Effect of polymer chain pattern on shape memory elastomer performance

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Abstract

Shape Memory Polyurethane (SMPU) is considered as one of the versatile smart materials due to its self-recovery ability and beneficial mechanical properties. To apply SMPU in various fields, the key lies in adjusting shape memory characteristics such as transition temperature (T_{trans}) and enhancing shape memory effects (SME). These characteristics can be modified by controlling the number of carbon atoms in the polyol monomer. When the polyol monomer with the same molecular weight has a greater number of carbon atoms, the reduction of ether groups within a polymer influences the key properties of the elastomer due to the reduced ether groups and relatively high charge density. In this study, we analyze trends based on the number of carbon atoms in the polyol monomer using polyethylene glycol (PEG) and polytetramethylene glycol (PTMEG) with different carbon chain lengths to predict behavior of a similarly structured polytrimethylene ether glycol (PO3G), which is gaining attention as an environmentally friendly polyol.

Synthesis

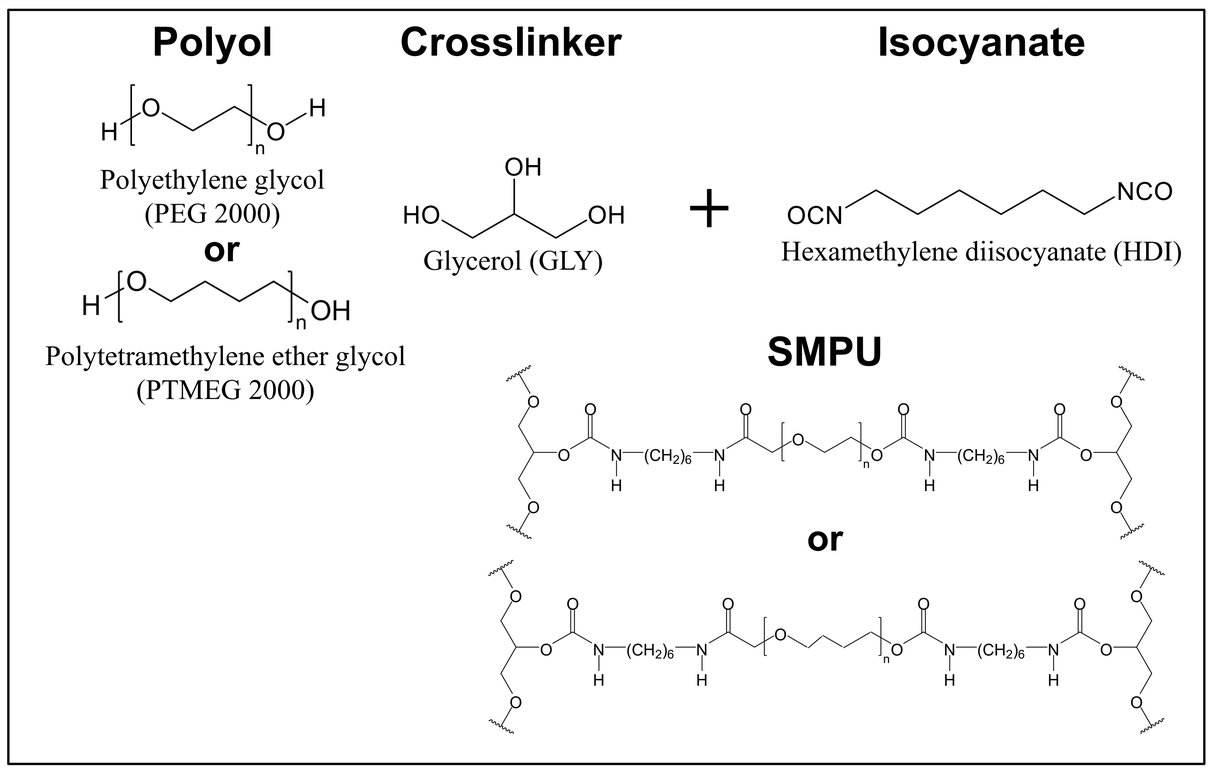

Figure 1. Chemical structure of materials and resulting elastomer.

- Two types of polyols (PEG and PTMEG) were used.
- Repeat unit of PEG contains two CH_2 groups
- Repeat unit of PTMEG contains four CH_2 groups; hence it has less ether group content in SMPU.

FTIR spectroscopy

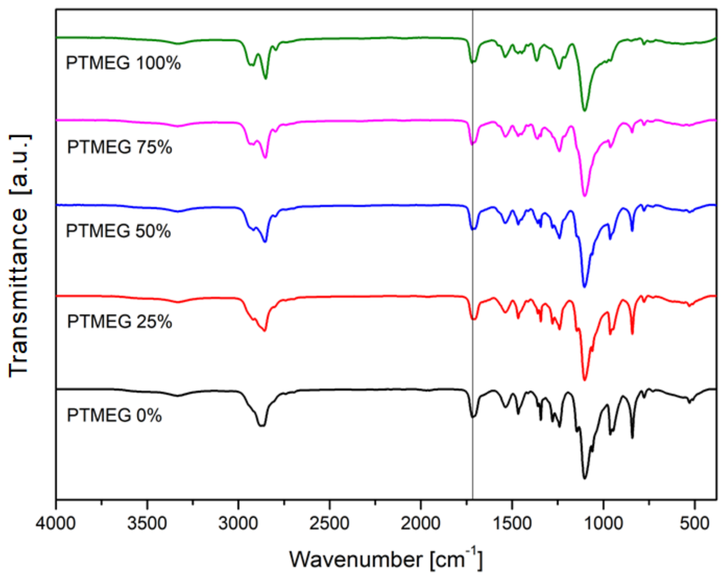

Figure 2. FTIR transmittance spectra of SMPUs synthesized with five different PTMEG content ratios, respectively.

- Absence of isocyanate peak (2250 cm^{-1}) shows there is no unreacted HDI.
- 2934 cm^{-1} peak is from asymmetric C-H stretching vibration of the CH2-group due to an increase in PTMEG content.
- 1700 cm^{-1} region shows the C=O stretching vibration peak, around 1465 cm^{-1} displays the C-N peak, and a small but noticeable N-H peak appears around 3300 cm^{-1}, indicating the formation of polyurethane through urethane linkage synthesis.

Shape memory effect

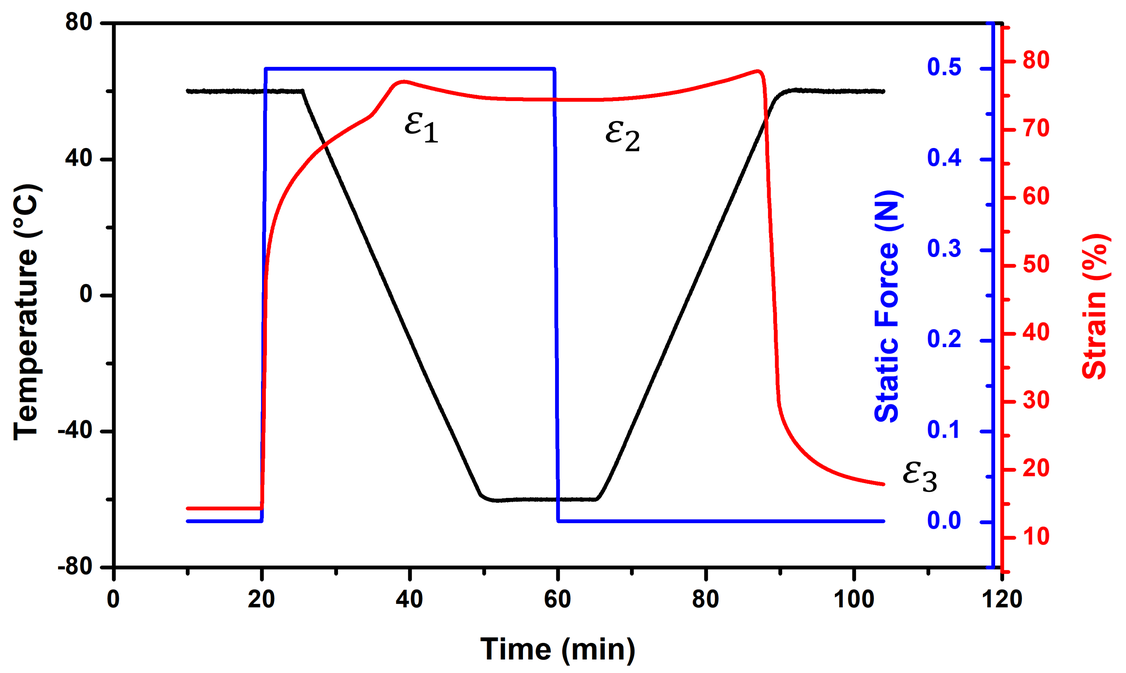

Figure 3. Shape memory behavior of PTMEG 25% SMPU from DMA analysis.

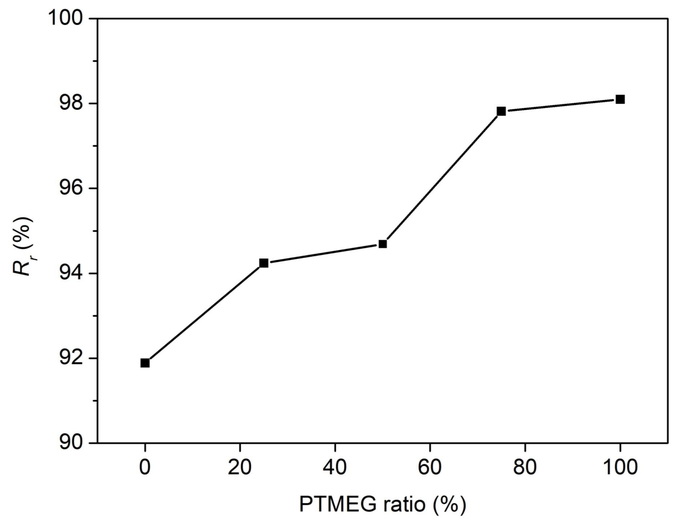

Figure 4. R_r values of SMPUs.

Shape recover ratio

$$R_r = \frac{\varepsilon_2 - \varepsilon_3}{\varepsilon_2} \times 100(\%)$$

ε_1: the maximum strain under the static force

ε_2: the strain at the temporarily fixed shape

ε_3: the strain after shape recovery

- SMPU based on PTMEG exhibits superior shape memory characteristics.
- The reduction of ether groups with a relatively high charge density induces an increase in entropic force. Consequently, the sample becomes more flexible, and the force attempting to return to its original shape strengthens.

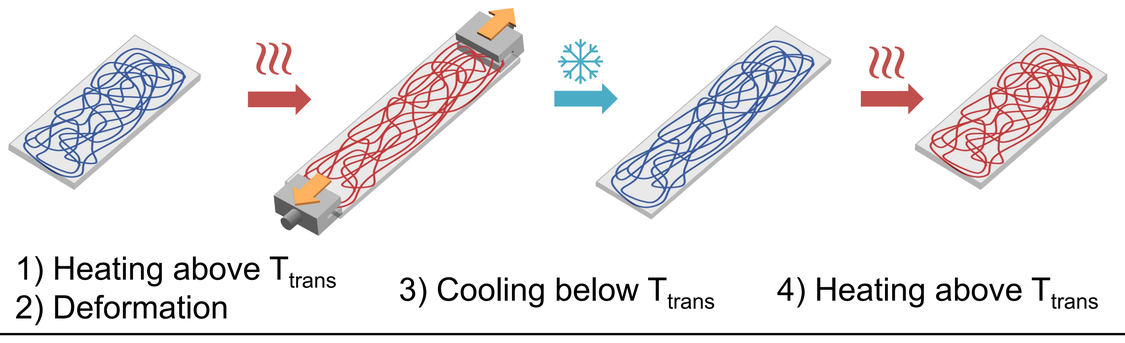

Figure 5. Schematic diagram of the shape memory cycle.

Tensile test

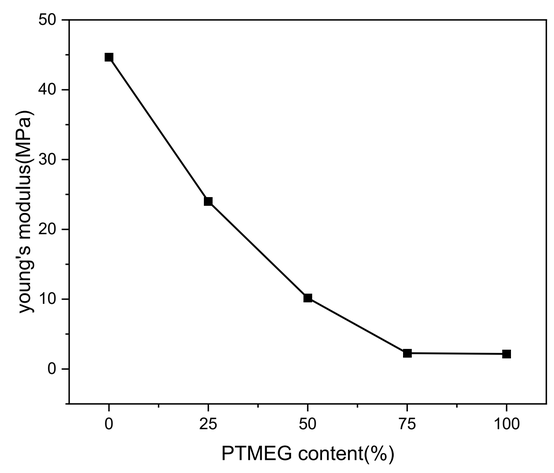

Figure 6. Young's Modulus of SMPUs.

- The test was conducted with UTM.
- The elastomer synthesized with PTMEG shows lower young's modulus which means that it is more likely to readily undergo deformation under external force.
- The result can be explained by the decreasing melting point with the increasing content of PTMEG, and indeed, the melting point eventually became lower than room temperature.

Acknowledgement

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