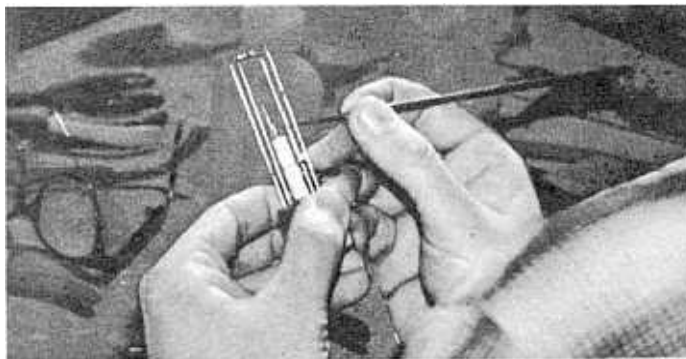


DESIGN REPORT

WHAT NEXT FOR EPOXIES?

The great versatility of this most unusual plastic is just being realized by industry.

Frank W. Kulesza, Epoxy Technology, Inc., Watertown, Mass.



Hygrometer sensing element is anchored to instrument base and given mechanical support by dab of structural epoxy adhesive. When compound sets, Panametrics instrument is sturdy enough to make in situ measurements in fast-flowing gases or liquids. (All photos courtesy of Epoxy Technology.)

Probably no plastic since the invention of celluloid has created such curiosity, opportunity, controversy and confusion as the epoxy resins. The more spectacular applications, such as making plastic dies and foundry tools, and bonding railroad track sections and airplane parts, have caught the imagination of the general public. Of far greater significance, however, is the burgeoning variety of industrial applications made possible by recent advances in custom formulation . . . for the epoxies, unlike any other plastic, offer an infinitely varied array of chemical, electrical and physical properties, and a wide choice of hardening agents, curing cycles, and methods of compounding, handling, storing, and manual or automatic application.

A New Field

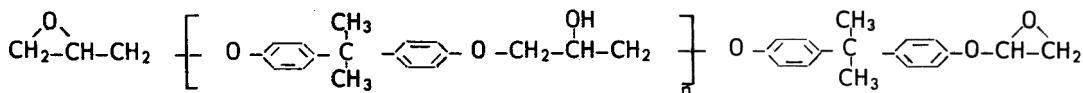
The chemical engineer can find a lifetime of study and opportunity in the epoxy field alone. It is a constantly changing field with infinite possibilities . . . something that is not wholly true of other plastics. Because of this, small groups and even individual experimenters

who apply qualified backgrounds in epoxies to industry's problems occasionally can come up with new formulations that offer unique properties.

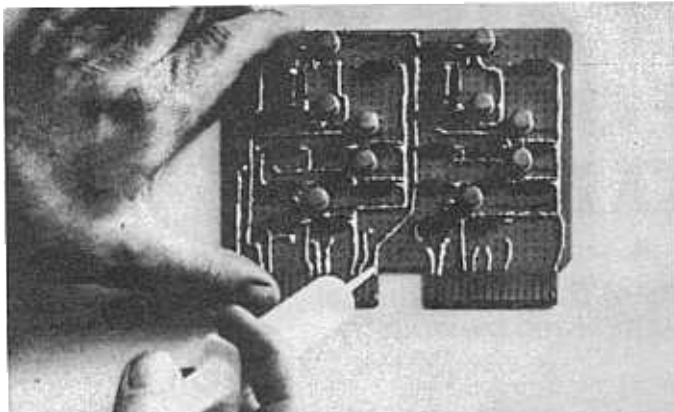
To take advantage of the almost unlimited versatility of the epoxies, the supplier cannot limit himself to a few stock items sold off the shelf. Stock compounds for a given class of application may be all right for a starting point, but invariably a higher order of efficiency can be achieved for an adhesive, a coating, an electronic potting compound or other material when it is custom-formulated and compounded to meet the job requirements. This facet of the plastic's nature is giving rise to the "epoxy engineer"—a new kind of specialist.

What Is an Epoxy?

The word "epoxy" is coined. It comes from the Greek word for "over", or "between", and the word "oxygen". Thus, an epoxy is an "oxygen between" compound and is postulated to contain the following molecular grouping:

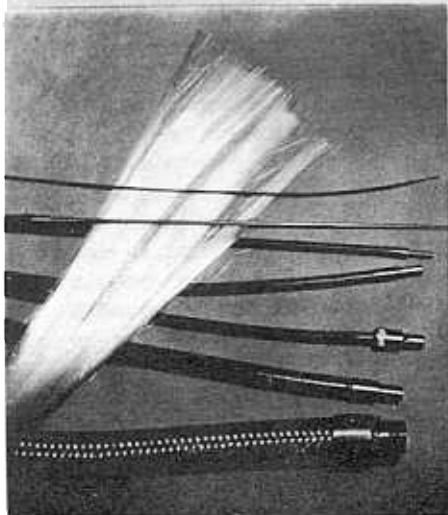
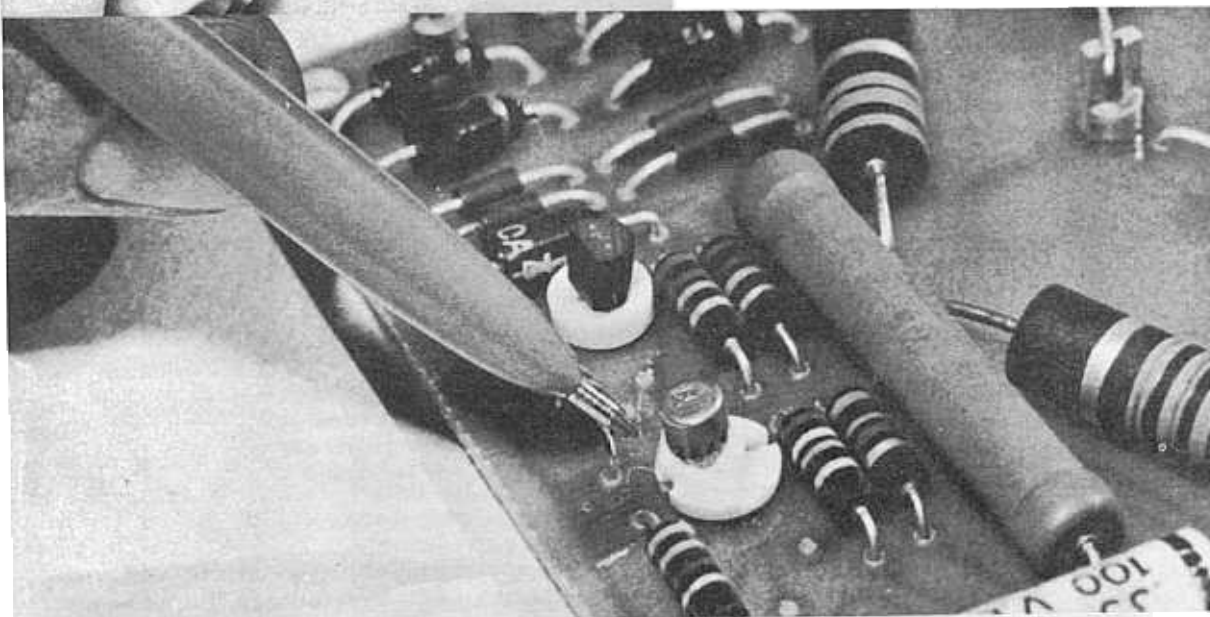


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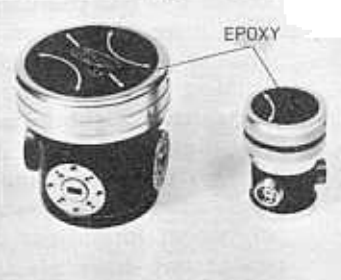
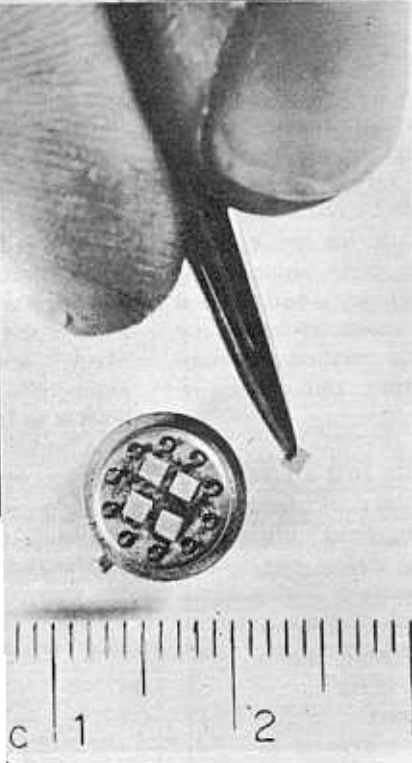


Prototype, double Schmitt trigger circuit is "drawn" on PC board with highly conductive silver epoxy. No soldering is needed.

Electronic components attached with electrically conductive epoxies require no soldering and thereby avoid heat damage. Method is especially useful on prototypes, where rapid changes may be required.



Clear amber epoxy compound used in fiber-optics manufacture turns bright red as curing progresses. This permits visual control without regard to time-temperature relationship and enables operator to observe wicking action as the material progresses along bundle of fibers. By varying application of heat, wicking can be terminated at any desired point.



Microwave control knobs are topped with coating of glossy black epoxy, producing tough, highly attractive surface well suited to various heat-stamping and printing techniques.

Chips are attached to thin-film hybrid circuit on TO-5 can with minute quantity of single component, gold-bearing epoxy.

To illustrate, a typical epoxy molecule made from bisphenol-A and epichlorohydrin can be represented as shown below.

The value of "n", the repeating unit, is less than 1 for the lowest-molecular-weight liquid resins. As the value of "n" is increased, the molecular weight also increases, and the material goes from a liquid to a solid resin.

Product Development

New epoxy compounds have been developed recently for the electronics industry, for special applications in optics, for silk-screening and printing, and a variety of other uses. In each instance, the material was tailored to meet the specific application's requirements.

One area of high interest and activity is that of the electrically conductive epoxies. Compounds containing pure silver in a 100-percent-solids thixotropic paste provide a soft-flowing material suitable for application by brush, spatula, hypodermic needle or automatic equipment. Volume resistivity of one such compound can be held rigidly to a range of 0.00005 to 0.00009 ohm-cm or close to that of pure copper wire. A similar compound designed for high-temperature use has excellent chemical and solvent resistance. Its electrical conductivity, which is highly reproducible, exhibits no change after exposure to 300C for 12 hours (Thermal conductivity of a typical electrically conductive epoxy measures 11.0 Btu/hr/sq ft/°F/inch by the comparative method. Tensile shear is 1000 psi. Low-temperature tests on cured films applied to glass substrates involved exposure to a liquid-helium temperature of 4.5K without loss of adhesion or electrical conductivity.)

Materials of this kind are suitable for making printed-circuit boards quickly and easily by applying the compound with a plunger-type applicator directly on penciled sketches, eliminating the need for soldering. They also are used in the construction of ground planes, shielding, microminiaturization, multilayer circuits and direct silk-screen application of complex circuits. Other variations in this series offer such properties as: extended shelf life, remaining stable in all of the essential characteristics when stored for 2 years at room temperature; pot life of the mixed components (two-component system) of at least 8 hours, and a special low-viscosity version that can be dispensed from a disposable medicine dropper.

There is a distinct savings in cost and better manual control through use of the medicine dropper in the construction of PC boards and other electronic components. The low-viscosity version (14,600 centipoise) is obtained without the use of solvents, so that the liquid paste is still a 100-percent-solids compound. Its excellent wetting and leveling properties make it

suitable for use as a dipping compound, and its tenacious adhesion permits it to bond firmly and make good electrical contact without prior cleaning, even on oxidized-copper surfaces.

The opposite approach—a thick paste form—provides a material ideally suited to brush application for coating resistors and other components to provide efficient, low-cost RF shielding.

Materials Versus Overall Cost

Paradoxically, the use of exotic materials often provides the lowest overall cost in production because of reductions in time or extra operations, the elimination of scrap and rejects, and often, the enabling of a process that could not be carried out without the new epoxies.

One example is an electrically conductive epoxy with pure gold powder. This single-component system was developed for applications requiring high electrical conductivity with good handling properties. It is being used successfully for the attachment of chips in hybrid circuits and for other sophisticated applications demanding the unique properties of gold. As electronic miniaturization progresses and integrated circuits become even more minute, the difficulty of soldering operations increases because of the danger of destroying delicate constructions with heat. Thus, the new epoxies, because they can supplant the soldering operation, are becoming indispensable.

A new low-viscosity epoxy potting compound pours easily, and its low exotherm avoids the problems often associated with reaction heat. It cures at room temperature to an attractive, high-gloss, smooth surface devoid of blemishes. While this material is more expensive than waxes, phenolics and other materials sometimes used for potting, its physical and chemical properties often provide the best possible approach to development and production problems.

And Now, Optical Clarity

A new two-component epoxy system produces an adhesive that is optically transparent from 3000Å to 2.6 microns. Opening up a large field of applications in instrumentation, the material has properties making it far superior to such traditional products as Canada balsam. It exhibits excellent adhesion to such substrates as glass, quartz, metal, ceramics and most plastics. Low viscosity and a resistance to air entrainment make it highly suitable for joining glass elements. It may, like most modern epoxy compounds, be modified when varying but definable properties are required.

Another optics application has been found for a two-component system that has the unique property of a progressive coloration reaction as curing progresses. This characteristic makes it possible to control the curing process by

(Continued on next page)

visual inspection, without regard to the time-temperature relationship. In one application binding bundles of optical glass fibers, the epoxy's wicking action may be observed while it turns progressively a deeper red and, by varying the application of heat, wicking can be stopped at any desired point.

What Comes Next?

Prognosticating tomorrow's development in epoxies is very difficult. Certainly the direction of progress will be determined by the needs. The epoxy resins are, in all probability, the most "obedient servants" of polymer chemistry, for they are among the most versatile of the new plastics for custom-tailoring to a given set of requirements.

Continuing investigations are aimed at extending epoxy's physical and chemical properties. Compounds capable of withstanding high temperatures are being improved constantly. The 500F temperature range currently represents the upper limit for most epoxies not compounded specifically for high temperatures.

Epoxy adhesives are well known for their tenacity to all types of materials and this field is fairly stable, but metal-filled epoxies, principally the adhesives, offer a variety of special properties. Also, an entire area remains to be investigated in the utilization of nonmetallic fillers.

In the furniture industry, it may be possible now to combine the bonding of laminates with high-speed silk screening of simulated wood-grain patterns and other designs for surfaces with one epoxy material and one pass through the machines. The technique, with some modification, shows promise for industries that must coat or treat large, flat surfaces.

The epoxy technologist is not the logical source for developing new applications for epoxy compounds. His role is to supply compounds designed to perform within known parameters. As a specialist, he has a "bag of tricks" far more clever than most engineers suspect.

Frank W. Kulesza spent 14 years as a "roving epoxy consultant" for International Business Machines Corp. He developed epoxy-resin compounds used in the production of millions of IBM computer parts and has designed epoxy systems to solve problems that resisted solution by other polymers. He was with Borden Chemical Co. for 2 years as a research chemical engineer in coatings and adhesives and has had experience in flock-coating processes. He holds a chemical engineering degree from Northeastern University.

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