**Towards Complex Shape Actuation: An Investigation of Local and Global Magnetoactive Gradients in 3D-Printed Multi-Stimuli Responsive Shape Memory Polymer Composites**

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This research project investigates multi-stimuli responsive multi-material structures by combining shape memory polymers (SMPs) with magnetoactive fillers. Our broad goal is to design 3D-printed composites with local and global magnetoactive filler gradients, enabling them to exhibit complex shape actuation under magnetic and thermal fields. In the first phase, a comprehensive study on the rheological properties of SMP dispersions filled with surface-treated magnetic particles was carried out to understand the effect of magnetic particle surface treatment, additives content, and shear rate on the complex flow behavior. Our findings reveal that dispersions filled with surface-treated magnetic particles exhibit enhanced shear thinning behavior and shape integrity compared to unfunctionalized dispersions. 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. To create complex actuation, a 3D printing system was designed in a way that the magnetic particle-SMP dispersions are oriented using shear and a magnetic field, enabling the composite to exhibit a local angular gradient of magnetic particles. In addition, a global gradient is designed in by controlling the volume fraction of magnetic particles in the SMP suspensions. By adjusting the local and global gradient of magnetic particles within the SMP, different actuation patterns can be achieved. Image analysis is done to show the effect of processing conditions on the magnetic particle ordering and their localization within the polymer matrix. Vibrating Sample Magnetometry (VSM) was conducted to study the magnetic properties of the resulting SMP composites. These findings contribute to the development of advanced stimuli-responsive materials with tunable properties for various applications that complex shape actuation is required, including soft robotics, and biomedical devices.