Special methods for catalysis of molecular crosslinking of composite materials based on polydimethylsiloxane

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Abstract

The production of polydimethylsiloxane includes a curing process at room temperature or external heating, which can be inconvenient in some situations. This paper describes the testing of a composite material of polydimethylsiloxane with silver nanoparticles to accelerate curing by microwave method, as one of the methods. The fabricated composite materials were investigated for general properties, from which it can be concluded that the bulk properties are similar to the original polydimethylsiloxane, while the surface properties are different.

Introduction

Polydimethylsiloxane (PDMS) as a material has a number of distinctive properties, which is why this substance is used in various applications [1]. The process of its production consists in the curing of a liquid prepolymer, which is the monomers of dimethylsiloxane, by forming perpendicular networks throughout the volume of the body as a result of a chemical reaction. In general, this process takes up to two days or is required with external heating, which reduces this time to 10 minutes (at 150 ° C), which can be problematic in some situations. This problem is being actively studied, and in recent years, various mechanisms for accelerating the molecular crosslinking of a polymer, such as exposure to various radiation, addition of substances, and magnetic induction, have been considered [2–5]. Due to its non-polarity, polydimethylsiloxane is inefficiently exposed to microwave irradiation. To correct this, it was proposed to introduce silver nanoparticles into the volume of polydimethylsiloxane (what physical principles shown in Fig.1). In this work, the possibility of accelerated crosslinking of a composite material based on polydimethylsiloxane with silver nanoparticles (AgNP) was tested and its main properties were studied.

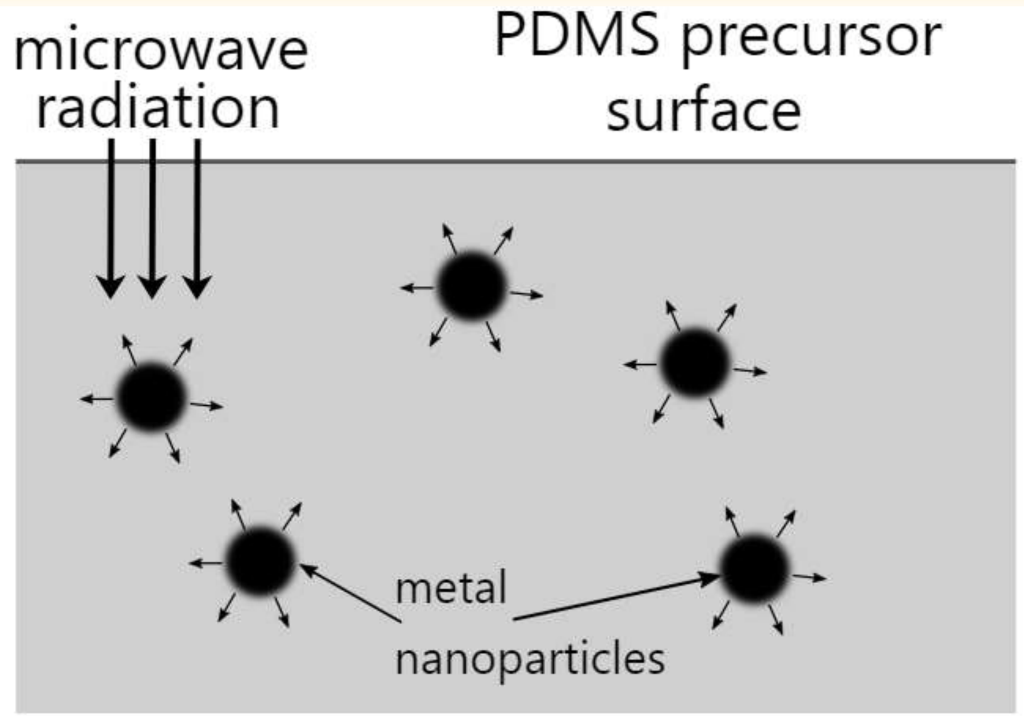

Fig. 1. Scheme of curing using electromagnetic microwave radiation of a liquid polydimethylsiloxane (PDMS) prepolymer filled with metal nanoparticles.

Table of fabricated elastomer materials and the main measured properties.

Sample	Silver nanoparticles, mass %	Time of microwave irradiation, h	Work of adhesion, J/m^2	Storage modulus (low-strain), MPa
PDMS (stock)	0	0	0.44	1.68
PDMS@1hMW	0	1	0.41	1.73
PDMS@2hMW	0	2	0.35	1.84
PDMS@3hMW	0	3	0.34	1.69
PDMS@4hMW	0	4	0.28	1.84
PDMS/AgNP	0.04	0	1.72	1.37
PDMS/AgNP@1hMW	0.04	1	>1.39*	1.61
PDMS/AgNP@2hMW	0.04	2	0.88	1.52
PDMS/AgNP@3hMW	0.04	3	0.8	1.47
PDMS/AgNP@4hMW	0.04	4	0.91	1.64

*) Lower boundary indicated due to the adhesion of the sample being too strong for the used experimental conditions.

Experiment

A composite material based on polydimethylsiloxane was made using the Sylgard 184 elastomeric kit in a ratio of 10:1 base to curing agent and silver nanoparticles with a diameter of 35-120 nm. In curing process the prepolymer were also subjected to microwave irradiation at a frequency of 3450 MHz at a power of 700 V with a duration of 0-4 hours.

To evaluate the resulting composites, SEM images of the samples were taken, and some important properties were studied, including the viscoelastic modulus, water wettability, adhesive interaction between glass and manufactured elastomers, and absorption spectra.

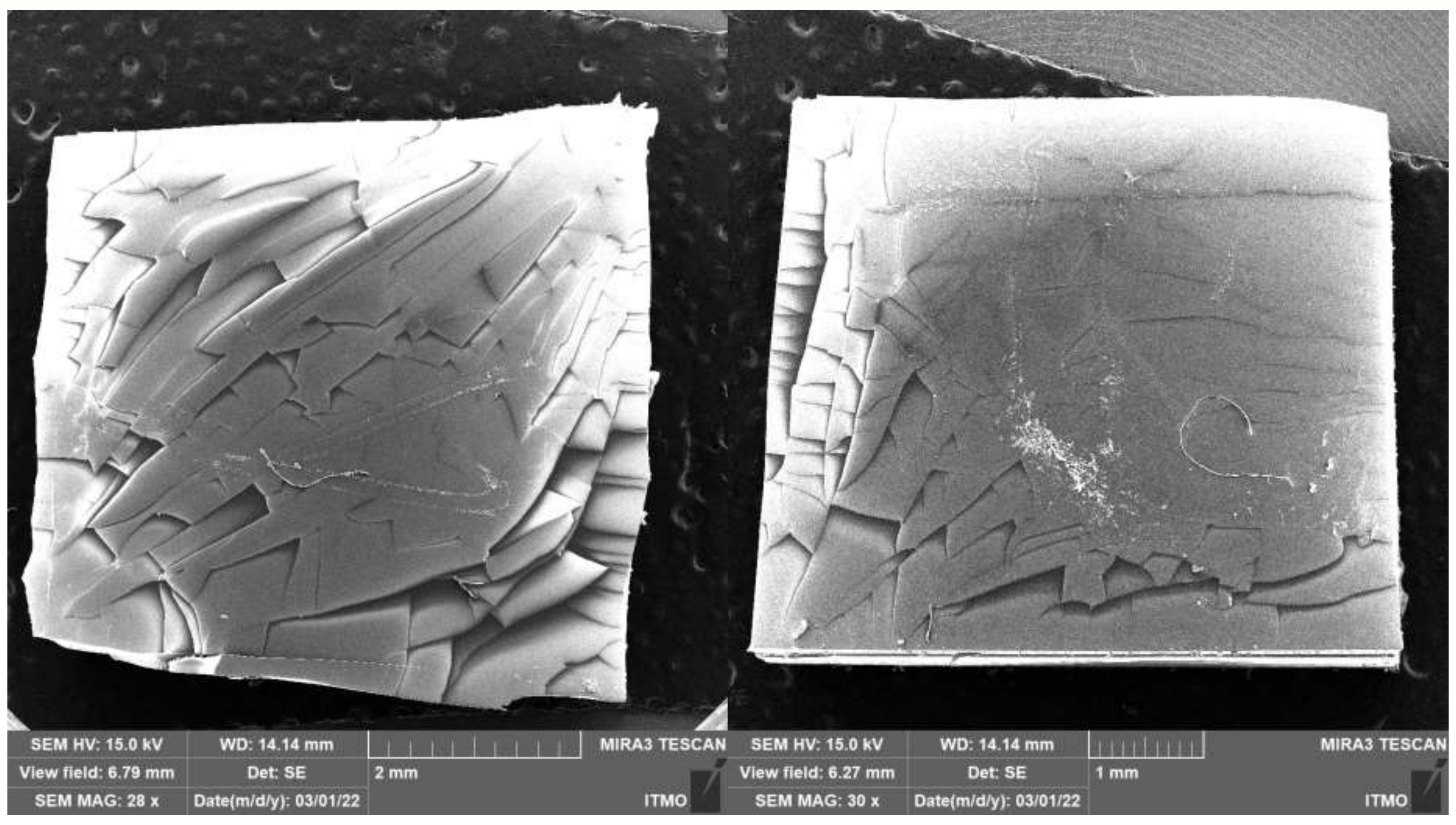

Fig. 2. SEM image of PDMS with AgNP without microwave treatment (left) and with four hours MW-treatment (right)

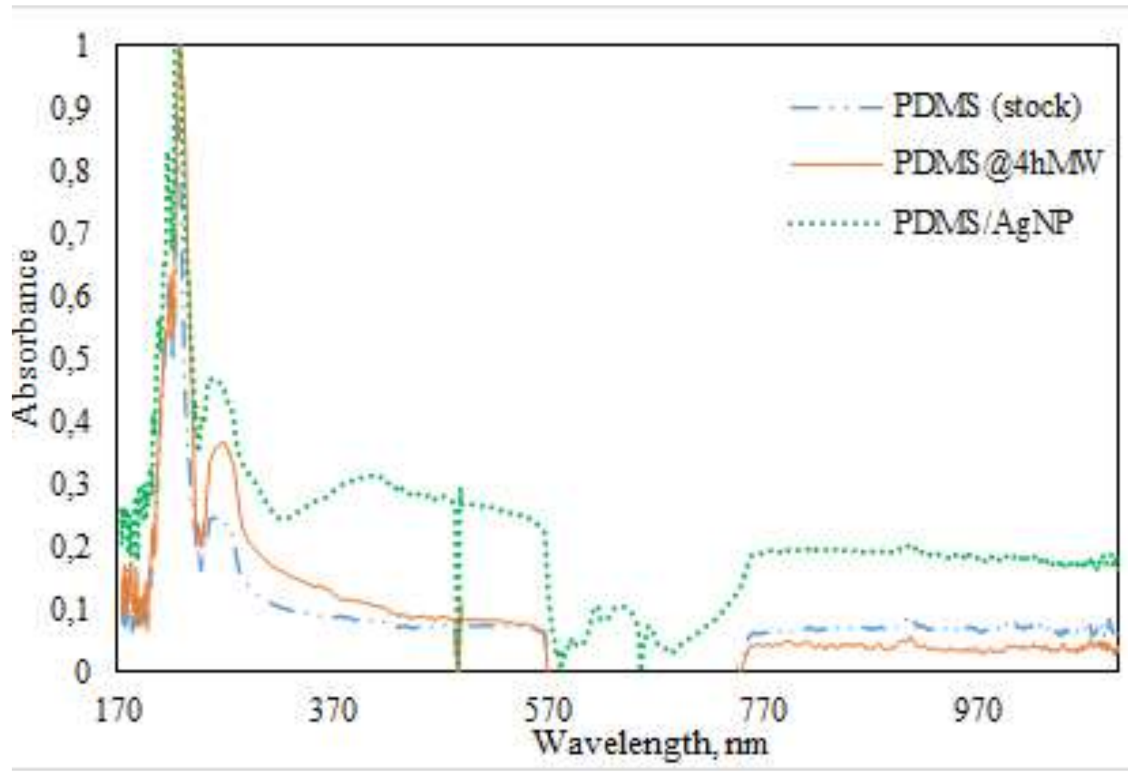

Fig. 3. Absorption optical spectra of the stock PDMS material, the sample with 4-hours treatment and PDMS material with AgNP.

Results and discussions

The equilibrium water contact angle for PDMS (stock), PDMS@4hMW, PDMS/AgNP@0hMW and PDMS/AgNP@4hMW was found to be 74.41°; 117.77°; 82.38° and 56.76° respectively. Based on the SEM images shown in Fig. 2, it can be concluded that under microwave exposure, the surface of the samples becomes smoother, which may mean more uniform curing. The absorption spectra of the samples are shown in Fig. 3, and generally show a slight increase in the absorption of polydimethylsiloxane when silver nanoparticles are added to it. The viscoelastic modulus and work of adhesion of the samples can be seen from the table.

In general, several conclusions can be drawn from the data obtained:

- When nanoparticles are added, the elastic modulus decreases (by 19.7%) and optical absorption increases (a peak appears at 415 nm), adhesion work (4 times) and slightly wettability.
- Treatment with microwave radiation during the curing of samples increases the elasticity of materials and insignificantly optical absorption, reduces the work of adhesion, but affects their wettability in different ways.
- A sample containing AgNP and processed for 4 hours is close to PDMS (stock) in its properties, except for the adhesion work.

Conclusions

Silver nanoparticles were tested as a reagent for accelerating the curing of polydimethylsiloxane using microwave irradiation and the properties of the composite material were evaluated in comparison with the original polydimethylsiloxane. In general, silver-containing materials turned out to be less transparent and elastic and more tenacious to glass and water. At the same time, microwave radiation increased elasticity and decreased adhesion. It can be concluded that silver nanoparticles can serve as an internal heater for PDMS elastomers to catalyze crosslinking under the action of microwave radiation. In this case, the presence of silver in the composite material slightly affects its optical and viscoelastic properties, but significantly changes the surface properties.

References

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