Gold nanoparticles/poly (vinyl alcohol) shape memory nanocomposites

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Keywords

Photothermal effect, supra-molecular network, light-induced microfluidic, shape memory polymer, nanocomposite

As emerging intelligent materials, shape memory polymers (SMP) have unique ability to recover their permanent geometry from large-strain deformation by external stimuli such as heat, light, magnetic field, or electric current [1,2]. The light-induced SMP can be remotely controlled without touching the material and topically activated without impacting other components. The gold nanoparticles (AuNPs) can efficiently convert light energy into thermal energy due to photothermal effect, so it can be used as light absorbent and nanoscale thermal source in the light-induced SMP nanocomposites[1-5]. Poly (vinyl alcohol)-based SMP (PVA) has good thermally-driven shape memory property and ample hydroxyl group[6-9]. However, only few studies attempted on application of light-induced gold nanoparticles/poly (vinyl alcohol) shape memory nanocomposites (AuNPs/PVA).

In this report, taking advantage of photothermal effect of AuNPs and SME of PVA-based SMP, a light-induced microfluidic miceovalve was demonstrated for the first time in preprogrammed microfluidic chip based on the shape memory AuNPs/PVA. The AuNPs/PVA displayed excellent light-induced shape memory property with nearly 100% recovery ratio in visible light. The liquid samples completely fill the microfluidic channel and arrive at the detection region of the light-induced microfluidic chip in visible light.

The light-induced AuNPs/PVA microfluidic chip can achieve transduction at smaller scales, simpler, more reliable, and lower-cost actuation in a restricted environment[10-12]. Most chemical and biological analysis systems require microfluidic operations at room temperature. The light-induced method can reduce actuation power consumption without significantly affecting samples or other components, so it would be better than thermal, electrical and other driven methods. Moreover, the light-induced SMP microfluidic chip is a typical single-use device and can benefit avoiding the cross-contamination in the chemical and biological analysis[10-19]. Therefore, the light-induced SMP AuNPs/PVA microfluidic device would be a promising alternative for disposable chemical and biological analysis microfluidic laboratories.

[1] J. S. Leng, X. Lan, Y. J. Liu, S. Y. Du, Shape-memory polymers and their composites: Stimulus methods and applications. Prog. Mater. Sci. 56, 1077-1135 (2011).

[2] J. L. Hu, S. J. Chen, A review of actively moving polymers in textile applications.

J. Mater. Chem. 20, 3346-3355 (2010).

[3] A. Lendlein, R. Langer, Biodegradable, Elastic shape-memory polymers for potential biomedical applications. Science 296, 1673-1676 (2002).

[4] W. X. Wang, Y. J. Liu, J. S. Leng, Recent developments in shape memory polymer nanocomposites: Actuation methods and mechanisms. Coordin. Chem. Rev. 320-321, 38-52 (2016).

[5] W. M. Huang, B. Yang, Y. Zhao, Z. Ding, Thermo-moisture responsive polyurethane shape-memory polymer and composites: a review. J. Mater. Chem. 20, 3367-3381 (2010).

[6] T. Hiral, H. Maruyama, T. Suzuki, S. Hayashi, Shape memorizing properties of a hydrogel of poly (vinyl alcohol). J. Appl. Polym. Sci. 45, 1849-1855 (1992).

[7] H. Y. Du, J. H. Zhang, Shape memory polymer based on chemically cross-linked poly(vinyl alcohol) containing a small number of water molecules. Colloid Polym. Sci. 288, 15-24 (2010).

[8] M. Seydou, J. Teyssandier, N. Battaglini, G. T. Kenfack, P. Lang, F. Tielens, F. Maurel, B. Diawara, Characterization of NTCDI supra-molecular networks on Au(111); combining STM, IR and DFT calculations. RSC Adv. 4, 25698-25708 (2014).

[9] U. Subramanyam, J. P. Kennedy, PVA networks grafted with PDMS branches. J. Polym. Sci. A: Polym. Chem. 47, 5272-5277 (2009).

[10] W. C. Jackson, H. D. Tran, M. J. O’Brien, E. Rabinovich, G. P. Lopez, Rapid prototyping of active microfluidic components based on magnetically modified elastomeric materials. J. Vac. Sci. Tech. 19, 596-599 (2001).

[11] F. Arias, S. R. J. Oliver, B. Xu, R. E. Holmlin, G. M. Whitesides, Fabrication of metallic heat exchangers using sacrificial polymer mandrils. J. Microelectromech. Syst. 10, 107-112 (2001).

[12] R. Jameson, Y. Chen, A. Pepin, D. Decanini, Imaging streamlines and interface profiles in microfluidicn geometries. Micro. Eng. 67-68, 930-937 (2003).

[13] K. S. Chow, H. J. Du, Dielectrophoretic characterization and trapping of different waterborne pathogen in continuous flow manner. Sensors and Actuators A 170, 24-31 (2011).

[14] D. R. Meldrum, M. R. Holl, Microscale bioanalytical systems. Science 297, 1197-1198 (2002).

[15] C. C. Hong, J. C. Chen, Pre-programmable polymer transformers as on-chip microfluidic vacuum generators. Microfluid Nanofluid 11, 385-393 (2011).

[16] G. M. Whitesides, A. D. Stroock, Flexible methods for microfluidics. Phys. Today 54, 42-48 (2001).

[17] Y. Chen, A. Pe ṕin, Nanofabrication: conventional and nonconventional methods. Electrophoresis 22, 187-207 (2001).

[18] K. W. Oh, C. H. Ahn, A review of microvalves. J. Micromech. Microeng. 16, R13-R39 (2006).

[19] S. Shoji, M. Esashi, Microflow devices and systems. J. Micromech. Microeng. 4, 157-171 (1994).