Shape Memory Polyurethane

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The inherent capability to deform and reform in a predefined environment is a unique property existing in shape memory polyurethane. The intrinsic shape memory ability of the polyurethane is due to the presence of macro domains of soft and hard segments in its bulk, which make this material a potential candidate for several applications. This entry is focused on manifesting the applicability of shape memory polyurethane and its composites/blends in various domains, especially to human health such as shielding of electromagnetic interference, medical bandage development, bone tissue engineering, self-healing, implants development, etc.

shape memory polyurethane composite biomedical application electromagnetic interference self-healing

1. Introduction

The unique capability to deform in predefined conditions and recover back to its original shape upon being triggered by different stimuli such as heat, radiation, pH, hydration, mechanical, magnetic, and electrical influences, etc. make polyurethane a potential candidate for several applications. Polyurethanes which are versatile materials with extraordinary characteristics, inherently have two macro-phase separated domains due to the presence of a urethane bond between soft and hard segments, alternatively. However, the urethane bond is formed due to the chemical reaction between hard segment (i.e., diisocyanate) and soft segment (i.e., polymeric diol). The capability of shape memory comes from the concept of these soft and hard segments in polyurethane. The presence of hard segment provides the mechanical strength which is responsible for it to remember the initial shape after deformation whereas the energy for dissipation is stored by soft segments providing the desired force to polyurethane in order to revive it to its initial form by the action of external stimuli. [1]The soft and hard segments in polyurethanes govern the transitions behavior triggered by radiation, sound, heat, etc., resulting in the shape memory effect. The shape memory effect in polyurethane and its composites can be one-way, two-way, triple or quadruple based on the number of transition temperatures and soft and hard contents [[2],[3],[4]].

2. Influence and application

The shape memory ability makes polyurethane a strong candidate for several applications such as self-tightening sutures, sensors, self-healing, implants, actuators [[5],[6]], wearable electronics, etc. It was first developed by Shunichi Hayashi and his group [[7],[8]]. However, it has been experienced by the scientific community that pristine polyurethane does not suffice the properties required for the desired applications. Therefore, they have come up with an idea to incorporate foreign materials such as polymer, fillers, etc., in the polymer matrix which can induce the desirable property for targeted application. Incorporation of the fillers in polyurethane matrix results in enhanced properties such as shape memory ability, self-healing, electrical property, sensing ability, induction of bone formation, antibacterial, biocompatibility, etc. It is also observed by the scientific community that incorporation of fillers in optimized volume does not adversely affect inherent properties of polyurethanes. Incorporation of fillers such as chitosan, carbon nanotubes, lignin, hydroxyapatite, etc., can be done using blending with other polymers, bulk mixing, or in situ reactions.

Such modifications also enhance the shape memory properties along with other properties such as mechanical, electrical, and biological activities in polyurethanes. These enhanced properties of polyurethane and its composites render this material suitable for several applications. Shape memory ability can broadly be used for the purpose of electromagnetic shielding, self-healing, pressure bandages, cardiovascular implants, bone tissue engineering, etc [[1],[9],[10],[11]].

Our group has demonstrated the development of polycaprolactone (PCL) based polyurethane composite with chitosan. Chitosan has an advantage of antibacterial property along with the induction of bone formation and wound healing ability which is shadowed by the limitation of its processing temperature. Due to the overlapping of melting temperature and thermal degradation temperature, chitosan cannot be thermally processed along with other polymers in order to fabricate composites. Therefore, dispersion or blending of chitosan in polymer matrix is always a challenging task. In this regard, our group has made efforts to homogenously disperse chitosan into the polymers by in situ polymerization instead of blending chitosan with the polymer matrix. We have fabricated PCL based polyurethane by in situ polymerization in presence of micro-to-nano sized chitosan. The advantage of using nano sized chitosan is that it provides several hydroxyl groups to react with isocyanate resulting in the formation of urethane bonds which lead to homogeneous dispersion and interfacial adhesion of nano chitosan in polymer matrix. We have found that the presence of chitosan in polyurethane matrix acts as crosslinking point in the polymer matrix which possibly enhances the mechanical property along with thermo-responsive shape memory ability of the composite. The use of chitosan as a filler in polyurethane matrix provides opportunities for developing polymers with tailored properties. The presence of chitosan in polyurethane matrix enhances the applicability of the polyurethane in several biomedical domains such as medical bandage development, bone tissue engineering, self-healing, implants development, etc.

References

1. C. Liu; H. Qin; P. T. Mather; Review of progress in shape-memory polymers. *Journal of Materials Chemistry* **2007**, *17*, 1543-1558, 10.1039/b615954k.
2. Qi Yang; Wenjie Zheng; Wenpeng Zhao; Chuang Peng; Juntao Ren; Qizhou Yu; Yanming Hu; Xuequan Zhang; One-way and two-way shape memory effects of a high-strain cis-1,4-

polybutadiene–polyethylene copolymer based dynamic network via self-complementary quadruple hydrogen bonding. *Polymer Chemistry* **2019**, *10*, 718-726, 10.1039/c8py01614c.

3. Taylor Ware; Keith Hearon; Alexander Lonnecker; Karen L. Wooley; Duncan J. Maitland; Walter Voit; Triple-Shape Memory Polymers Based on Self-Complementary Hydrogen Bonding. *Macromolecules* **2012**, *45*, 1062-1069, 10.1021/ma202098s.
4. Jiayu Xian; Jieting Geng; Yan Wang; Lin Xia; Quadruple-shape-memory effect of TPI/LDPE/HDPE composites. *Polymers for Advanced Technologies* **2017**, *29*, 982-988, 10.1002/pat.4209.
5. Martin Bothe; Thorsten Pretsch; Bidirectional actuation of a thermoplastic polyurethane elastomer. *Journal of Materials Chemistry A* **2013**, *1*, 14491-14497, 10.1039/c3ta13414h.
6. Nam Seo Goo; Il Hyun Paik; Kwang Joon Yoon; The durability of a conducting shape memory polyurethane actuator. *Smart Materials and Structures* **2007**, *16*, N23-N26, 10.1088/0964-1726/16/4/n01.
7. Hisaaki Tobushi; Shunichi Hayashi; Shinichi Kojima; Mechanical Properties of Shape Memory Polymer of Polyurethane Series : Basic Characteristics of Stress-Strain-Temperature Relationship. *JSME international journal. Ser. A, Mechanics and material engineering* **1992**, *35*, 296-302, 10.1299/jsmea1988.35.3_296.
8. Hisashi Hara; Hisaaki Tobushi; Etsuko Yamada; Shunichi Hayashi; Thermomechanical properties in a thin film of shape memory polymer of polyurethane series. *Smart Materials and Structures* **1996**, *5*, 483-491, 10.1088/0964-1726/5/4/012.
9. Qinghao Meng; Jinlian Hu; A review of shape memory polymer composites and blends. *Composites Part A: Applied Science and Manufacturing* **2009**, *40*, 1661-1672, 10.1016/j.compositesa.2009.08.011.
10. Andreas Lendlein; Oliver E. C. Gould; Reprogrammable recovery and actuation behaviour of shape-memory polymers. *Nature Reviews Materials* **2019**, *4*, 116-133, 10.1038/s41578-018-0078-8.
11. Thakur, S.; Hu, J. Polyurethane: A Shape Memory Polymer (SMP). In Aspects of Polyurethanes; Faris, Y., Ed.; IntechOpen: London, UK, 2017.

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