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Tunning Switch Temperature of Shape Memory Polyacrylamide Hydrogel

Introduction

Shape memory polymers are smart materials that can remember their permanent shape. These materials include ceramics, alloys, gels and polymers. Shape memory effects in polymers could happen at low temperatures by programming, considering this feature these materials can use in biological applications. The switch temperature in amorphous and semi-crystalline polymers is glass transition temperature (T_g) and melting temperature (T_m), respectively. In polyacrylamide (PAAm) as an amorphous polymer, the switch temperature is T_g.
In this work, chemically cross-linked polyacryl PAAm hydrogel prepared by free radical polymeriztion. The effect of water content on T_g of hydrogel was investigated using dynamic mechanical analysis (DMA). Shape memory behaviour of the chosen hydrogel was considered for a full cycle, i.e. four steps, by DMA.

Materials

PAAm hydrogel was synthesized by free radical polymerization of Acrylamide (AAm) monomers with N,N'-methylene bisacrylamide (MBAAm) as monomer and crosslinker, respectively. Ammonium persulfate (APS) and tetra ethylene methylene diamine (TEMED) were used as redox system. All the materials purchased from Merck, Germany.

Hydrogel Preparation

PAAm was prepared by the simultaneous radical polymerization and chemical crosslinkin. The monomer and crosslinker were dissolved in distilled water which contained 10 %w/v of AAm. The concentration of MBAAm was fixed at 0.5 wt%. Then the reaction was carried out at a constant temperature of 60±1 ºC using a water bath for 12 h. The obtained hydrogel was immersed in an excess of distilled water in order to remove unreacted agents for 7 days. The sample was dried at 40 ° C under vacuum until a constant weight was obtained. Then hydrogel containing 25% water was obtained by re-immersing the dry gel in water and weighing it at specified time intervals.

Experiments and Results

DMA test was carried out by DMA 242C Netzsch, Germany, at a heating rate of 5 ºCmin^{-1} in the range of -50 ºC to 70 ºC.

The compression mode was used in order to determine Tg. The transition temperature, i.e. the desired switch temperature for our work, was chosen around ~ 30 ºC by tunning the water content of hydrogel at 25%, Fig. 1.

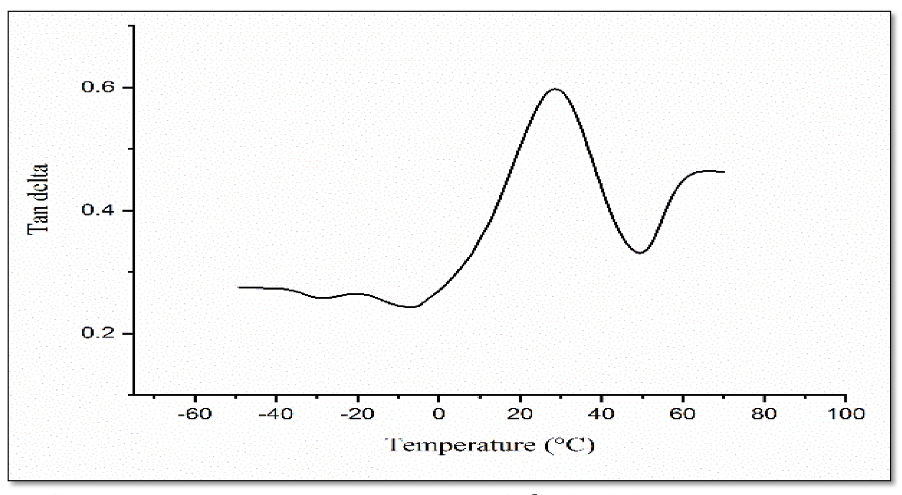

Fig 1. DMA curve PAAm with 25% water.

Subsequently, the tension mode was employed for investigating shape memory effect. The four steps procedure performed at a constant heating/cooling rate of 5ºC.min^{-1}. First, the sample was heated to 50 ºC (above the switch temperature) and stretched to a certain strain (ε) under a constant force (Step 1). Then, the deformed sample was cooled to -50ºC under the fixed force (Step 2). The force then removed and the temporary strain was measured (ε_{temp}) (Step 3). Finally, the sample was reheated to 50 ºC and kept for 50 min in this temperature, then the recovery strain recorded (ε_{rec}) (Step 4). The shape fixing ratio (R_f) and shape recovery ratio (R_r) as the main characteristics of shape memory polymeric system calculated from Fig. 2 according to the following equations: (I) $\boldsymbol{R_f} = \frac{\varepsilon_{temp}}{\varepsilon}$ (II) $\boldsymbol{R_r} = \frac{\varepsilon - \varepsilon_{rec}}{\varepsilon}$

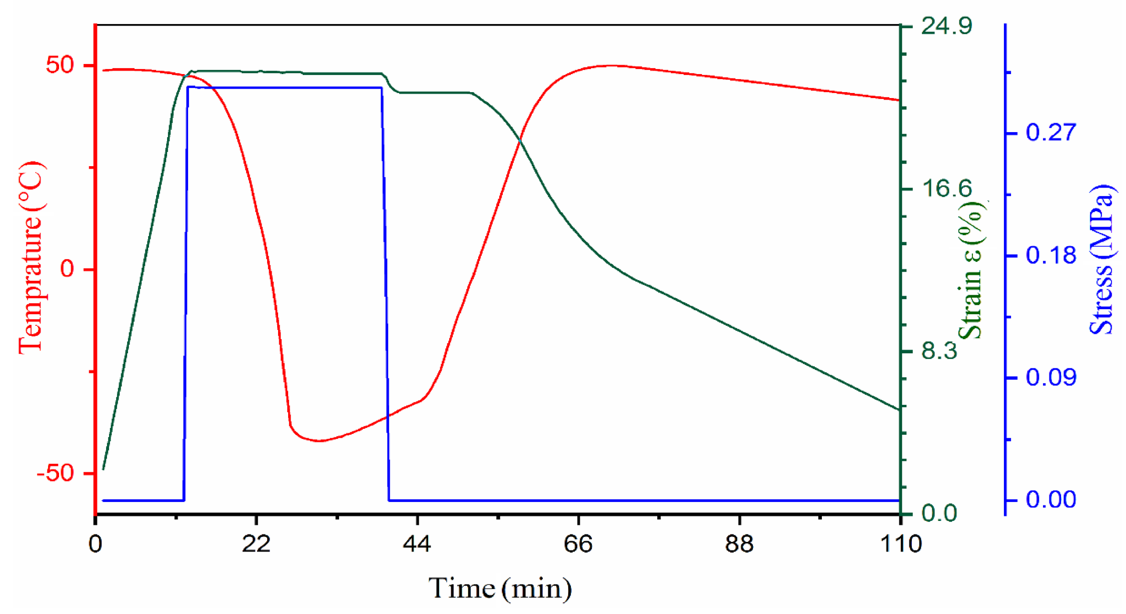

Fig 2. Shape memory behavior of PAAm with 25% water.

The results indicated that the shape fixing ratio and shape recovery ratio of the system were 96% and 78%, respectively. Recovering to orginal shape was started around 10 ºC. The sample showed good shape fixity because of existence the hydrogen bonds between PAAm and water. Hydrogen bonds as physical cross linkers could improve structural strength of the sample.

Conclusions

PAAm hydrogel containing 25% water was synthesized by the simultaneous radical polymerization. The switch temperature of this sample was around 30 ºC. The shape fixing ratio and shape recovery ratio of PAAm hydrogel with 25% water were 96% and 78% respectively which indicate reasonable shape memory behaviour.

Biography

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Sonia Norouzi Esfahany has just completed her MSc from Tarbiat Modares University (TMU). This article is a portion of her MSc thesis. Her field of interest is investigating the shape memory hydrogels and nanocomposites.

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Mehrdad Kokabi acted as an academic member of Tarbiat Modares University (TMU) in Tehran, Iran, since 1990. At the time being, he is known as a professor in polymer engineering, active in the field of Smart Nanocomposite Systems.

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