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Magnetically Tunable Adhesion and Stiffness of Compliant Magnetoactive Elastomer Surfaces

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Magnetoactive elastomers (MAEs) are promising smart materials whose mechanical and interfacial properties can be actively tuned by external magnetic fields. In this work, isotropic MAE samples were prepared using a silicone-based compounding process. Vinyl-functional PDMS was blended with monovinyl PDMS, SiH-terminated PDMS, and silicone oil, then filled with carbonyl iron powder (CIP SQ) and crosslinker. Curing was initiated with a Pt-catalyst and controlled by an inhibitor, followed by vacuum degassing and casting to obtain defect-free elastomers.

We present a comprehensive experimental investigation of the coupled evolution of stiffness, adhesion, and surface roughness in these materials with CIP concentrations ranging from 60 to 80 wt%. Micro-indentation experiments combined with the Johnson–Kendall–Roberts (JKR) contact model were employed to extract the field-dependent Young's modulus and work of adhesion under magnetic flux densities up to 360 mT.

The results show a strong dependence of stiffness on both particle concentration and magnetic field, with up to an order-of-magnitude increase in modulus at intermediate concentrations. A saturation-like behavior is observed at high filler content (≥70 wt%) and high magnetic fields. In contrast, the work of adhesion exhibits a non-monotonic dependence on magnetic field: it increases at intermediate field (240 mT) and decreases at higher field (360 mT). Surface analysis shows that roughness decreases with increasing particle content and increases with magnetic field.

These findings highlight the complex interplay between bulk mechanics and surface properties in MAEs and identify an optimal operating regime (~75–80 wt%, ~240 mT) for maximizing both stiffness and adhesion. The study provides important insights for the design of magnetically tunable soft robotic systems and adaptive interfaces.

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