NATURE COMMUNICATIONS | 7:10929 | DOI: 10.1038/ncomms10929
www.nature.com/naturecommunications

A three-dimensional actuated origami-inspired transformable metamaterial with multiple degrees of freedom

Johannes T.B. Overvelde, Twan A. de Jong, Yanina Shevchenko, Sergio A. Becerra, George M. Whitesides, James C. Weaver, Chuck Hoberman & Katia Bertoldi

Supplementary Information

Supplementary Figures 1-4, Supplementary Table 1 and Supplementary References. (PDF 7972kb)

Supplementary Movie 1

Stiffness of extruded polyhedral. Our work is inspired by snapology, a type of modular unit-based origami in which paper ribbons are folded and assembled to create complex geometric extruded polyhedra. Interestingly, we found that some of the resulting geometries (such as the extruded icosahedron) are stiff and almost rigid, while others (such as the extruded cube) have multiple degrees of freedom and can be easily deformed. (MOV 5319 kb)

Supplementary Movie 2

Possible shapes of the unit cell. The unit cell considered in this study can be transformed into multiple highly distinct shapes by varying $\gamma 1$, $\gamma 2$ and $\gamma 3$. Because of contact occurring between its faces, only the combinations of angles contained within the regular tetrahedron with vertices at $(\gamma 1, \gamma 2, \gamma 3) = (0, 0, 0)$, $(\pi, \pi, 0)$, $(\pi, 0, \pi)$ and $(0, \pi, \pi)$ are feasible. (MOV 9155 kb)

Supplementary Movie 3

Transformable metamaterial. The highly flexible unit cell can be used to form mechanical metamaterials whose shape and volume can be dramatically altered. Here, we connected the outer edges of 64 identical unit cells to form a $4 \times 4 \times 4$ cubic crystal. Importantly, the assembly does not constrain any degrees of freedom, so the mechanical metamaterial deforms in exactly the same manner as each constituent unit cell. (MOV 11667 kb)

Supplementary Movie 4

Actuation of the unit cell. The shape and volume of the unit cell can be actively programmed by strategically positioning inflatable pockets on the hinges of the unit cell. By pressurizing the air pockets, the shape of the unit cell can be effectively controlled. (MOV 8397 kb)

Supplementary Movie 5

Actuation of the metamaterial. Similar to the unit cell, the shape and volume of the metamaterial can be actively programmed by strategically positioning inflatable pockets on the hinges of the unit cells. (MOV 11270 kb)

Supplementary Movie 6

Recovery of the unit cell. The response of the unit cell is always elastic. Even after applying 10,000