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EuroEAP 2015
International conference on Electromechanically Active Polymer (EAP) transducers & artificial muscles
Tallinn, 9-10 June

ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE

Poster ID:
2.2.2

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Pad printing 1-10 μm thick elastomer membranes for DEAs

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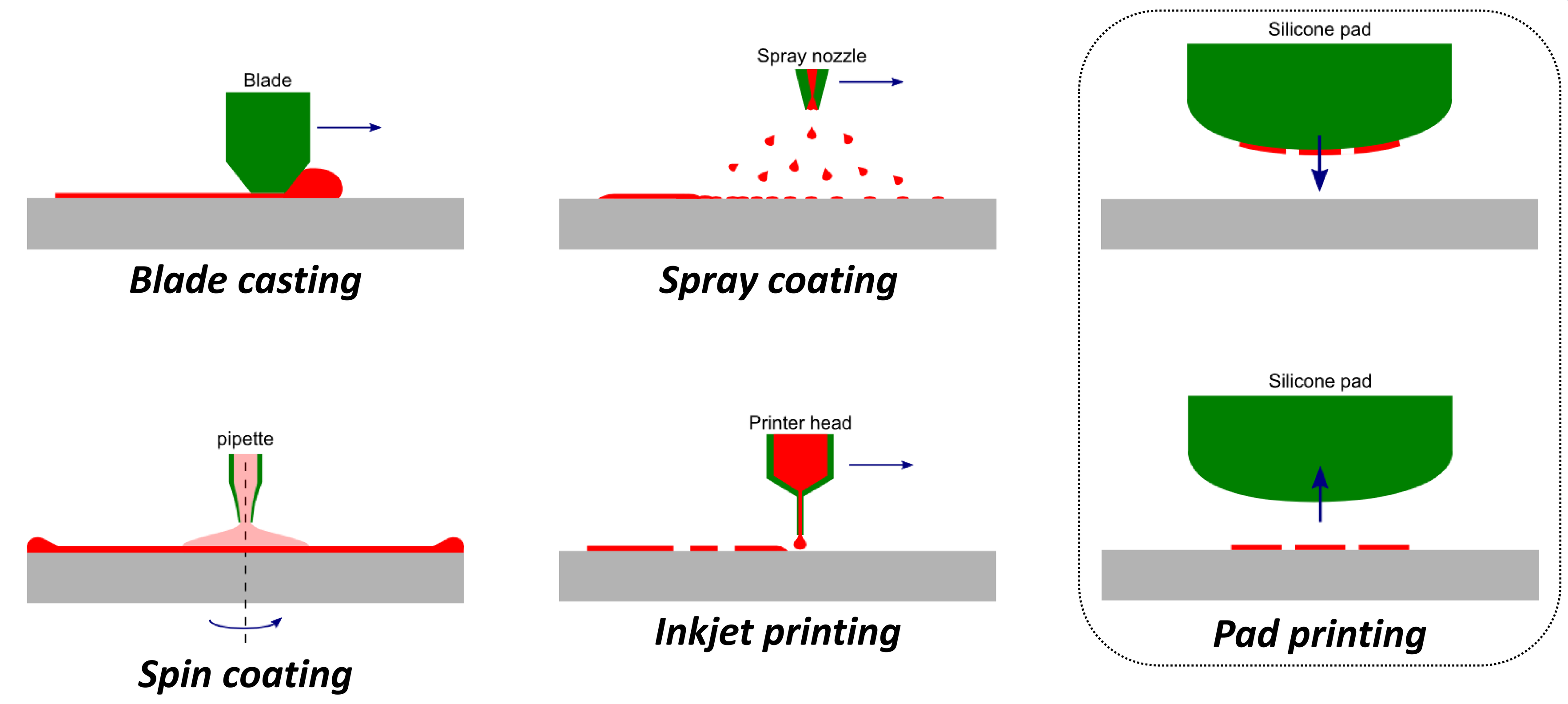
Abstract

We present a technique for stamping patterned silicone elastomer membranes with thicknesses ranging from 1 to 10 um. Silicone elastomers are becoming the material of choice for dielectric elastomer transducers. The variety of readily available materials, their versatility in terms of film thicknesses and their excellent mechanical properties have made them a very appealing alternative to the widely used acrylic elastomer VHB from 3M. Silicone films are typically blade casted or spin coated, two complementary techniques allowing for large area (> 10 cm x 10 cm) and ultra-thin (< 1 μm) membranes respectively.

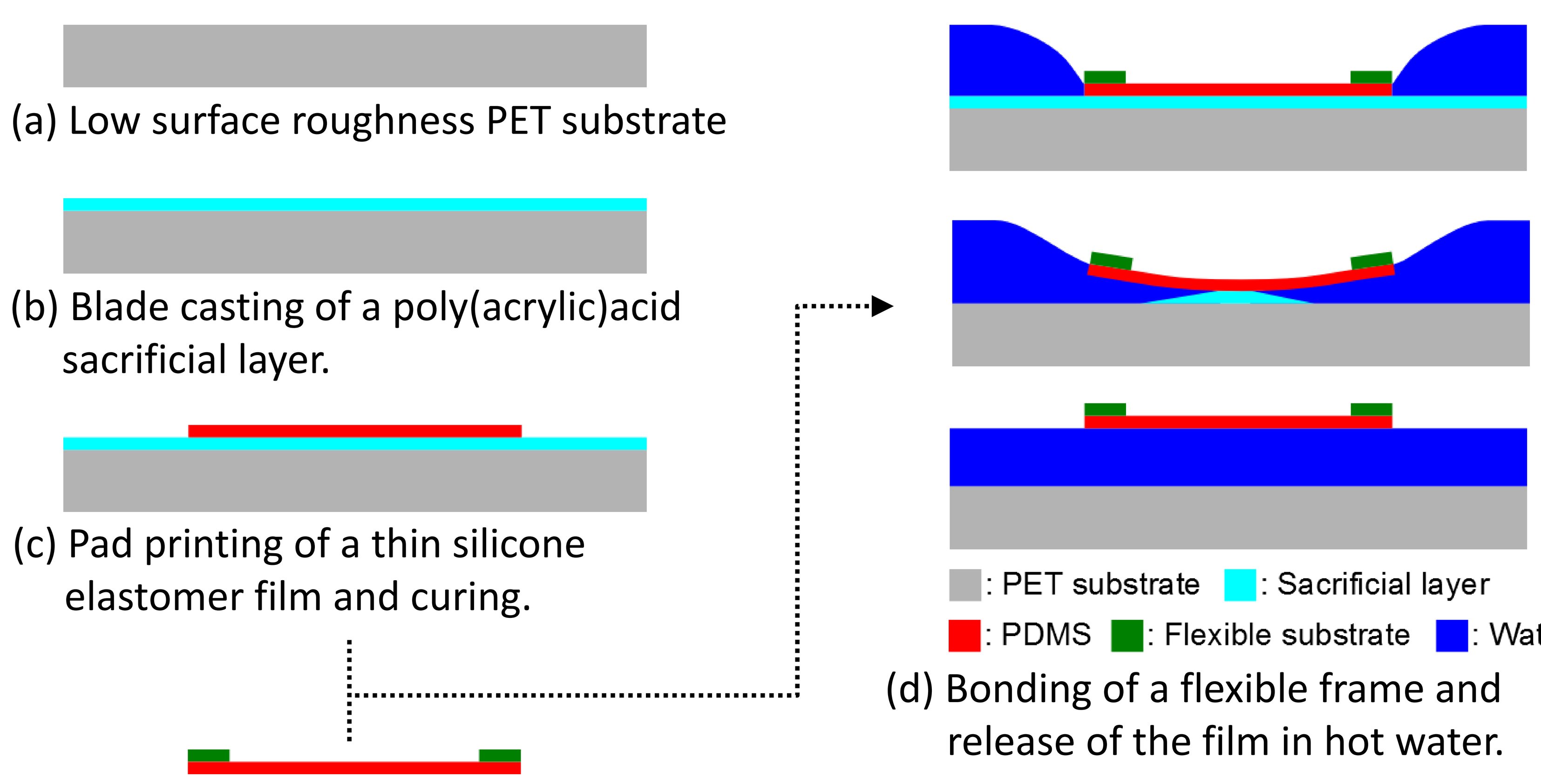
We present a stamping method for membranes up to 5 cm x 5 cm in area and with thicknesses ranging from 1 to 10 μm. Unlike blade casting and spin coating this technique enables direct patterning of the membrane, thus providing great design flexibility. Combined with the ability to pattern stretchable electrodes using the same method [1], functional structures such as dielectric elastomer actuators (DEAs) with high level of integration (vertical integration) can be fabricated. As a proof of concept we characterized a stamped DEA, as well as a stamped vertical electrical connection for layers interconnection.

I – Silicone elastomer films production methods



Membrane:	Blade casting	Spin coating	Spray coating	Inkjet printing	This work: Pad printing
Thickness	Medium-high	Low-high	Medium-high	Low	Low
Uniformity	Good	Medium	Medium	Medium	Medium
Area	Large	Medium	Large	Medium	Medium
Geometry	Rectangular	Circular	Substrate	Arbitrary	Arbitrary
Complexity	Low	Medium	Medium	High	Low

II – Pad printed silicone elastomer thin membranes



(a) Low surface roughness PET substrate

(b) Blade casting of a poly(acrylic)acid sacrificial layer.

(c) Pad printing of a thin silicone elastomer film and curing.

(d) Bonding of a flexible frame and release of the film in hot water.

(e) Silicone membrane suspended on a flexible frame

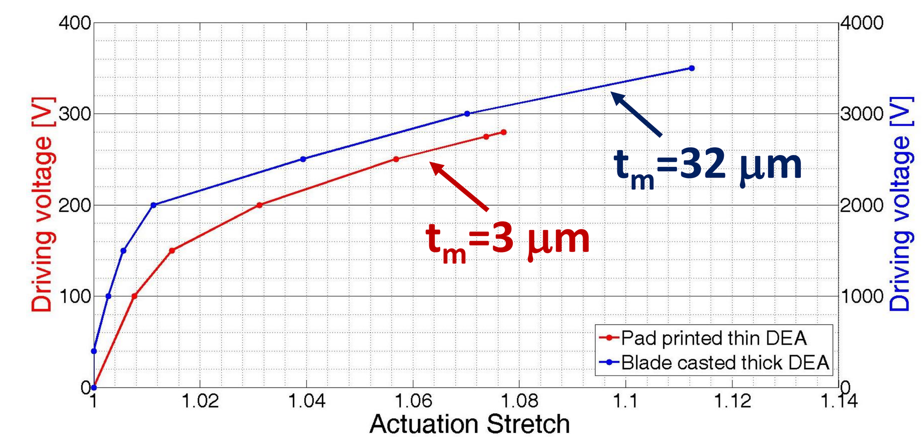
Silicone elastomer membranes of 1 to 10 μm in thicknesses were printed by simply adjusting the number of prints and the pressure exerted on the substrate by the pad.

The viscosity of the printed solution, its self-leveling properties and its pot life at room temperature are important parameters that influence the membrane quality.

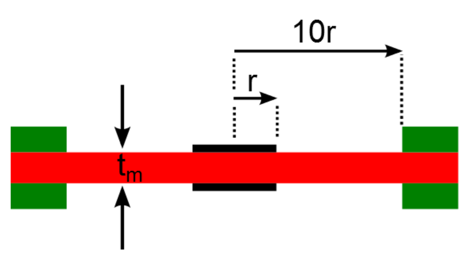
III – Low voltage actuation in all-printed DEA

The same printing technique can also be used to pattern stretchable electrodes on the membrane and manufacture DEAs.

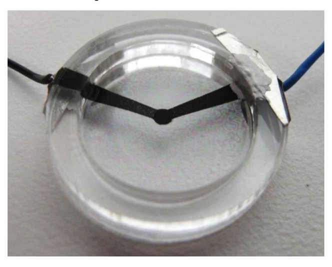
Using a 3 μm thick membrane we achieved 8% stretch (biaxial) at 280 V, a voltage ten times lower than the one required with our standard 30 μm thick membranes.



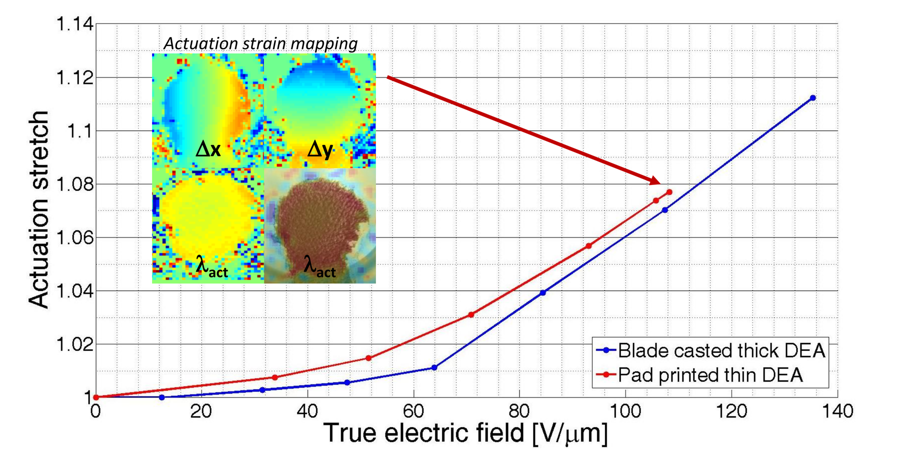
Schematic cross section



All-printed DEA

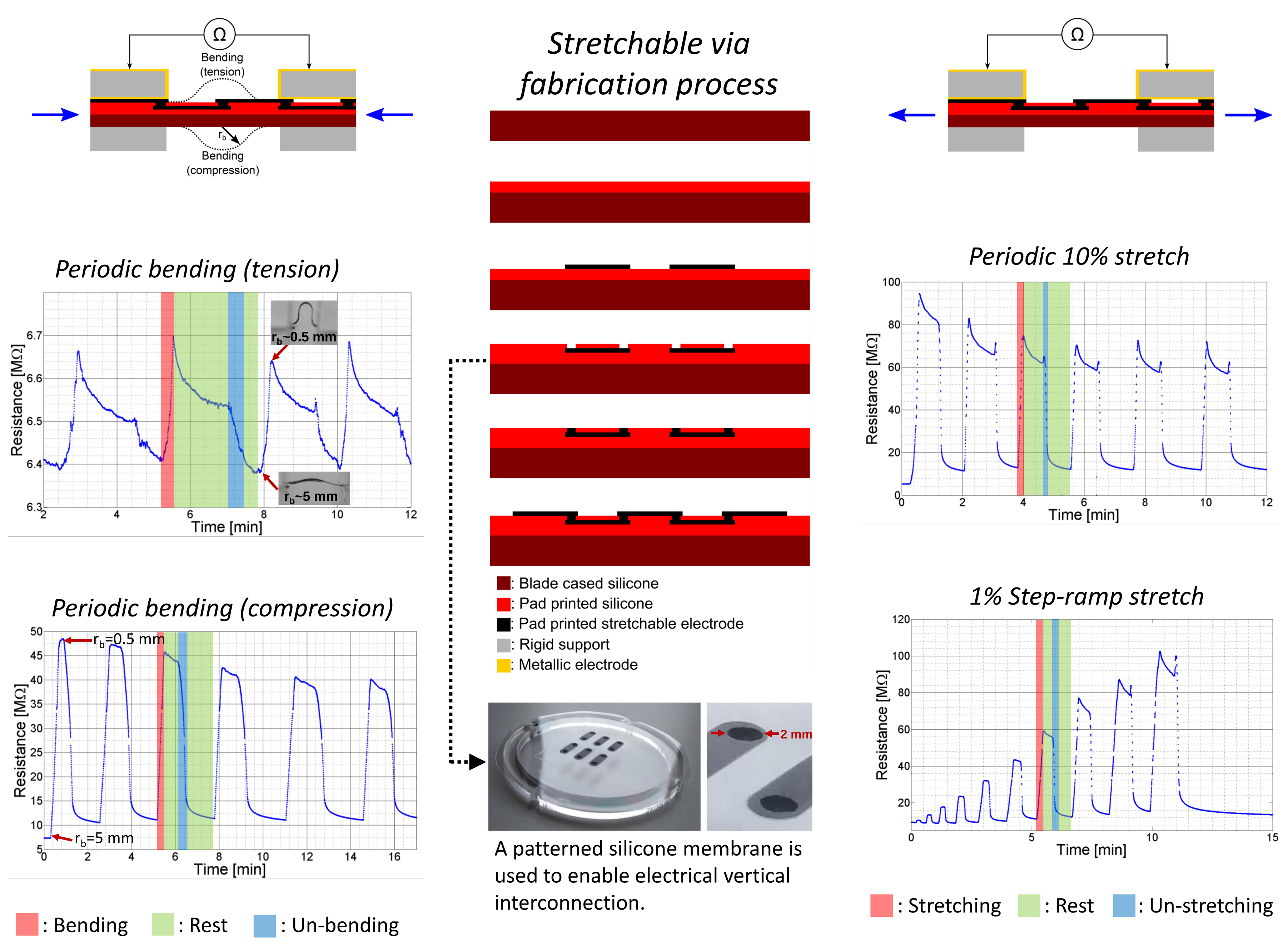


Silicone elastomer:........................Sylgard 184
Pre-stretch: 1.2
Thicknesses after pre-stretch:
Blade cased DEA.............................t_m=32 μm
Pad printed DEA ....t_m=3 μm



IV – Stretchable vertical electrical interconnection (via)

Using a multi-step process, stamping silicone and electrodes, we fabricated stretchable vias to demonstrate an application of membrane patterning. Lines of four vertical via were fabricated and characterized under pure shear stress and bending. The via (∅=2mm) remained conductive at bending radius lower than 0.5 mm and at stretch greater than 10%.



Conclusion

We demonstrated a new silicone elastomer films production method for DEAs which presents interesting advantages:

- Ability to manufacture thin (1-10 μm) silicone membranes.
- Ability to directly pattern the silicone membrane with 100 μm feature size.
- Same technique can be used to pattern elastomer-based stretchable electrodes.
- Low system complexity

An all-printed silicone-based DEA working at a voltage 10 times lower then its equivalent blade casted actuator was presented.

A stretchable via was fabricated to demonstrate the advantage of direct membrane patterning. The via remained conductive at bending radius below 0.5 mm and under tensile stretch higher than 10%.

Acknowledgments

This research was supported by the Swiss National Science Foundation (SNSF) under Grant No. 200020_140394, Grant no. No. 200020_153122 and the SNSF R'equip program. 206021_139187.

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1. S. Rosset and H. Shea. Towards fast, reliable, and manufacturable DEAs: miniaturized motor and Rupert the rolling robot. Electroactive Polymer Actuators and Devices (EAPAD), San Diego, 2015.