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Non-destructive validation method for understanding water uptake processes of moldings in electronic packaging

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Summary:

The long time stability of molding compounds in electronic packages is critical for many applications. Modern characterization methods focusing on pass / fail criteria, so that a deeper understanding of degradation mechanisms could not be achieved in that way. EIS and FTIR , commonly used in corrosion research, were transferred and demonstrated as validation method for the water uptake and chemical changing during loading scenarios. The usability of these non-destructive methods will be demonstrated and the results were used to generate degradation models for such molding materials.

Keywords: Electrochemical impedance spectroscopy, Fourier transform infrared spectroscopy, molding compound, degradation mechanism

Motivation

All electronic devices consist of metallic conductors and insulating materials as substrates or moldings. Interfaces between these materials groups are unavoidable. Main purpose of mainly organic molding materials are corrosion protection of conductors and electronic components. Therefore, the longtime stability of these materials against different loading scenarios is critical for many applications. Usually, modern test scenarios only focus on pass or fail results, e.g. mechanical characterization methods like shear strength measurement following MIL Std. 883 [1]. Such tests are regularly performed before and after defined loading scenarios like damp heat, temperature cycling or pressure cooker treatment. Unfortunately, the results only summarizes the accumulated alteration at the time of test. An deep understanding of the fundamental reaction processes or kinetics can´t be achieved in that way, but is necessary for further improvement of materials and technologies. Therefore, transferring these methods from the corrosion research on electronic materials can overcome this not acceptable state of knowledge.

EIS and FTIR for electronic industry

Electrochemical impedance spectroscopy (EIS) and Fourier-transform infrared spectroscopy (FTIR) are standard methods in the corrosion research. Using these methods to characterize electrical and chemical conditions of a molding or encapsulation in-situ during loading scenarios can help to generate degradation models of these inspected materials.

Results

Epoxy based molds with typical applications like encapsulation or dam and fill were selected and cured on printed circuit boards (PCB) with electroless nickel immersion gold (ENIG) finishes. These samples were aged for up to 96 h in a pressure cooker test according [2] and further inspected regarding their shear strength stability on the substrate surface (see Fig. 1)

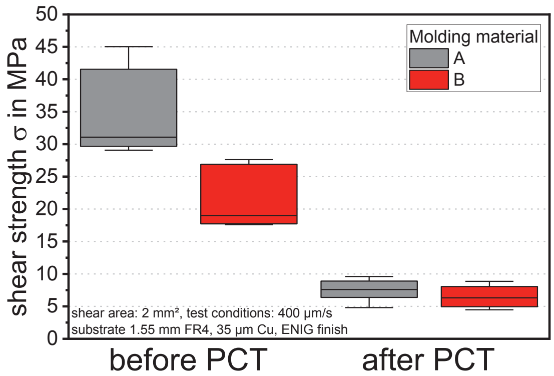

Fig. 1. Shear strengths of epoxy based molds from ENIG surfaces before and after pressure cooker treatment (PCT)

The optical inspection of all fracture zones shows adhesive as well as cohesive failure mechanisms. Consequently, no clear degradation mechanism could be observed. Optical inspection of the molding surface shows, that mold *A* shows in some regions defects like blisters, pinholes or inclusions. Mold *B* seems to be nearly free of defects.

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Further samples were inspected with EIS and FTIR before and after PCT to generate a better understanding of the degradation mechanism.

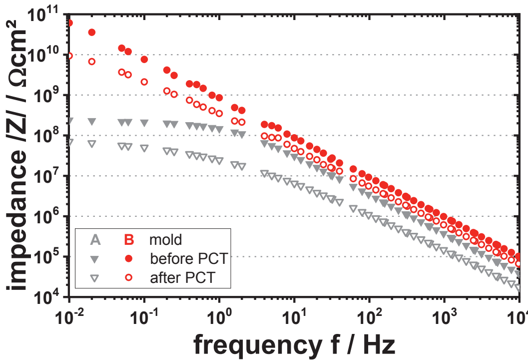

Fig. 2. EIS: Impedance of mold A (left) and B (right) before and after pressure cooker treatment (PCT).

EIS helps to get more into detail and focusing on electrical parameters of the molding compound itself. Especially the change in capacity during different loading scenarios is used to calculate water uptake WU of the material by using eg. (1) according [3].

$$WU = \frac{\lg\left(\frac{C_t}{C_o}\right)}{\lg 80} \cdot 100\ (Vol.\%) \qquad (1)$$

The water uptake was calculated to approximately 21 Vol.% for mold A and 11 Vol.% for mold B. The different results indicate different water penetration scenarios. For the nearly perfectly cured mold B, liquids could only penetrate the material by a more or less homogeneous diffusion across the mold. A mold with several surface defects (mold A) offers the possibility for inhomogeneous penetration of any kind of liquids into deeper material regions along preferred paths and accelerates the degradation in this way. Selective penetration could be found in phase shift of the impedance during EIS measurement and was used to generate following equivalent circuits according [4, 5].

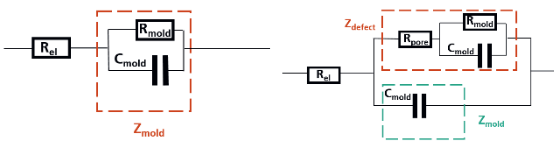

Fig. 3. Equivalent circuits of molds on metallic surfaces without surface defects (left) and with liquid penetrated pores (right).

Therefore, pre-existent defects previously detected by optical microscopy of mold A could clearly been seen in the initial EIS measurement (lower impedances) and their influence on environment stability could be described using the shown methods. In that way, a better understanding of different degradation mechanisms could be found without destruction of the molding samples, which demonstrates the usability of this measurement method as material and application controlling method. For a complete understanding of the ongoing degradation mechanisms during the applied loading scenarios FTIR inspections must be applied. This method focus on the actual material state instead on the electrical characteristics of the material. In that way, alteration of material due to environmental impact or degradation can be inspected more in detail (see Fig. 4).

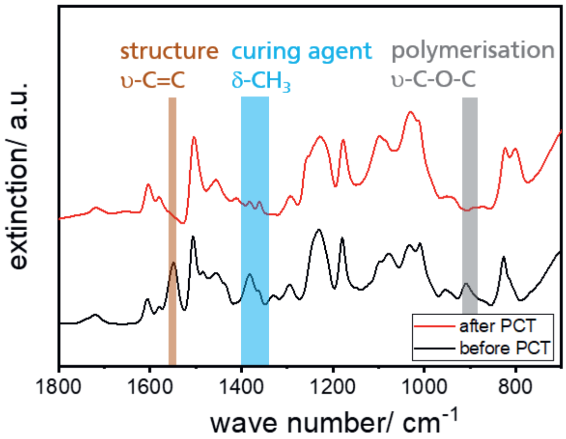

Fig. 4. FTIR band spectrum of mold A before and after pressure cooker treatment with highlighted changes in characteristic wavelengths.

The obviously change in intensity of characteristic bands of aromatics, solvents or epoxy indicates a significant change of the material during the load scenario. Results like this are apprpriate to generate better understanding in material degradation mechanism and material state monitoring over product lifetime cycles. Therefore, methods like EIS and FTIR are highly recommended to be transferred from the corrosion research to the electronic industries.

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