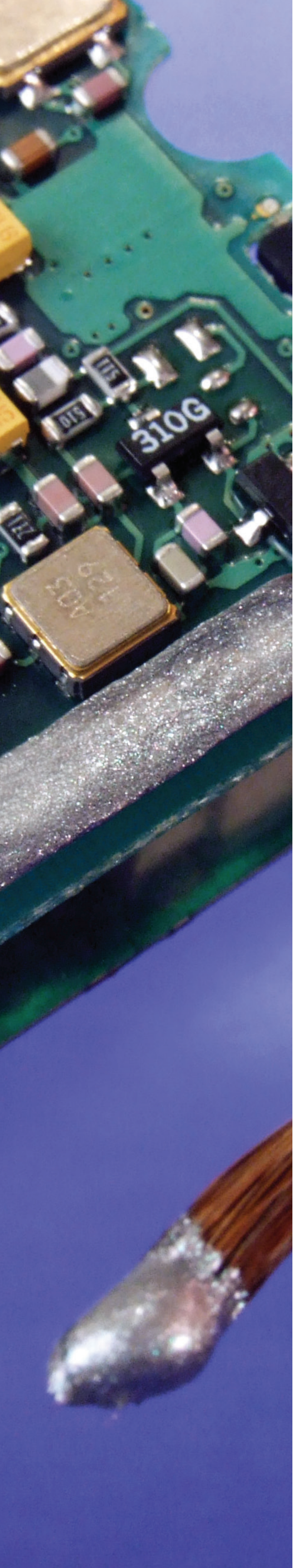

CASE STUDY

EP21TDCS-LO: Conductive Bonding Agent for Space-Environment Assemblies

Master Bond Inc. 154 Hobart Street, Hackensack, NJ 07601 USA
Phone +1.201.343.8983 | Fax +1.201.343.2132 | main@masterbond.com

EP21TDCS-LO: Conductive Bonding Agent for Space-Environment Assemblies

Conductive bonding agents play a fundamental role in ensuring reliable electrical connectivity in many electromechanical assemblies designed to operate at the extremes of temperature and pressure of space. Failure of a single bond between conductive components in an assembly can ripple rapidly through mechanical and electrical systems, ultimately threatening spacecraft integrity and crew safety. In two applications, Master Bond EP21TDCS-LO conductive epoxy met critical requirements for maintaining robust bonds in electromechanical systems intended to operate in space conditions.

Master Bond Polymer System EP21TDCS-LO is a two component, silver-filled epoxy designed to ensure high-strength conductive bonds between dissimilar materials at temperatures down to 4 K. Unlike most two-part silver-filled adhesives, Master Bond EP21TDCS-LO uses a simple one-to-one mix ratio that remains workable for 30-40 minutes and cures at room temperature in 24-48 hours or in 1-2 hours at 200°F. With volume resistivity less than 10-3 ohm-cm, this adhesive cures to an electrically conductive bond that combines high strength (shear strength over 850 psi) and flexibility (T-peel strength over 5 pounds per linear inch) – properties unusual in a silver epoxy. Along with its workability and performance characteristics, Master Bond EP21TDCS-LO meets critical requirements for space operations including passing NASA low outgassing test criteria.

The applications listed in the table below highlight use of Master Bond EP21TDCS-LO in ensuring high-strength, conductive bonds in assemblies designed to survive the harsh conditions of space.

Table. Applications of Master Bond EP21TDCS-LO

Industry	Application	EP21TDCS-LO Role	Critical Properties
Aerospace	Creating a space-like test environment for studying electrostatic discharge (ESD) effects on spacecraft[1]	Bonding samples for extended ESD testing at low temperature and pressure	Ease of use, bond conductivity and durability in high electric fields, non-reactive, no volatiles, NASA low outgassing compliant
Aerospace	Studying properties of an electrohydrodynamic (EHD) pump[2]	Bonding electrodes needed to generate electric fields for EHD	Ease of use for bonding dissimilar materials, bond conductivity and durability through extended mechanical, thermal, and electrical stress, non-reactive, no volatiles, NASA low outgassing compliant

Conclusion

Conductive bonding agents play a fundamental role in ensuring mechanical stability and electrical connectivity in many electromechanical assemblies designed to operate in the space environment. With its unique characteristics, Master Bond EP21TDCS-LO meets stringent requirements for ensuring high-strength, conductive bonds in applications designed to operate reliably despite electrical, mechanical, and thermal stress.

Bonding Samples in a Low Temperature Space Environment Testing System

Application

Electrical charge can build quickly on surfaces of spacecraft because excited electrons created by thermal sources are less likely to move through insulating materials at the low temperatures of space. As a result, electrostatic discharge (ESD) can occur from the many separate insulated areas of a spacecraft. Indeed, this phenomenon is both so prevalent and powerful that ESD is often the leading factor in electrical and mechanical failures in spacecraft. For this reason, the ability to study ESD under controlled conditions in a simulated space environment is vital for spacecraft operations and crew safety.

Key Parameters and Requirements

To enable studies of ESD and other effects, a research team developed a test chamber capable of reproducing different combinations of pressure, temperature, and radiation encountered in spacecraft operations. Within the test chamber, a helium cryostat chamber enables researchers to study the effects of electrons, ions, and photons on different material samples at conditions reaching below 40K (the temperature of a passively cooled spacecraft in orbit) and five millipascals (well below the ~30 mPa of pressure found at 100 km altitude – the boundary that formally defines the edge of space). After the cryostat chamber has reached the desired pressure and temperature, scientists can focus a beam of electrons on a material specimen to study the effects of different levels of energy density and flux. Besides using the built-in Faraday cup to measure beam current in real time, scientists can monitor the effects on the samples at wavelengths ranging from 250 nm to 5500 nm with a variety of cameras and spectrometers.

Just as important, scientists can study a variety of material samples without repeatedly recycling the chamber between simulated space conditions and normal atmosphere. Here, researchers can mount different materials on 10 mm copper cylinders designed to be placed in one of four available slots on a rotating holder (Figure 1). Rather than cycle the chamber to study a different specimen, researchers simply rotate the desired specimen into position within the chamber. To work successfully, this approach depends on the strength and reliability of a thin layer of bonding material that holds each sample to a copper cylinder. For each multi-specimen study to succeed, the bonding agent must maintain a stable, conductive bond between the specimen and copper cylinder despite stresses due to holder rotation, wide excursions in test chamber temperature and pressure, and high electric fields generated during different test scenarios.

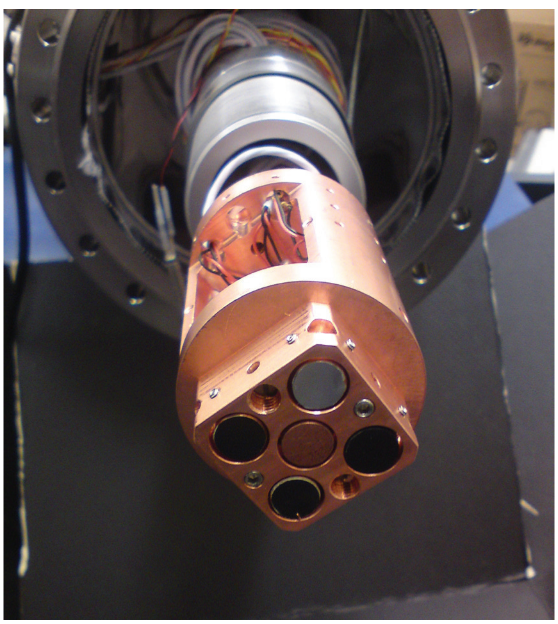

Figure 1: Within the space environment testing chamber, the interchangeable sample pedestal holds a central Faraday cup and four slots for 10mm copper cylinders, each with a different material specimen mounted with Master Bond EP21TDCS-LO conductive epoxy.[1]

Results

To ensure reliable conductive bonds under extremes of temperature and pressure, the research team used Master Bond EP21TDCS-LO conductive epoxy to attach material specimens to the copper cylinder mounts. Despite extremes of temperature and pressure, Master Bond EP21TDCS-LO epoxy fully met requirements for bond stability and conductivity through the full course of extended experimental studies.

Bonding Electrodes in an Electrohydrodynamic Conduction Pump

Application

Despite their advantages in size and flexibility, active thermal control systems are typically not used in space platforms due to concerns about the reliability of conventional mechanical pumps. In contrast, electrohydrodynamic (EHD) pumps involve no moving parts, using electric fields to move fluids. In concept, an EHD pump is simple in design, consisting of pairs of electrodes embedded within the fluid passage itself. To move fluid through a cooling duct, an EHD-based active cooling system needs only apply a DC voltage across each electrode pair. The resulting electric field passes through the fluid between the electrodes, resulting in the creation of a current of charge carriers that moves through the field, propelling the fluid along with it.

With their lack of mechanical parts, EHD pumps can offer an effective solution for active systems and even control fluid flow in highly branched cooling networks. Miniature EHD pumps can be embedded throughout the cooling network, sized to fit complex geometries and built into even the smallest ducts. In some thermal control applications, these pumps can serve as the primary method of fluid flow. In others, they can be used to reroute fluid flow generated by larger pumps, increasing or decreasing flow through individual ducts or specific sections of the network.

Key Parameters and Requirements

Although EHD pumps offer great potential, effective application of this technology depends on a number of factors. Besides optimizing structural elements such as fluid-channel geometry and electrode placement, engineers need to create the optimal conditions for optimal electric field strength and charge-carrier generation, among other parameters. To help identify appropriate design strategies, a research project focused on the design an EHD pump and an associated testbed to characterize the pump's fluid-flow characteristics.

At the heart of this pump design, sets of electrode-pair assemblies provide the electric field needed to create fluid flow. For this pump, an individual electrode assembly comprises a thin stainless-steel disk for the ground electrode, a thick stainless-steel disk for the high-voltage electrode, and a thin non-conducting polycarbonate disk as an insulator. Machined into each disk, a triangular opening provides a duct for fluid passage. The EHD pump itself stacks several of these assemblies in series, each separated by a thick polycarbonate insulator disk and oriented to allow fluid to pass freely through the triangular opening in every disk. (Figure 2).

Within each electrode-pair assembly, each electrode disk provides a hole on one end for bonding the disk to its respective bus line and a cutout on the other for preventing contact with the opposite bus line. The ability to reliably bond each disk to its bus line is critical because of the fundamental importance of electrode-pair interactions in EHD technology. Along with low resistivity for the electrical connection itself, the bonding agent must provide sufficient strength to maintain integrity despite the mechanical and thermal stresses involved in spacecraft operations. Just as important, the bonding agent must remain non-reactive with the cooling fluid itself and ensure compliance with NASA outgassing specifications.

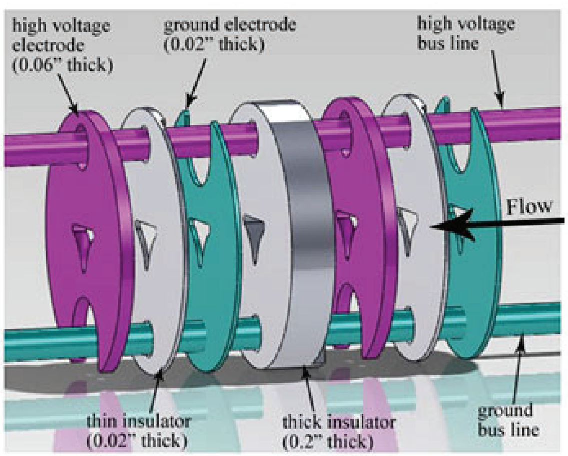

Figure 2: For the EHD research project, the EDH pump comprised a stack of electrode-pair assemblies such as the two shown here, using Master Bond EP21TDCS-LO conductive epoxy to bond each high-voltage and ground electrode to its respective bus line.[2]

Results

To meet the EHD pump's diverse requirements, the research project used Master Bond EP21TDCS-LO conductive epoxy to ensure the robust connections required between electrodes and bus lines in this design. The ability of Master Bond EP21TDCS-LO to maintain stable bonds proved itself in the final pump design, which comprised 15 electrode-pair assemblies stacked in series.

In a series of tests conducted on the final EHD pump, various DC voltages ranging from 0 to 3500 volts were applied to each electrode pair to obtain different measurements of dynamic and static performance. While some tests examined flow-through rates at different voltage levels, other tests studied static pressure created within the pump over a period of time. Master Bond EP21TDCS-LO epoxy maintains reliable connections throughout this regime of varying electric field, flow rate, and pressure.

Conclusion

To build an electrohydrodynamic (EHD) pump, a research project required a bonding agent able to maintain reliable connections within electrode assemblies needed to generate electric fields at the heart of EDH technology. Using stacks of electrode assemblies bonded with Master Bond EP21TDCS-LO conductive epoxy, the final EHD pump successfully achieved dynamic fluid flow and static pressure.

References

[1] Dekany, Justin; Johnson, Robert H.; Wilson, Gregory; Evans, Amberly; and Dennison, JR, "Ultrahigh Vacuum Cryostat System for Extended Low Temperature Space Environment Testing," All Physics Faculty Publications, Paper 1455, 2012.

[2] Sinnamon, Samuel, "Coolant Distribution Control in Satellite Structural Panels Using Electrohydrodynamic Conduction Pumping," MS thesis, Mechanical Engineering, University of New Mexico, May 2012.