PROGRAMMABLE LIQUID CRYSTAL ARCHITECTURES MADE BY 4D MICROPRINTING

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Humankind always sought to create tools which allow the accomplishment of tasks that would be difficult or couldn't be done otherwise. However, reproduction of simple tools at the microscale often require time consuming and multi-steps processes. To respond to increasing needs in healthcare and in manufacturing, nanorobotics has to change paradigm to overcome the current limitations on dexterity, compactness, range, and precision. 4D printing concept appears in 2013 with the idea to facilitate the assembling of macroscopic objects. The fourth dimension refers not only to the ability for material objects to change form after they are produced, but also to their ability to change function after they are printed. At the microscale, 3D direct laser writing (3D DLW) based on multi-photon polymerization has become the gold standard for submicrometer additive manufacturing.[1-2] Various stimuli-responsive materials, especially hydrogels and liquid crystal elastomers (LCEs) have been employed to manufacture advanced microactuators by 3D DLW. In particular, LCEs have attracted considerable attention in the last 5 years due to their reversible, large shape-morphing and their fast response towards temperature or light stimuli. However, their processability by 3D DLW is not easy and the resulting objects rarely exhibit controlled and predictable deformation. The deformation of LCEs microactuators is mainly controlled by the mesogenic alignment design, which should be programmed before photopolymerization. Interestingly, this programming mainly lies in coating industry strategies and is thus not appropriated to 3D microfabrication process. In order to increase the complexity of deformation and thus to fulfil the requirements of nanorobotics, new programming strategies must be implemented in parallel with the development of new photosensitive resins dedicated to 3D DLW.

In this work, we propose a new alternative to perform the alignment of LCEs in a precise manner. By playing both on the orientation strategy and the fabrication parameters, different deformations (curling, bending, twisting…) can be programmed starting from a single CAD model. A collection of building block is first demonstrated, then assembly of these building block is achieved, leading to 3D micro-objects presenting sophisticated behaviour. Finally, the fine control offered by our approach is illustrated by building a micro-actuator and investigating its performance (amplitude, speed of deformation… Fig. 1). This work opens up new prospects for moving from a programmable material to a functional 3D-printed device.

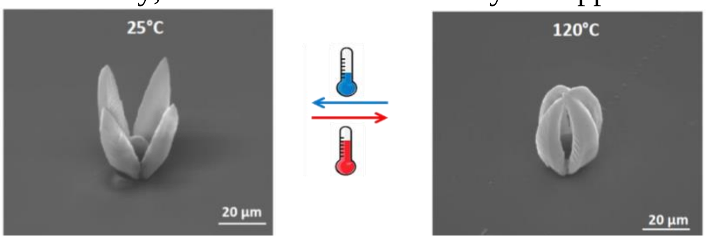

Fig. 1: Thermal actuation of LCE clamp like structure made by 4D microprinting. Case of simple reconfiguration from an open to a close form.

References

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