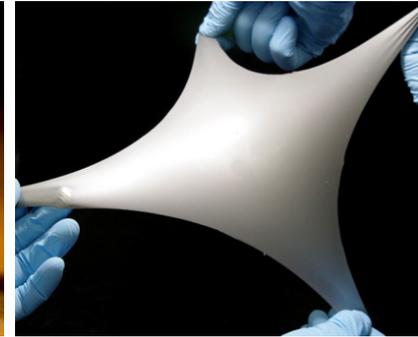
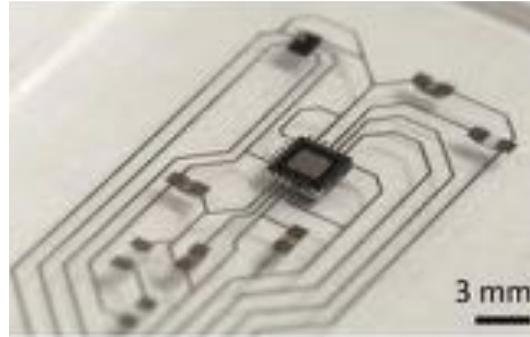
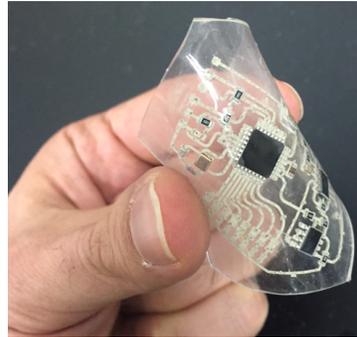
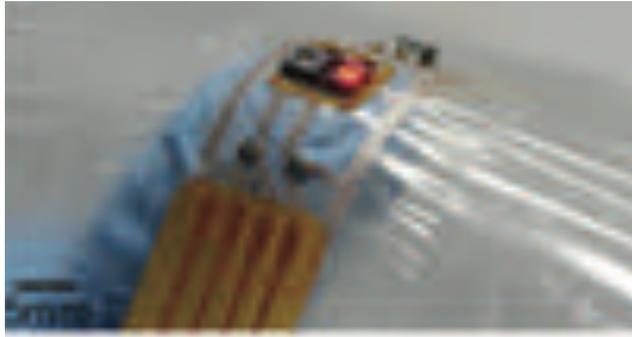


# Intelligent Soft Materials for Sensing & Robust Actuation



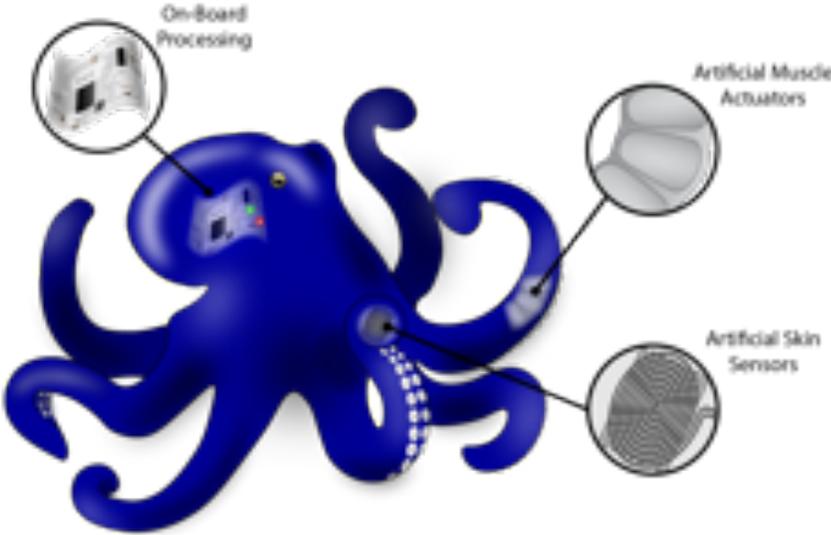
**Carnegie  
Mellon  
University**

**Carmel Majidi**  
Mechanical Engineering  
Carnegie Mellon University  
Pittsburgh, Pennsylvania  
cmajidi@andrew.cmu.edu

**Soft Machines Lab**  
<http://sml.me.cmu.edu>



# AUTOMONOMOUS SOFT ROBOT

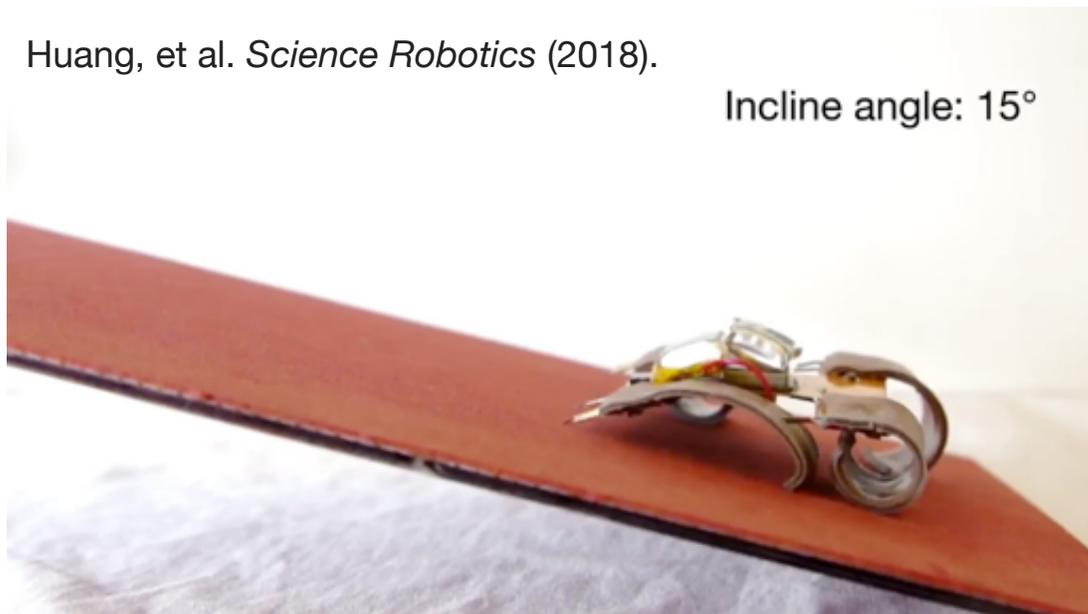


		Modality	
		Sensing and Circuitry	Actuation
Methods of Achieving Functionality	Deterministic	i 	ii Unactuated   Actuated 
	Fluidic	iii 	iv 
	Bio-hybrid	v 	vi 

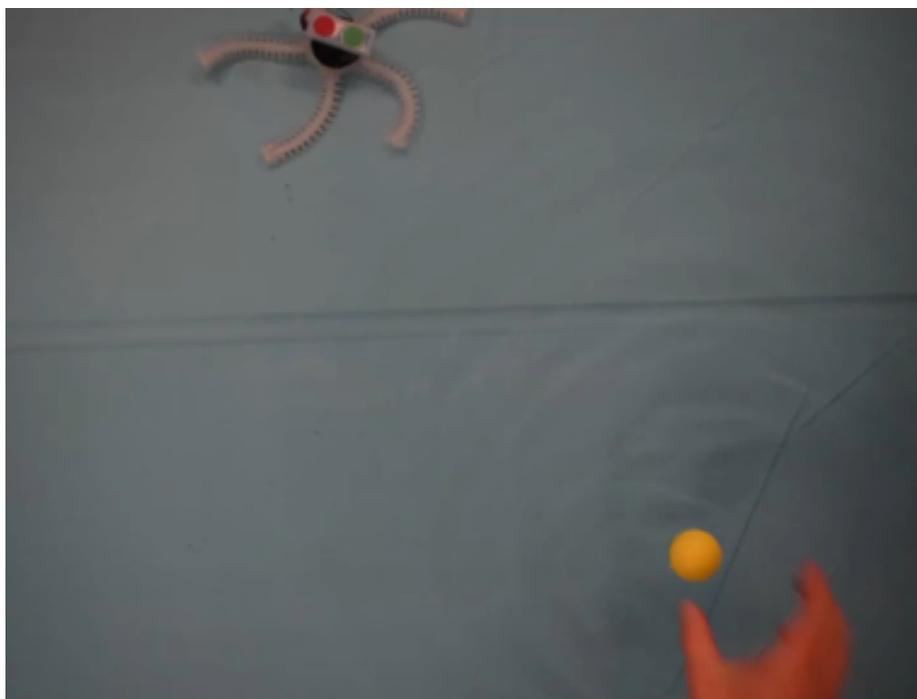
# SOFT ROBOTS WITH SHAPE MEMORY ALLOY

Huang, et al. *Science Robotics* (2018).

Incline angle: 15°



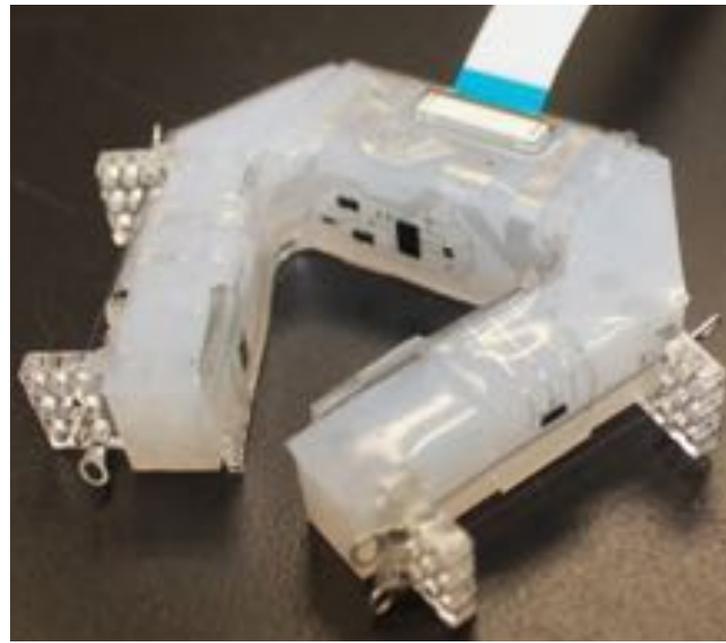
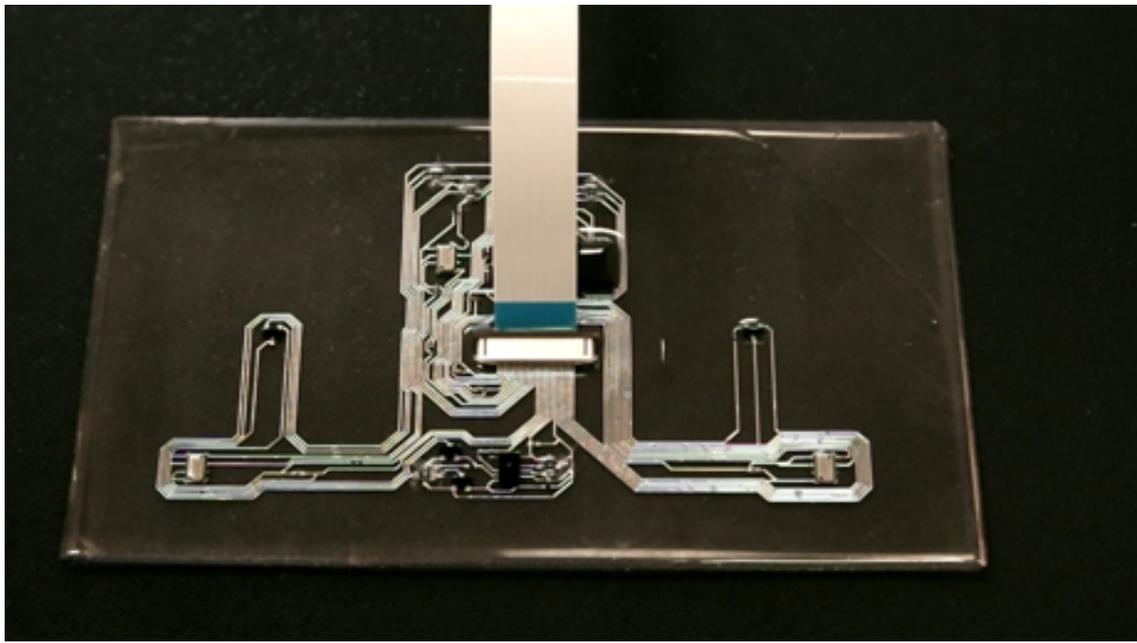
Patterson,  
Sabelhaus, Chin,  
Hellebrekers, Majidi,  
IEEE IROS 2020



Xiaonan  
"Sean"  
Huang



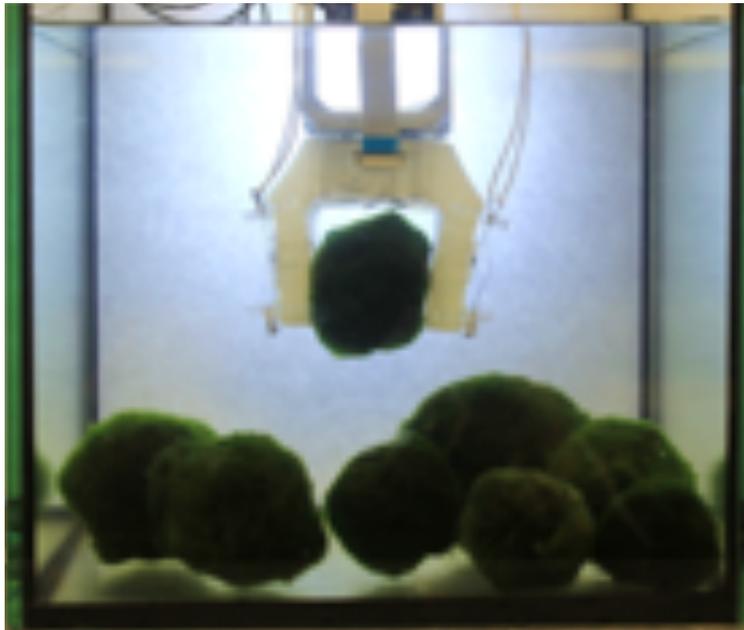
Zach  
Patterson



Tess  
Hellebrekers



Jessica Yin



Hellebrekers, et al., *IEEE IROS* 2018

Closed-Loop Control with  
Liquid-Metal Hybrid Electronics  
and Binary Soft Gripper

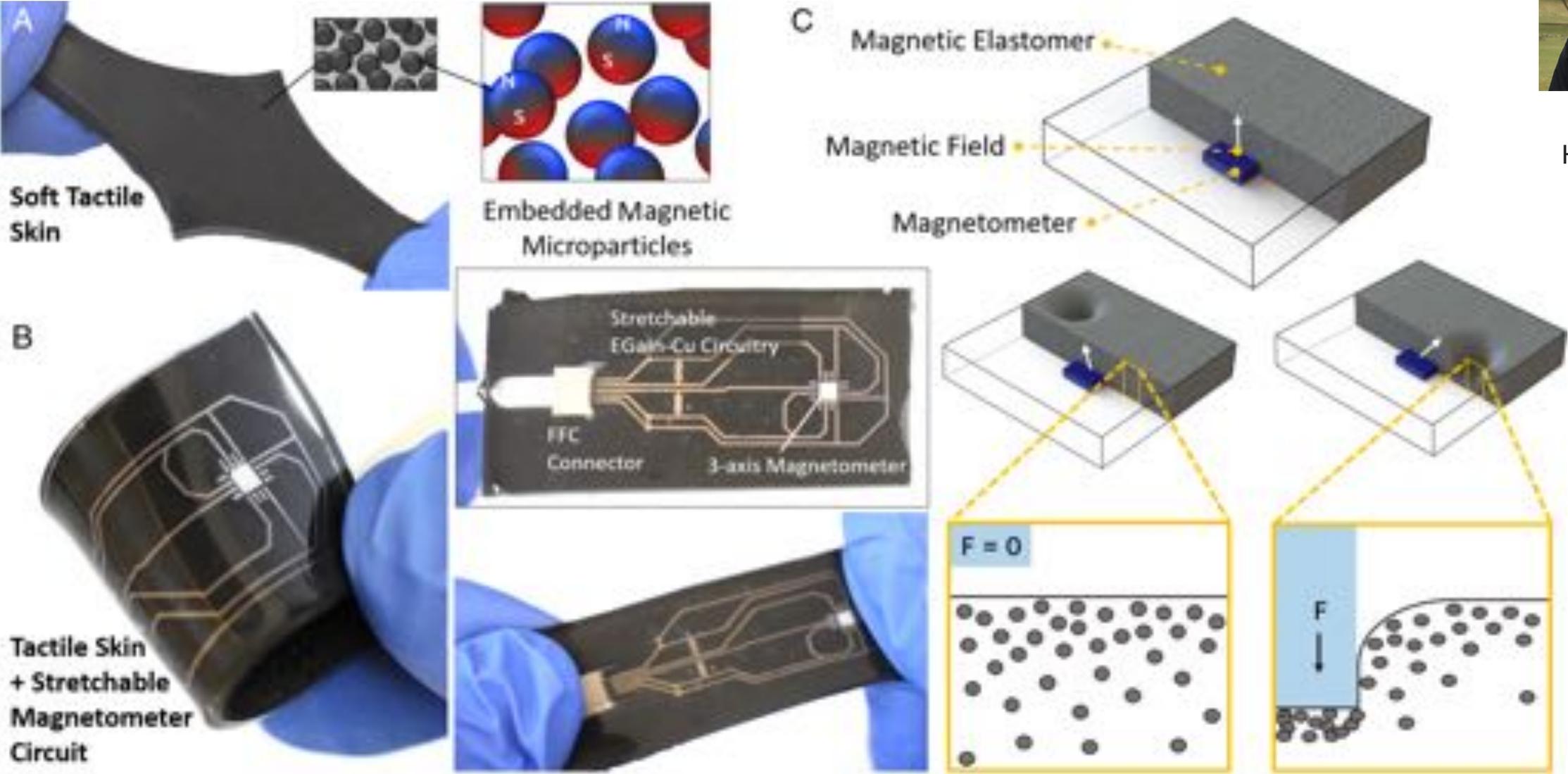
Jessica Yin, Tess Hellebrekers, and Carmel Majidi  
Soft Machines Lab  
Carnegie Mellon University

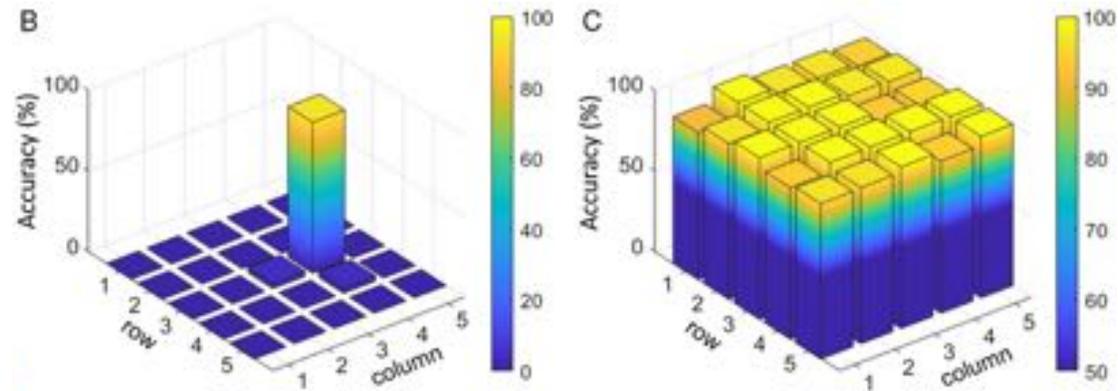
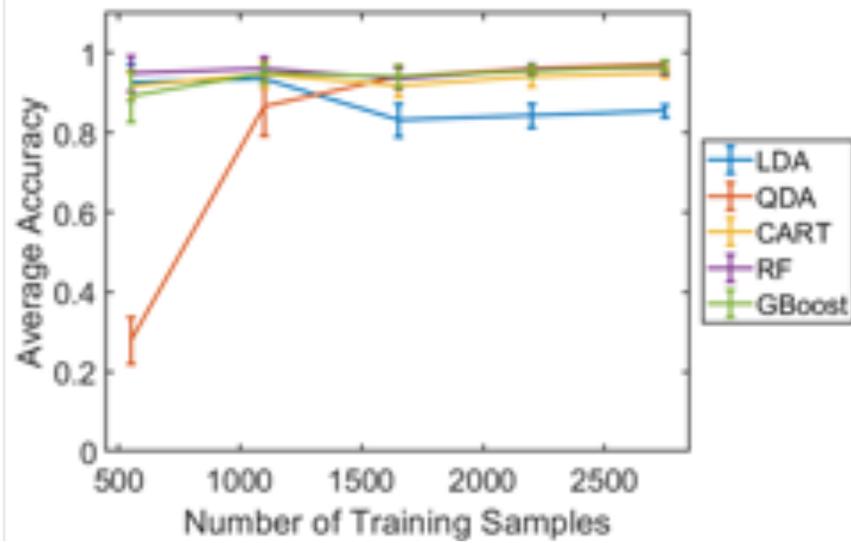
Yin, et al. *IEEE RoboSoft* 2020

# SOFT MAGNETIC TACTILE SENSOR

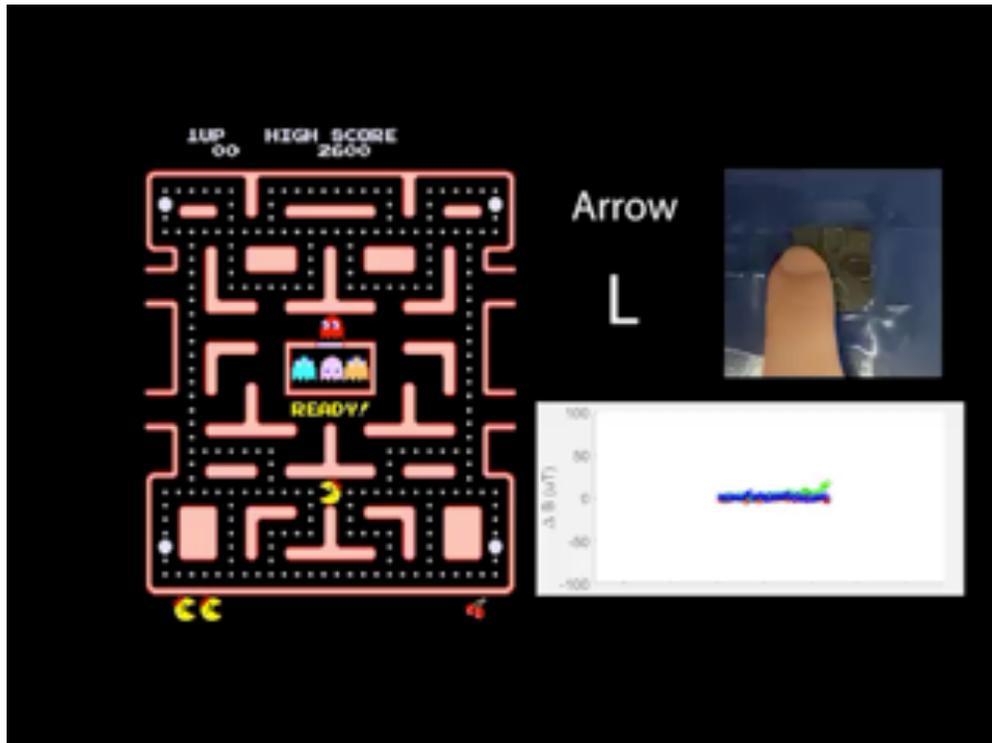


Tess Hellebrekers





Hellebrekers, Zhang, Veloso, Kroemer, Majidi, *IEEE IROS*, 1(4), p.1900025 (2020).



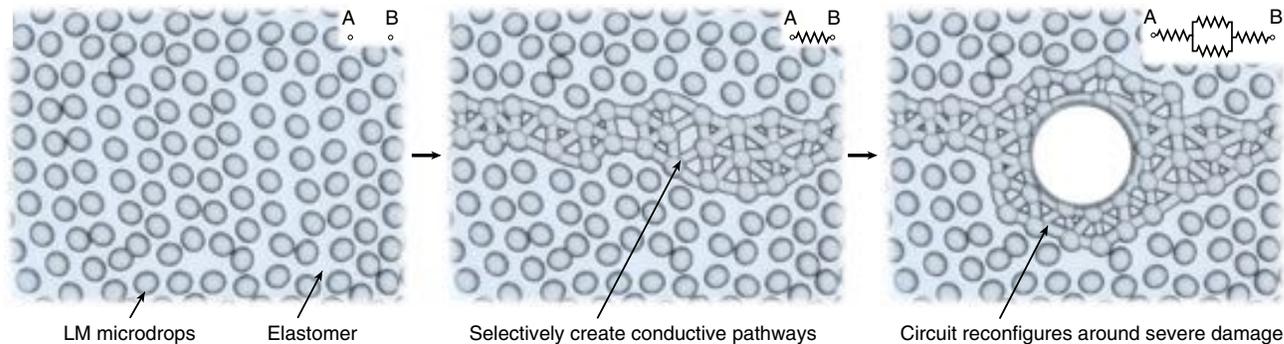
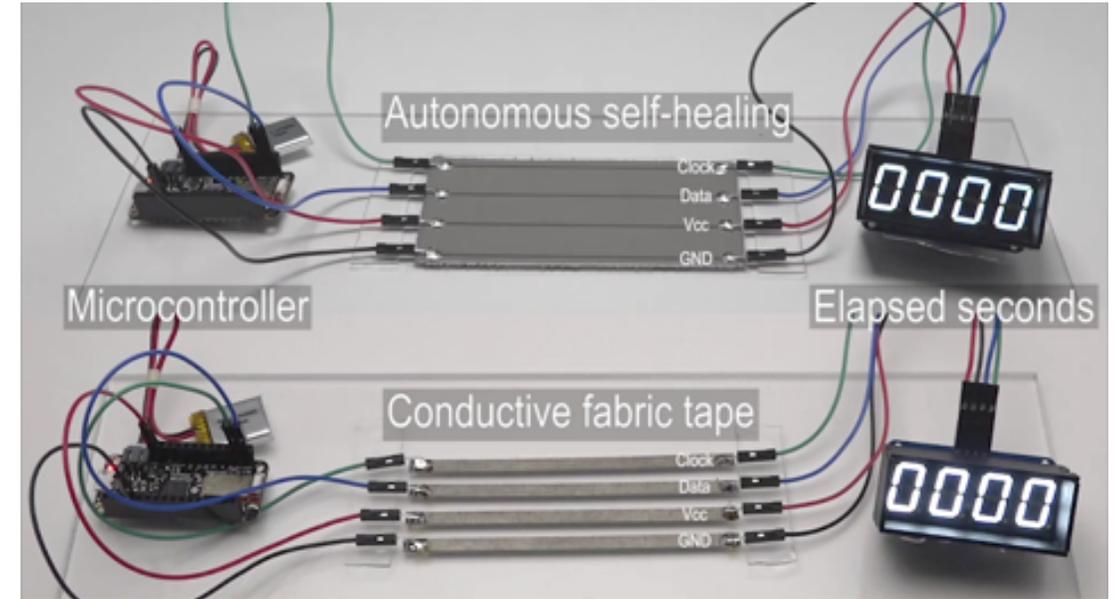
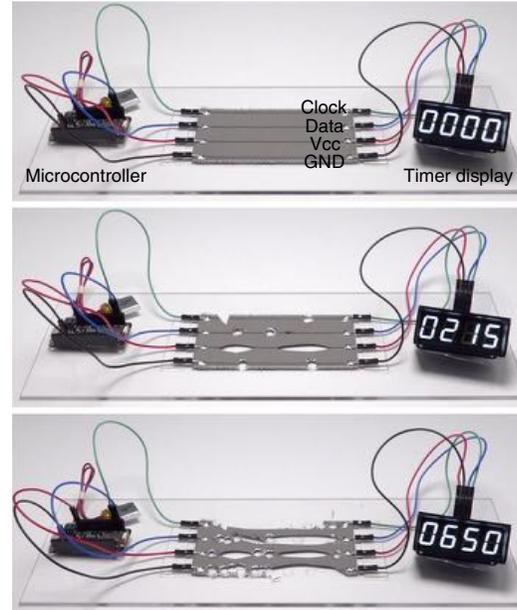
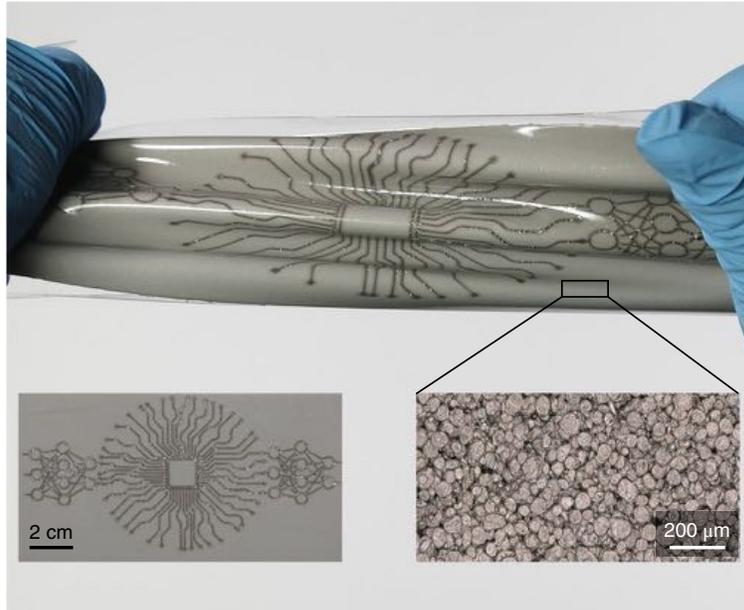
# Localization and Force-Feedback with Passive Soft Magnets for Robotic Manipulation

Tess Hellebrekers, Kevin Zhang, Manuela Veloso, Oliver Kroemer, Carmel Majidi

Carnegie Mellon University

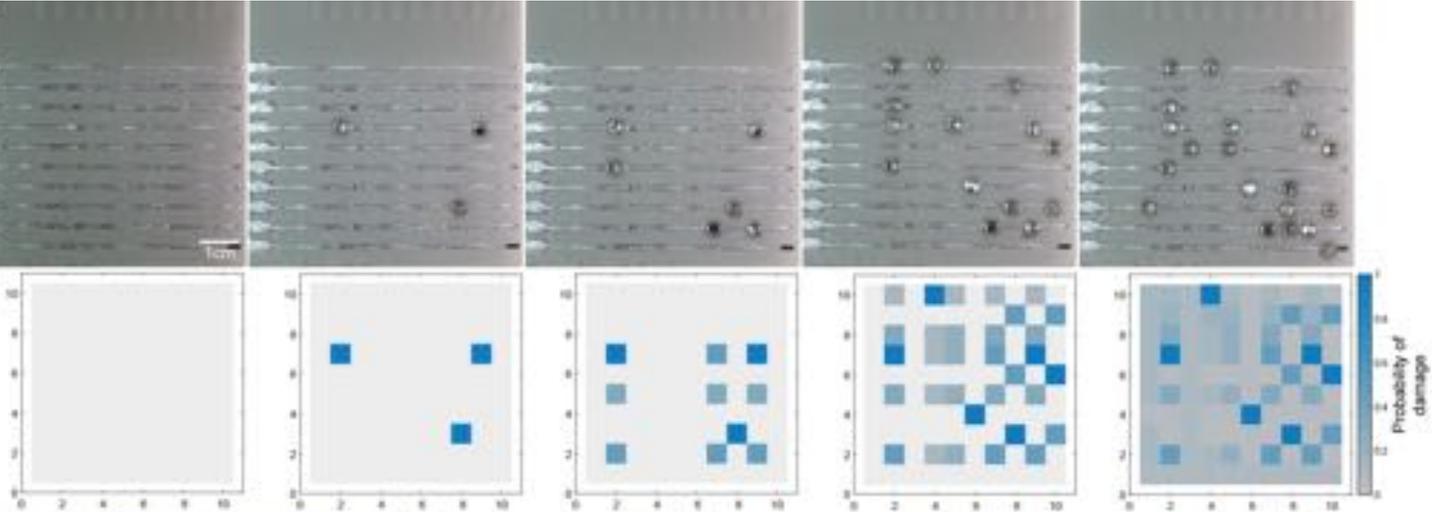
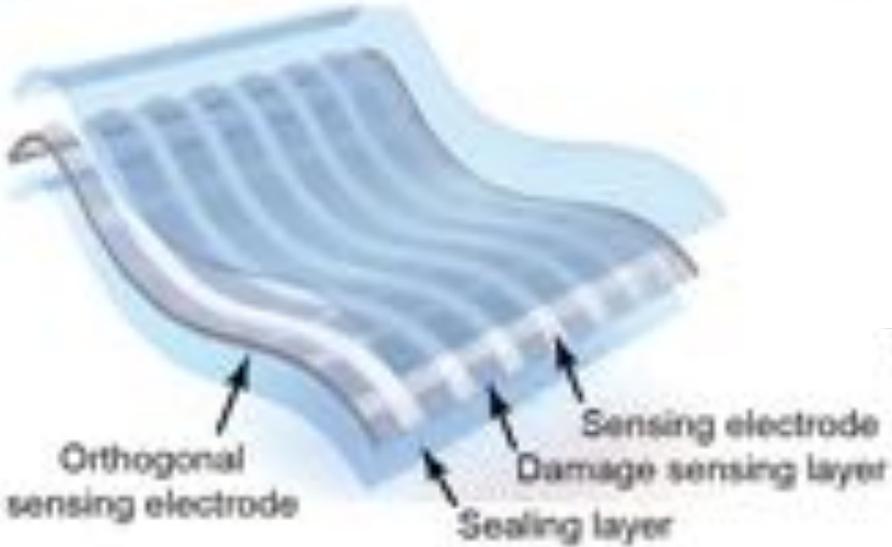
# ELECTRICAL SELF-HEALING LM-POLYMER COMPOSITES

## “Self-Healing” Electrical Wiring

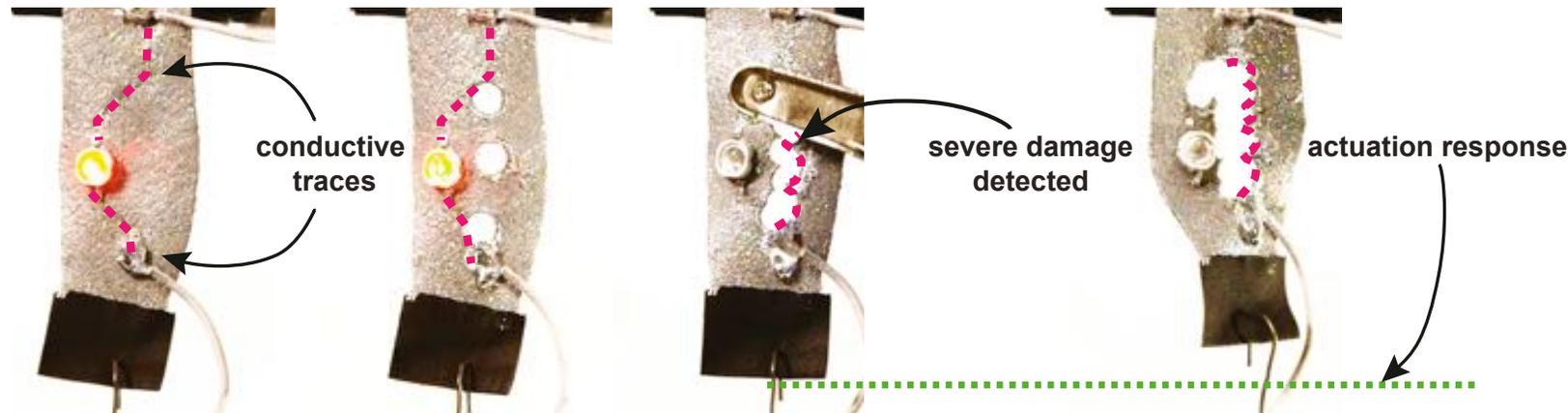
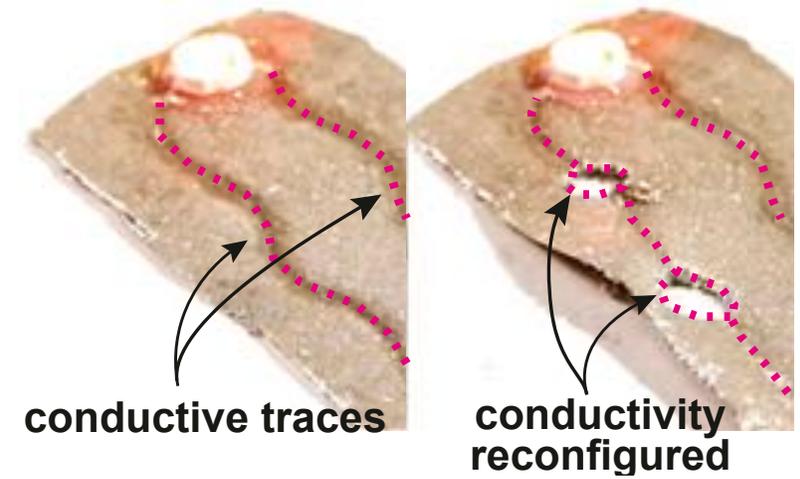
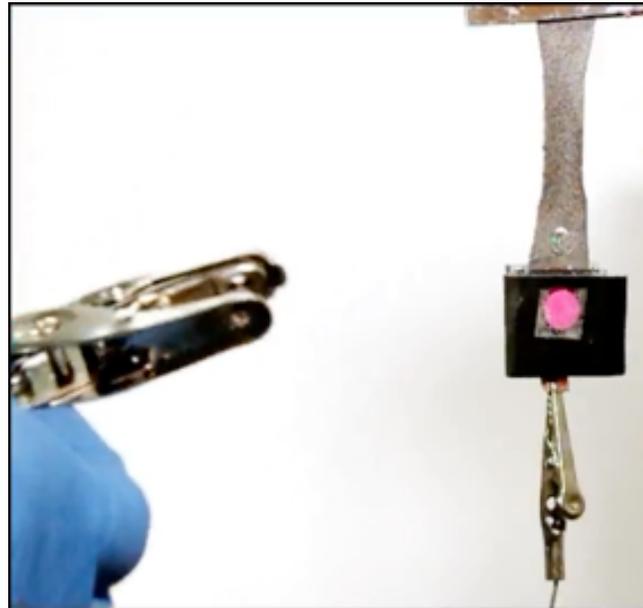
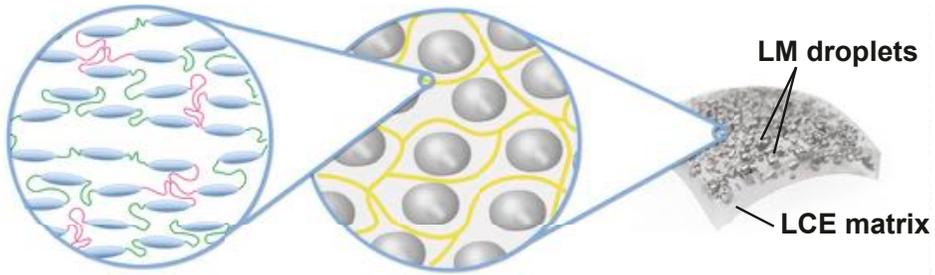


# ELECTRONIC DAMAGE DETECTION

Markvicka et al. *Adv. Funct. Mater.* 2019

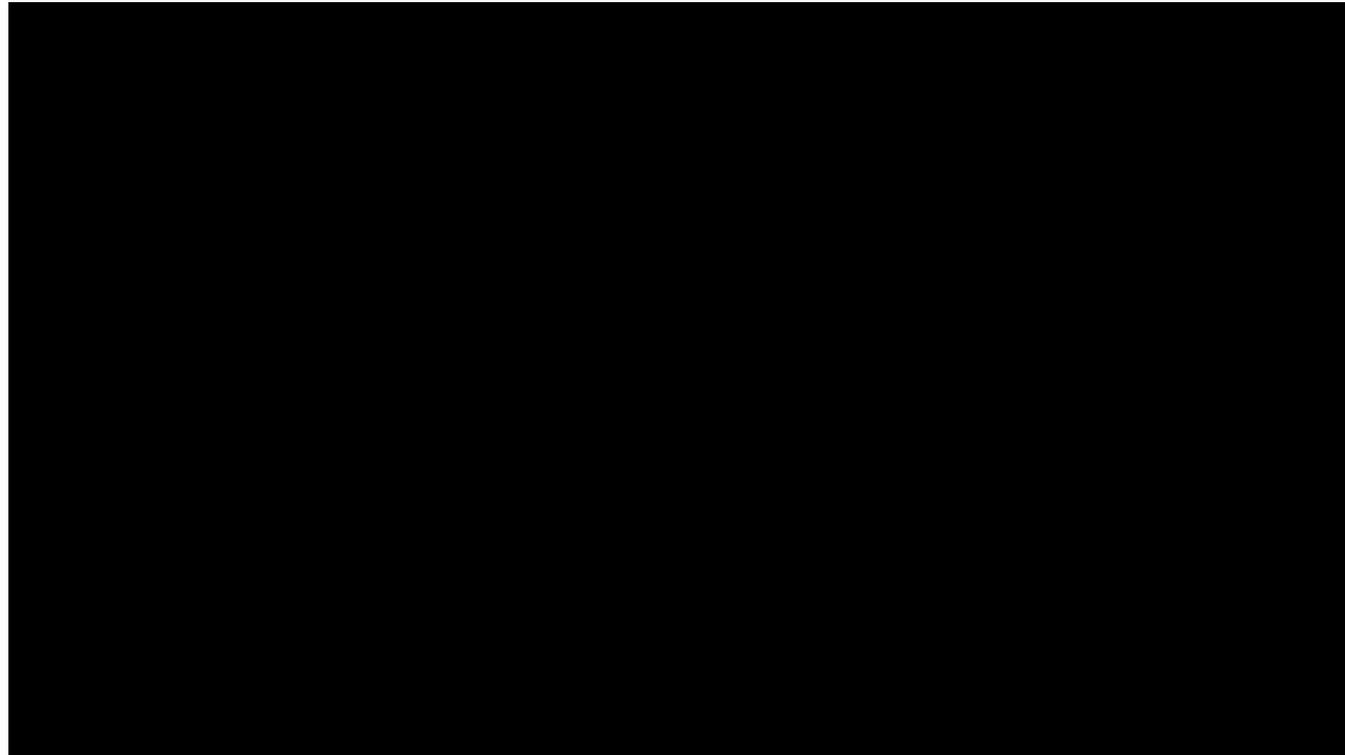
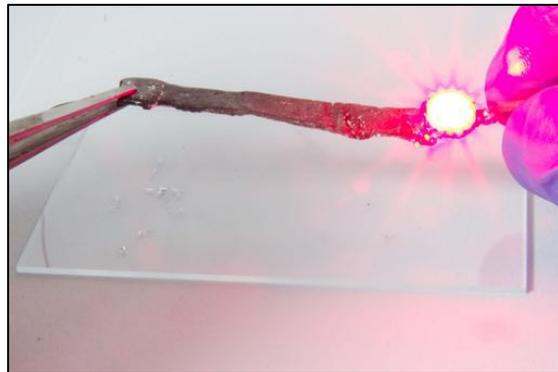
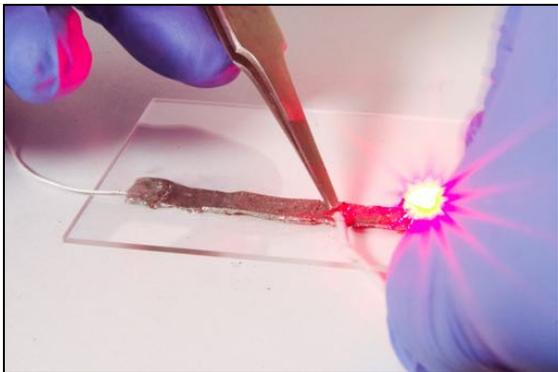
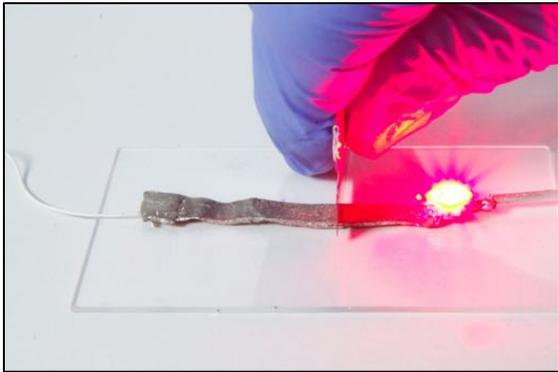


# LM-LCE LIQUID METAL + LIQUID CRYSTAL ELASTOMER



Michael Ford et al.  
*PNAS* 2019

# SELF-HEALING & REPROGRAMMABLE LM-POLYMER COMPOSITES



# INTELLIGENT SOFT MATERIALS

## How can materials be intelligent?

- Use sensory information to make decisions and perform tasks
- Maintain robust functionality through adaptation
- Reprogrammable such that the same material can achieve various sensing or motor functions
- Process information for MIMO functionality

## Why does this matter?

- Materials can exhibit intelligence but not be very useful
- Should we develop intelligent materials first and find applications later?
- Can biomimetics be useful in designing intelligent materials?