Guest Editorial for the Special Section "Recent Advances in Soft Multifunctional Materials"

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Recent progress in materials science is increasingly measured by the ability of materials to perform functions traditionally reserved for mechanical systems. In this context, soft multifunctional materials have emerged as key enablers of sensing, actuation, adaptation, and interaction with their environment. Over the past two decades, these materials have shifted the paradigm from passive load-bearing components to integrated systems capable of operating as distributed, compliant *machines*.

Soft multifunctional materials combine low elastic modulus and large deformability with responsiveness to external stimuli such as electric and magnetic fields, temperature, light, humidity, or chemical environments. Their mechanical compliance enables substantial reversible deformations, geometric adaptability, and safe interaction with biological tissues or delicate structures. When coupled with stimuli-controlled or environmental activation, these materials can reversibly alter shape or property. Such capabilities are particularly attractive for applications ranging from actuators and sensors to soft robotics, wearable electronics, and bio-integrated devices.

Representative material classes include magneto-active polymers, electro-active elastomers, liquid crystal elastomers, and shape-memory polymers. Their functionality arises from carefully engineered internal architectures; for example, elastomeric matrices containing aligned magnetic particles, percolated conductive networks, or mesogen-oriented polymer chains. These microstructural features give rise to strongly nonlinear and coupled multi-physical responses. Consequently, progress in this field depends not only on advances in polymer chemistry, but also on precise microstructural design into predictable macroscopic behavior.

In many magneto- and electro-active composites, a soft matrix is combined with functional inclusions whose distribution, orientation, and volume fraction determine effective properties. From a theoretical standpoint, this heterogeneity necessitates rigorous homogenization strategies and multiscale modeling frameworks to establish structure-property relationships.

Predictive constitutive models that incorporate large-strain kinematics and coupled electro-, magneto-, and thermo-mechanical effects are essential for guiding material development and ensuring their integration.

Parallel advances in fabrication technologies have significantly accelerated the development of soft multifunctional materials. Additive manufacturing techniques enable spatial control of material composition and architecture to achieve graded properties and embedded functionality within a single object. Electrospinning and related microfabrication approaches further extend capability to fibrous and hierarchical structures, potentially leading to metamaterials with programmable mechanical responses. Complementary progress in experimental characterization, such as full-field deformation mapping, *in situ* electromechanical testing, and microscale imaging, provides critical insight into deformation mechanisms, instabilities, damage evolution, and long-term durability.

The present Special Section reflects the interdisciplinary and rapidly evolving character of this research field. The twelve contributions, including three reviews and nine research articles, span advanced fabrication, mechanical characterization, theoretical modeling, and practical applications.

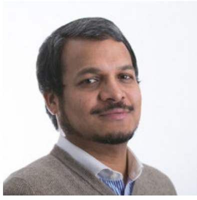
Several articles focus on fabrication and structural design. Feng *et al*. (Recent Progress in 3D Printing Polymer-Based Bone Scaffolds - Feng - Advanced Engineering Materials - Wiley Online Library) systematically review 3D printing technologies for polymer-based scaffolds in bone tissue engineering. Zolfagharian *et al*. (Bistable Mechanisms 3D Printing for Mechanically Programmable Vibration Control - Zolfagharian - Advanced Engineering Materials - Wiley Online Library) design bistable structures via fused filament fabrication and integrate them into tuned mass damper systems to enhance passive vibration control adaptability. Liu *et al*. (Fabrication of Stretchable and Conductive Liquid Metal Microfibers through Coaxial Emulsion Electrospinning - Liu - Advanced Engineering Materials - Wiley Online Library) develop a coaxial emulsion electrospinning method to fabricate stretchable and conductive liquid metal microfibers and demonstrate their potential in wearable electronics, Joule heating devices, and strain sensors.

A fundamental understanding of mechanical behavior is crucial for the applications of soft materials. Alzughaibi *et al*. (Energy Dissipation during Crack Growth in Rubbers with Mullins Softening - Alzughaibi - Advanced Engineering Materials - Wiley Online Library)experimentally investigate the effect of Mullins softening on crack growth resistance in carbon black-filled and unfilled styrene-butadiene rubbers using particle tracking methods. They find that fillers enhance intrinsic toughness, while Mullins softening contributes significantly to bulk energy dissipation. Rezayat *et al*. (Enhancing Corrosion Resistance and Mechanical Strength of 3D-Printed Iron Polylactic Acid for Marine Applications via Laser Surface Texturing - Rezayat - Advanced Engineering Materials - Wiley Online Library) explore laser surface texturing to enhance corrosion resistance and mechanical strength of 3D-printed iron polylactic acid for marine applications. Narayanan *et al*. (Leveraging Instabilities in Multifunctional Soft Materials: A Cutting Edge Review - Narayanan - Advanced Engineering Materials - Wiley Online Library) review the utilization of mechanical, surface, and chemical instabilities (e.g., buckling, wrinkling) in multifunctional soft materials.

Stimulus-responsive behavior of soft active materials and the related applications constitute another theme. Yang *et al*. (Piezoresistive Effects in a Highly Sensitive Conductive Elastomer: Experiments and Artificial Neural Network Study - Yang - Advanced Engineering Materials - Wiley Online Library) fabricate carbon fiber/polydimethylsiloxane conductive elastomers with high piezoresistive sensitivity and employ an artificial neural network model to analyze strain and resistance change rates and optimize composite proportions. Si *et al*. (Voltage-Controlled Vibrations in Bending-Deformed Soft Electro-Active Slabs - Si - Advanced Engineering Materials - Wiley Online Library) investigate the small-amplitude free vibration of bending-deformed soft electro-active slabs under inhomogeneous biasing fields using analytical and numerical methods, demonstrating that electro-mechanical biasing fields can regulate vibration characteristics. Garai and Haldar (A. Garai, K. Haldar, Adv. Eng. Mater. **2026**)fabricate magneto-active polymers by embedding carbonyl iron powder into polydimethylsiloxane characterize their magneto-mechanical responses and develop a filler-dependent coupled magneto-mechanical constitutive model that effectively captures the effects of magnetic fields and filler concentrations on stress responses. Zeng *et al*. (Advances in Shape-Memory Polymers and Composites for Biomedical Device Applications - Zeng - Advanced Engineering Materials - Wiley Online Library) review the biomedical applications of shape-memory polymers and composites as bone scaffolds, lumen stents, drug carriers, and provide insights on clinical translation challenges and future opportunities.

Several contributions also advance theoretical frameworks for soft active materials. Zhang *et al*. (Light-Fueled Self-Oscillation of a Viscoelastic Liquid Crystal Elastomer Oscillator - Zhang - Advanced Engineering Materials - Wiley Online Library) examine the complex functional behaviors of liquid crystal elastomers under external stimuli and explore the development of multi-field coupled models for their practical application. Liu *et al*. (Design Principle in Localized Density Coefficient of 3D-Printing Foamlike Mechanical Metamaterials Toward a High-Compression Strain Energy - Liu - Advanced Engineering Materials - Wiley Online Library) propose a 3D theoretical model based on the plate theory for 3D-printed foamlike mechanical metamaterials and investigate the effects of geometric parameters on strain energy and deformation.

This Special Section offers a dynamic snapshot of current research into soft multifunctional materials, although it cannot encompass every facet of this fast-growing field. Several emerging research directions will shape its future development but are not fully represented here. In particular, multi-material 3D printing is essential for engineering materials with spatially graded properties and building fully integrated, functional soft devices, which stands as a critical area for future research. Stretchable electronics constitute a foundational platform for next-generation wearable health monitors, electronic skins, and implantable devices. Finally, soft robotics represents both a major scientific challenge and greatest potential for soft active materials.

	**Mokarram Hossain** is Full Professor at the Zienkiewicz Institute (ZI) for Modelling, Data, and AI in Swansea University. After completing his Bachelor in Bangladesh University of Engineering and Technology, Prof Hossain obtained Masters in Computational Engineering (2005) from Technical University of Braunschweig, Germany. He obtained a PhD in Mechanical Engineering (2010) from University of Erlangen-Nuremberg, Germany. Prof Hossain obtained the best Postdoc Paper Prize from the UK Association for Computational Mechanics (UKACM). He published more than 140 peer-reviewed journal papers in many leading journals across disciplines of materials, mechanics, and computations.
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