Implementation of Mechanophore into Shape Memory Polymer to Create a Self-Sensing, Self-Healing Composite Material

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Background

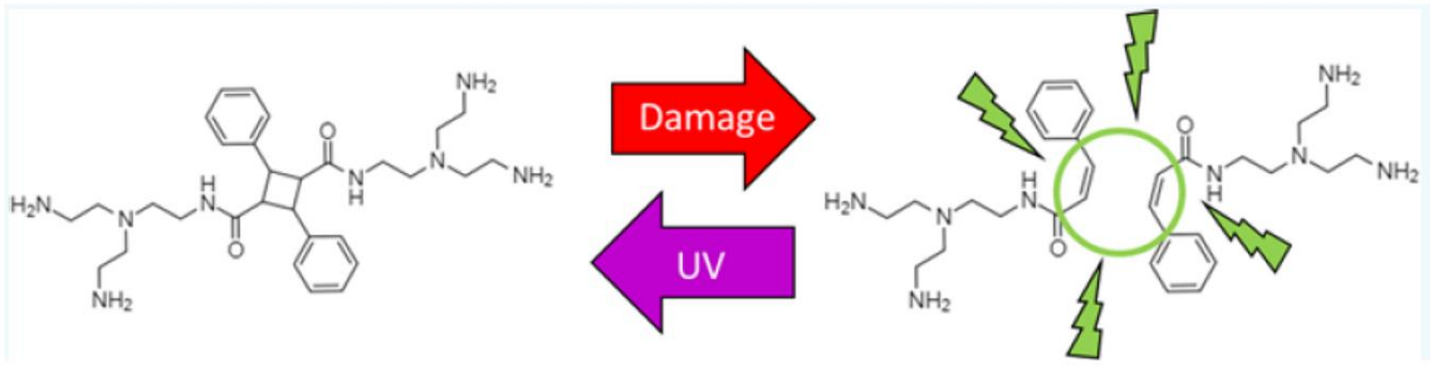


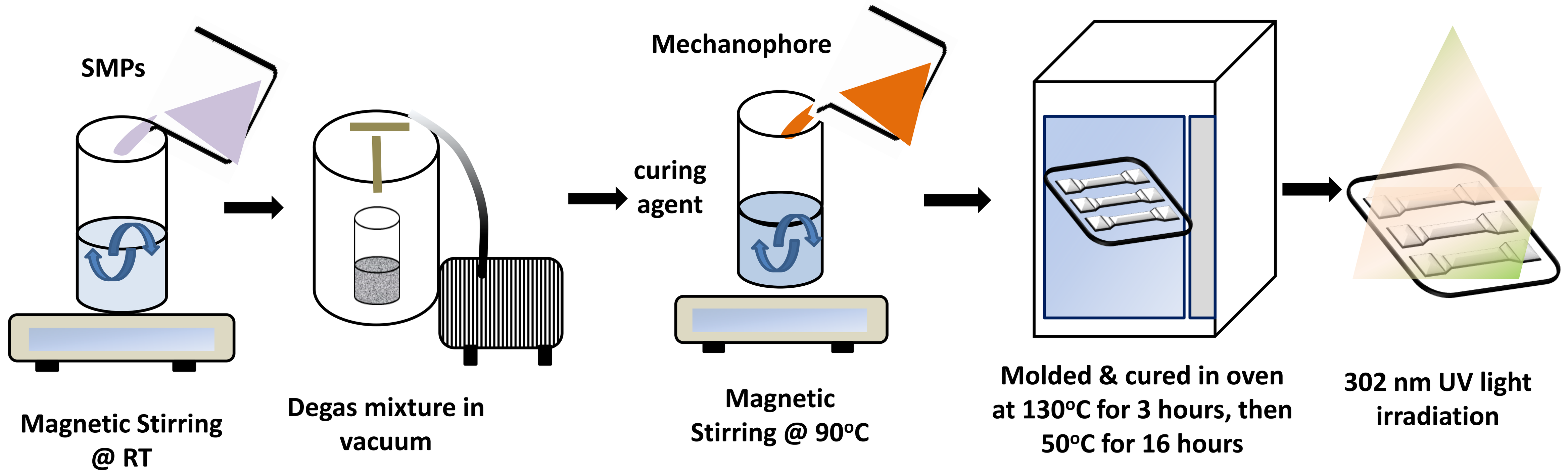
Fig. 1: Cinnamoyl-based Mechanophore Fluorescence and Self-healing Mechanism
Gunckel et al., ACS Applied Polymer Materials 2020, 2, 3916-3928

- Mechanophore is a type of functional material that undergoes a chemical reaction in answer to a mechanical force
- Previous work created cinnamoyl-based mechanophores that fluoresce under stress
- Mechanophore cross-linking repairs under UV irradiation, permitting repeated damage detection
- Current work incorporates mechanophores into shape memory polymer (SMPs) epoxy, enhancing composites with shape-recovery capability

Goals

1. Revise curing conditions to improve mechanophore integration into epoxy and to increase homogeneity and prevent the development of bubbles in composites
2. Understand the effects of weight-loading of mechanophore on the mechanical and thermal properties of composite material using dynamic mechanical analysis (DMA) and Differential Scanning Calorimetry (DSC) analysis

Materials and Methods



Results

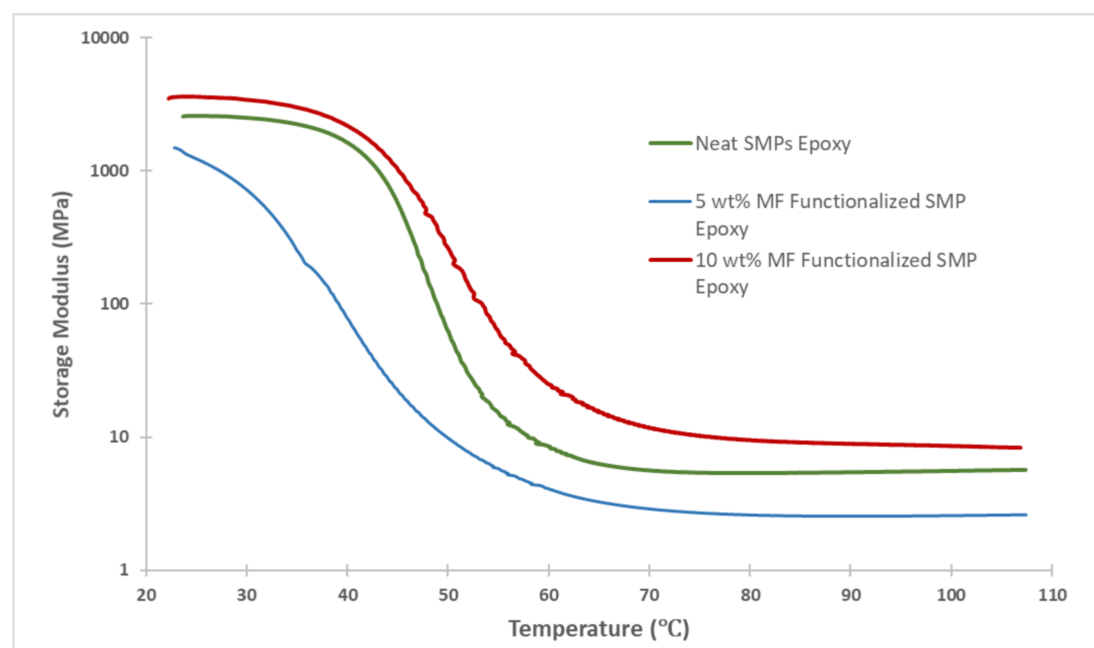


Fig. 4: Storage Modulus by DMA for Composites

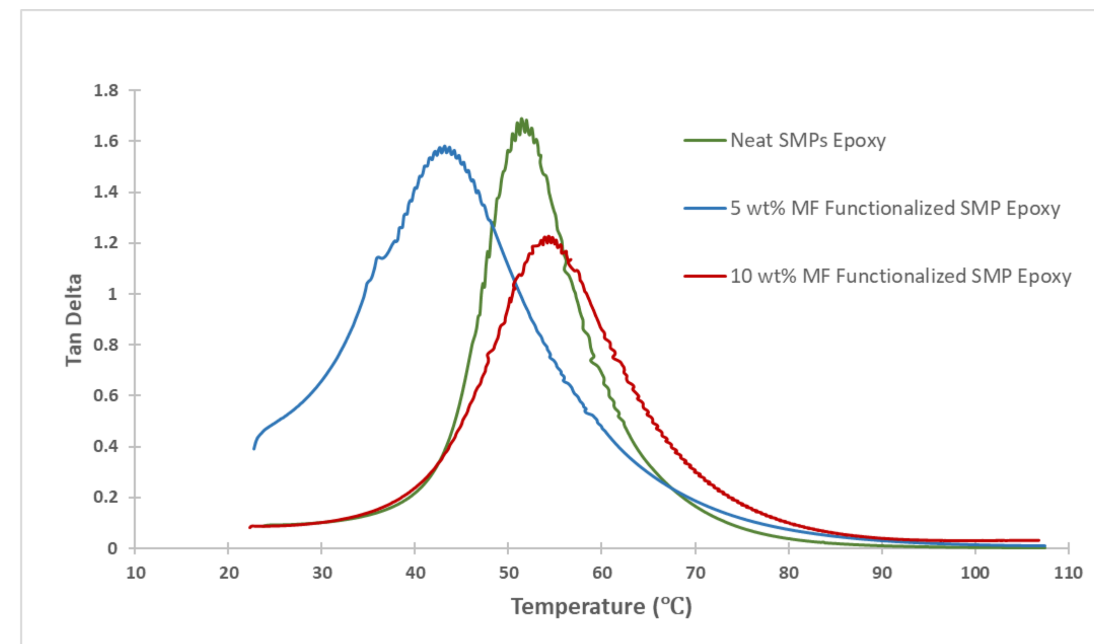


Fig. 5: Tan Delta by DMA for Composites

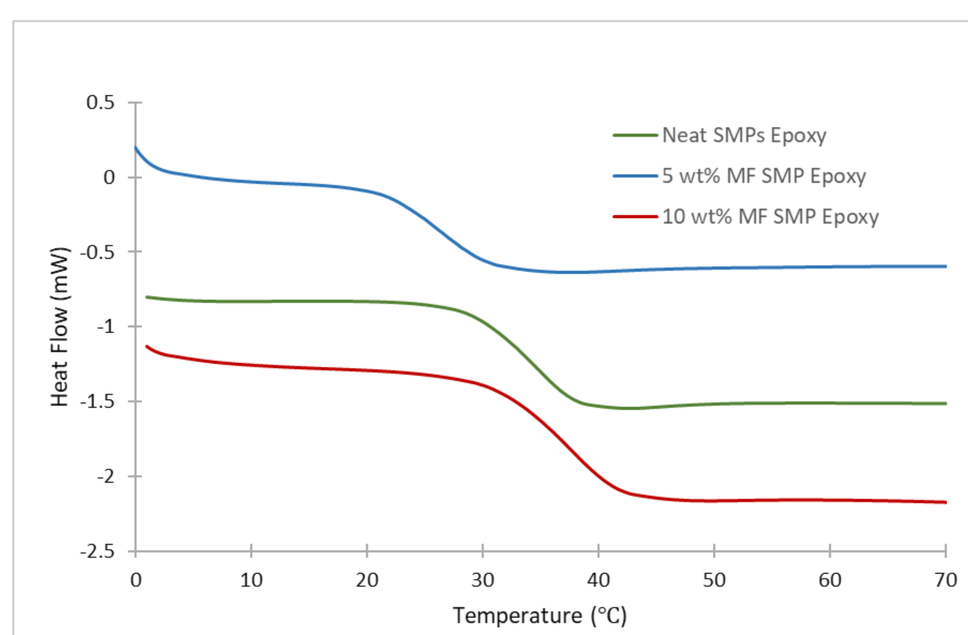


Fig. 6: DSC Heat Flow for Composites

- Improved hardness for 10 wt% composite, but worsened for 5 wt% composite
- Slight increase of glass transition temperature by 2.6°C for 10 wt% but lowered 9.5°C for 5 wt% versus neat SMP
- Crosslinking improved by over 50% for 10 wt% composite, but worsened by nearly 56% for 5 wt% compared to neat SMP
- Possible relationship between weight loading of mechanophore and curing quality

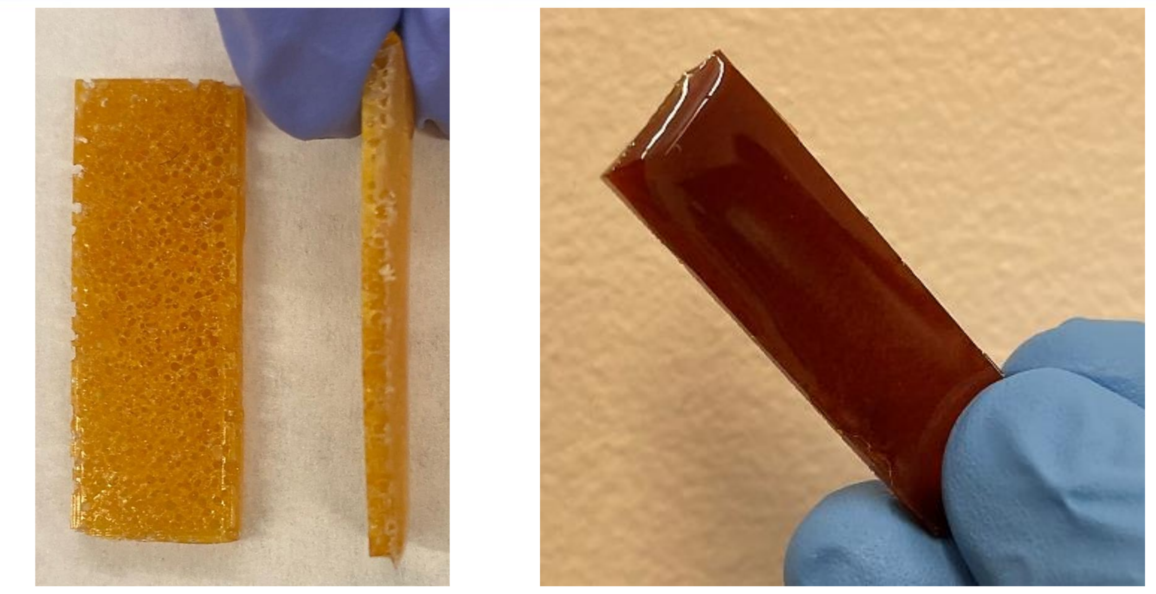


Fig. 3: Mechanophore-Incorporated Composites Under Original and Revised Curing Conditions

Sample	T_g (C) from DMA	$\rho_{xl}\ (\frac{mol}{cm^3}) * 10^{-3}$
Neat SMPs Epoxy	52.74±1.38	0.591 ± 0.011
5 wt% Mechanophore Functionalized SMP	43.22±0.00	0.262±0.013
10 wt% Mechanophore Functionalized SMPs	55.36±0.42	0.892 ± 0.004

Future Work

Fluorescence response by mechanical activation

- Characterize the mechanophore incorporated SMPs epoxy resin using fluorescence microscope
- Calculate the change in intensity of fluorescence before and after cracks happen using integrated density information
- Interpretate and correlate between fluorescence emission & stress-strain response

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