Iranian Polymer Journal (2018) 27:621–628
https://doi.org/10.1007/s13726-018-0638-1

ORIGINAL RESEARCH

Microwave-induced shape-memory poly(vinyl alcohol)/poly(acrylic acid) interpenetrating polymer networks chemically linked to SiC nanoparticles

Haiyan Du[1] · Zhe Ren[1] · Yuyu Xu[1]

Received: 23 February 2018 / Accepted: 14 May 2018 / Published online: 23 June 2018

Abstract

Microwave (MW)-induced shape-memory poly(vinyl alcohol)/poly(acrylic acid) (PVA/PAA) interpenetrating polymer networks (SMP-IPNs) were prepared through in situ polymerization. Silicon carbide (SiC) nanoparticles were modified by 3-(methacryloyloxy) propyltrimethoxysilane (KH570). 3-(Methacryloyloxy) propyltrimethoxysilane was covalently bonded on the surface of SiC through the reaction of silanol and the methoxy groups. The polymerization of acrylic acid (AA) using *N,N′*-methylenebis (2-propenamide) (MBA) as cross-linker in PVA solution was initiated through the double bonds of KH-570 grafted on SiC, leading to a PAA polymer network cross-linked with MBA. The PVA molecular chains run through the PAA cross-linking network and form an IPN structure. Therefore, SiC as a strong MW absorbing material could be chemically cross-linked into polymer matrix. The effect of composition on the properties of SMP-IPN was studied using dynamic mechanical analysis, dielectric properties and shape memory effect (SME) test. The results showed that the introduction of SiC in IPNs not only provided samples with excellent MW-induced shape memory effect (SME), but also caused a higher equilibrium temperature under MW irradiation. Moreover, both SiC content and applied MW power affected the shape recovery properties of PVA/PAA interpenetrating composites. MW-induced SMPs offered great advantages such as fast recovery, high recovery rate, and remote actuation. This study provides the potential applications of the fast and environmentally friendly SMPs used as MW-responsive sensors, implantable devices, etc.

Keywords Shape-memory polymer · Microwave-induced interpenetrating polymer networks · Poly(vinyl alcohol) · Poly(acrylic acid)

Introduction

Shape-memory polymers (SMPs) can change from a temporary shape to original shape after being exposed to an appropriate external stimuli, e.g., heat, light, and solvent [1–3]. Among the present various stimuli-induced SMPs, thermal-induced SMPs have been widely studied and the shape recovery mechanisms behind shape memory effect (SME) also have been discussed [4–6]. In general, SMPs consist of a fixing phase and an elastic phase. The fixing phase determines the original shape, and the elastic phase is responsible for fixing the temporary shape [7–9]. Among the reported SMPs, many works focus on using direct heat as the stimulus. Other specific external stimuli like IR, laser irradiation, and electric and magnetic fields are used as indirect heating sources [10–12], and good results have been achieved in many studies.

In recent studies, microwave (MW) has been used as the driving force of SMPs. MW heating has great advantages compared to conventional heating, including non-contact heating, rapid heating, time-saving and low cost [13, 14]. Leng and co-workers have reported MW-induced SMP/CNT composites and biodegradable shape-memory polycaprolactone foams [15, 16]. Our previous work showed that MW-induced SME of moist poly(vinyl alcohol) (PVA) could present fast recovery and high shape recovery ratio, but the water molecules in the polymer influenced the stiffness and mechanical stability of shape-memory poly(vinyl alcohol) negatively [17]. After that, silicon carbide (SiC) was physically filled into the PVA matrix to overcome the

✉ Haiyan Du
duhaiyan428@163.com

1 College of Chemistry and Chemical Engineering, Taiyuan University of Technology, Taiyuan 030024, China