Additively Manufactured Morphing Structures with Embedded Smart Actuators

Danayit Mekonnen, Stanislav Sikulskyi, Zefu Ren, Aleiya Holyoak, Natalia Thackorie, Dr.Daewon Kim

Abstract

Observing volant creatures has demonstrated that adapting the shape of the wing to the changing flight environment increases flight efficiency and performance. Current aerial vehicles have stiff aerodynamic surfaces that limit any adapting capability. The development of the concept of fully morphing structures is enabling the creation of bio-inspired, adaptable structures with outstanding performance. However, current morphing structures suffer from poor implementation that often brings more drawbacks than advantage to the final product. This research focuses on an effective implementation of morphing technology to fully realize it's potential. This can be achieved by employing a novel additive manufacturing method that can fabricate morphing structures with integrated and distributed actuation systems. Dielectric elastomer actuators (DEAs) are one of the most intensively studied soft, smart actuators due to their promising electromechanical properties. As such, this project utilizes DEAs as the primary material for the morphing structure. Preliminary work has been completed in selecting and validating the additive manufacturing method as well as material selection and improvement. The main goal of this research is to implement additive manufacturing coupled with morphing structures to design, build and test a fully morphing wing structure suitable for small aerial vehicles.
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Figure 1: Morphing wing with active cellular structure (2017 Jenett, B., Calisch, S., Cellucci, D., Cramer, N., Gershenfeld, N., Swei, S., & Cheung, C. K. (2017). Digital Morphing Wing: Active Wing Shaping Concept Using Composite Lattice-Based Cellular Structures. Soft Robotics, 4(1), 33-48.

Methodology

- Estimate DEA's actuation capabilities through numerical analysis.
- Perform a thorough study on electrode and dielectric elastomer materials for morphing structure application.

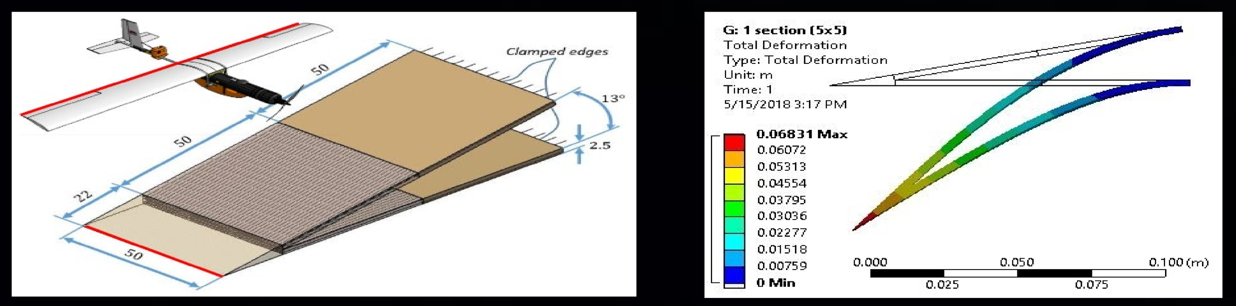
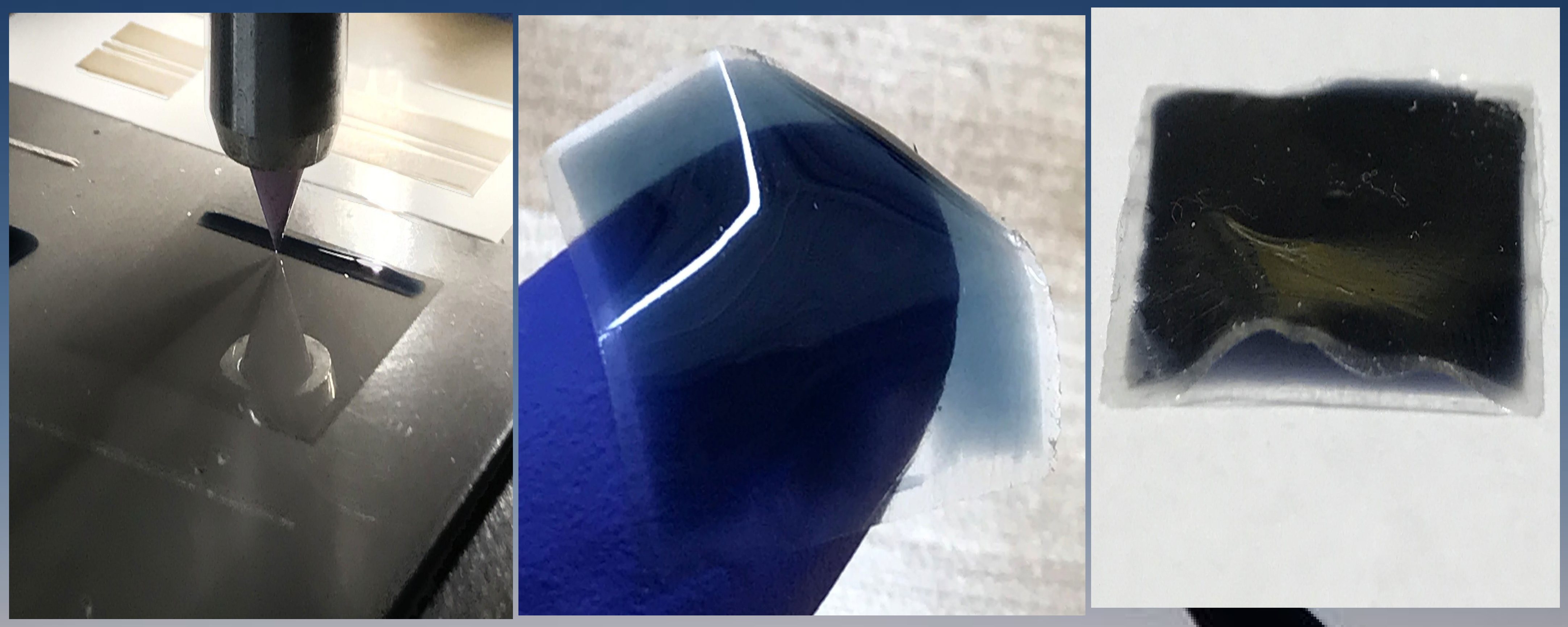


Figure 2 : CAD model of a UAV wing trailing edge (left) with embedded DEAs and FEM simulation of its deflection capabilities (right)

- .Select and validate additive manufacturing method that is applicable for DEAs.
- Adjust the additive manufacturing method specifically for printing
  - a. Individual DEAs.
  - b. Structures with integrated DEAs.
- Conduct testing on the 3D printed actuators and simple structures with integrated DEA to validate their performance and evaluate fabrication quality.
- Manufacture DEA embedded morphing structure for a small UAV wing and validate its performance through testing.

Results

- Validated the ability to 3D print DEAs..



.Figure 3. First successfully printed samples of silicon and electrode material via microdispensing

- Selected dielectrics and elastomeric material through testing.

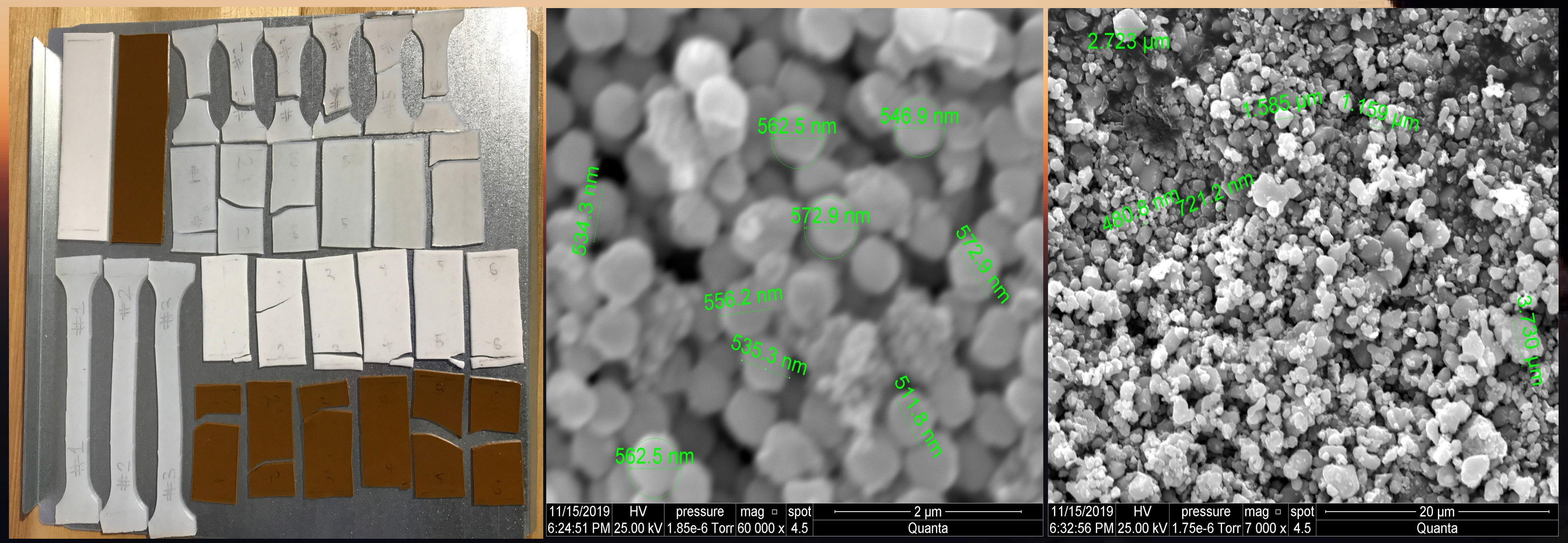


Figure 4: **Coupons for material testing (left) with Barium Titanate (center) and Calcium Copper Titanate (right) fillers Scanning Electron Microscope (SEM) pictures**

- Currently a work in progress, Hyrel 30 M 3D printer has been set up and an initial layer of elastomer has been printed.

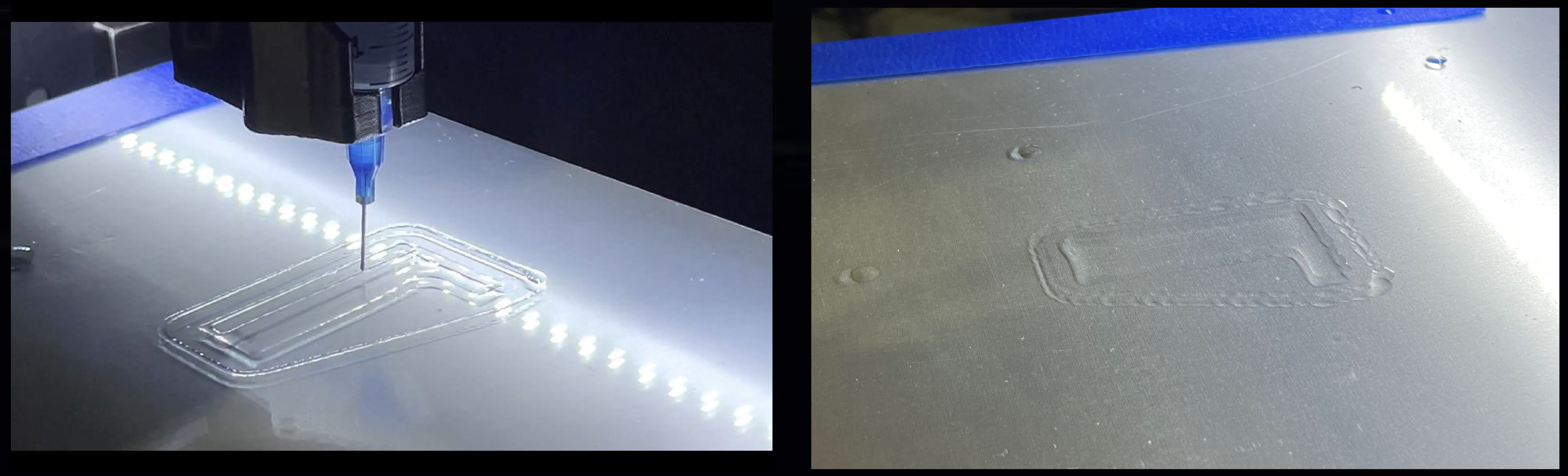


Figure 5 Images taken while printing Sylgard 184

Conclusion

- Utilizing smart actuators coupled with additive manufacturing would address the need for an embedded structure that demonstrates homogeneous functionality. As previously stated, morphing structures have the conflicting requirements of being soft enough to enable change but stiff enough to withstand load. By coupling 3d printing with DEA, the realization of manufacturing a structure with embedded, distributed actuators that can enable wing morphing while withstanding load could be possible.
- Through the coupling of additive manufacturing and DEA, this project could demonstrate the feasibility of realizing morphing wings. Current research is mostly theoretical with lack of experimental validation. This project could enable a shift to more experimental research.

Future Work

- Continue printing until a stacked DEA with expected desired results is produced.
- Utilize the three headed printer to embed the DEA into the tailored frame.
- Once integrated system is printed, proceed to test and implement on a small UAV to validate morphing skin.
- Produce a manuscript to be published and share information through conferences.

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