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ORIGINAL PAPER

Modeling attempt of shape memory performance of epoxy resin with experimental methods

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Abstract Epoxy resin samples with low cross-linking density were prepared, and their shape recovery rate and glass transition were studied. The results showed that the shape fixity ratio was over 99 % for all of the samples. Without constraint, the final recovery ratio was approximate to 100 % for all of the samples. The temperature with rapid recovery rate for different samples changed in accordance with T_g. Under a constant temperature, the folding angle for the samples of EP80 decreased with the increase in time rapidly, at first, and then tended to level off. Curves can be fitted with the formula of $y + A_0 = A/(1 + \exp((t - t_0)/\tau))$ with R^2 higher than 99.9 %. The fitting results demonstrated that the value of τ decreased from 15.1 to 6.39 when the temperature increased from 88 to 98 °C for EP80. The recovery rate decreased a little by extending the holding time from 10 to 60 s. By keeping the testing temperature constant, glass transition temperature (T_g) decreased with the increase in curing agents, and the value of τ reduced with the decrease in T_g. Usually, when temperature was close to T_g, segments of macromolecules were idle to move, and then, the relaxation process, τ, was lengthened and the shape recovery rate decreased accordingly. In a word, τ showed the similar change rules with that of relaxation process of polymers; therefore, the shape recovering process could be predicted with the model of relaxation time and modulus according to relaxation formulas.

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Introduction

With the development of space technology, large-scale space structure is widely used. However, due to the size limitation, the large-scale structure is difficult to transmit to space directly. For shipping purpose, the large-scale structures are needed to be folded sufficiently before launching and then can be deployed fully after launching. Most of space deployable systems are mechanical structure, for the different surface condition and stress state between earth surface and space orbit, and locking events of deployable systems have occurred occasionally, which may result in big economic loss [1].

There are some works to attempt to use shape memory materials for making space large-scale structures [2]; for example, the structure of hinge can be deployed within 100 s [2] and a prototype reflector was tested to deploy accurately [3].

Shape memory materials recover their shape spontaneously under some conditions and can facilitate the reliability and simplify the deployable system. In most deployable materials, thermosetting polymers are light, have good sizing, mechanical and chemical properties, and can be tailored according to requirements; therefore, they show significant potential to be adopted widely.

Shape memory polymers can be thermo-sensitive, electrical-sensitive, and photo-sensitive or chemical-sensitive. For certain application, thermo-sensitive shape memory polymers attract great attention due to their rapidly response and greatly recovery strains. The cycle of thermo-sensitive polymer can be illustrated in Scheme 1 [4]. From the figure,