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ADVANCES IN THE FIELD OF SHAPE MEMORY POLYMERS

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ABSTRACT

Heterogeneous polymers, because of their viscoelasticity and because of the presence of hard and soft segments in their structure present specific behaviors like shape memory effect (SME). In the field of shape memory polymers, there are a lot of research works showing different aspects of this behavior. In the present study a review of shape memory polymers (blend and rubbers) with their specific properties will be presented. In this review, some new concepts regarding certain aspects related to shape memory effect will be shown.

Keywords: shape memory effect, partial shape memory effect, rubber, blend, recovery.

INTRODUCTION

A review of the literature gives a great deal of valuable information [1-3] about the shape memory polymers (SMP); however the answers to a number of serious and foremost questions are still shrouded in mystery. Recently certain new concepts for shape memory polymers have been proposed (4-5). Some of these concepts can be presented as follows:

Property Memory Effect (PME), Partial Shape Memory Effect (PSME), Micro-Structural Shape Memory Effect (MSSME), Microshape changes and shape memory effect. It is usually common to consider shape memory effect (SME) as macroscopic and visual shape changes. However, this effect may be observed also in certain cases when the shape change is in a microscopic scale. For example, in the following cases, one can see the effect of shape memory: Elasticity, Shrinkage, Swelling, heat expansion, etc.

RESULTS

i) Property Memory Effect (PME)

Stress-strain tensile tests and mono and multi-frequency DMA (dynamic mechanical analyzer) tests on virgin and 100% recovered samples of PU (rubber) revealed that the polymer at the end of the shape memory tests regains 100% of its initial form without regaining some of its physical properties like glass transition temperature, tensile modulus, heat expansion coefficient and free volume fraction (table 1).

The change of certain properties after recovery test even when the shape memory polymer (SMP) regains 100% of its initial shape, may be related to the microstructure irreversible changes. This microstructure changes may induce the microchange of volume, which cannot be regained after recovery test. In study of SME, generally, the authors measure the macrochange of volume. They do not do attention on this microchange of volume. In fact in macroscopic scale the microchanges cannot be measured and they are neglected.

Table 1 - Some properties of virgin and recovered PU

PU	Tg (K)	Young modulus (MPa)	Stress at 100% strain	Δα	Free volume fraction (fg)
Virgin	318.5	165	20	$5.5\ 10^{-5}$	0.0301
Recovered (100%)	314	128	17.4	$5.2\ 10^{-5}$	0.0326

ii) Partial Shape Memory Effect (PSME)

After recovery tests on a stretched sample of the majority of the polymers, they regain only a certain percentage of its initial shape. The (DSME is defined as parameter showing the percentage of initial shape regaining.

The successive cyclic tensile tests (Figure 1) on partial shape memory polymers (PSMP), show that the degree of shape memory effect increases by increasing the number of cycle. This test also showed the shape capacity of polymer increases by the number of cycles (table 2). This increase is related to the increase of residual stress in the sample. This new concept of shape memory effect is of very important value. We can in a legitimate way suppose that a polymer without shape memory effect can be transformed into a shape memory polymer.

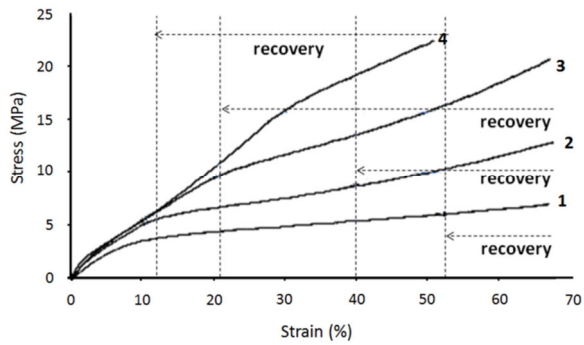

Fig. 1 - Real stress *versus* real strain (tensile tests) at the beginning of each cycle of shape memory tests at 70 °C. (1) First cycle; (2) Second cycle; (3) Third cycle; and (4) Fourth cycle.

Table 2 - Evolution of shape memory effect during multi-cycle shape memory test cycles

Cycle N.	stage	Residual stress (MPa)	Recovery (%)
0	initial	0	-
1	Before recovery	7.2	
	After recovery	6.5	24%
2	Before recovery	13.1	
	After recovery	9.5	42%
3	Before recovery	21	
	After recovery	11	71%
4	Before recovery	22.9	
	After recovery	6.5	82%

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