MASTERBOND®

CASE STUDY

EP65HT-1: Utilized by NASA in Thin-Film Organic Photovoltaics

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A NASA publication documented the use of Master Bond EP65HT-1 for use in organic photovoltaic devices.[1] These thin-film organic solar cells are lightweight, and their use in space-based applications is of particular interest. Devices used on the external portions of spacecraft encounter wide-temperature shifts as well as the vacuum of space. To meet the requirements of this target application, Master Bond EP65HT-1 provided superb service temperature range, rapid-cure, and compliance with NASA outgassing requirements when constructing their experimental devices. The choice of sealant is critical for maintaining the integrity of the device and protecting the sensitive contents from both terrestrial and space environments.

Application

The NASA researchers sought to create an experimental device using fullerene-containing polymers to improve the performance of organic thin-film photovoltaic cells. Fullerenes are highly conductive and assist with efficient electron transfer due to their spherical symmetry. These devices operate based on the mechanism of photoinduced charge separation and utilize conductive polymers. In photovoltaic devices, adsorption of a photon of suitable energy by the light-absorbing material results in excitation of an electron from the highest occupied molecular orbital (HOMO) to the lowest unoccupied molecular orbital (LUMO). This results in the generation of a positive charge (hole) and a negative charge (electron) called an exciton. A bicontinuous network of conductive polymers possessing donor and acceptor characteristics allow for the presence of a heterojunction to enable transport of the hole and electron to the cathode and anode, respectively, resulting in the generation of electric current.

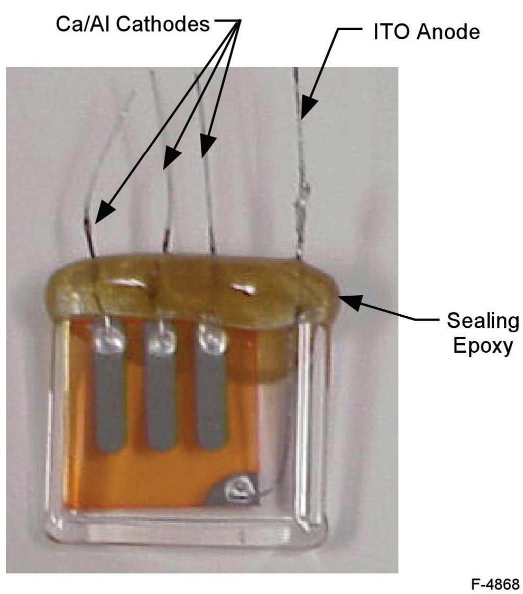

Figure 1: Photo of fullerene-containing thin-film photovoltaic cell using Master Bond EP65HT-1.[1]

As fullerenes possess limited solubility in conductive polymers, soluble derivatives called [6,6] PCBM and [5,6 PCBM] were used for the acceptor phase while MEH-PPV was used for the donor phase.[1] The cathode comprised either calcium (Ca) or aluminum (Al) while indium tin oxide (ITO) served as the anode. The device was constructed by spin-coating a solution of donor and acceptor-type polymers in chlorobenzene or chloroform onto ITO coated glass fitted with wire electrodes. Polymer film thickness ranges from 600 to 1000Å. Construction was finalized by thermally evaporating metal contacts onto the polymer film surface with subsequent encapsulation in glass. Finally, Master Bond EP65HT-1 was used to seal the device to provide protection against air and other environmental factors encountered during the testing. See **Figure 1**. Device configurations of ITO/Polymer/Ca/Al and ITO/Polymer/LiF/Al were constructed. The anodic and cathodic material provide an internal field within the device to drive holes to the ITO/polymer interface and electrons to the Ca/Polymer interface, respectively. The devices were evaluated for efficiency and open-circuit voltage.

Key Parameters and Requirements

Adhesive and sealant systems destined for use on space-based craft must pass the requirements for NASA outgassing. The vacuum of space will cause volatilization of residual solvent or small molecules which may then migrate and subsequently condense on electrical components or sensitive lens structures. To mitigate the potential for rendering space-based equipment inoperable, all adhesives and sealants used must meet NASA's stringent requirements. Master Bond EP65HT-1 provides excellent outgassing performance exceeding the NASA requirements for Total Mass Loss (TML) 0.366% [Specification: 1% Maximum] and Collected Volatile Condensed Material (CVCM) of 0.005% [Specification: 0.1% Maximum]. This test was performed after the product was cured for 4 days at room temperature (15 gram mass).

Devices mounted on the exterior of spacecraft face a harsh thermal environment. In low-earth orbit, a device is expected to experience approximately 6000 thermal cycles per year.[1] During orbit, the craft and associated devices cycle between being exposed and unexposed to the solar rays. Solar intensity is not attenuated by any atmosphere so device temperatures may reach upwards of 80°C or more when exposed to solar radiation. Conversely, when not exposed to solar radiation, device temperatures drop severely to -80°C or more. Such thermal cycling calls for a robust adhesive capable of handling extreme temperature cycling. The glass transition point (T_g) is a critical measure that relates to a polymeric material's ability to withstand high temperature excursions. Low temperature performance is assured by choosing materials that do not become too brittle under such environments. Master Bond EP65HT-1 exhibits a high glass transition temperature of 125-135°C while maintaining excellent low-temperature performance providing a service temperature range of -51°C to +204°C [-60°F to +400°F].

As with all adhesive and sealant-based applications, bonding is critical. In the case of the thin-film organic solar cells made in the NASA construction, the adhesive must adhere well to the glass structure used in the solar panel construction. Master Bond EP65HT-1 exhibits excellent adhesion to glass as well ceramics, metals and some plastics. To assure a robust bond, coefficient of thermal expansion (CTE) of the adhesive must also be considered when a device experiences wide shifts in temperature. If the expansion and contraction of the adhesive and substrate areextremely different and changing widely across the operating temperatures, debonding may occur or thermal stresses could result in damage to the substrate.

For electronic applications, the sealant must also be a good electrical insulator to avoid compromising the performance of the circuit. Most polymeric materials are excellent electrical insulators by nature, with epoxy-based systems being an especially good example. As the sealant may be in contact with electric wires or components, assuring a high-volume resistivity is key. Master Bond EP65HT-1 is a two-component epoxy system providing a high-volume resistivity of $>10^{14}$ ohm-cm suitable for use in electronic devices.

As a practical matter, an ideal adhesive or sealant system will provide for convenient and efficient device manufacture. A fast set-up time is definitely relevant since this will determine how quickly the two-part epoxy system will harden. This allows for rapid device construction and prototyping. Generally, there is a compromise between fast set-up and outgassing. Rapidly curing adhesive systems often do not provide low-outgassing characteristics. The unique nature of Master Bond EP65HT-1, however, allows for both rapid-cure and compliance with NASA's stringent low-outgassing criteria. Master Bond EP65HT-1 has a set-up time of just 9-12 minutes at room temperature (10-20 gram mass) while providing excellent out-gassing performance. Another compromise with cure speed tends to be a loss of heat resistance. However, EP65HT-1 is capable of providing relatively high glass transition temperatures of up to 125-130°C (cure dependent).

Results

The NASA researchers found that solutions containing 2% polymer deposited from chlorobenzene provided the highest efficiencies while PCBM containing constructions were superior to those without the fullerene derivatives. Compared with literature, the efficiencies and open-circuit potentials of their constructions were lower than the best found in the literature. The researchers suspected that the lower performance compared with the literature arose from the lack of purification performed on the sensitive conductive polymer prior to construction. Purification of the conductive polymers is critical to device performance and longevity. Master Bond EP65HT-1 served its function as a low-outgassing, epoxy sealant that provided for fast set-up and ease of use. The scope of the researchers work on these devices did not encompass an environmental or thermal cycling evaluation, which might be part of potential future endeavors.

References

[1]Bailey, S. G., Harris, J. D., Hepp, A. F., et al. Thin-Film Organic-Based Solar Cells for Space Power. NASA/TM-2002-211833. IECEC-2002-20154.