heat during cure, giving rise to a high exotherm, which can damage electronic components and cause high mechanical stresses on both components and the circuit.

Polyurethane resins

Polyurethane resins are elastomeric or rubbery in their cured state and are preferred where circuits to be potted contain delicate components such as ferrites or glass reed switches. It is much easier to tailor the cure speed with urethane systems and the usable life and gel time of these can be adjusted to suit customer requirements, lead-

ing to faster process times and less work in progress. Polyurethanes show lower exotherm during cure than epoxies – the heat generated is not usually a problem, even for fast cure systems. Conventional polyurethanes can be subject to attack by water, especially at high temperatures. Polybutadiene-based urethanes are available, however, and these are very resistant to water attack, both during the curing process and in the final cured state. Electrolube differentiate between the two types of polyurethane in the numbering system that is used – UR 50** and UR 51** materials are based on polybutadiene chemistry. UR 55** and 56** materials are conventional urethanes. The ease of variation of process characteristics and final properties with polyurethane resins is leading to their increasing use in electronics and electrical encapsulation.

Silicone resins tend to be more expensive than epoxies or urethanes, but find a use where high continuous operating temperatures (above 180oC) are involved. Also the exothermic temperature rise with silicone systems is very low indeed.

Polyester systems have been used for potting and encapsulation, but

they show a very high exotherm and high level of shrinkage on cure. This can cause component and circuit damage. Also the high level of odour from styrene containing systems makes them unpleasant and difficult to use.

One and two-part resins

Electrolube offers a comprehensive range of epoxy and polyurethane resins for potting, encapsulation and other applications. The great majority of these are two-part systems where a resin has to be mixed with a hardener in a defined ratio before use. Two-part resin systems are available in bulk or kits – the latter have the resin and hardener pre-weighed into containers in the correct ratio, thus avoiding the necessity for weighing by the user. Resinpacks are also available – these consist of a plastic bag divided into two compartments by a removable clip and rail. Once again the resin and hardener are in the correct ratio and also, after the clip and rail have been removed, both parts can be thoroughly mixed in the bag without introducing air. The bag can then be used as a dispenser to pot the unit concerned. Electrolube do

offer a limited range of one-part epoxies, which are heat cured and can be used for small encapsulations. It is possible to formulate one part resins that can be cured by UV, but this technology is not well suited to the formulation of potting resins because of shadow and penetration problems of the UV when curing thick sections with inserts. One-part moisture curing polyurethane resins are available, but moisture penetration in order to obtain full cure is a problem with potting or encapsulation.

Most resin systems in use are complex products with process characteristics and final properties adjusted to suit customers' needs using the skill of the formulator. Epoxy resins usually contain diluents or viscosity reducers, which can make the resin thinner and easier to process. Diluents can be reactive, taking part in the cross-linking process, or non-reactive, being chemically inert. Reactive diluents can contain one (mono-functional) or two (di-functional) epoxy group(s) per molecule – the former give better viscosity reduction but a lower level of mechanical properties than the latter. Non-reactive diluents generally induce a slightly greater level of flexibility into the cured product, but can give rise to reduced adhesion, especially at high temperatures. Electrolube's ER 1448 is an example of a very low viscosity epoxy resin formulated using a proprietary blend of diluents of both types – it gives rapid and efficient air displacement from small complex circuitry without the necessity for evacuating to remove entrapped air. Non-reactive diluents can be used at very high levels in polyurethanes to give soft potting compounds that can easily be removed from circuitry for fault investigation or repair. Electrolube's UR 5048 is an example of such a resin – UR 5044 is a flame retardant version of this approved to Underwriters Laboratories UL 94 V-0. UR 5083 utilises a diluent of different chemical type and, when cured up, gives a soft self-

healing gel that enables repeated insertion and removal of wires from a cable joint without damage to the resin.

The importance of the hardener

The hardener used with the epoxy resin makes a very important contribution to final properties, and the choice of hardener is the main way of altering the speed of cure. The earliest hardeners used were a rather aggressive class of chemicals called primary aliphatic amines. These give a fast cure but a consequent high exotherm – they are corrosive to the skin and can give rise to dermatitis and asthma if not handled with care. The less reactive and less aggressive chemical com-



Figure 2 - Electrolube's extensive packaging range for a broad spectrum of applications

pounds known as aromatic amines give rise to higher continuous operating temperatures in the cured product, but although they are less dermatitic and sensitising, there are increasing concerns about their carcinogenicity. Amine hardeners are often supplied as complex blends of different materials, and involve specialist formulating skills in their own right. Organic acid anhydrides give low viscosity epoxies with very high continuous operating temperatures, but suffer from the disadvantage that they usually need to be supplied as three-part rather than two-part

systems and always need to be cured at high temperatures.

Protecting the resin from water

Conventional polyurethane resins can be based on polyether type polymers (such as polypropylene oxide) or polyester type resins (such as castor oil). The former generally exhibit better water resistance but the latter show improved adhesion. The second component of the resin is an isocyanate, usually diphenyl methane di-isocyanate (MDI, the safest of the usual isocyanates). It is important to protect both parts of the resin from moisture. If the resin component becomes wet, then the water will react with the isocyanate and produce bubbles of carbon dioxide gas throughout the cured product. If the isocyanate becomes wet, a solid deposit will be produced within the material, together with carbon dioxide gas, which may pressurize the can. The usual cause of wet resin or hardener is the repeated opening and closing of the containers – each time the container is opened moist air enters the air space above the liquid, and the water is absorbed into the material. Containers should be opened and closed as quickly as possible – flushing the can with dry Nitrogen before closing will help prevent problems. If this is not possible, the only solution may be to purchase the material in smaller container sizes, if these are available. When using polyurethanes in mix and dispense machines, it will be necessary to protect both components from moisture, either by fitting desiccant traps to the tanks or by flushing the tanks continuously with dry Nitrogen. The isocyanate is the hazardous part of the formulation and should not be heated or sprayed as this will increase the levels in the atmosphere and hence the sensitising effect on the lungs. If there are two hydroxy groups on each polyether or polyester chain (a diol), a soft cured product results – hardness can be increased by using increasing amounts of triol (three hydroxy groups per chain). Polybutadiene based urethanes

have a long hydrocarbon chain with a few hydroxy groups tacked on – this hydrocarbon chain gives rise to a much lower attraction to water both during and after cure, resulting in the advantages previously mentioned.

Speed of cure in urethane systems is very easily adjusted by adding increasing amounts of catalyst to the resin component. These catalysts can be of several types, including amines, Tin compounds and Mercury compounds. The latter give the best balance of characteristics – a low sensitivity to any water present, and a long usable life coupled with a quick sharp cure. Unfortunately EEC legislation is set to increasingly restrict the use of Mercury compounds over the next few years – chemists have yet to discover a perfect replacement.

Solid fillers – flame retardants and cost cutters

Solid fillers are a very important constituent of many resin systems. They can be added to simply reduce cost e.g. powdered limestone. The cost savings are generally slightly less than might be suggested by the cost per kg, as filled systems have a higher density than unfilled ones. This means

that whereas a unit might require 3 grams of resin of density 1.0 to fill it, it will require 4.5 grams of a resin of density 1.5. In each case the volume is 3ml. Cost comparisons of competing resins should always be done on a per litre basis, rather than a per kg basis.

The presence of solid fillers will usually give rise to a harder and stiffer cured product. Fillers can be added to act as flame retardants. Aluminium hydroxide is commonly used for this purpose: this has the added advantage of resulting in low smoke emission and a low level of toxic fumes. Electrolube's ER 2188 and ER 2195 are examples of alumina hydrate filled flame retardant epoxies – both are fully approved to Underwriters Laboratories category 94 V-0. UR 5097, UR 5604 and UR 5608 are examples of flame retardant polyurethanes utilising the same mechanism for achieving flame retardancy – once again each is fully approved to UL 94 V-0. The disadvantage is that high loadings of alumina hydrate are required, resulting in a relatively high viscosity formulated resin. Bromine compounds, such as decabromobiphenyl oxide, can also be used as flame retardants. These are used at much lower levels, giving lower viscosity systems: they usually work best in the presence of some

antimony oxide. However, their use gives rise to a higher level of smoke and toxic fumes. There are health and safety questions over both the decabromobiphenyl oxide (thought by some to produce dioxins on incineration, but this is disputed) and the antimony oxide – the future of the former is under consideration in Europe at present. Electrolube's ER 2160 and ER 2165 are examples of this type of low viscosity flame retardant epoxy – the latter is approved to UL 94 V-0. Pentabromobiphenyl ether-based flame retardants have already been banned in Europe. New bromine based flame retardants of completely different chemical type are now becoming available and are unaffected by European legislation. UR 5110 is an example of a polyurethane using this very new technology.

Many other types of fillers can be used in epoxies and polyurethanes. Hollow glass and plastic spheres give reduced density and low dielectric loss. When potting RF circuitry the potting resin can introduce capacitance effects between conductors on the printed circuit board and alter unacceptably the characteristics of the circuit. It may be possible to overcome these problems by use of a hollow sphere containing resins of low dielectric constant – typical examples of such Electrolube resins are ER 2193, ER 2175 and UR 5111. Nickel and Silver powder give electrical conductivity in the resin – Electrolube's ER 2141 is an electrically conductive Nickel filled epoxy. Zinc oxide and aluminium oxide give improved thermal conductivity, but aluminium oxide is extremely abrasive and causes severe wear problems in mix and dispense equipment. ER 2074 and ER 2183 are very popular examples of zinc oxide filled thermally conductive epoxies. Silica flour gives lower cure shrinkage and coefficient of thermal expansion but is very prone to sedimentation. Milled glass fibres give improved impact resistance; barium sulphate gives opacity to X-rays and so on.

Figure 3 - Resin twin pack system: resin and hardener to the correct ratio in an airtight convenient pack

