Terahertz Spectroscopy of Aged Epoxy Resin Adhesive

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***Abstract* — We present a THz TDS study of different aged epoxy resin adhesive to investigate the potential of this technique for contact-free, non-destructive detection of ageing. The samples were aged artificially over 10 days and a conventional THz TDS system was used to evaluate their dielectric properties. Our results indicate that aged and unaged samples can be distinguished.**

I. INTRODUCTION

The detection of aged adhesive material is of outmost importance for quality control of long-term used polymer materials. Especially epoxy resin adhesives represent an interesting material class as they are the basis of many modern adhered compounds [1]. The joint strength decreases under the influence of high temperature, UV radiation, or water. In order to detect aged materials, destructive mechanical tests are commonly used. In this study, we investigate cured plates of Polytec EP601-T epoxy resin adhesive, which are either thermally aged at 100°C UV irradiated or inserted into water each for one week. The samples were characterized with a standard fiber coupled THz-TDS system.

II. RESULTS

For data extraction the algorithm described in [2] was used. The differences in the absorption coefficient are negligibly small. Only the water aged samples show a higher absorption because of water embedment. However, the refractive index of the samples varies significantly. Figure 1 illustrates the

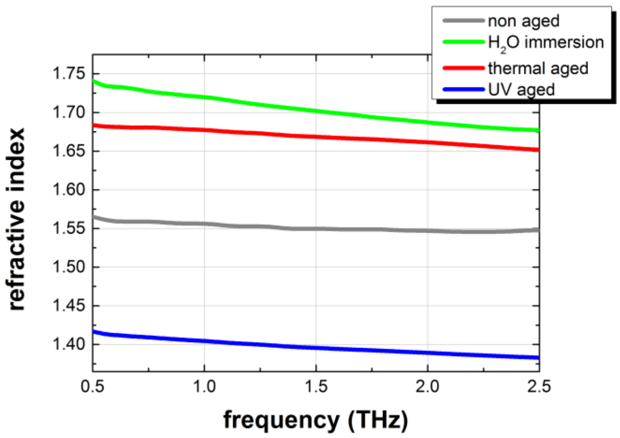

Fig. 1. Refractive index of different aged epoxy polymers over a frequency range 0.5 up to 2.5 THz.

frequency dependent refractive index of the differently aged epoxies. The refractive index of unaged polymers is about 1.55, whereas it increases during thermal aging. Here, post-cure and cross-link effects of the epoxy molecule may occur and the morphology changes. During the water immersion, the water molecules are embedded in the polymer matrix and therefore the refractive index increases, as previous studies suggested [3]. In opposite to the thermally aged samples, UV irradiation leads to a decrease in the refractive index allowing a distinction between the two ageing mechanisms. For a real application it is important to make a classification of the results, since the behavior slightly differs for different samples due to statistical fluctuations even if the same ageing mechanism is applied to the material. Therefore, a principle component analysis (PCA) of the frequency dependent refractive indices could be a more reliable method. Figure 2 shows the score plot of different aged samples, illustrated by

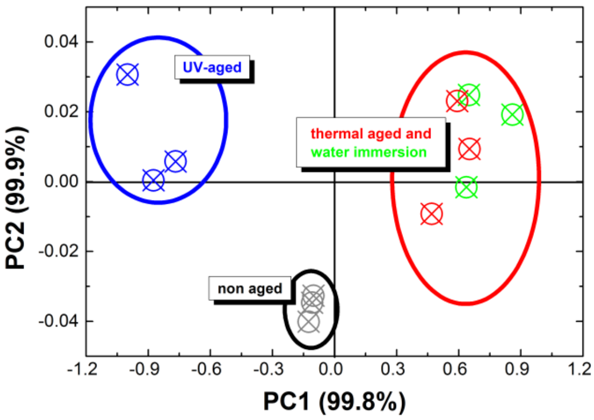

Fig. 2. Principle component analysis (score plot) of the refractive index spectra from different aged epoxy polymers.

their first two main components. It is possible to differentiate between three classes of aged (blue and red circles in fig. 2) and unaged (black circles) epoxies. However, it is yet not possible to distinguish thermal aged epoxies from water inserted, because in both cases the refractive index increases (see fig. 1).

III. SUMMARY

With THz TDS it is possible to characterize aged epoxy polymers nondestructively by comparing their refractive indices. A PCA could be a powerful tool to distinguish different aged epoxies. Further studies should focus on comparative measurements of mechanical tests and THz-TDS.

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