An Air-Assisted "Airless" Conformal Coating Process

A need to move beyond aerosol sprays and dipping leads to a development that answers tough requirements for controlled coverage, low waste, and environmental restrictions.

by Steven Felstein and Joan Lum,
Hughes Aircraft Co.,
Electro-Optical Systems,
El Segundo, California

Hughes Aircraft Co. has been working on a CECOM (Communication and Electronics Command) contract1 to investigate and qualify a repairable, environmentally friendly, ultraviolet (UV) curable conformal coating meeting the requirements of Mil-I-46058, and a production line for applying the coatings. (The production line will be delivered to the Tobyhanna, PA Army repair and maintenance depot.) The current process to conformally coat PCBs consists of spraying a conventional, air-drying acrylic material from an aerosol can. This process requires extensive masking to ensure areas such as connectors do not become coated. Aerosol can application also produces considerable hazardous waste in the form of overspray on surrounding surfaces and into the air. Further, the one-part coatings in the cans contain considerable amounts of solvent and require long cure times. Accordingly, the objective of the program is to select a suitable production line to optimize the application of the conformal coating, and to minimize: waste products, haz-

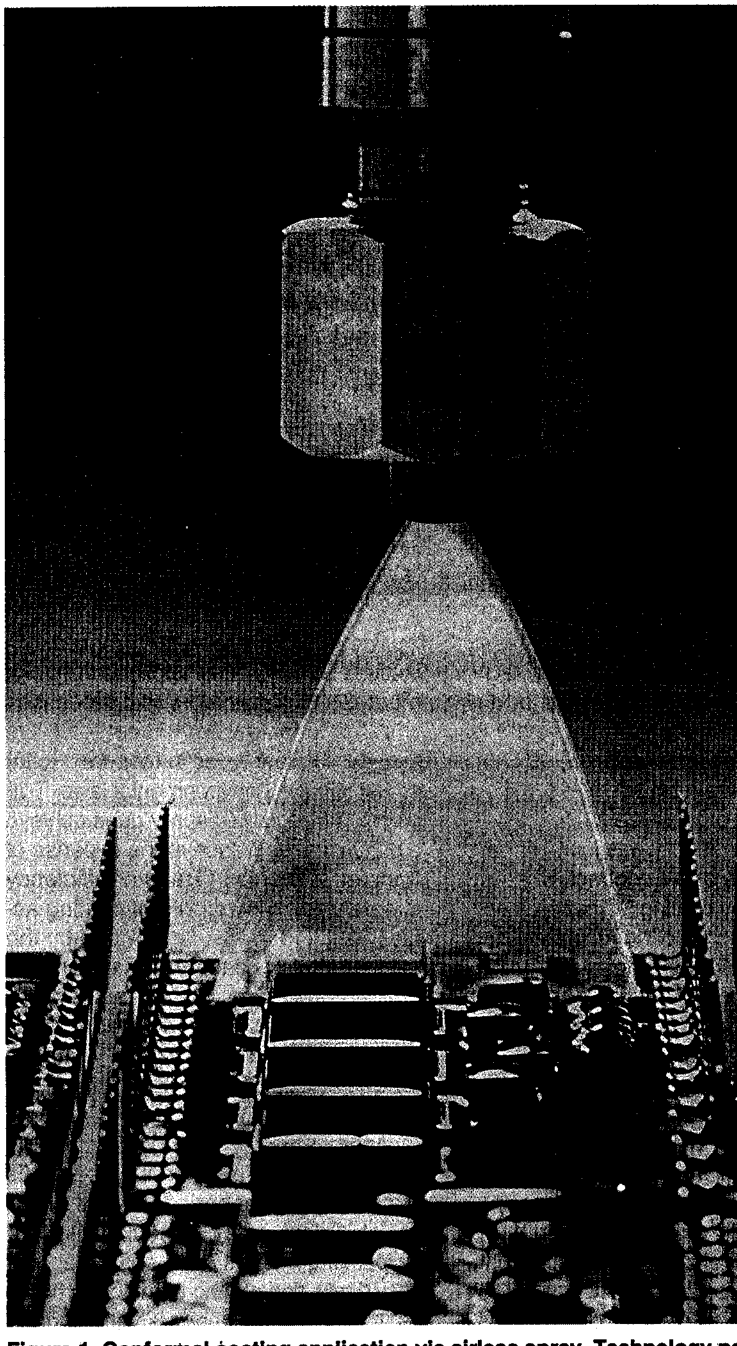

Figure 1. Conformal coating application via airless spray. Technology pe high transfer/low waste of material via tight control of movement and lo of spray.

ardous air pollutant emissions, the need to mask, and turnaround time.

Demands Beyond the Mil Spec

Automated application and cure equipment would be an important step toward meeting the objectives. Such equipment, however, poses difficult restrictions on the conformal coating to be used, while adding requirements beyond those of the military specification to produce the desired results. For example, the coating had to possess UV curability to increase throughput, secondary mechanism to ensure cure of shadowed areas, a solvent-free 100 percent solids composition to minimize creation of hazardous air pollutants, low viscosity to ensure compatibility with spray equipment, and low modulus to facilitate rework and repair.

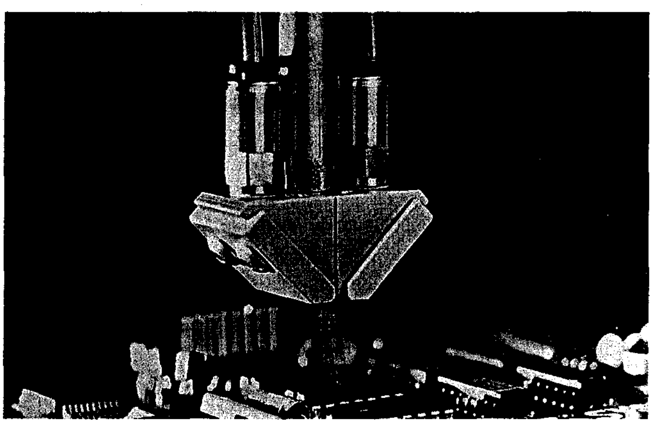

Figure 2. To maintain desired viscosity and coating weight, "air-assist" lines are added to the spray nozzle, in a new development, although the system remains basically airless.

Material Selection

The "secondary cure mechanism" of a UV conformal coating means that its formulation must include a way to cure areas of a PCB shadowed from direct UV light. It also is most desirable to effect this cure without further processing. Of the materials tested, "UV 7900"† was found to best meet the needs of the contract. Shadow cure is tested by coating "Y" patterns and exposing them only to the recommended secondary cure cycle instead of UV radiation. These coupons were then exposed to a ten-cycle moisture resistance test per Mil-I-46058. Whereas other coatings tended to remain tacky after secondary cure when not exposed to UV light (or required oven cures) the UV 7900's secondary cure performed well. Further, UV 7900 showed almost no darkening after exposure to humidity and heat. Being more sensitive to solvents than other UV coatings (and also somewhat softer), it is easier to rework using mechanical methods. A standard hot knife and softening via nontoxic strippers accelerates the removal process. Lastly, the glass transition temperature (Tg) of UV 7900 (-12°C) is lower than other UV curable materials tested (except silicones).

Production Line Selection—the Applicator

The new automated production line consists of three modules: coating application, solvent flashoff, and UV curing. A solvent flash-off module was mandated because previous qualified coatings contained solvent to permit spraying. Solvents pose a problem for UV-curable materials because the latter cure rapidly. Trapped solvents cause bubbles in the coating, tackiness, or an inhibited cure. When used with 100 percent solids coatings, the solvent flashoff module is useful for facilitating the flowout and uniformity of coating thickness.

The key to meeting the program objectives is the coating application equipment. Spray applicators (dip processes were not considered) have evolved to several different types in response to increasingly strict environmental laws. Traditional air-atomized spray guns achieve a uniform appearance at the expense of transfer efficiency. (Transfer efficiency is defined as the amount of coating actually applied to the part divided by the total amount of coating sprayed.) Air-atomized processes usually achieve no more than 30 percent transfer efficiency; the 70 percent "overspray" coats the area surrounding the part and/or is exhausted into the air.

Another type of coating applicator utilizes a process in which the coating is pumped and dispensed without an air assist. Airless spray technology is used for painting bridges and applying acoustic ceilings and stucco coatings to houses. Its transfer efficiency is very high because of the absence of atomization, virtually eliminating overspray waste.

A conformal coating application that combines airlessness with minimum waste was evaluated as a possible solution to the challenges of the program. The manufacturer's* design features miniaturized fluid lines and a nozzle placed on a computerized X-Y-Z plotter. High transfer efficiency is achieved by movements that are very close (approximately 0.5") from the PCB. The coating is dispensed in a fan, on-off pattern (see figure 1) so that the system can avoid areas to be left uncoated, thus avoiding the need to mask most areas. These advantages, plus compatibility with a conveyorized in-line orientation desired for the contract, resulted in its selection for the production line.

Material Compatibility

Several challenges associated with material compatibility then arose. First, as a continuous production process, the material had to have a long pot life to prevent gelling in the fluid lines. Also, the airless applicator requires a coating with a very low (150 cps) and stable viscosity, while the coating thickness applied is higher than that of air-atomized systems—reasons why this equipment had previously been used almost exclusively with solvent-containing coatings. (Solvents not only reduce viscosity but also the weight of the cured coating. If a coating is applied at 0.003" and is 50 percent solvent, the final coating weight will be only 0.0015".) Finally, the low, stable viscosity requirement necessitated the addition of an in-line heater, adding to the complexity of the operation.

The materials selected to meet the military specification and viscosity and stability requirements of the coating module left one remaining challenge—coating thickness, which could not be reduced to a one-pass thickness of less than 0.0025" with 100 percent solids materials even by increasing the speed of the applicator. In response, the manufacturer developed an applicator "option" in which air-assist lines were added to the nozzle, thus producing an air-assisted "airless" coating application system.

Designated as CPX (see figure 2), the immediate benefits realized included low coating thicknesses (in the 0.0005-0.001" range), and increased viscosity limitation (from 150 to over 900 cps). The new nozzle system also permitted application of material higher in viscosity than that of the previous airless system because the air atomizes the coating into a cone pattern. This results in lower coating weight because a given volume of coating is dispersed over a larger area. The higher viscosity upper limit also permits many more types of conformal coatings to be evaluated with the equipment, especially the "environmentally friendly" 100 percent solids types. Further, the coating pump and heater need not be used except when coatings over 900 cps must be evaluated. Finally, since running the coating module with the airless nozzle produces high coating weights with each pass, it is not desirable to use multiple coats. To ensure 100 percent coverage in one pass, a more traditional overlapping box coat technique can be used, which minimizes the chance of unintended uncoated areas.

UV Curing Module

The UV curing module required use of ultraviolet sources capable of curing without heat build-up that would be detrimental to the PCB. An electrodeless UV source that uses microwave energy to generate the light from all-glass, one-piece lamps offered the following features: low heat build-up, long bulb life, stable UV output, and optional doped bulbs to produce different wavelengths of UV light.** The lack of a metal electrode-to-glass seal, as required on conventional electrode-type bulbs, eliminates the major cause of UV bulb failure, cracking, or seal loss at the metal-to-glass interface due to differing coefficients of thermal expansion (CTE). The bulbs and irradiator assemblies are housed in a conveyorized curing module*** that reciprocates the UV sources over the PCBs on the conveyor system. These sources ensure that high-profile parts do not cast shadows while further minimizing heat build-up. For UV 7900 conformal coating, it was found that the standard mercury H bulb provides the most efficient cure.

Conclusion

Testing to evaluate a Mil-I-46058-qualified UV curable conformal coating with a shadow cure capability resulted in the selection of UV 7900. This 100 percent solids, solvent-free coating was found to be compatible with the automated coating module, coupled with the CPX air-assisted airless applicator, and to provide an optimum selective application of coating with minimal masking and coating weights consistent with military requirements. When coupled with the UV source and curing module, the production line was found to consistently apply and cure a high quality conformal coating with minimal generation of solid, liquid, or airborne wastes.

The authors wish to acknowledge the assistance for this report of G. Frost, G. Harrold, and R. Christyson of Nordson Corp.; D. Sudduth and A. Garcia of Lesco Inc.; P. MacGraw of Grace Specialty Polymers; and the Environmental Technology Committee and Radar Systems of Hughes Aircraft Co. **smt**

†Grace Specialty Polymers
*Nordson "SelectCoat"
**Fusion Systems
***Lesco Multicure

Reference

[1] Work performed by Hughes Aircraft Co. under contract to the U.S. Army's Communication and Electronics Command, Ft. Monmouth, N.J., Contract No. DAAB07-89-C-A-065.

Contact authors at Hughes Aircraft Co., P.O. Box 902, EO/E1/F150, El Segundo, Calif. 90277; telephone: 310/616-5789 or 310/616-1087.