Electronic Supporting Information (ESI)

Hydrogel-matrix encapsulated nitinol actuation with self-cooling mechanism

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Table S1. Customized recipe for acrylamide-sodium alginate hydrogel

Ingredient/Variable	Concenteration (%wt)
Deionised (DI) Water	75.3
Acrylamide (AA)	22.6
Sodium Alginate (SA)	1.5
Photoinitiator	0.53
N,N' – Methylenebis acrylamide (MBA)	0.020
UV Exposure	120 min
Resting Time	1 day

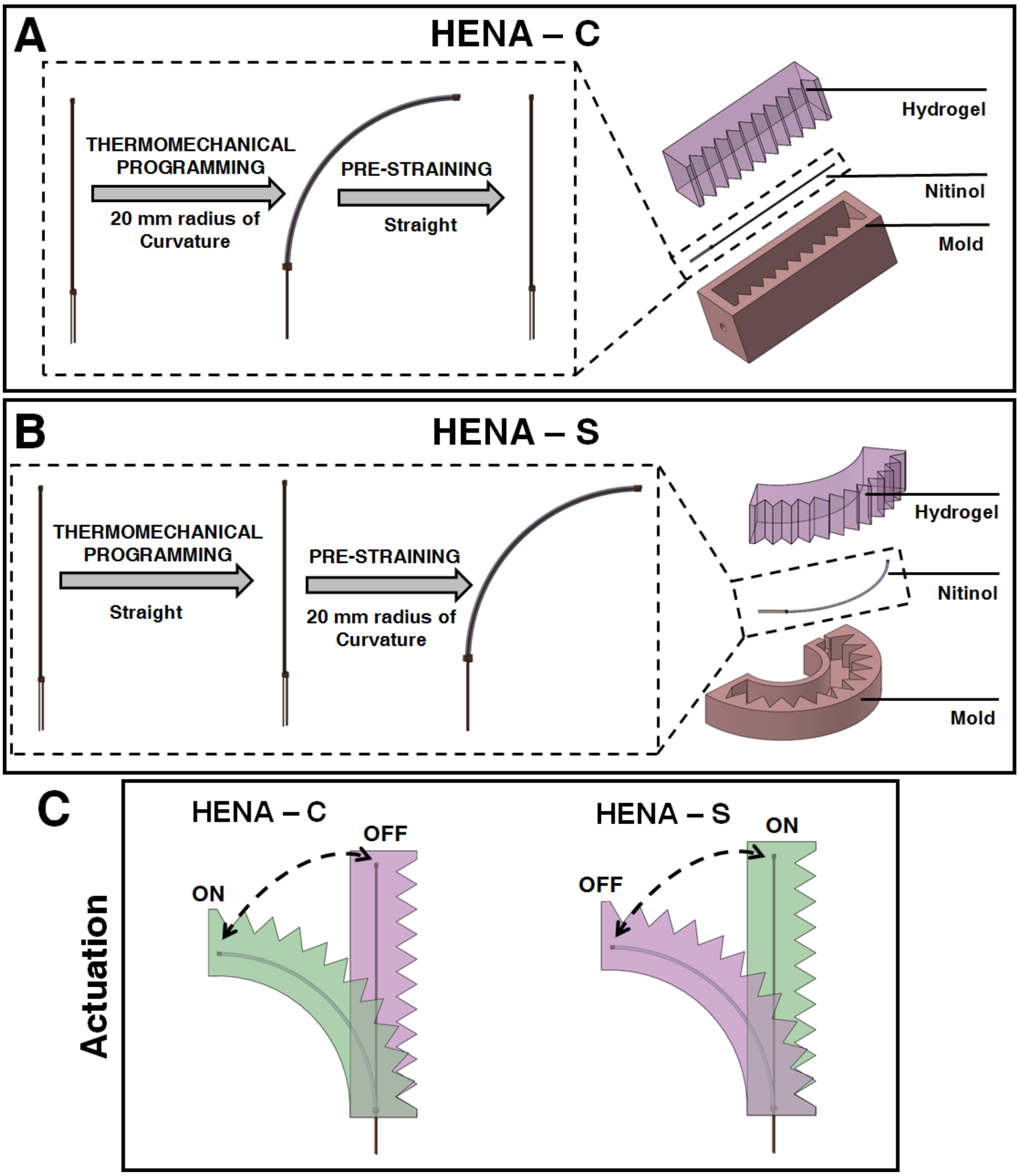

Fig. S1 Fabrication steps. **(A)** Fabrication of Hydrogel-matrix Encapsulated Nitinol Actuator–Curved (HENA-C). Nitinol is thermomechanically programmed curved (20 mm radius) and cured with hydrogel in a straight mold. **(B)** Fabrication of Hydrogel-matrix Encapsulated Nitinol Actuator–Straight (HENA-S). Nitinol is thermomechanically programmed straight and cured with hydrogel in a curved (20 mm radius) mold. **(C)** Actuation of HENA-C and HENA-S. When Nitinol is activated, the conformation of the prototype changes to the thermomechanically programmed conformation of Nitinol due to the force exerted by the Nitinol and when the Nitinol is deactivated. The prototype changes to its original conformation due to the release of strain energy from the hydrogel which is stored during the actuation phase.

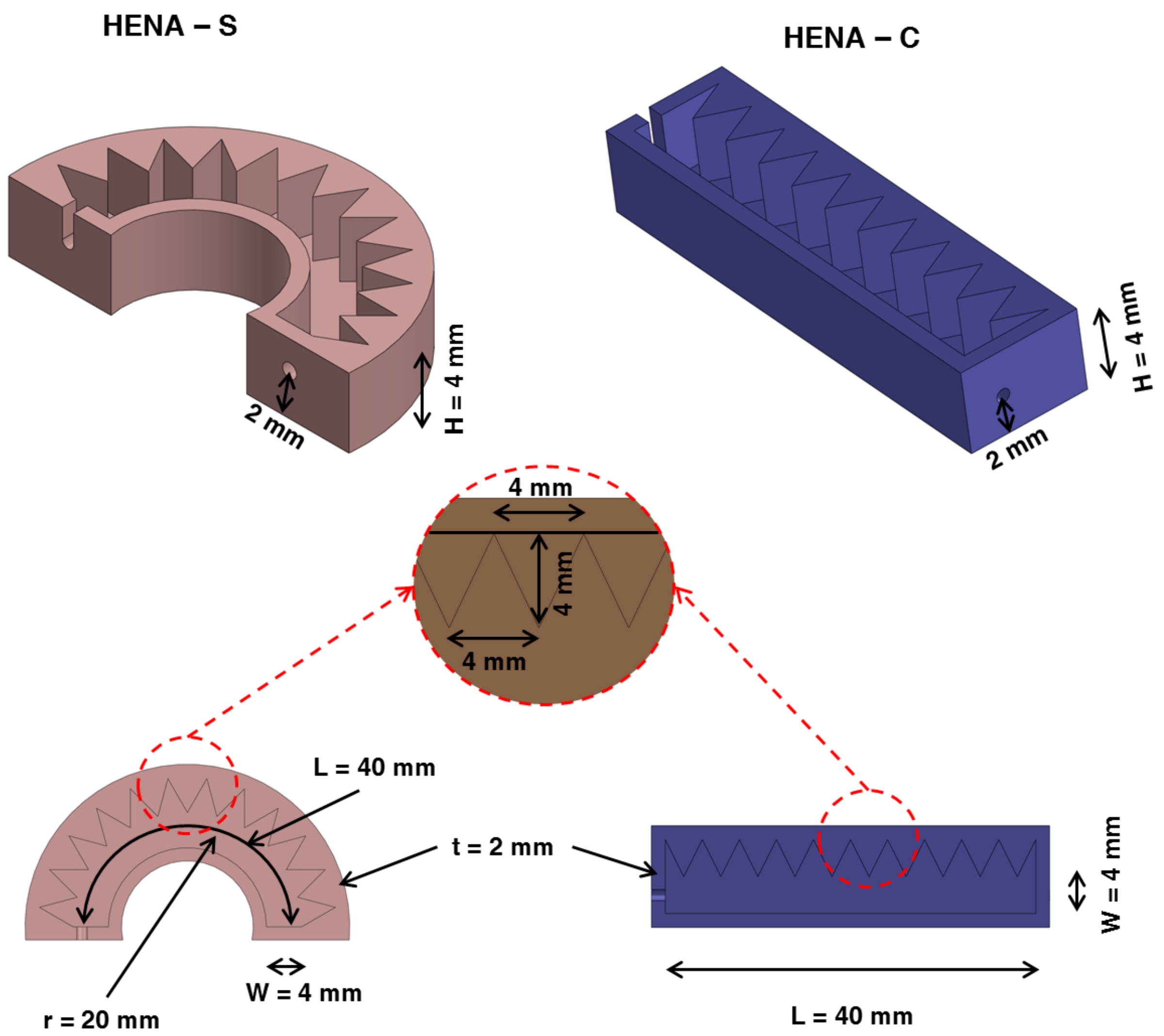

Fig. S2 Mold design for HENA-S and HENA-C with dimensions. *L* is the length of the curing region of the mold (excluding the thickness of the mold), *W* is the width of the curing region of the mold, *H* is the height of the curing region of the mold, *t* is the thickness of the mold. The continuous notchs on one side of the actuator aids in bending during actuation.

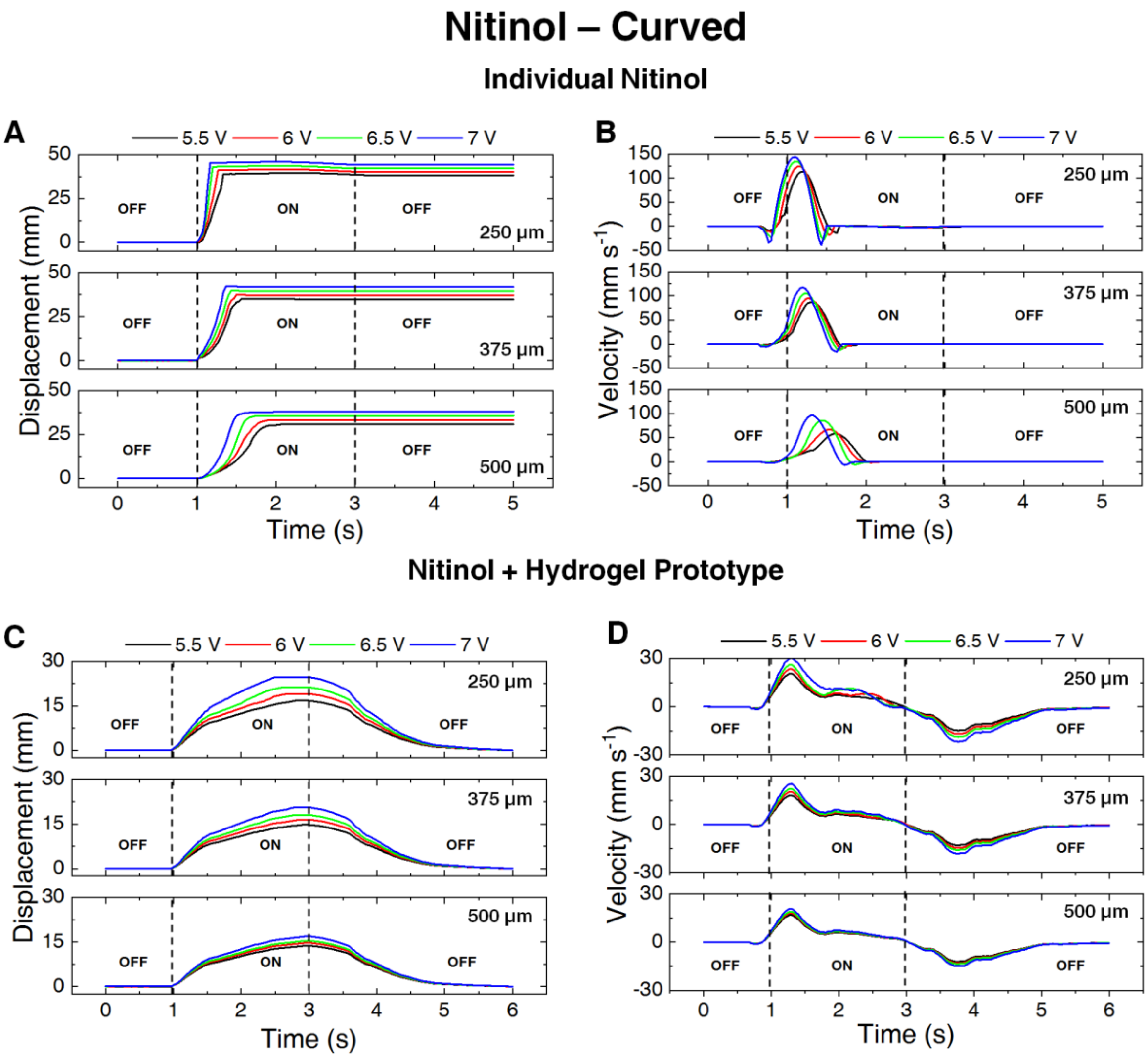

Fig. S3 Actuation of the prototype (Nitinol thermomechanically programmed curved). **(A)** Change in displacement of individual Nitinol with time when actuated at different voltages (5.5–7 V). **(B)** Change in velocity of individual Nitinol with time when actuated at different voltages (5.5–7 V). **(C)** Change in displacement of HENA-C with time when actuated at different voltages (5.5–7 V). **(D)** Change in velocity of HENA-C with time when actuated at different voltages (5.5–7 V).

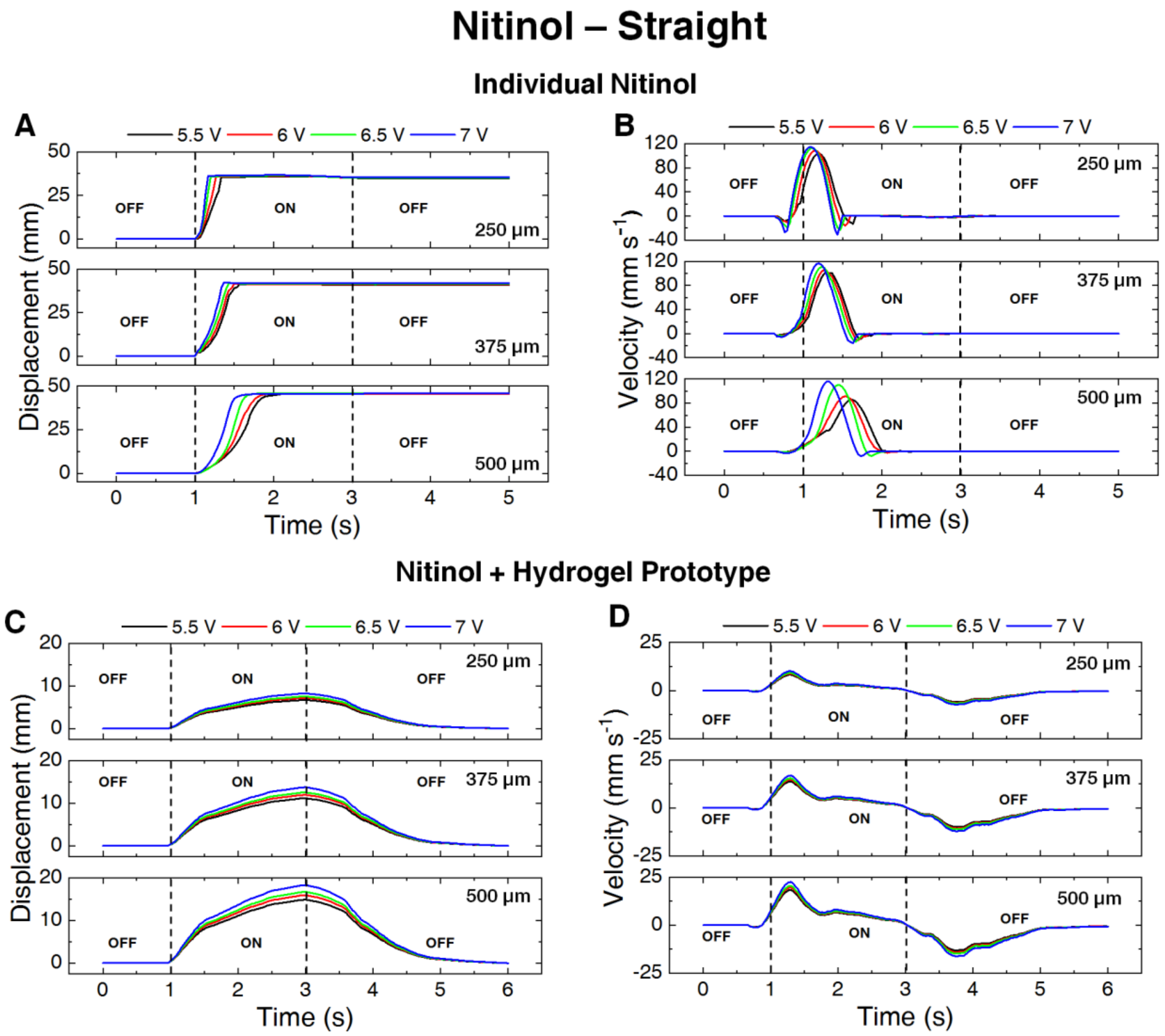

Fig. S4 Actuation of the prototype (Nitinol thermomechanically programmed straight). **(A)** Change in displacement of individual Nitinol with time when actuated at different voltages (5.5–7 V). **(B)** Change in velocity of individual Nitinol with time when actuated at different voltages (5.5–7 V). **(C)** Change in displacement of HENA-S with time when actuated at different voltages (5.5–7 V). **(D)** Change in velocity of HENA-S with time when actuated at different voltages (5.5–7 V).

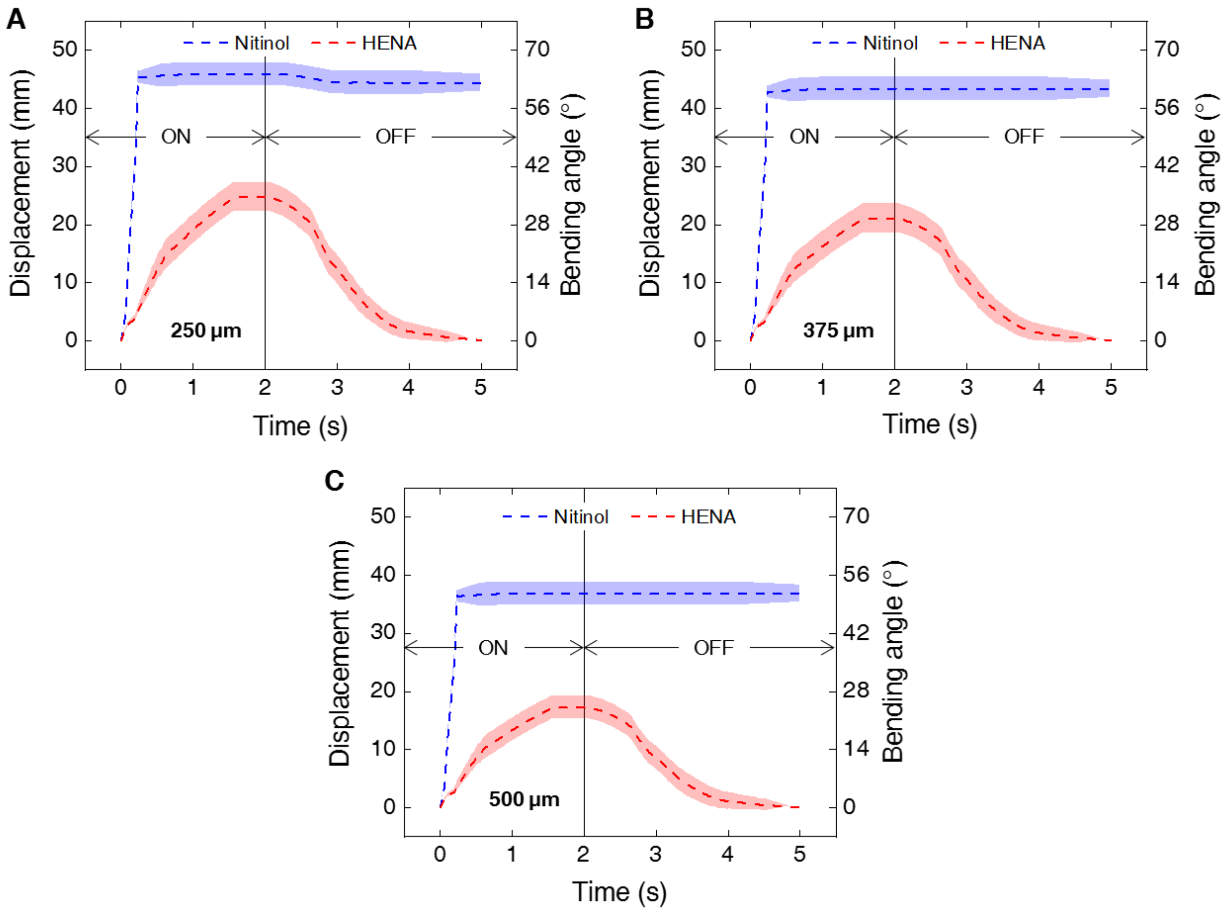

Fig. S5 Actuation of different diameters (250, 375, and 500 µm) Nitinol wires and HENA. **(A)** Dynamic displacement (with error bars) of 250 µm individual Nitinol and HENA-C at 7 V. **(B)** Dynamic displacement (with error bars) of 375 µm individual Nitinol and HENA-C at 7 V. **(C)** Dynamic displacement (with error bars) of 500 µm individual Nitinol and HENA-C at 7 V.

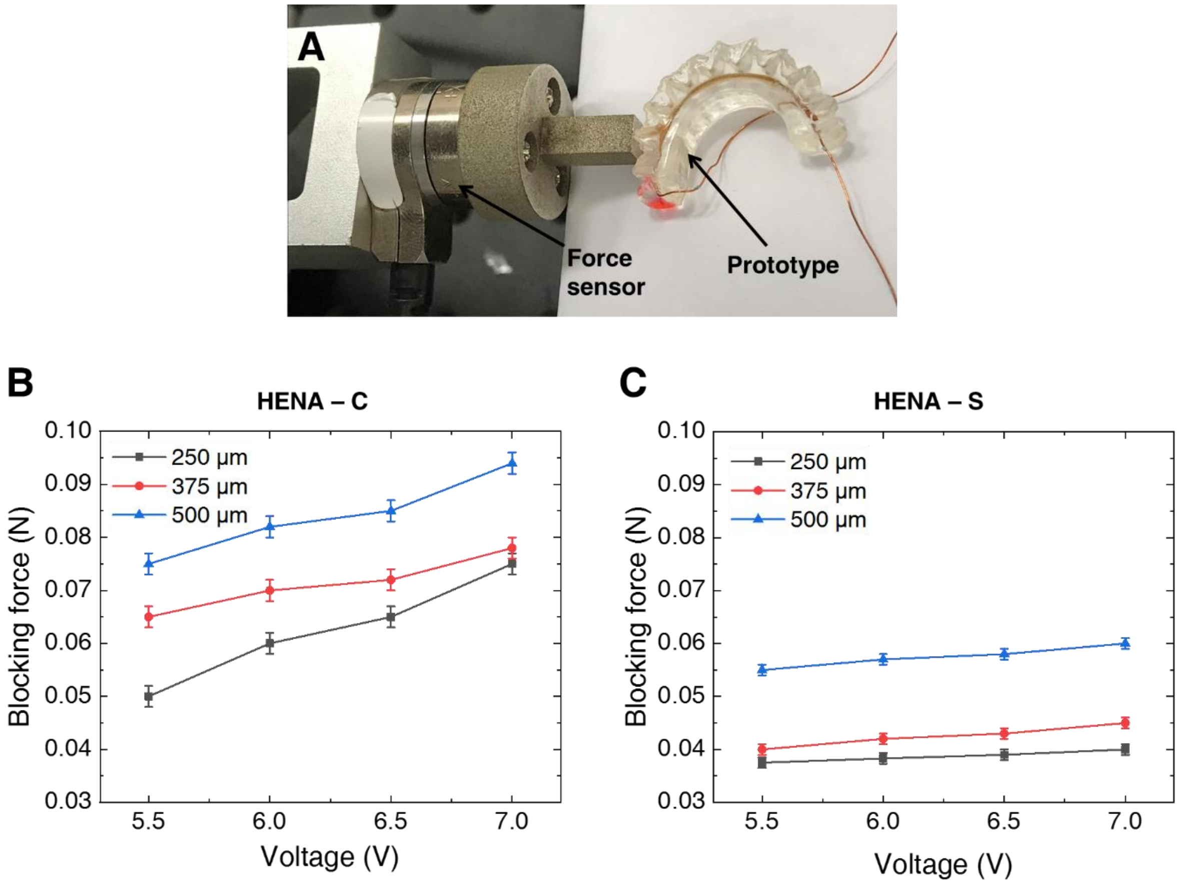

Fig. S6 Blocking force from HENA. **(A)** Set-up to record the blocking force exerted by the actuator. **(B)** Force exerted by HENA-C when actuated at different voltages (5.5–7 V). **(C)** Force exerted by HENA-S when actuated at different voltages (5.5–7 V).

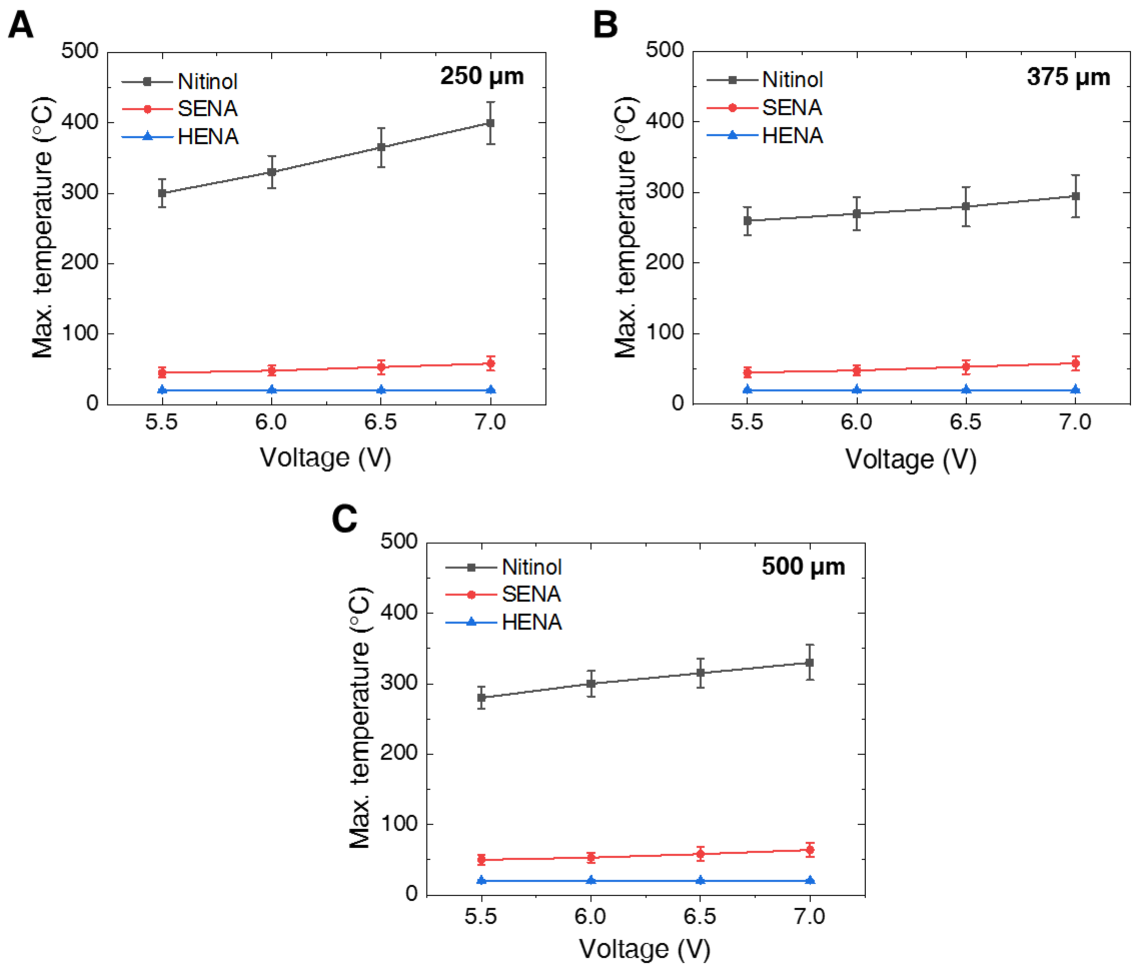

Fig. S7 Temperature during actuation of prototypes at different voltages (5.5–7 V). **(A)** Maximim temperature at the surface of bare Nitinol, SENA, and HENA (Nitinol diameter = 250 µm). **(B)** Maximim temperature at the surface of bare Nitinol, SENA, and HENA (Nitinol diameter = 375 µm). **(C)** Maximim temperature at the surface of bare Nitinol, SENA, and HENA (Nitinol diameter = 500 µm).

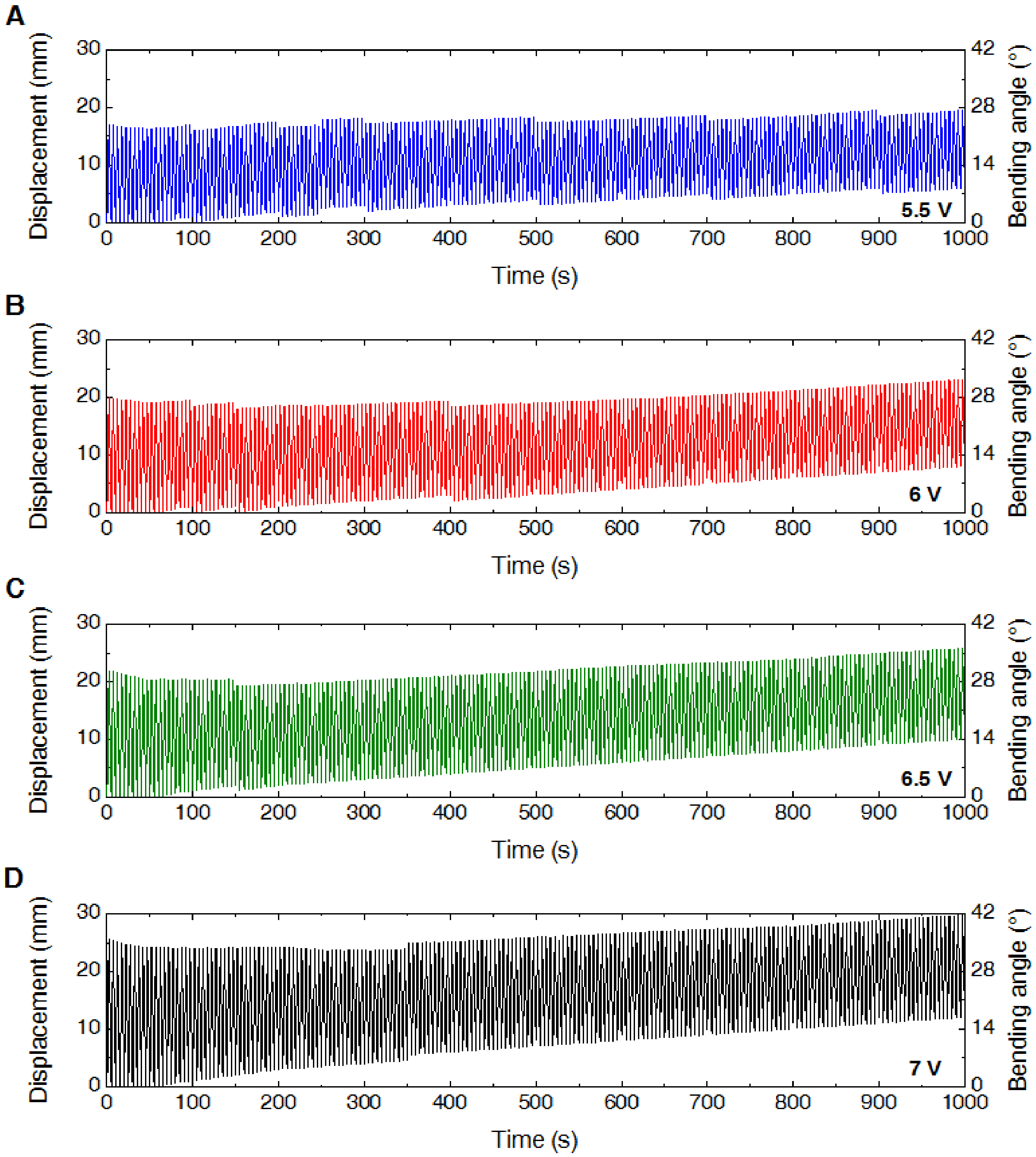

Fig. S8 Actuation of HENA-C (250 μm) for 200 cycles at different voltages. **(A)** Dynamic change in displacement and bending angle of HENA-C actuated at 5.5 V for 200 cycles (1000 s). **(B)** Dynamic change in displacement and bending angle of HENA-C actuated at 6 V for 200 cycles (1000 s). **(C)** Dynamic change in displacement and bending angle of HENA-C actuated at 6.5 V for 200 cycles (1000 s). **(D)** Dynamic change in displacement and bending angle of HENA-C actuated at 7 V for 200 cycles (1000 s).

Movie S1. Demonstration of bending performance during actuation of HENA-C and HENA-S with 250 µm Nitinol wire actuated at 7 V.

Movie S2. Demonstration of HENA soft robotic gripper for grasping delicate, low-melting-point 3D objects such as table tennis ball and food items (e.g. cheese, chocolate, tofu) with different morphology.