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Small, fast and tough: an overview of our silicone-based actuators

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One of the main reasons why so much attention has been brought to the field of dielectric elastomer actuators (DEAs) is the exceptionally large strain that they can produce compared to alternative technologies. A key factor in this well-deserved fame is the acrylic elastomer VHB from 3M, which is at the centre of the record-braking strains displayed by DEAs, first in 2000 with the demonstration of actuation strains larger than 100%[1], and then in 2012 with a gigantic surface strain of 1692%[2]. Because of this large strain ability, and due to the fact that this material is provided in film form by the manufacturer, it is the most widely used dielectric in DEAs. However, VHB suffers from a number of drawbacks, such as a high viscoelasticity leading to slow devices, a reduced design freedom due to the inability to choose the membrane thickness and prestretch independently, and the need for large prestretch levels that often leads to reduced lifetime.

Now that research in the field of DEAs is maturing and moving towards the development of concrete applications that can take advantage of the large actuation strain of this class of actuators (such as tuneable optics or soft robotics), there is a need to work towards improving the reliability and lifetime of DEAs. One of the first steps in that direction consists in replacing VHB with another material that can actuate faster and over a large number of cycles (several millions). We can note that none of the few companies active in the field of dielectric elastomer transducers (Artificial Muscles, Stretchsense, Optotune, etc.) use VHB as membrane material, because for commercial applications, reliability and lifetime are key factors that VHB cannot provide.

Silicone elastomers are an interesting alternative to VHB and represent the second largest class of elastomeric materials used as membrane for DEAs. Because silicones can be bought in their uncrosslinked state and are available in a broad range of Shore hardness, they offer unlimited design flexibility, as they can be casted to any desired thickness, and they generally have a much lower mechanical loss factor compared to VHB.

In our laboratory, we have established a reliable fabrication process for silicone-based DEAs, including large area (A4) membrane manufacturing on flexible substrates, and precise patterning of compliant electrodes, either by pad printing of a conductive silicone, or by implantation of gold ions at the surface of the silicone membrane. Our electrode patterning technologies allow us to rapidly and reliably manufacture actuators with sizes ranging between 10 cm and 100 µm.

The speed potential of silicone-based DEAs has been demonstrated through a project in collaboration with F. Carpi consisting in realizing his bio inspired tuneable lens concept[3] with silicone membranes. A process flow has been developed to encapsulate a liquid between two silicone membranes using oxygen plasma bonding. Sub millisecond response time was demonstrated and when the lens was mounted on a CCD camera, it was possible to change the focus between infinity and 90mm with settling times well below 1ms.

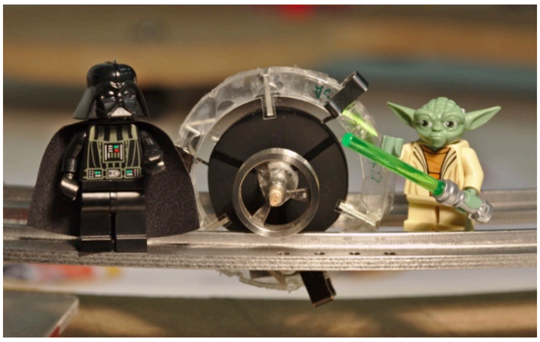

Figure 1: Rupert the Rolling Robot with its two inventors.

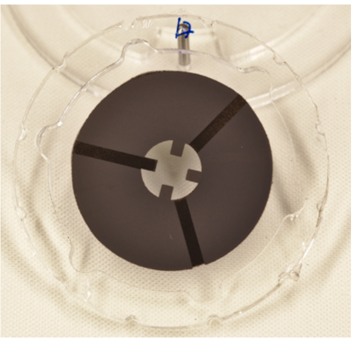

Figure 2: Printed membrane with 3 independent actuators for Rupert.

Speed and reliability have also been demonstrated with *Rupert the Rolling Robot* (***Figure 1*** and ***Figure 2***), a self commutating 3 phases motor, which rolls on a 2.15m long circular track at an average speed of 15 cm/s. The actuator consists of two membranes in parallel meaning that the device consists of 6 actuators which must work together in order to keep the device rolling. The failure of one of them causes the failure of the whole device.

Up to now a maximal distance of 25km has been achieved with the tested device before dielectric breakdown of one of the actuators (i.e. 11628 track turns), and the goal is to reach the distance of a marathon.

References

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