Conformation of Organic Electronics to the Hemispherical Shape Using Elastomeric Transfer Elements

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Abstract:

A camera inspired by the human eye offers attractive design features for imaging devices. The hemispherical detector geometry enables a simpler and superior optical imaging system facilitating wide field of view with few-component imaging optics. We have demonstrated a simple fabrication process with reduced cost that takes advantage of the flexible nature of organic electronics by constructing an image sensor using organic field-effect transistors. The transfer process demonstrated in this work can transform organic electronics on polyimide substrates into unconventional three-dimensional shapes that can be applied not only to the artificial eye camera but also to many bio-inspired applications to come.

Introduction:

The conventional camera, due to the planar nature of its imaging sensor, requires elaborate optical components to obtain good quality images. In comparison to the planar geometry, the human eye is an optical system with an attractive hemispherical surface enabling an outstanding imaging system with simple lens design, wider field of view, and low aberrations [1]. Biomimetic-inspired research and product design are transferring optimum designs from nature to technical applications and creating a demand for flexible electronics that will conform to three-dimensional shapes such as the electronic eye camera [2].

Ko, et. al., has created a single-crystalline silicon based hemispherical electronic eye camera using planar semiconductor device fabrication technologies [3]. Islands of silicon diodes and connecting compressible bridges made of metal and polyimide capping layers were used to make an imaging array. The planar layout of the image sensor was released using a hydrofluoric acid etch and mechanical lift-off and transformed using elastomeric transfer elements made of polydimethylsiloxane (PDMS) into a hemispherical geometry.

Organic field-effect transistors (OFET) have many benefits over silicon-diode-based electronics such as low cost; flexible nature; lightweight and potentially easier conformation to the hemispherical sensor. However, organic semiconductors are sensitive to aggressive wet chemical etching. The objective of this project was to design a release and transfer method to conform OFETs to the hemispherical surface using relatively gentle anodic dissolution as a release mechanism. Moreover, we aimed to optimize processing steps such as the bridge and island method. We would then fabricate device structures using the proposed process, and assess the conformity.

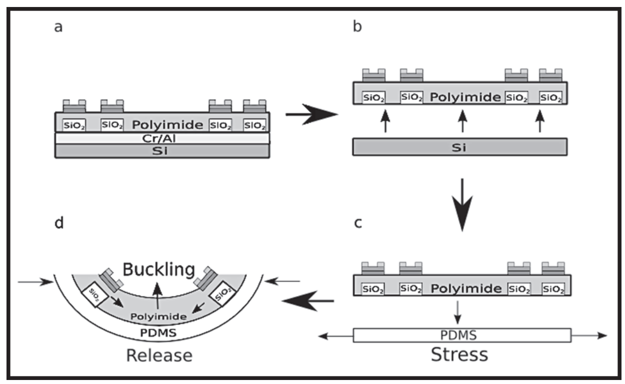

Figure 1: Release and transfer process of OFET based image sensor. A) Device fabrication. B) Anodic dissolution lift-off. C,D) Transformation to hemispherical surface.

Release and Transfer Process:

Figure 1 shows a detailed visualization of the release and transfer process method. The fabrication was carried out on a Si carrier wafer with a Cr/Al sacrificial layer, SiO_2 islands (1 µm thick) and polyimide (1.2 µm thick). The OFETs were stacked on the polyimide supportive layer

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directly above the SiO_2 islands. Following fabrication, the substrate was released from the carrier wafer by anodic dissolution. Using electrolysis, the Cr/Al sacrificial layer was the anode and platinum was the cathode in a NaCl catalyzed solution. Anions were absorbed on the surface of the passive aluminum-oxide layer and caused the breakdown of the passive oxide film, which was then followed by the pitting corrosion of the Cr/Al layer and its release from the carrier wafer [4].

Once the substrate was removed from the carrier wafer it was ready to be transferred onto a transfer element made using Teflon® coated balls placed in a beaker of PDMS that was cured for six hours at room temperature. Both the image sensor and the transfer element underwent ~ 10 seconds of O_2 plasma treatment. The transfer element was then stretched from its hemispherical surface to form a planar surface for O_2 plasma bonding to the SiO_2 islands. The transfer element was then released and the image sensor conformed to the hemispherical surface. Finally, the polyimide support was compressed around the SiO_2 islands causing uniform buckling on the hemispherical surface.

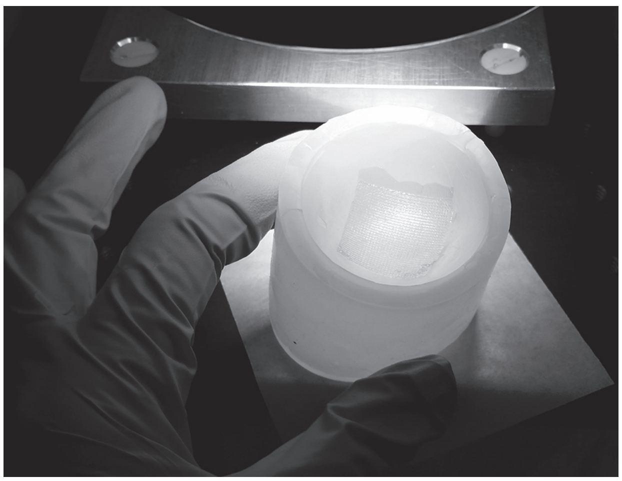

Figure 2: Substrate conformation to hemispherical surface.

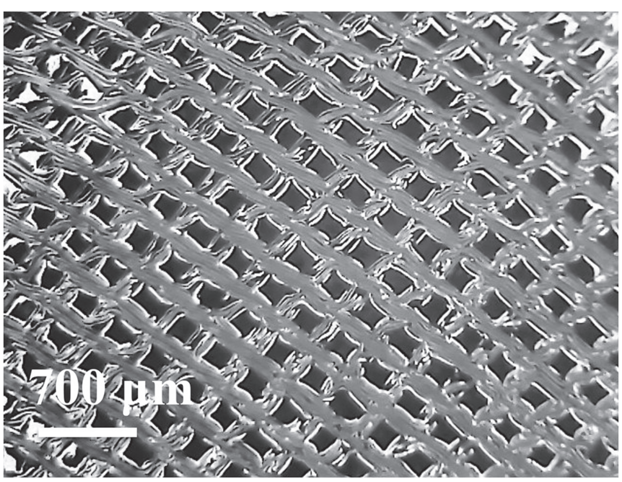

Figure 3: Polyimide and SiO_2 conformation to substrate.

Release and Transfer Process Results:

We were able to reach our project objectives by observing a damage free release of the substrate from the carrier wafer using anodic dissolution, and the successful conformation of the substrate to the transfer element, as seen in Figure 2. By using selective adhesion of the SiO_2 islands to the PDMS transfer elements, we were able to control the contractive buckling of the polyimide in between the bonded regions. According to the images taken with the optical microscope in Figure 3, uniform buckling is observed.

Summary:

We designed an effective release and transfer method for the OFET based image sensor by demonstrating an effective release method for polyimide films sub 2 µm thick, and reducing the production length and cost by eliminating the island and bridge method. For future work we would like to demonstrate the release and transfer method with the full device fabrication and test the electrical and optical performance once the release and transfer process are complete.

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