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Assessment and Characterization of Dual-Hardening Adhesion Promoter for Self-Healing Mechanisms in Metal-Plastic Hybrid System

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Abstract : In mechatronics or sensor technology, plastic housings are used to protect sensitive components from harmful environmental influences, such as moisture, media, or reactive substances. Connections, preferably in the form of metallic lead-frame structures, through the housing wall are required for their electrical supply or control. In this system, an insufficient connection between the plastic component, e.g., Polyamide66, and the metal surface, e.g., copper, due to the incompatibility is dominating. As a result, leakage paths can occur along with the plastic-metal interface. Since adhesive bonding has been established as one of the most important joining processes and its use has expanded significantly, driven by the development of improved high-performance adhesives and bonding techniques, this technology has been involved in metal-plastic hybrid structures. In this study, an epoxy bonding agent from DELO (DUALBOND LT2266) has been used to improve the mechanical and chemical binding between the metal and the polymer. It is an adhesion promoter with two reaction stages. In these, the first stage provides fixation to the lead frame directly after the coating step, which can be done by UV-Exposure for a few seconds. In the second stage, the material will be thermally hardened during injection molding. To analyze the two reaction stages of the primer, dynamic DSC experiments were carried out and correlated with Fourier-transform infrared spectroscopy measurements. Furthermore, the number of crosslinking bonds formed in the system in each reaction stage has also been estimated by a rheological characterization. Those investigations have been performed with different times of UV exposure: 12, 96 s and in an industrial preferred temperature range from -20 to 175°C. The shear viscosity values of primer have been measured as a function of temperature and exposure times. For further interpretation, the storage modulus values have been calculated, and the so-called Booij–Palmen plot has been sketched. The next approach in this study is the self-healing mechanisms in the hydride system in which the primer should flow into micro-damage such as interface, cracks, inhibit them from growing, and close them. The ability of the primer to flow in and penetrate defined capillaries made in Ultramid was investigated. Holes with a diameter of 0.3 mm were produced in injection-molded A3EG7 plates with 4 mm thickness. A copper substrate coated with the DUALBOND was placed on the A3EG7 plate and pressed with a certain force. Metallographic analyses were carried out to verify the filling grade, which showed an almost 95% filling ratio of the capillaries. Finally, to estimate the self-healing mechanism in metal-plastic hybrid systems, characterizations have been done on a simple geometry with a metal inlay developed by the Institute of Polymer Technology in Friedrich-Alexander-University. The specimens have been modified with tungsten wire which was to be pulled out after the injection molding to create a micro-hole in the specimen at the interface between the primer and the polymer. The capability of the primer to heal those micro-cracks upon heating, pressing, and thermal aging has been characterized through metallographic analyses.

Keywords : hybrid structures, self-healing, thermoplastic housing, adhesive
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