Summer 2020

The Applications of Auxetic Material

Faizal Arifurrahman

The views expressed in these works are entirely those of their authors and do not represent the views of the Fulbright Program, the U.S. Department of State, or any of its partner organizations.

THE APPLICATIONS OF AUXETIC MATERIAL

By FAIZAL ARIFURRAHMAN

Supervised by Jacqueline R Schneider and Deborah J McGraw. August 7th, 2020

ABSTRACT

To date, increasing structural efficiency has become a main objective in material science and engineering. One focus is an auxetic material with a unique characteristic obtained by fabricating cellular forms. With its higher strength-to-weight ratio, auxetic is becoming popular in the real-world to produce products that are light but more durable. This study examines potential application of auxetic compared to that of conventional material.

INTRODUCTION

- Researchers are currently developing lightweight material [1]. One of these is auxetic material.
- Auxetic is a modern class of material whose properties differ from those of conventional material. If auxetic is pulled in one direction, then it will expand in another direction, instead of shrinking or becoming slimmer as conventional material would [2].
- The potential for auxetic materials to replace conventional materials should be explored, such as their application in the defense, aerospace, automotive, civil engineering, medical, and fashion sectors.

AUXETIC AS AN EXOTIC MATERIAL

- Contrary to conventional materials, if auxetic material is pressed, the mass will gather to the center so that at the pressure point, it will be more resistant to withstand the pressure. This unique property of auxetic causes it to have a higher capability of impact, fracture, shear, and vibration but lower mass. [3]–[5].
- If it is compared with steel or aluminium , auxetic could withstand a higher load with the same amount of structure mass.

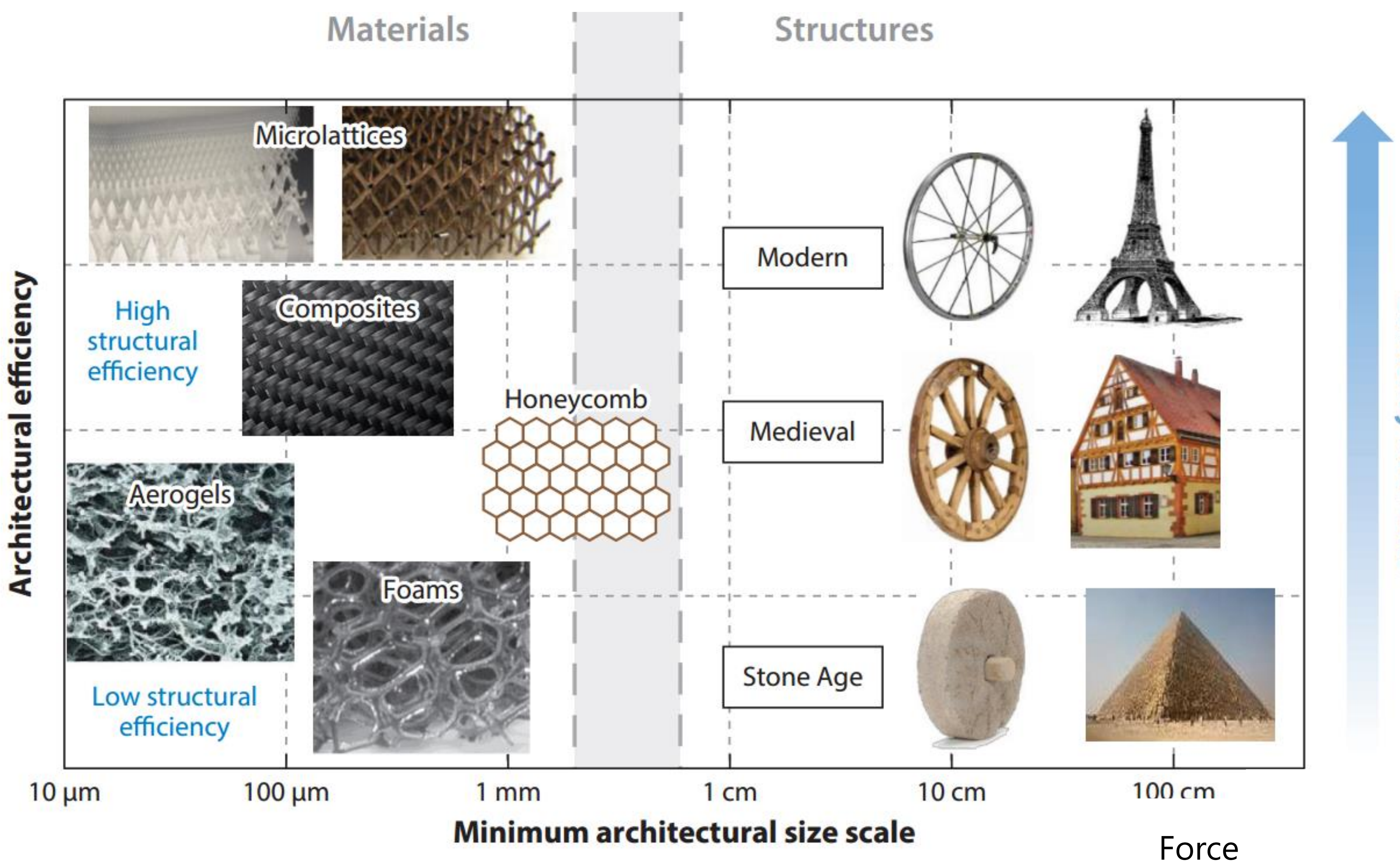


Figure 1. Complex architected material has higher structural efficiency. [1]

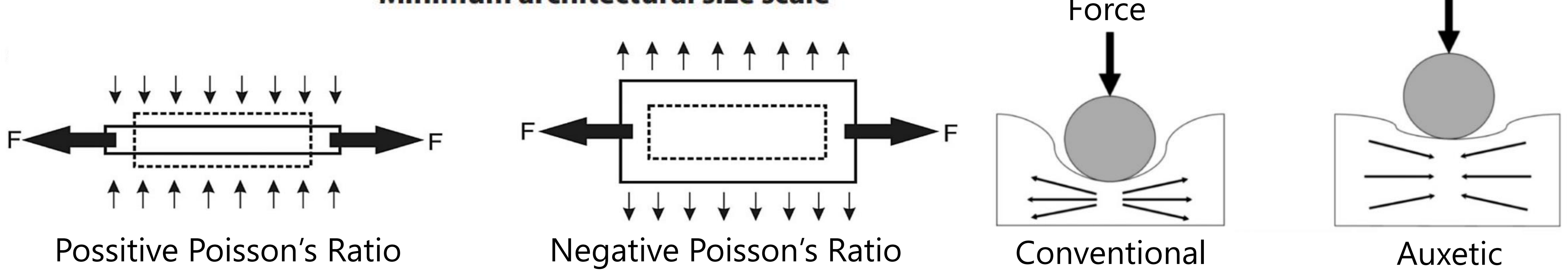
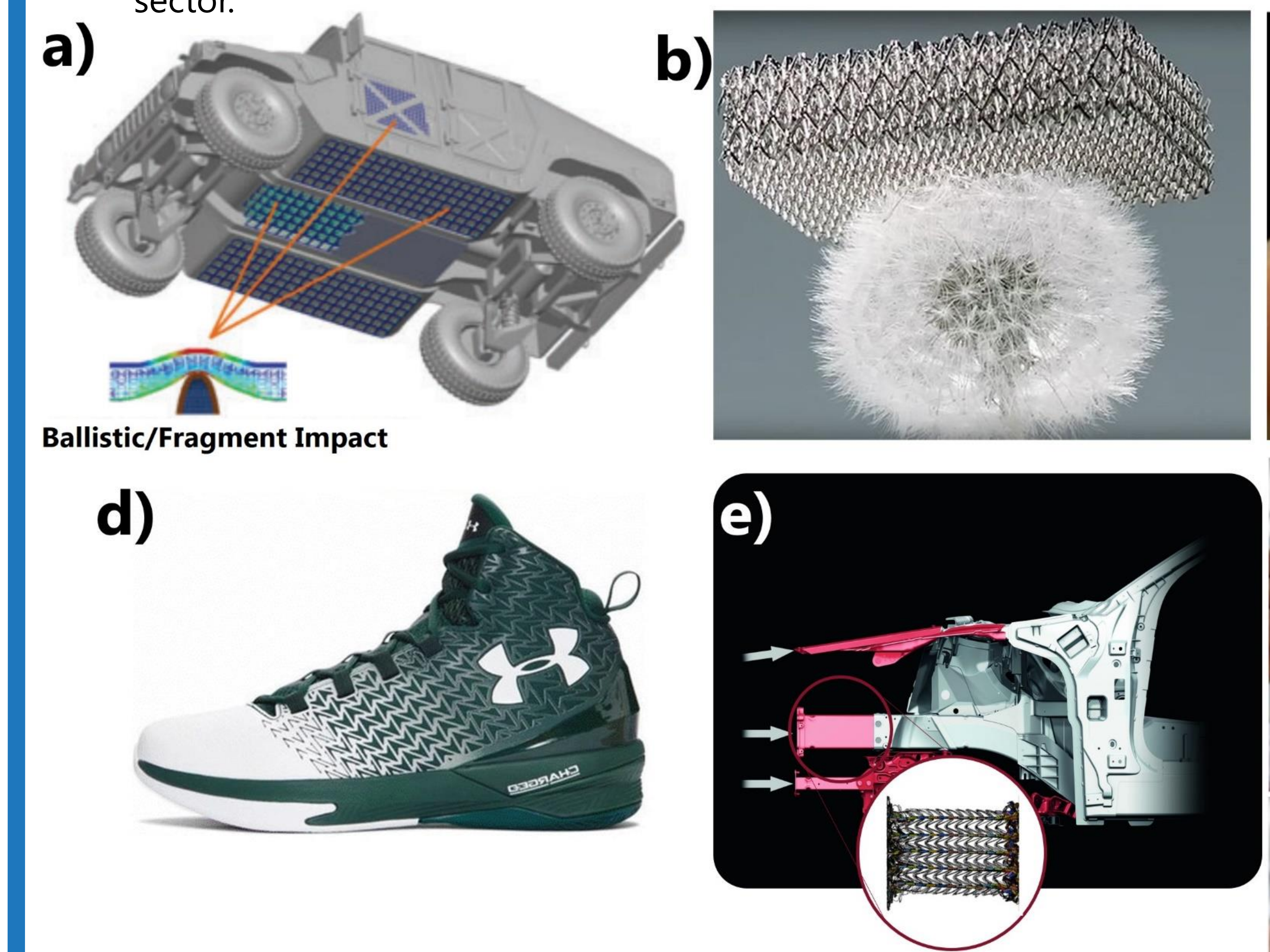


Figure 2. Auxetic material behaviour [6]

APPLICATIONS

- In nature, we can find auxetic structures in high temperature polymorphic mineral [6], and biological tissues, i.e., cat skin and cow teat skin [7]. Moreover, auxetic has the potential to replace conventional material in heavy industries (defense, aerospace, mechanical, etc), medical, civil engineering, and fashion sector.



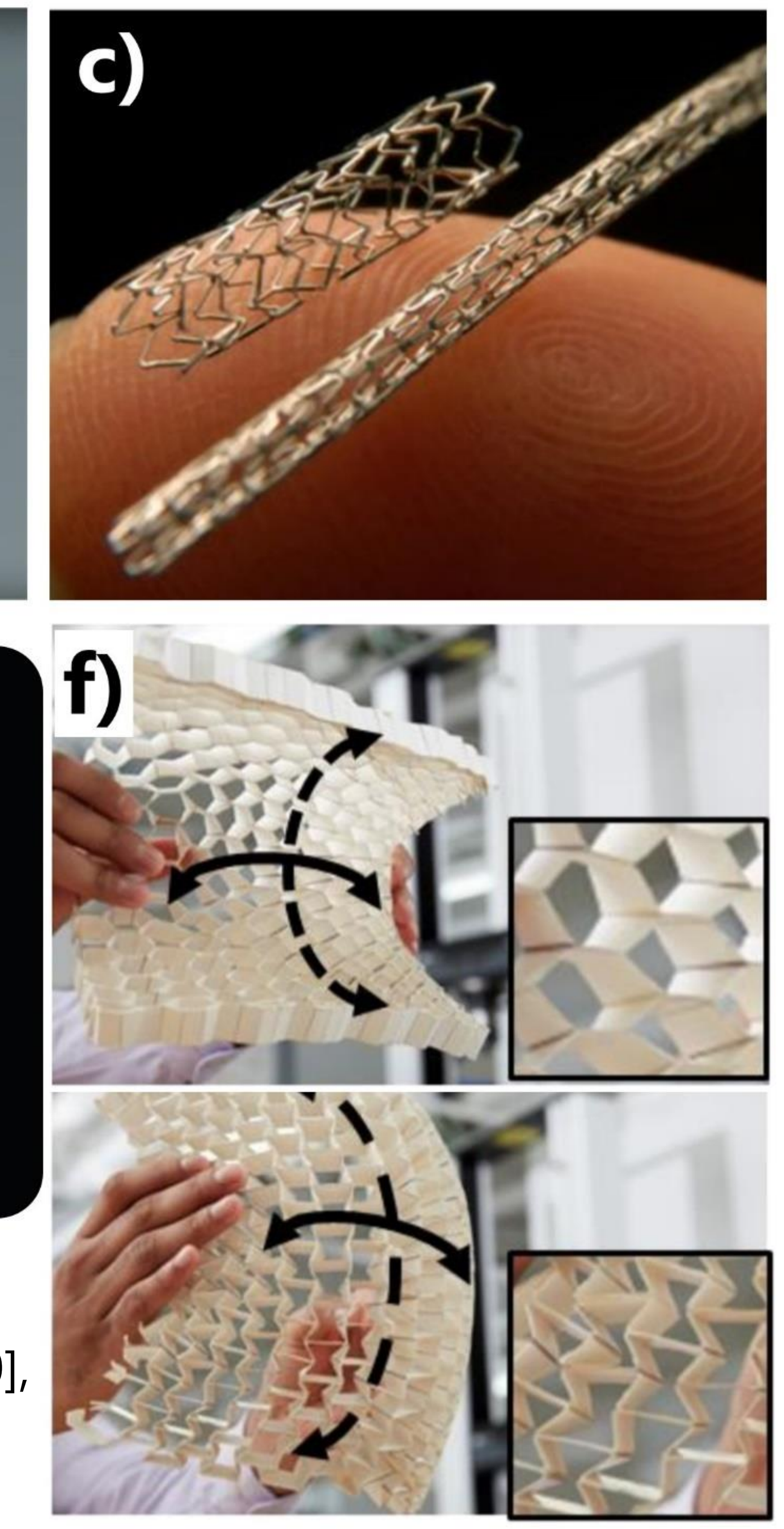


Figure 3. a) blast protector [8], b) aircraft material [9], c) coronary stent [10], d) auxetic form in shoes design [11], e) crashbox in car [12],[13], and f) dome basic structure [14]

CHALLENGES

- Unavailable for mass-scale production.
- High cost production
- Unreliability of product performance

CONCLUSION

- The opposite behaviour of auxetic compared to conventional material increases the structure capacity to withstand higher force and absorb higher energy.
- The minimum in scale production is due to the limitation of manufacturing technology.
- There are many applications to be explored in other sectors.

REFERENCES

[1] T. A. Schaedler and W. B. Carter, "Architected Cellular Materials," Annu. Rev. Mater. Res., vol. 46, pp. 187–210, 2016.

[2] R. S. Lakes, "No contractile obligations," Nature, vol. 358, pp. 713–714, 1992.

[3] J. P. Donoghue, K. L. Alderson, and K. E. Evans, "The fracture toughness of composite laminates with a negative Poisson's ratio," Phys. Status Solidi Basic Res. Res., vol. 246, no. 9, pp. 2011–2017, 2009.

[4] J. B. Choi and R. S. Lakes, "Nonlinear properties of polymer cellular materials with a negative Poisson's ratio," J. Mater. Sci., vol. 27, pp. 4678–4648, 1992.

[5] C. P. Chen and R. S. Lakes, "Micromechanical analysis of dynamic behavior of conventional and negative Poisson's ratio foams," J. Eng. Mater. Technol., vol. 288, pp. 285–288, 1996.

[6] J. N. Grima, R. Jackson, A. Alderson, and K. E. Evans, "Do Zeolites Have Negative Poisson's Ratios ?," Adv. Mater., vol. 12, no. 24, pp. 1912–1918, 2000.

[7] C. Lees, J. F. V. Vincent, and J. E. Hillerton, "Poisson's ratio in skin," Biomed. Mater. Eng., vol. 1, no. 1, pp. 19–23, 1991.

[8] G. Imbalzano, P. Tran, T. D. Ngo, and P. V. Lee, "Three-dimensional modelling of auxetic sandwich panels for localised impact resistance," J. Sandw. Struct. Mater., vol. 19, no. 3, pp. 291–316, 2017.

[9] "The Lightest Metal Ever," 2015. [Online]. Available: https://www.boeing.com/features/2015/10/innovation-lightest-metal-10-15.page. [Accessed: 03-Aug-2020].

[10] F. Amin, M. N. Ali, U. Ansari, M. Mir, M. A. Minhas, and W. Shahid, "Auxetic coronary stent endoprosthesis: Fabrication and structural analysis," J. Appl. Biomater. Funct. Mater., vol. 13, no. 2, pp. E127–E135, 2015.

[11] James-N Grima-Cornish, "Auxetics: Don't Pull Me, I'll Get Fatter!," 2019. [Online]. Available: https://www.iucr.org/news/newsletter/volume-27/number-2/auxetics. [Accessed: 03-Aug-2020].

[12] "Crash safety - Audi Technology Portal." [Online]. Available: https://www.audi-technology-portal.de/en/body/stiffnes-crash-safety/crash-safety. [Accessed: 03-Aug-2020].

[13] F. Wang and C. Gao, Eds., Protective clothing: Managing Thermal Stress. Woodhead Publishing Series in Textiles: Number 154, 2014.

[14] O. Duncan et al., "Review of auxetic materials for sports applications: Expanding options in comfort and protection," Appl. Sci., vol. 8, no. 6, 2018