WEEK 4

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

QUESTIONS 4a

1. The paper states that, based on the Nernst Equation, changing the temperature will change the driving voltage. How exactly would that change of temperature relate to the driving voltage? Could a different temperature allow for the maximum actuation frequency to be increased?

2. The triangular panels contain holes allowing access to the sacrificial layer for etching during the fabrication process. How do the holes in the triangular panels affect the performance and durability of robots, and could their design be optimized? Do they influence flexibility, actuation speed, or structural integrity? Could adjusting their size, shape, or placement improve energy efficiency or enable new functionalities?

3. The actuation mechanism of the metasheet robots exhibits notable hysteresis in the SEA response, particularly in the transition between folded and flat configurations (Figures 2b,c). In what types of applications could this hysteresis be strategically harnessed rather than minimized? What trade-offs would this entail in terms of actuation responsiveness, energy efficiency, and control precision? Hysteresis in the electrochemical actuation shows that the deformation response lags behind applied voltage changes and retains memory of previous states. How does this hysteresis affect actuation repeatability and locomotion accuracy? In Figure 2b the cyclic voltammetry shows a current down peak when the voltage is around -0.25. What is the reason for this peak?

4. The article states that the measured center-of-mass (COM) speed exceeded the theoretical friction-limited velocity, with experiments showing speeds over 50 μm/s, while theoretical calculations based on friction and hydrodynamic viscosity predicted a maximum of 3.2 μm/s. What factors could explain this discrepancy? Why is friction alone insufficient to explain its movement, and what role do lubrication forces play in this process? What experimental setup could isolate and confirm the role of lubrication forces in locomotion?

5. Figure 2c shows a unit cell switching between states in roughly 100 ms, limiting the maximum actuation frequency to about 5 Hz. Why is this frequency limit observed, and which factors—such as redox reaction kinetics, viscous damping from the fluid environment, or mechanical deformation rates—primarily set this operational constraint? What happens if the command delay is lower than the mechanical delays of the structure to change its position? What would be the resulting geometry of the shape? May this structure get into resonance mode? Why is the switching time in both directions identical, although the voltages are not the same? Hinges can move through multiple steps like open, closed, or anything in betwen. Would it be possible to control them to keep a hinge at a specific angle anywhere between 0° and 180°, rather than just flipping between fully open or fully closed?