WEEK 4

Article: Liu *et.al.*, Electronically configurable microscopic metasheet robots, *Nature Materials*, 2024.

QUESTIONS 4b

1. How does the oxidation-reduction cycle make the unit cells expand and contract? Two other mechanisms are mentioned, namely adsorption/desorption and absorption/desorption. Are these two mechanisms acting in the same way? The authors propose to improve durability by using an adsorption-desorption of OH- driven actuation instead of oxidation-reduction. What would be the modifications needed in order to change the chemical reaction in the hinge from redox to adsorption-desorption of OH-? And how could it impact the bending performance?

2. The authors use a voltage range of -0.5V to 1.0V to drive the platinum-based electrochemical actuators. Given that higher voltages could theoretically increase actuation speed and deformation amplitude, why was this specific voltage range chosen? Would operating at voltages beyond 1V lead to faster response times, or would it introduce undesirable effects? In the paper, it is written that the reaction can take place more than 1000 cycles before due to corrosion. Does corrosion reduce bending efficiency over time? Does the reaction become slower or create a smaller angle? The reaction is said to be directed by electrical wires. Do the wires activate a specific hinge or a zone of several hinges?

3. Figures 4a and 4c illustrate how phase-delayed actuation of the head and tail regions leads to locomotion. How could modifying the phase offset between these regions influence both the speed and directionality of movement? In The robot is able to crawl in the direction of its head due to the asymmetry in his design. How does this design could be modified, if possible, to make the robot crawl in both direction or even turn?

4. Figures 2e–h graph the curvature distribution of the tethered metasheet. How would free-boundary condition alter these curvature profiles? It is explained in the paper and shown in Supplementary Fig 7e,f that the metabots with the square tessellation can not actuate when the boundary is fixed. Could you explain in more detail why? Is there a theoretical limit for the achievable Gaussian curvature using this metasheet design? Normally, we expect structures to settle into low-energy configurations. Why do some actuation pathways lead to high elastic energy and asymmetric deformations rather than finding a more relaxed shape? Could this be exploited to create metastable states that enable shape memory or programmable stiffness?

5. During the reduction phase, the micro-splay origami linkage is expected to be fully folded, achieving an areal expansion ratio (λ) of 1.2, while the linkage should gradually close during oxidation. However, why does the maximum expansion ratio (λ=1.4) occur during the oxidation process (when the voltage relative to Ag/AgCl reference electrode is increased)? In Figure 2a, the authors show how the effective area of an individual unit cell changes with voltage. Could you elaborate on the physical or structural reasons why the unit cell expands further at intermediate voltages before contracting again? Additionally, why does the transition back to an open state occur over a narrower range of voltages? The paper also notes that the areal expansion ratio λ increases up to a peak value ($\lambda \approx 1.4$) and then decreases to a minimum ($\lambda \approx 1.0$) as the linkage flattens — what determines these peak and minimum values of λ?