Origami for Dexterity in Miniature Manipulation and Testing

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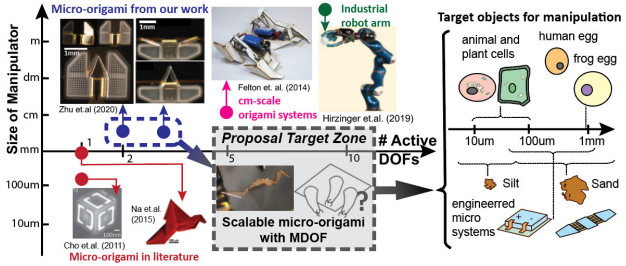
Motivation and Objective

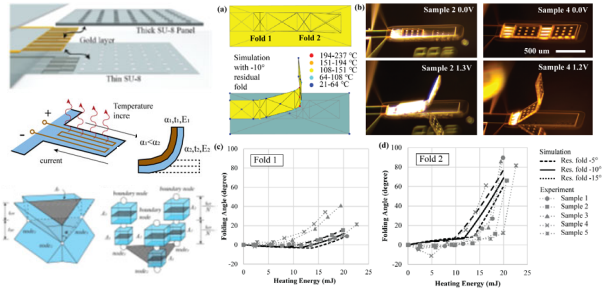
Challenge: Existing micro-robotic systems have limited dexterity for complex motions, active manipulation, and object sensing.



Objective: Establish integrated methodology for fabrication, analysis, design, sensing, and control of multi-degree-of-freedom *miniature origami* for dexterous manipulation and testing of physical matter.

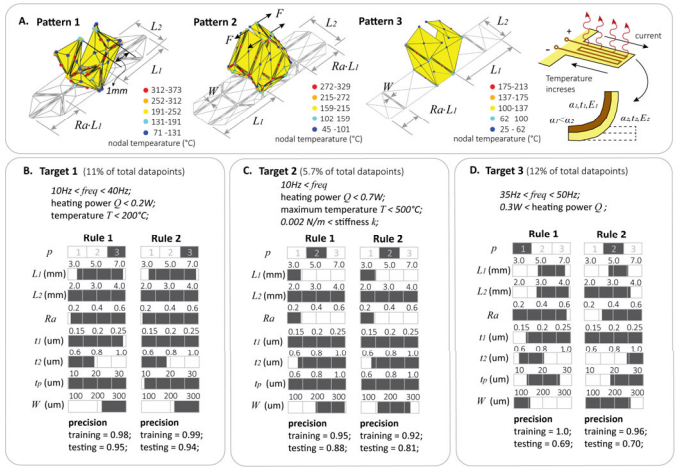
Aim A. Enable multi-scale fabrication of MDOF micro-origami
Aim B. Rapid simulation and task-specific inverse design
Aim C. Integrate sensing and control capabilities

Simulation of Electro-Thermal Micro-Origami



Achievement: New rapid simulation to capture the folding motion and electro-thermo-mechanical coupling in the micro-origami. These models are made publically available. (see Ref. 3 and Ref. 4)

Machine Learning for Inverse-Design of Origami



Achievement: Interpretable machine learning for design of multi-physical active origami. Method can select between categorical variables (e.g. origami pattern) while also optimizing continuous features. (Ref. 2)

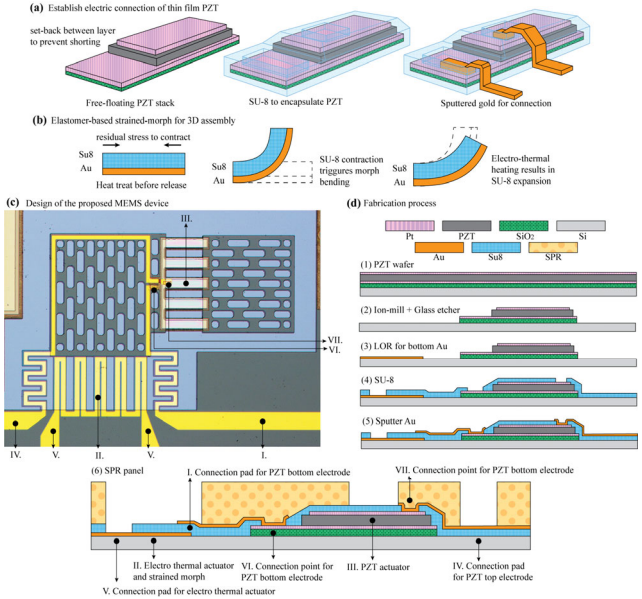
Scientific Impact

- Micro-origami with increasingly complex MDOF motions will be fabricated and investigated to give insight to practical challenges.
- New simplified analytical models to simulate complex folding behaviors in active origami and to enable inverse design for functional tasks.
- Develop new sensor integration and control protocols for micro-origami systems to achieve advanced sensing and manipulation.

Broader Impacts

- Enabling widespread application of micro-manipulators for extraction and testing of organic cells, micro-system packaging, testing of granular matter, micro-robotic arms and more.
- Hands-on origami activities to engage Girls in Science and Engineering
- New course on origami and research opportunities for transfer students

Integration of PZT for Sensing and Precise Actuation



Achievement: Fabrication approach integrates thin-film PZT materials with electro-thermal micro-origami systems to enable sensing, precise actuation, and control. (Ref. 1)

References & Products

1. Yi Zhu, Joonyoung Yu, Kenn R. Oldham, Evgueni T. Filipov, **2022**, Folding 3D Thin-Film PZT Micro-Systems Using Electro-Thermal Actuation. **(In Preparation)**
2. Yi Zhu, Evgueni T. Filipov, **2022**, Origami Feature Design and Pattern Selection with Interpretable Machine Learning. **(In Preparation)**
3. Yi Zhu, Evgueni T. Filipov, **2021**, Rapid Multi-Physics Simulation for Electro-Thermal Origami Systems, *International Journal of Mechanical Sciences*, 202-203, 106537.
4. Yi Zhu, Evgueni T. Filipov, **2021**, Sequentially Working Origami Multi-Physics Simulator (SWOMPS): A Versatile Implementation, *2021 IDETC & CIE Conference*, DETC2021-68042. August 17th –19th 2021 Simulation package available at: https://drsl.engin.umich.edu/software/
5. Yi Zhu, Mayur Birla, Kenn R. Oldham, Evgueni T. Filipov. **2020**. Elastically and Plastically Foldable Electrothermal Micro-Origami for Controllable and Rapid Shape Morphing. *Adv. Funct. Mater.* 2003741.

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