19th INTERNATIONAL CONFERENCE ON EXPERIMENTAL MECHANICS

19th INTERNATIONAL CONFERENCE ON EXPERIMENTAL MECHANICS
ICEM•2022
17-21.07.2022 Kraków
POLAND

BOOK OF ABSTRACTS

KRAKÓW, POLAND

17 - 21 July, 2022

Book Editors:
Zbigniew L. Kowalewski
Mateusz Kopeć
Dariusz Rudnik
Jacek Widłaszewski

www.icem19.org

DYNAMIC MECHANICAL ANALYSIS IN INVESTIGATIONS OF SMART MATERIALS: A POLYMER CHEMIST THINKING

M. Cristea[1], D. Ionita[1] and E.A. Pieczyska[2]
[1] "Petru Poni" Institute of Macromolecular Chemistry, Iasi, Romania
[2] Institute of Fundamental Technological Research, Warsaw, Poland

1. Introduction

Smart materials are simply defined as stimuli-responsive materials that experience reversible changes of their properties under the action of external stimuli like temperature, pH, electric/magnetic field. The most known smart materials are shape-memory materials (polymers, metal alloys or ceramics) that have the ability to fix a temporary shape, and recover later to original shape upon the application of an external stimulus, mostly temperature [1]. Even if dynamic mechanical analysis (DMA) is the method of choice for determining the glass transition temperature of polymers, it provides much more. A meaningful dependence of their viscoelastic parameters (elastic modulus E', viscous modulus E'' and loss factor tan δ) with temperature/time is required in order to establish the adequate conditions for featuring the shape memory process.

The presentation aims to put forward the utility of the method as a research instrument in the field of smart materials, with connections to examples encountered in the polymer domain.

2. Methods

The DMA experiments were performed on a Perkin Elmer Diamond DMA instrument, in tension, bending and shear mode. The isochronal experiments were run on various types of elastomers by increasing the temperature in ramp mode until the E' value was too small to allow the experiment to be continued. Multifrequency experiments were conducted in order to establish the nature of some transitions and to construct master curves by using the time-temperature superposition principle [2].

3. Discussions

Specialists in polymers have a good understanding of the structure-property relation. They can choose reactants, modify the synthesis conditions or the processing parameters in order to get polymeric materials with appropriate characteristics. A DMA isochronous experiment will emphasize the main four characteristic regions: glassy, glass transition, rubbery plateau and flowing. Any atypical trend of E', E'' or tan δ in any of these regions can be a clue for a specific phenomenon (solvent removal, crystallization, melting) that can take place with increasing temperature and or under the action of the small oscillatory deformation [3]. Their identification is of foremost importance because that transition temperature can represent the external stimulus for the shape memory process or may interfere with an ongoing process.

The glass transition temperature represents a key index for the glass transition-type shape memory polymers. Nevertheless, the argumentation of the structure-property relation by considering only one value of temperature is a simplistic approach that frequently turns into wrong conclusions. The glass transition process is not indicated by a single temperature value, but by an interval, as large as the structure of the polymer is less homogeneous. The E' drop of three orders of magnitude during the glass transition of a polymer indicates its amorphous nature. Still, a DMA multifrequency experiment can help in assessing whether other phenomena occur during glass transition that can interfere with the classic behavior of an amorphous polymer.

These materials will be thoroughly perceived only by taking into account the dynamic relation between mechanics and phase structure, that depends invariably on chemical structure. On one side, the phase-structure of the material depends invariably on mechanical loads: external load can prevent or enhance phase separation. Here the changes in temperatures that may accompany mechanical deformation with perceptive effects on phase structure can be mentioned [4]. On the other side, the structural changes result in strong mechanical response.

4. References

[1] M.R. Aguilar and J. San Roman (2014*). Smart polymers and their applications*, Woodhead Publishing, Cambridge, 1-11.
[2] D. Ionita, M. Cristea, C. Gaina (2020). Prediction of polyurethane behavior via timetemperature superposition: meanings and limitations, *Polym. Test.*, **83**, 106340.
[3] R.P. Chartoff, J.D. Menczel, S.H. Steven (2009). *Thermal analysis of polymers. Fundamentals and applications*, John Wiley & Sons Inc., Hoboken, 387-495.
[4] E. Pieczyska, M.Maj, K. Kowalczuk-Gajewska, M. Staszczak, A. Gradys, M. Majewski, M. Cristea, H. Tobushi and S. Hayashi (2015) Thermomechanical properties of polyurethane shape memory polymer-experiment and modelling, *Smart Mater*