Supplementary Information for "A Wirelessly Controlled Shape-Memory Alloy-Based Bistable Metal Swimming Device"

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This file includes:

Figures S1 to S12

Movies S1 to S10

Other Supplementary Materials for this manuscript include the following:

Movies S1 to S10

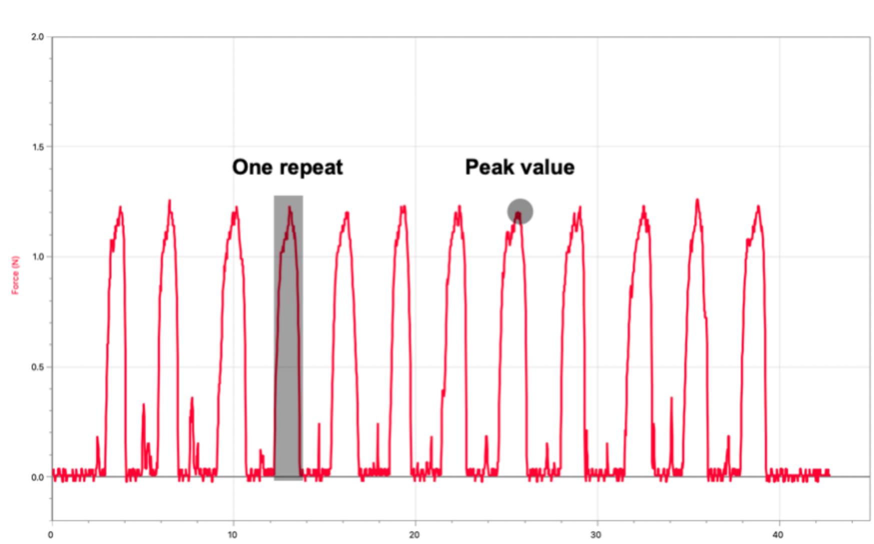

Figure 1: Figure S1. Force-Time diagram recorded on Logger Pro software (Reset for 4-3 taper ratio at 60 degree angle). Each spike represents the force evolution for one test repeat (e.g., dark rectangle). The peak values are picked (e.g., dark circle) and analyzed to represent the force required to reset the metal strip.

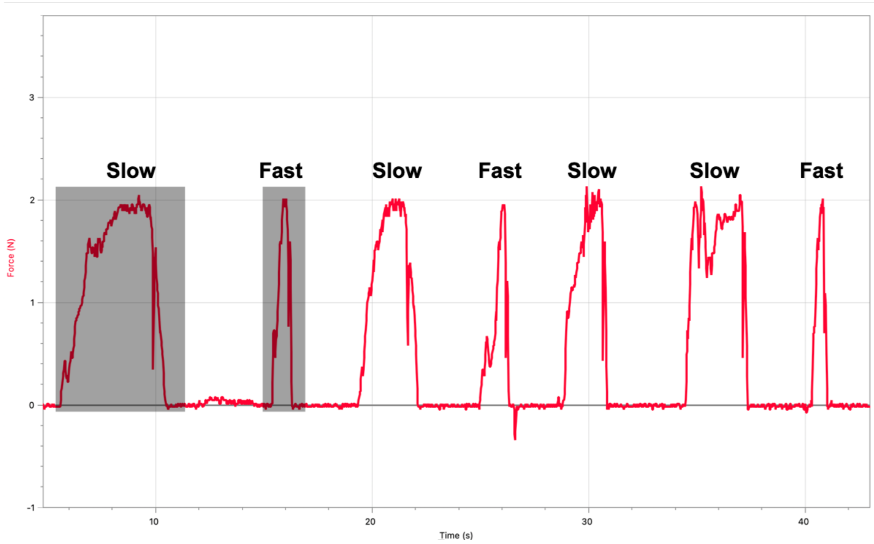

Figure 2: Figure S2. Force-Time diagram recorded at different pulling rates. Slow rate was about 2 cm/s, fast rate was about 10 cm/s. Different pulling rates yielded similar peaks indicating similar forces.

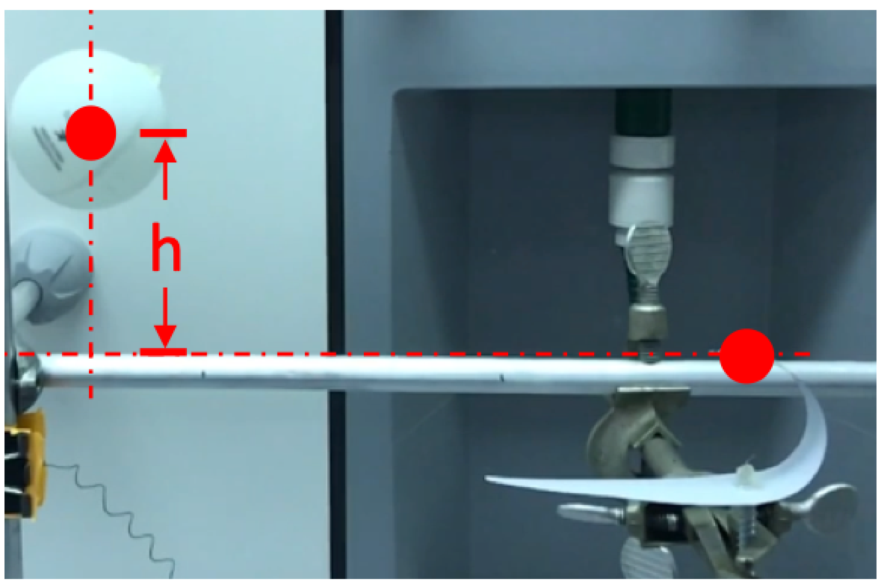

Figure 3: Figure S3. Setup of ping pong ball test for determining bistable metal strip snapping energy output. (Bottom right red dot represents the initial position of ping pong ball; top left red dot represents the highest position the ping pong ball reaches; the height elevation is marked by the vertical height difference between the two positions)

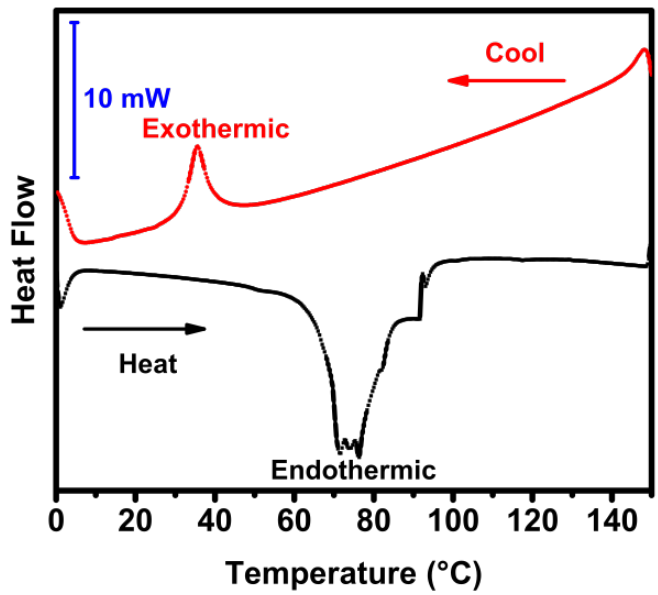

Figure 4: Figure S4. Differential scanning calorimetry result for a piece of Nitinol. Black curve is the heating process and red for cooling. The blue scale bar for Y-axis represents 10 mW heat flow difference.

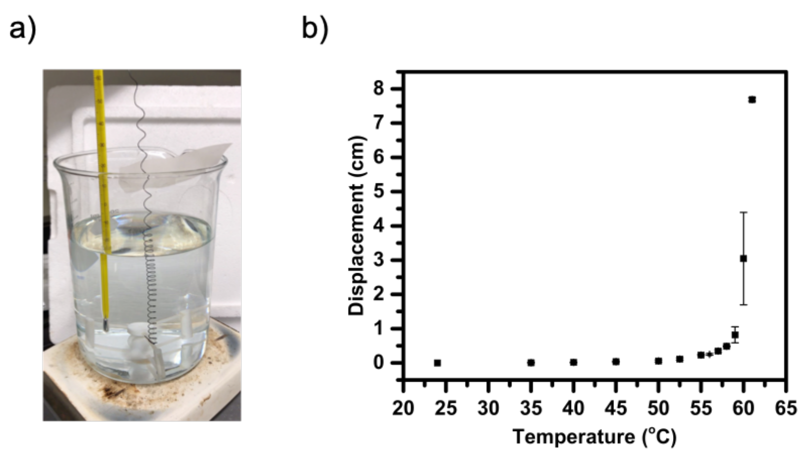

Figure 5: Figure S5. **a)** Setup for water bath actuation temperature test **b)** Plot of displacement of Nitinol coil at the indicated temperatures.

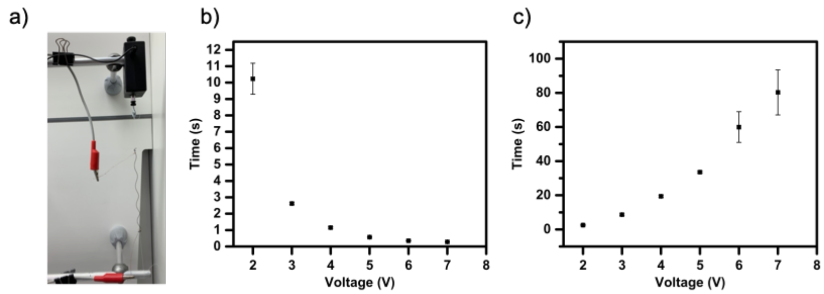

Figure 6: Figure S6. **a)** Setup for no displacement actuation test (stretched Nitinol wire tied one end to the hood accessory bar, the other to a force sensor (black); red alligator clips with copper wire to apply voltage onto the Nitinol wire). **b)** Time needed for actuation at different voltages. **c)** Normalized cooling time for different voltages per unit time of heating.

Figure S7. Joule heating calculation. Assume pure resistance circuit, Ohm's law applies and no resistance change. $I=U/R$, $H=I^2Rt$. I is current; U is voltage; R is resistance; t is time; H is the heat produced. If we assume heat capacity does not change and the heat is use for temperature increase, $\Delta T=Q/mc$, $Q=H$. ΔT is temperature change; m is mass, c is specific heat capacity.

Figure S8. Swimming calculation. Slow swimming speed is calculated based on Video S3 4.42 sec to 6.04 sec. Snapping mode swimming speed is calculated based on Video S4 5.83 sec to 7.03 sec. 180 degree turning calculation is based on Video S5 6.36 sec to 16.34 sec.

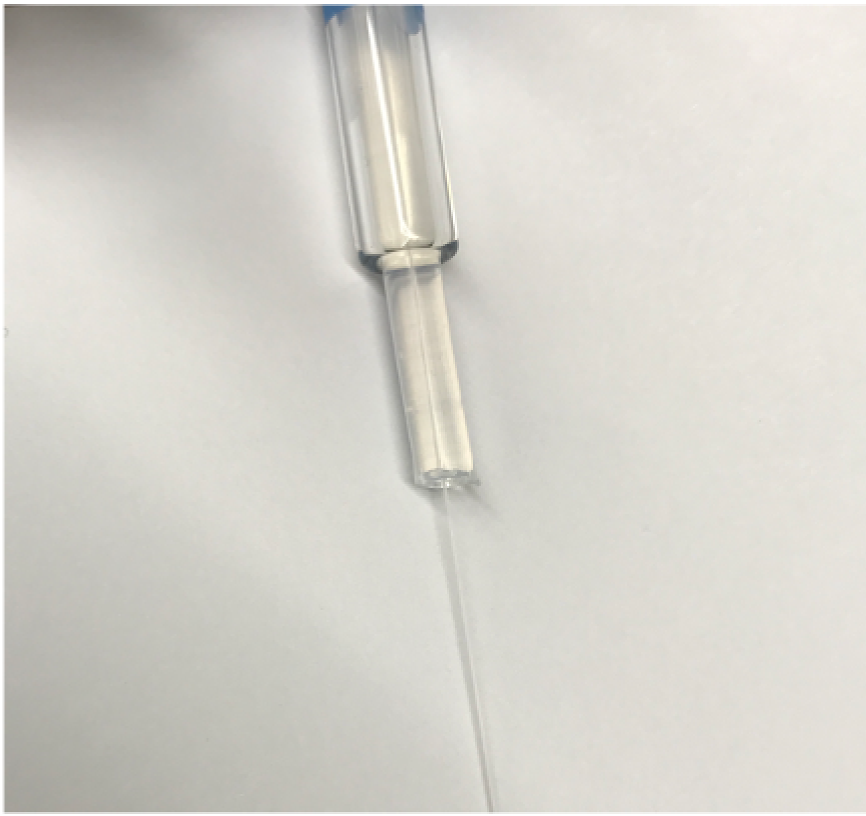

Figure 7: Figure S9. Hollow channel introduction. Outer layer is a straight glass tube. A plastic tube is inserted in the glass tube to get supported to avoid being bent. A long fishing thread is placed in the middle of the plastic tube.

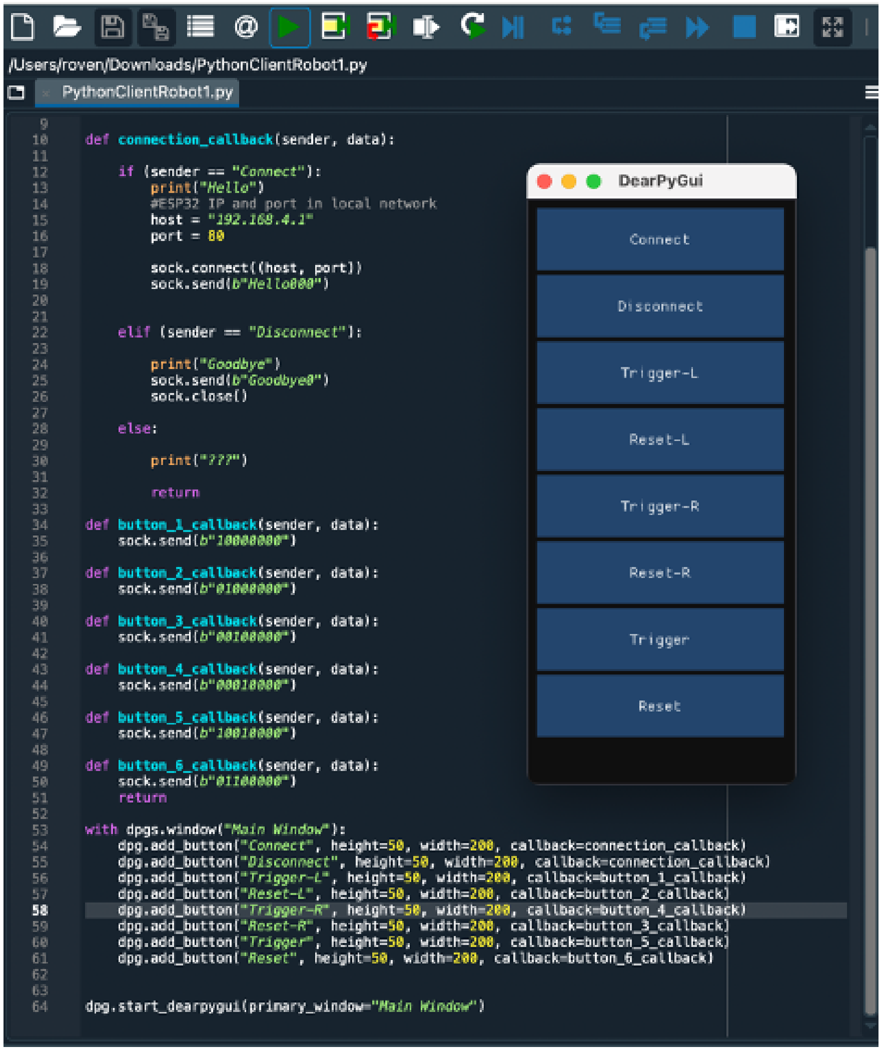

Figure 8: Figure S10. Programming and coding. Arduino and Spyder is used to upload the code and program the Wi-Fi module. DearPyGui is used as a control panel to actuate the swimming device.

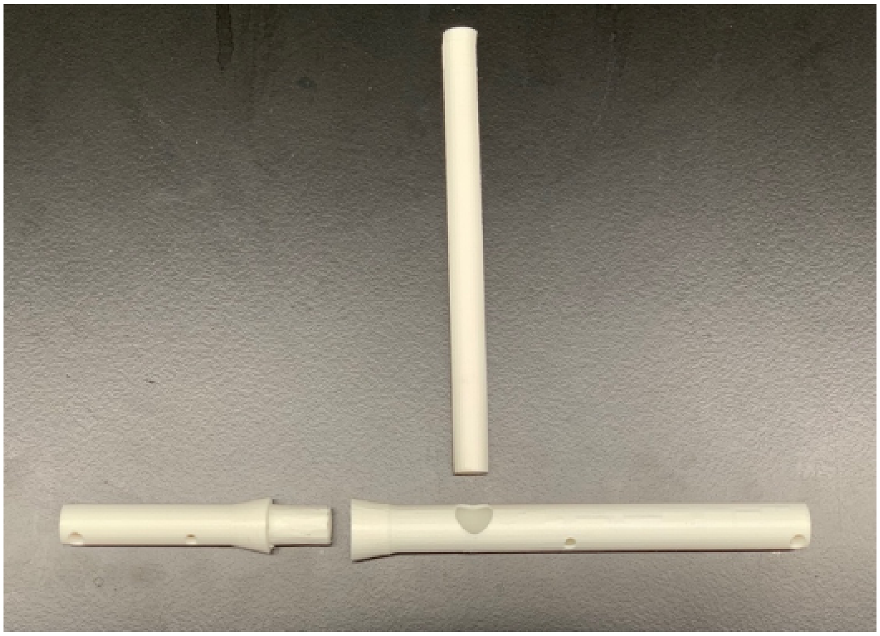

Figure 9: Figure S11. Layout for the 3D printed parts of the swimming device. All connecting wires can go inside the parts to avoid cluster and keep neat.

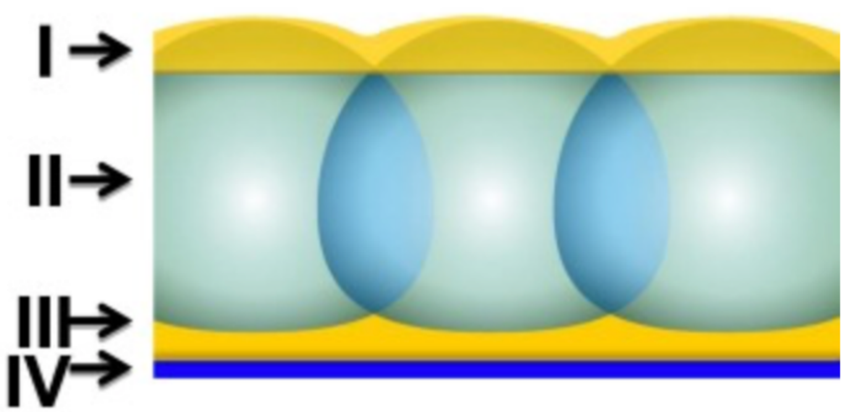

Figure 10: Figure S12. Picture shows the basic structure of pNIPAm microgel-based etalon composed of a monolith of microgel layer (II) sandwiched between two gold layers (I and III) on a support glass substrate (IV). To fabricate etalon chips, first, PNIPAm-based microgels containing 10% acrylic acid (AAc) (pNIPAm-co-10%AAc) were prepared by free radical precipitation polymerization of the monomer NIPAm with N,N'-Methylenebis(acrylamide) (BIS) as the crosslinker and AAc as a comonomer. The resulting microgels have a size about 750 nm in diameter. For the etalon chip, 2 nm Cr and 15 nm Au layer were subsequently coated on to the glass slides using thermal evaporator. A layer of microgel was coated and then another 15 nm Au layer was deposited.

Video S1-S10.

Rich media available at https://youtu.be/Omji9J9idpA

Rich media available at https://youtu.be/lKmwzB1BLm8

Rich media available at https://youtu.be/mKmGnBUbKsI

Rich media available at https://youtu.be/7g6Vbt_m8-4

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