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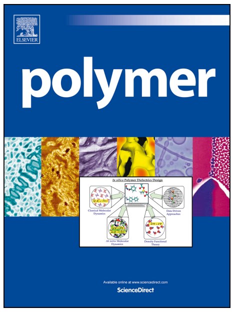

Fast switchable, epoxy based shape-memory polymers with high strength and toughness

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Fast switchable, epoxy based shape-memory polymers with high strength and toughness

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ABSTRACT: A fast switchable, epoxy based shape-memory polymer is presented. For this, a partially crystalline epoxy resin was formed by cationic polymerization in the presence of a high meltable polyester polyol, namely poly(ω-pentadecalactone) (PPDL). Under certain polymerization conditions, this system generates a high degree of crystallinity compared to the respective poly(ε-caprolactone) (PCL) counterpart. Thus, such an epoxy/PPDL composite exhibits very fast shape-fixity and a good shape-memory cycle stability. Furthermore, the formation of a heterogeneous morphology by segregation and crystallization leads to enhanced strength and toughness compared to the respective epoxy/PCL composites.

1. Introduction

Shape-memory polymers (SMPs) are “smart” materials exhibiting at least one switching segment in addition to a segment which gives the permanent shape of the polymer. Thus, the switching segment, commonly a crystalline phase, features a transition temperature which, in this case, corresponds to the melting temperature. Such “smart” materials can be used as, for example, implants or medical materials, sensors, switchable adhesive surfaces, actuators, or self-healing materials.[1-9] In addition to temperature stimulation for the so-called programming, moisture[10], light[11], magnetic field[12-13], and electrical activation[14] are also suitable alternatives for the triggering of shape changes.

As well as known SMPs, composed of polyurethane,[15] an important class of SMPs is based on epoxy resins.[8,16-22] Such epoxy resins have generally been cured with amines. A novel cationically polymerized epoxy based SMP has recently been reported.[23] This SMP uses a cycloaliphatic epoxy resin as a matrix for the permanent shape and poly(ε-caprolactone) (PCL) as a switching component responding to a thermal stimulus. Polyesters, such as PCL, are well known for soft segments in SMPs having low transition temperatures.[5,16,23-33] In order to reach a higher melting point and, therefore, an increased transition temperature, poly(ω-pentadecalactone) (PPDL) is a suitable component for shape transition.[12,28-30] For this reason, cationically polymerized epoxy resins containing PPDL should lead to both enhanced strength and toughness as well as shape memory behavior with a high transition temperature and fast crystallization. Crystallinity enhancement should be achievable in cationically polymerized epoxides through the control of the reaction conditions, especially the control of the degree of epoxide consumption by the so-called activated monomer mechanism (AM) which proceeds to some extent concomitantly to the pure epoxide propagation. The AM is a chain transfer reaction which leads to chain termination by, e.g., an alcohol and simultaneously to the release of a proton[34-37], which accelerates the polymerization and allows for it to proceed at lower tem-