Additive Manufacturing of Liquid Crystal Elastomers: From 4D Printing to Motile, Autonomous Soft Robotic Systems

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Liquid crystalline elastomers (LCEs) are a unique class of stimuli-responsive materials capable of producing large, anisotropic shape changes in response to external stimuli such as heat, light, or humidity. Their combination of elasticity and liquid-crystal order makes them particularly promising for soft robotics, where motion can be programmed directly into the material.

In this lecture, I will present the work of the Advanced Manufacturing Laboratory (AML) at the Institute of Nanoscience and Materials of Aragón (INMA) in Spain, focusing on our contributions to the additive manufacturing and 4D printing of LCEs. Our group has developed fabrication strategies that enable precise control of molecular alignment during printing, allowing complex shape transformations and actuation behaviors to be encoded directly during manufacturing. I will also highlight our recent advances toward more functional and autonomous systems, including multiresponsive materials, biomimetic soft robotic devices with light- and magnetic-field-driven motion, and multimodal architectures integrating sensing, actuation, and environmental responsiveness. These developments illustrate how combining liquid crystal materials with advanced manufacturing enables a new generation of soft robotic systems in which structure, material, and function are designed simultaneously.

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