Electrically Driven Liquid Crystal Elastomer Actuator Matrix for Haptic Surfaces*

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I. Introduction

Liquid crystal elastomers (**LCE**s) have great potential for thin and flexible devices that interface human-environment interactions, thanks to their ability to reversibly actuate to high strains with light or heat exposure [1]. Here, an **electrically-driven LCE actuator matrix** with the potential to be scaled up to large area production is developed. The device functions by LCE actuation, driven by the **Joule heating** of a resistive element. The multilayer device (Fig. 1) consists of series of active LCE elements coupled with an electronic layer, used to interconnect the elements and operate the device. These two layers are placed onto a stretchable substrate, which allows out-of-plane actuation. The presented concept shows potential for applications in texture changing surfaces or programmable Braille text.

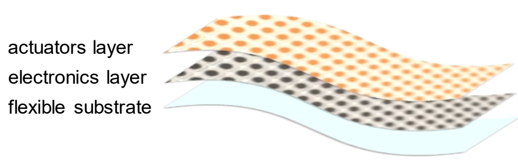

Figure 1. Schematics of the multilayer structure for the haptic surface.

II. Materials and Method

The LCE was synthesized via a Michael addition reaction and direct ink written in the nematic phase temperature range. Molecular alignment was provided by shear forces during **printing** [2]. The samples were then polymerized via UV light exposure. Successfully aligned planar samples of 15 × 3 mm^2 showed **a reversible contraction of 40%** of their initial length upon heating from 25 to 130°C. Azimuthally aligned samples showed expected conical deformation (Fig.2).

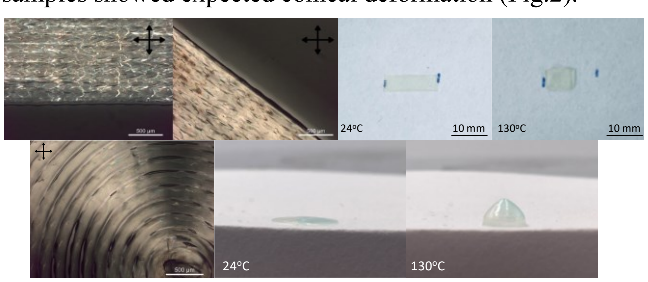

Figure 2. *top:* POM images and actuation behavior of a linear 15x3 mm^2 strip. *bottom*: POM images and actuation behavior of an azimuthal sample.

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A commercially available resistive ink was selected as e-heater and screen printed onto 90 µm-thick TPU foil.

III. Results and Discussion

To couple the heater ink to the actuating LCE element the optimal configuration (LCE-on-heater *vs* heater-on-LCE) was tested. The first configuration was found to provide better adhesion of the layers to each other as well as better homogeneity of the heater, crucial to prevent the formation of hot spots, which would lead to device failure. The behavior of the bilayer samples prepared this way was tested applying a voltage sweep to 10 V and measuring device temperature with an IR camera while simultaneously recording its actuation. Trilayers, combining TPU substrate, heater and LCE were also tested with respect to their e-driven actuation with a voltage sweep to 40 V. Around its T_g, TPU softens and is easily bent by the LCE actuation. This deformation is not recovered upon cooling due to the freezing in of the TPU.

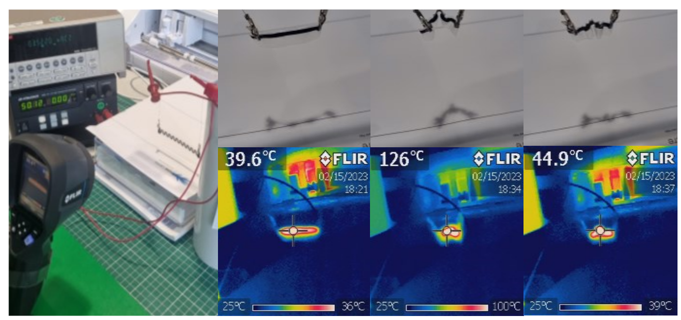

Figure 3. *left:* Set-up for Joule heating tests of the trilayer strip made of TPU substrate, e-heater and LCE actuator. *top-right:* deformation sequence of a trilayer (R = 4.7 kΩ) with applied voltage V = 10 V, 40 V and 10 V. *bottom-right*: sequence of corresponding IR images.

IV. Conclusions and Perspectives

The work shown here is leading towards proof of concepts of how LCEs can be exploited in **low-power electrically driven haptics**, tailored to specific applications by tuning the LCE properties. [3] Joule heating has successfully been used as the physical principle to drive the LCE actuation. In the future, different plastic foils will be tested as substrates and out-of-plane actuating elements will be developed. The actuator matrix will be finally tested for e-Braille.

References

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[3] M. Barnes et al., *Understanding the effect of liquid crystal content on the phase behavior and mechanical properties of liquid crystal elastomers,* Soft Matter, 2022, vol. 18, pp. 5074–5081.