Origami-Inspired Micro-Robotic Arm

CNF Project Number: 2416-16

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Primary Source(s) of Research Funding: National Science Foundation, Contract DMR-1719875; Army Research Office, Contract W911NF-18-1-0032

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Primary CNF Tools Used: Arradiance ALD Gemstar-6, Oxford ALD FlexAL, Oxford PlasmaLab 80+ reactive ion etchers, ABM contact aligner, AJA sputter deposition, AJA ion mill, Heidelberg mask writer - DWL2000

Abstract:

Origami, the Japanese art of paper folding, has recently found use in various engineering applications, leading to the development of origami-inspired systems ranging from the macro to the microscale. At and below the microscale, origami-inspired designs have allowed the use of planar lithographic fabrication methods to build systems that can self-fold into complex three-dimensional (3D) geometries. In our work, we make use of origami design principles to create a microscale robotic arm, which can be fabricated in large numbers using standard lithographic techniques. We envision that these devices will find uses in lab-on-a-chip devices, tissue manipulation and minimally invasive surgery.

Summary of Research:

Our group has previously demonstrated an approach capable of creating complex self-folding microsystems based on atomic layer deposition (ALD) nanofilms [1]. The method we have developed automatically generates photomasks for arbitrarily complex origami-inspired designs, which can then be used to fabricate self-folding microdevices based on ultra-thin ALD films.

One application being pursued with this approach is a microscale robotic arm based on ultra-thin, ALD based surface electrochemical actuators (SEAs) [2,3]. SEAs, which consist of 7.5 nm of platinum, deposited using the Arradiance ALD Gemstar-6, and a 2 nm thick titanium capping layer, deposited using the AJA sputter deposition system, operate in electrolyte and can bend down to several micron scale radii of curvature in response to electrical signals.

To microfabricate our design for the origami-inspired robotic arm (Figure 1A-B), we generate photomasks suitable for SEAs (Figure 2). Our design for the micro-robotic arm incorporates the origami-inspired surgical forceps (Oriceps) [4] as the gripping element, and includes folding hinges to generate translation and tilt, resulting in a total of three degrees of freedom. The leftmost photomask pattern shown in Figure 2 defines the regions that will be used to create upward bending, while the photomask pattern shown in the middle defines the regions that will be used to create downward bending. The rightmost photomask pattern defines the rigid, flat panels that will be used to restrict bending. These patterns are generated as BMP files and imported into L-Edit to create the full mask layout, which is then used to fabricate photomasks with the Heidelberg mask writer - DWL2000.

Figure 3 shows the first prototypes for our origami-inspired micro-robotic arm design, which include three electrodes to address the translation, tilt, and gripping degrees of freedom, and thin, isolated strips of platinum to carry applied electrical signals throughout the device. The three electrodes are permanently bonded to the substrate, which makes the devices semi-tethered. After the devices are released by wet etching the underlying Al release layer, the electrodes make it possible to apply driving voltages by making contact with a Pt/Ir micromanipulator probe.

We envision that the microscale manipulation capabilities offered by this SEA-based, origami-inspired micro-robotic arm will find uses in lab-on-a-chip devices, tissue manipulation and minimally invasive surgery.

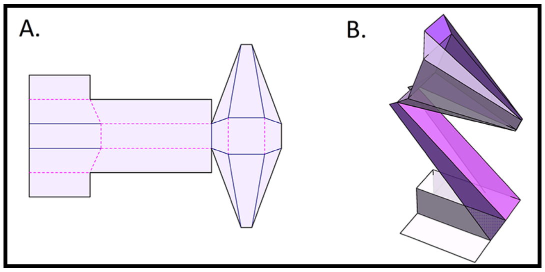

Figure 1: (A) Fold pattern and (B) 3D model for our origami-inspired robotic arm design, which incorporates the Oriceps [4] as the gripping element, and includes folding hinges to generate translation and tilt.

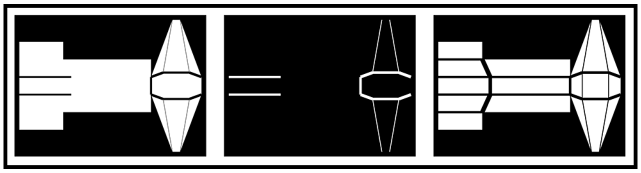

Figure 2: Photomask patterns used in fabrication of the micro-robotic arm design. The leftmost photomask defines the regions that will be used to create upward bending, while the photomask shown in the middle defines the regions that will be used to create downward bending. The rightmost photomask defines the rigid, flat panels that will be used to restrict bending.

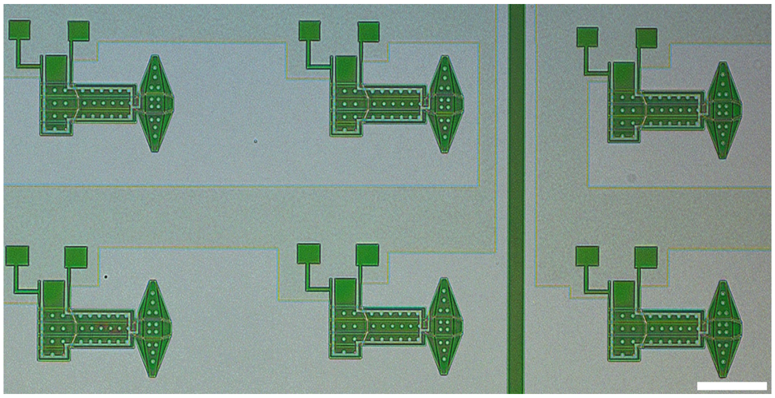

Figure 3: An array of microscale robotic arm devices prior to release. Each device is attached to three fixed electrodes that address the translation, tilt, and gripping degrees of freedom. Scale bar is 200 µm.

References:

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