Magnetic and Rheological Properties of Shape Memory Epoxy-Iron Oxide Composite Inks

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Our research investigates the development of multi-stimuli responsive multi-material structures by combining shape memory polymers (SMPs) with magneto-active fillers. Our broad goal is to process, fabricate and characterize various combinations of these materials systems and demonstrate their actuation in response to thermal and magnetic fields. In this poster, our study focuses on the impact of iron oxide (Fe_3O_4) functionalization by Polyethylene Glycol (PEG) on the magnetic and rheological properties of SMP composites. Optical microscopy shows improved Fe_3O_4 particle dispersion and distribution as a result of the PEG coating. Magnetic characterization using Vibrating Sample Magnetometry (VSM) reveals enhanced mass magnetization of the functionalized iron oxide–loaded SMP composites. By replacing unfunctionalized Fe_3O_4 with Fe_3O_4_PEG(20), the saturation magnetization of SMP(0.044)_Fe_3O_4 composites improved by 19%. Rheological tests reveal that fumed silica, added as a thickening agent, has a major effect on the shear thinning behavior of SMP_Fe_3O_4 dispersions. In addition, PEG functionalized dispersions exhibit enhanced shear thinning behavior and shape integrity compared to unfunctionalized dispersions. Shape integrity test revealed the reduction of die-swell of SMP dispersions loaded with surface-treated Fe_3O_4 and improvement in percent deformation from 439% (SMP(0.044)_Fe_3O_4(2.5)) to 5% (SMP(0.044)_Fe_3O_4(12.5)_PEG(30)). In summary, the presence of PEG enhances particle dispersion and interaction with the polymer matrix, resulting in more effective Fe_3O_4 alignment through magnetic field and reduced agglomeration under shear. The improved rheological behavior and shape integrity are important results that indicate that PEG-functionalized SMP composites are promising candidates for 3D printing using direct ink printing. These findings contribute to the development of advanced stimuli-responsive materials with tunable properties for various applications, including soft robotics, and biomedical devices.

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