Structural, Magnetic, and Mechanical Characterization of Fe_3O_4-filled Magnetoactive Elastomers for Soft Robotics Applications

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Magnetoactive elastomers (MAEs) are gaining significant attention in the field of soft robotics due to their versatile functional properties and actuation potential. This study investigates the structural, magnetic, and mechanical properties of composites based on a Dragon Skin™ 10 silicone matrix reinforced with magnetite (Fe_3O_4) particles. A series of samples with varying filler concentrations were synthesized and systematically characterized. X-ray diffraction (XRD) measurements confirmed that the crystal structure of Fe_3O_4 remained stable throughout the fabrication process, with no observable phase transitions. Density measurements, conducted via the Archimedes method, validated the compositional accuracy of the prepared composites. Magnetic characterization revealed that the materials exhibit soft ferromagnetic behavior, with magnetic parameters scaling predictably with filler loading. Specifically, the saturation magnetization (M_S) was found to decrease linearly with reducing filler content, ranging from 77.87(5) emu/g for pure Fe_3O_4 to 10.26(1) emu/g for the for a sample containing 10% Fe_3O_4. The experimental data were fitted using a linear model, $M_S(x) = \text{slope} \cdot x$, where x represents the filler mass fraction; the obtained slope value of 0.78(1) indicates a consistent magnetic contribution from the Fe_3O_4 phase. Notably, the coercive field (H_C) remained nearly constant at approximately 4 mT, confirming the structural stability of the magnetic filler. Mechanical testing demonstrated that increasing the Fe_3O_4 concentration leads to a progressive increase in the stiffness of the composites. This correlation suggests that a precise selection of the filler fraction allows for the fine-tuning of mechanical properties to meet specific operational requirements. Consequently, these findings provide a framework for the optimization of Dragon Skin-based MAEs, enabling the design of robust and efficient magnetically controlled soft actuators tailored for specialized applications.