MASTERBOND®
CASE STUDY

EP31: Adhesive for Piezoelectric Microfiber Composites, Molecular Diagnostics, and CO_2 Flow Systems

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

EP31: Adhesive for Piezoelectric Microfiber Composites, Molecular Diagnostics, and CO_2 Flow Systems

Overview of EP31

Master Bond EP31 is a two-component epoxy-based resin that is primarily designed for bonding applications. As with our other epoxy-based adhesives, it features high strength after curing. As shown by the case studies below, this compound can bond a variety of dissimilar substrate pairs, including aluminum-acrylic and Kevlar-polyimide. The case studies below provide illustrative examples of EP31 used to bond components of aeronautical wings (piezoelectric actuators), biological apparatuses (DNA amplification), and thermocouple housings.

Piezoelectric Microfiber Composite Actuators for Morphing Wings

Application

Morphing wings are desired in aircraft applications due to their advantages compared with fixed wings, including being able to responsively adapt to aerodynamic drag. Researchers from California State University at San Bernardino have developed two approaches for obtaining control surfaces (aerodynamic devices that allow pilots to adjust the flight attitude of an aircraft) on morphing wings using microfiber composite (MFC) actuators. The authors explored the effectiveness of using two bonding approaches: a flap approach in which the MFC actuator was bonded to each side of a metal substrate and a direct bonding approach in which MFC actuators were directly bonded to the Kevlar wing using Master Bond EP31.

Key Parameters and Requirements

For the direct bonding approach, the authors bonded the MFC actuator as close to the trailing edge as possible while simultaneously avoiding knotted areas in the air bladder of the wing. The actuator was bonded to the airfoil using Master Bond EP31. According to the authors, EP31 was chosen because of its high shear strength of 20 kN, which helped reduce compliance problems that would have otherwise reduced the actuator's performance. After cleaning the surface of the actuator and the airfoil with acetone, the adhesive was cured for 28 hours at room temperature.

Results

The bonding reliability was assessed by repeatedly applying sinusoidal voltage signals to the actuator over a frequency range of < 1 Hz to > 1 kHz. After visually inspecting the bond, the authors found no visible signs of debonding. Furthermore, when using the direct bonding approach, the authors conducted bonding reliability tests for several days and successfully reproduced their experimental results several times. The authors noted that > 90% of the actuator formed a strong bond with the wing, and this bonding percentage could be further increased by increasing the temperature during bonding. After successfully bonding the MFC actuators to the wings, the authors compared the two bonding approaches. Their results showed that, although the flap approach produced greater displacements, it also made the wing less flexible. By directly bonding the MFC actuator to a metal substrate and then attaching it to the trailing edge of the wing (similar to traditional wing flaps), the authors were able to maintain the flexibility of the wing but observed problems with tension loading at higher wing pressures. As noted by the authors, EP31 played a key role in ensuring the reliability of the direct bonding approach.

Molecular diagnostics in a teacup: Non-Instrumented Nucleic Acid Amplification (NINA) for rapid, low cost detection of *Salmonella enterica*

Application

Salmonella enterica is responsible for more than half of all food-borne illnesses worldwide. In the US, food safety is ensured by testing for the presence of Salmonella by shipping samples to dedicated laboratories, which involves the use of expensive instrumentation. Researchers at the University of Hawaii at Manoa have developed a novel method based on loop-mediated isothermal amplification (LAMP) that does not require the use of such instruments to detect the presence of Salmonella DNA in milk. As part of this approach, Master Bond EP31 was used to bond the cylinders that housed the phase-change material (PCM) that was responsible for maintaining the reaction temperature of the device.

Key Parameters and Requirements

To detect the presence of Salmonella DNA in samples, the authors' DNA amplification device needed to maintain a constant reaction temperature for at least 30 minutes to ensure reaction completion. The continuous reactions were heated by adding a small volume of boiling water, and the temperature was maintained for 90 minutes due to the use of a PCM that was housed in an aluminum shell with acrylic caps. Master Bond EP31 was used to fit these pieces together by overnight curing, and then the temperature within the device was measured by using three thermocouples fixed with the epoxy.

Results

The custom-made device successfully maintained the target temperature even longer than was necessary. The authors showed that the fluorescence signal of their custom fluorimeter had comparable performance to real-time PCR. Master Bond's EP31 played a key role in ensuring that the PCM did not leak from its enclosure, helping the device maintain the temperature required to run the Salmonella DNA amplification reactions. This approach provides a simple approach for detecting Salmonella, especially for developing countries that seek an inexpensive alternative to instrument-based methods due to unreliable electricity grids.

Laboratory Experimental and Numerical Investigations of Heat Extraction From Porous Media by Means of CO_2 Application

Application

Geothermal energy systems attempt to extract thermal energy in locations where sub-optimal geological conditions are present. Part of this process involves reservoir stimulation to overcome the lack of porosity/permeability of the rock using either physical or chemical processes with the use of a heat-transfer process fluid. Supercritical CO_2 can be used as the working fluid due to its lower viscosity and greater density difference between the cold and hot fluids used in this process. Researchers at the University of California, Berkeley performed a variety of experimental and numerical investigations to determine the performance of supercritical CO_2 to extract heat from porous rock for geothermal applications. Due to the sparsity of academic literature on how best to construct a lab-scale supercritical CO_2 flow system, the authors took it upon themselves to construct an apparatus to continuously flow temperature-controlled supercritical CO_2 under controlled conditions into a pressure vessel. They measured the temperature of this vessel at 23 locations within the sample using thermocouples. Master Bond EP31 was critical to ensuring that the thermocouples measured the temperature without leaking supercritical CO_2.

Key Parameters and Requirements

The authors inserted 23 thermocouples from the bottom of the vessel through two stainless steel pipes that were sealed using EP31. To optimize the bonding, the authors internally threaded the stainless steel pipes and then cleaned them before assembly. Once the thermocouples were inserted and properly adjusted, a compression fitting cap was attached to one end of the pipes to allow the thermocouples to pass through. The pipes were filled with EP31, and the entire apparatus was vacuumed to remove air bubbles.

Results

The developed apparatus provided data that may be useful for validating CO_2-based porous media flow models for field-scale geothermal applications. When working with supercritical CO_2, effusion of the gas is a major concern, especially at higher temperatures and pressures. The authors investigated a variety of material combinations to obtain seals that prevented CO_2 leaks. After a trial-and-error approach, the authors finally used Master Bond EP31 to seal the thermocouples into their stainless steel housing. Without threading and cleaning, the authors noted that insufficient bonding was obtained, further highlighting the importance of thoroughly cleaning the bonding surfaces before applying and curing EP31. The authors noted that EP31 remained intact and maintained a seal throughout the duration of their experiments, preventing the leakage of supercritical CO_2 during experiments.

References

[1] Usher, T. D.; Ulibarri, K. R.; Camargo, G. S. Piezoelectric Microfiber Composite Actuators for Morphing Wings. ISRN Mater. Sci. 2013, 2013. https://doi.org/10.1155/2013/189659.

[2] Kubota, R.; Labarre, P.; Weigl, B. H.; Li, Y.; Haydock, P.; Jenkins, D. M. Molecular Diagnostics in a Teacup: Non-Instrumented Nucleic Acid Amplification (NINA) for Rapid, Low Cost Detection of Salmonella Enterica. Chin. Sci. Bull. 2013, 58 (10), 1162–1168. https://doi.org/10.1007/S11434-012-5634-9.

[3] Magliocco, M. J. (2015). Laboratory Experimental and Numerical Investigations of Heat Extraction From Porous Media by Means of CO2. UC Berkeley. ProQuest ID: Magliocco_berkeley_0028E_15079. Merritt ID: ark:/13030/m55f1wcg. Retrieved from https://escholarship.org/uc/item/8f79p33s