J Polym Res (2013) 20:113
DOI 10.1007/s10965-013-0113-9

ORIGINAL PAPER

Effect of strain on the thermomechanical behavior of epoxy based shape memory polymers

A. Revathi · Sandhya Rao · Kavitha V. Rao · M. Muralidhar Singh · M. Sendil Murugan · Shylaja Srihari · G. N. Dayananda

Received: 12 November 2012 / Accepted: 19 February 2013 / Published online: 11 April 2013

Abstract The effect of deformation strain on the thermome chanical (TM) behavior of a commercially available bifunctional epoxy resin modified with 5 % carboxyl-terminated butadiene acrylonitrile (CTBN) was studied. The results were compared with those for the unmodified epoxy SMP. The glass transition temperatures (T_g) as well as the moduli of these SMPs were determined. Static tensile tests were carried out at both 25 °C and 115 °C to study the effect of CTBN addition on the failure strain. TM cycling tests were conducted for two prescribed strain values: 15 % and 25 %. Further, the effect of the prescribed strain values and TM cycling on the shape-frozen and recovery responses of these SMPs were studied. In addition, microstructure studies were carried out in order to examine the dispersion of the CTBN and the fracture behavior of the CTBN-epoxy SMP. The results show that adding CTBN to the epoxy matrix leads to a slight reduction in storage modulus and T_g. Static tensile tests revealed that there was a noticeable improvement in the failure strain of the CTBN-epoxy SMP when it was tested at 115 °C rather than at 25 °C. The cyclic thermomechanical tests performed here prove that the CTBN-epoxy SMP has a better endurance than the unmodified epoxy SMP, as well as enhanced shape-recovery characteristics.

Keywords Thermomechanical cycle · Shape memory · Epoxy-CTBN · Shape frozen · Strain recovery

A. Revathi · S. Rao (✉) · K. V. Rao · M. M. Singh · M. S. Murugan · S. Srihari · G. N. Dayananda
Centre for Societal Missions and Special Technologies, CSIR—National Aerospace Laboratories, Bangalore 560017 Karnataka, India
e-mail: sandhya.rao@nal.res.in

Introduction

Shape-memory polymers (SMPs) are a class of intelligent or adaptive materials that offer great promise in a number of applications across various sectors, ranging from the aerospace industry to medicine and consumer electronics [1, 2]. They are promising because they have properties that differentiate them from other adaptive materials, such as shape-memory alloys (SMAs) and ceramics. Compared to SMAs, SMPs are lighter (in weight), are capable of recovery strains of hundreds of percent, can be processed using standard polymer processing techniques, are inexpensive, and are electrical and thermal insulators.

The basis of the shape-memory effect in polymeric materials is a significant change in modulus at the phase-transition temperature. The modulus decreases as the polymer is heated from the glassy phase to the rubbery phase. Consequently, strain can be introduced into the polymer with relative ease at temperatures above the transition temperature. If this strain is then maintained while the temperature of the material is decreased below the transition temperature, the strain is "frozen in." This strain can be recovered when the polymer is heated above the transition temperature again [3]. In thermoresponsive SMPs, softening of the transition segment may be realized by means of heating to the glass transition temperature or the melting temperature. As such, the transition temperature may refer to the glass transition temperature (T_g) or melting temperature (T_m) [4].

A variety of SMPs, such as *trans*-polyisoprene (TPI), poly(styrene-*co*-butadiene), polynorbornene, polyurethanes, and epoxies, have been developed till date. In particular, shape-memory polyurethanes (SMPUs) have been drawing a great deal of attention lately because of their ability to recover large deformations, and hence have a potential to be