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Structural characterization and investigation of shape memory performance of thermoset polyurethane shape memory polymer

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In this study, we present a comprehensive investigation of the structure and shape memory performance of a thermoset polyurethane shape memory polymer PU-SMP with a glass transition temperature of 45 °C, denoted by MP4510. The chemically crosslinked network of this PU-SMP ensures exceptional shape memory behavior, making it highly desirable for various applications. The advantage of this smart polymer is that its activation temperature range is close to room and human body temperature which opens up possibilities for use in biomedical and industrial applications, e.g. fast-response actuators.

In order to better understand the behavior of the material in various conditions and to select the appropriate parameters for the thermomechanical loading program the extensive program of the PU-SMP structural characterization was performed by dynamic mechanical analysis (DMA), differential scanning calorimetry (DSC), scanning electron microscopy (SEM) and atomic force microscopy (AFM). The conducted structure characterization confirmed the high strength and high shape memory properties of the PU-SMP.

Shape memory properties, i.e. shape fixity and shape recovery parameters, were determined in the thermomechanical loading program. A modified experimental approach that considered the polymer's sensitivity to external conditions, such as temperature and humidity variations, was applied. The obtained results indicate that the PU-SMP exhibits a shape fixity ratio of approximately 98%, which remains relatively consistent throughout subsequent cycles of thermomechanical loading due to the stability of chemical crosslinks in the thermoset material's structure. In terms of shape recovery, the polymer demonstrated a value of about 90% in the first cycle, which progressively improved to surpass 99% in the third cycle. These findings confirm the positive impact of thermomechanical training on enhancing the shape recovery of the PU-SMP in the subsequent cycles, as well as the influence of thermoset material stability on the repeatability of shape memory parameters.

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