



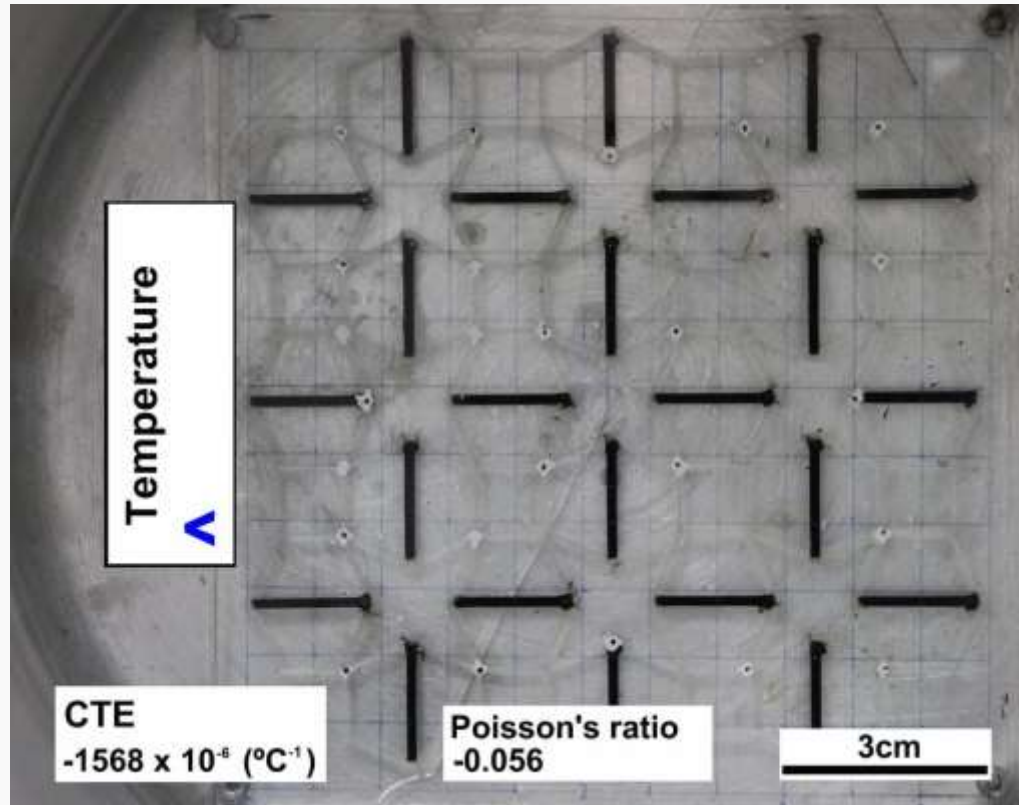
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# Additive Fabrication of Anepectic Meshes

J. S. Raminhos, J. P. Borges, A. Velhinho



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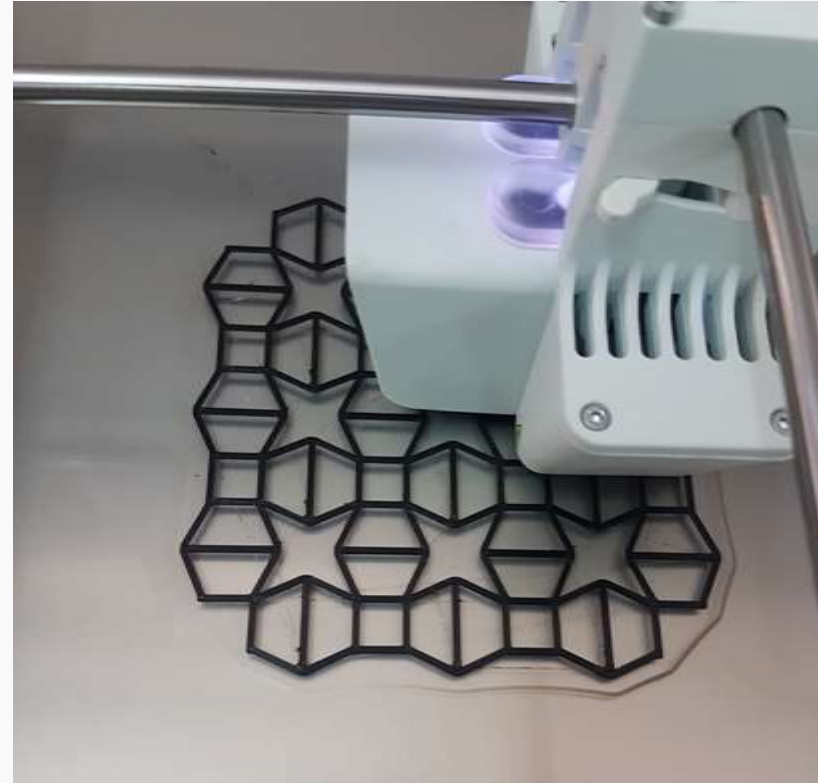


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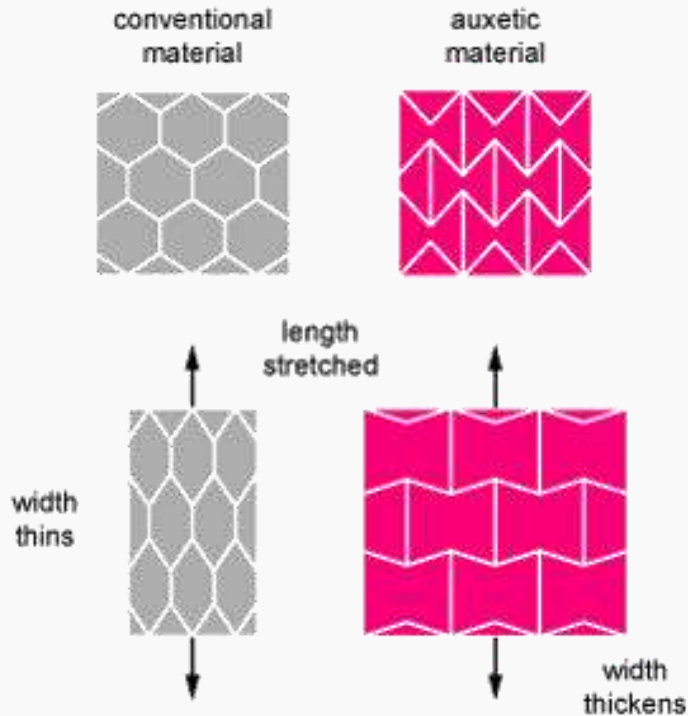
# Presentation Outlook

- Introduction
- Objective
- Methods
  - Mesh Design
- Results and discussion
  - Effect of material combination on CTE
  - Effect of mesh architecture on CTE
  - Effect of mesh scale on CTE
  - Effect of plastic flow during heating
- Conclusion





- **Auxetic behaviour** (negative Poisson's ratio)



Structure of conventional auxetic material



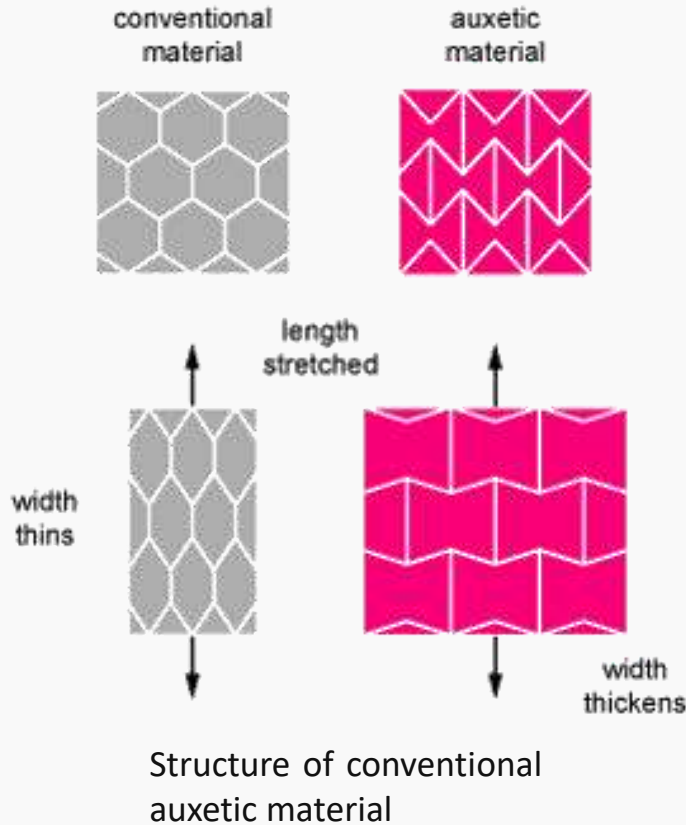
Animation of the behaviour of an auxetic material when undergoing uni-axial tension

Enright, R. (2017, March 15). Unconventional Materials - Auxetic Foams, <https://www.bayly.com.au>

University of Manchester "The strange behaviour of auxetic foams" - <https://www.youtube.com/channel/UCUpAwoi2vo1QRkfmrS-BEEQ>

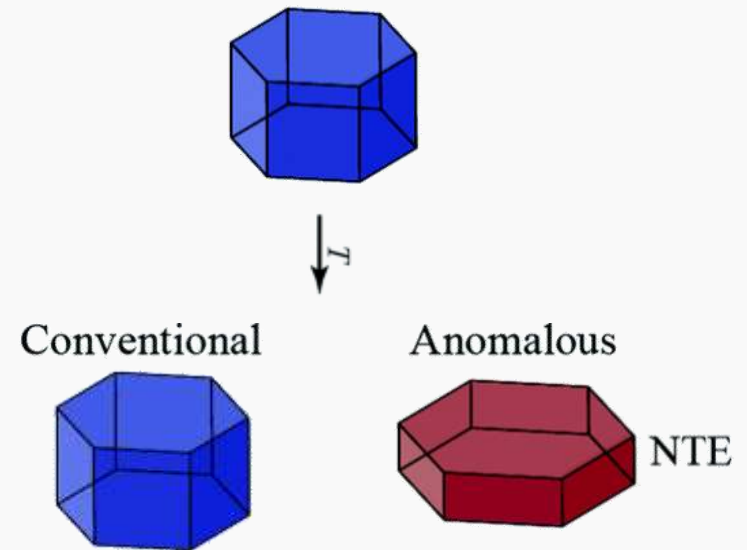


- Auxetic behaviour



Enright, R. (2017, March 15). Unconventional Materials - Auxetic Foams, <https://www.bayly.com.au>

- Negative thermal expansion

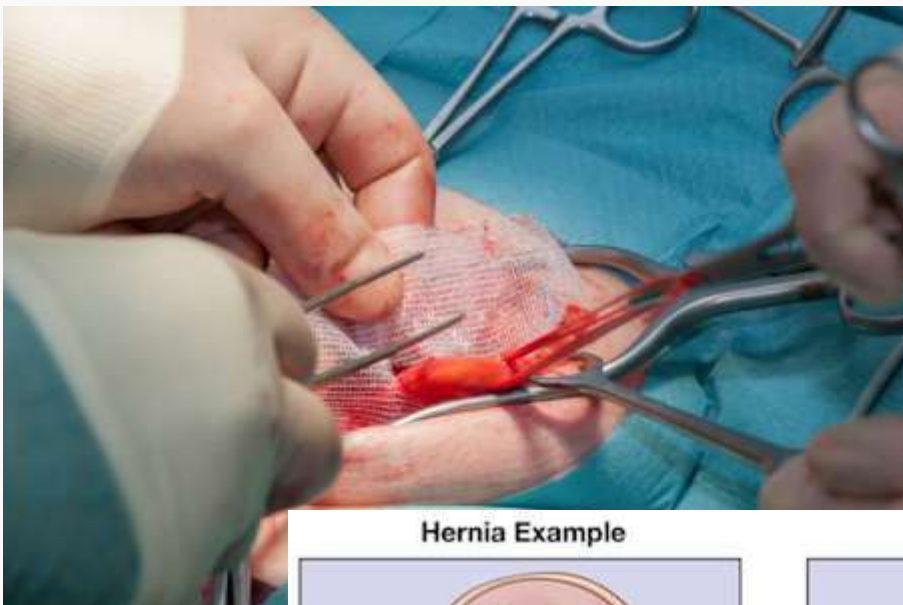


Reaction of the structure of a conventional material and a material that has negative thermal expansion when undergoing heating

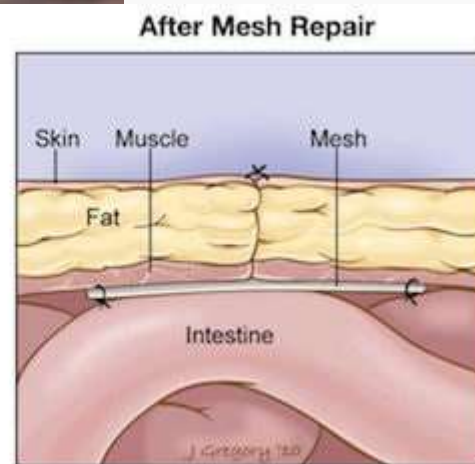
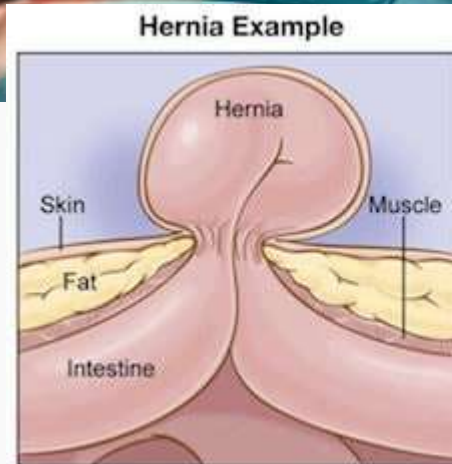
I. E. Collings, M. G. Tucker, D. A. Keen, and A. L. Goodwin, CrystEngComm, vol. 16, no. 17, pp. 3498–3506, 2014.



# Potencial applications



<https://herniameshlaw.suit.ca/article/defective-inguinal-hernia-mesh-complications/>



[https://www.2xu.com/au/p/compression-socks-for-recovery/MA2440e-BLK\\_BLK-XS.html?lang=en\\_AU](https://www.2xu.com/au/p/compression-socks-for-recovery/MA2440e-BLK_BLK-XS.html?lang=en_AU)

<https://www.mountsinai.org/care/surgery/services/general-surgery/conditions/hernia>

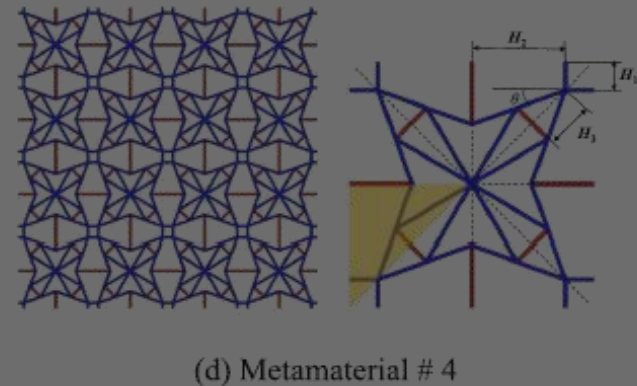
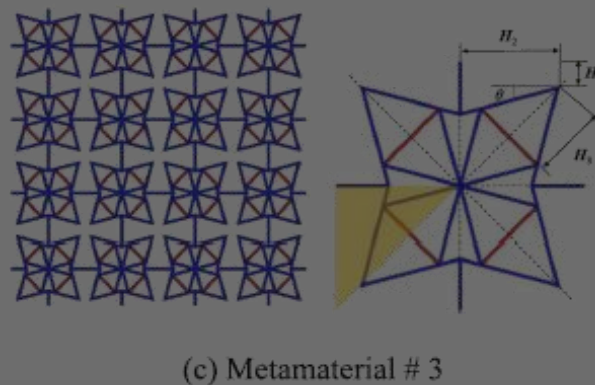
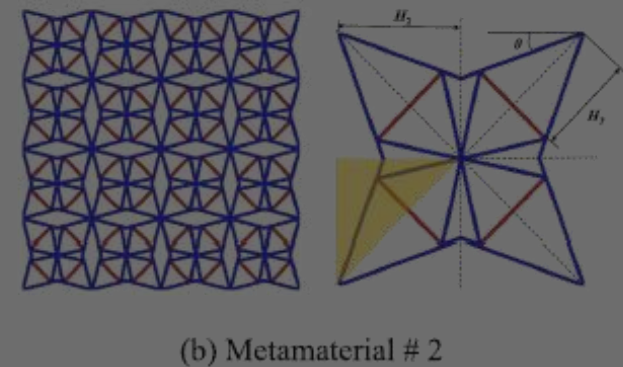
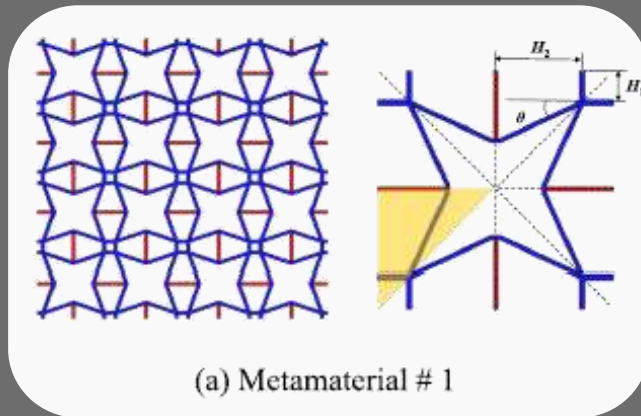
## Additive Fabrication of Anepectic Meshes

J. S. Raminhos, J. P. Borges, A. Velhinho



# Anepectic metamaterials – Designs for metals

- Ai and Gao 2017



Four metamaterial design models

## Additive Fabrication of Anepectic Meshes

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**Fabricate** the first anepectic polymeric meshes

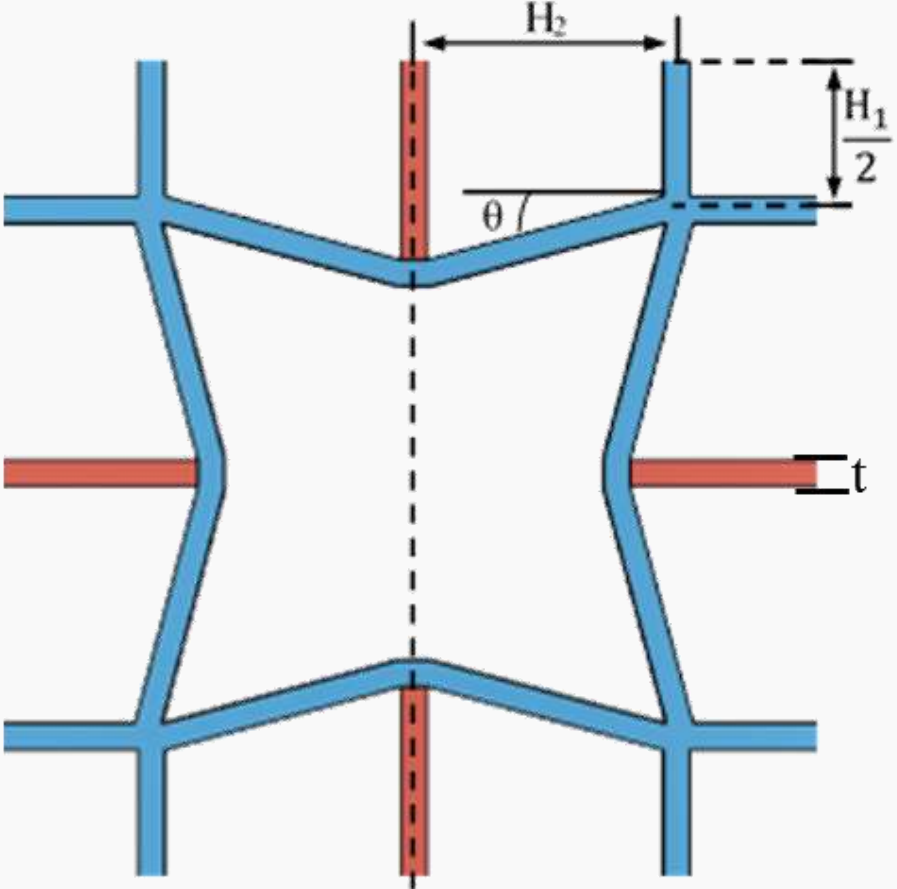


**Characterize** the behaviour of the composite

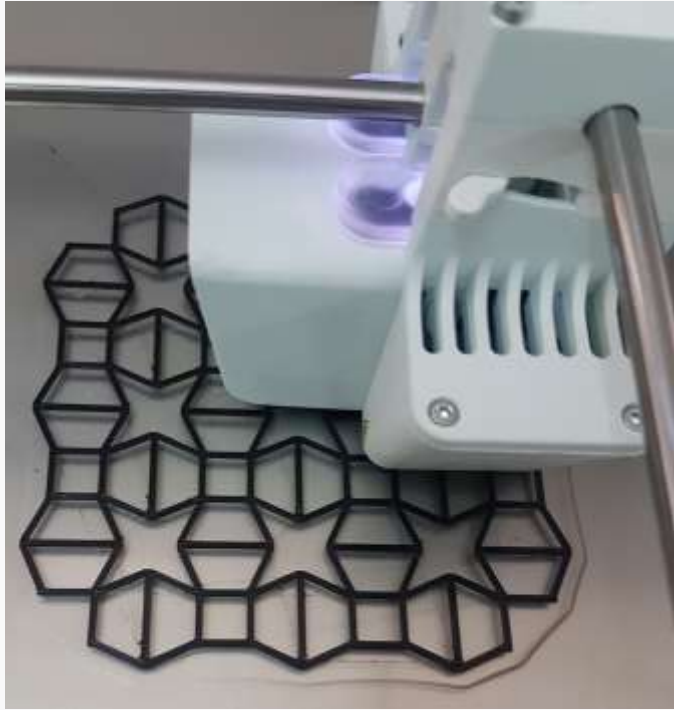
If possible, understand the processes that lead to its **optimization** and adjustability



Parameters	$H_1$ (mm)	$H_2$ (mm)	$\theta$ ( $^\circ$ )	$t$ (mm)
Mesh #1	10	10	15	1,0



Geometry of the unit cell



Print time: 1h30 – 2h

Number of printed meshes: ~100

Additive Fabrication of Aneptic Meshes

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• **Blue**

↓ CTE

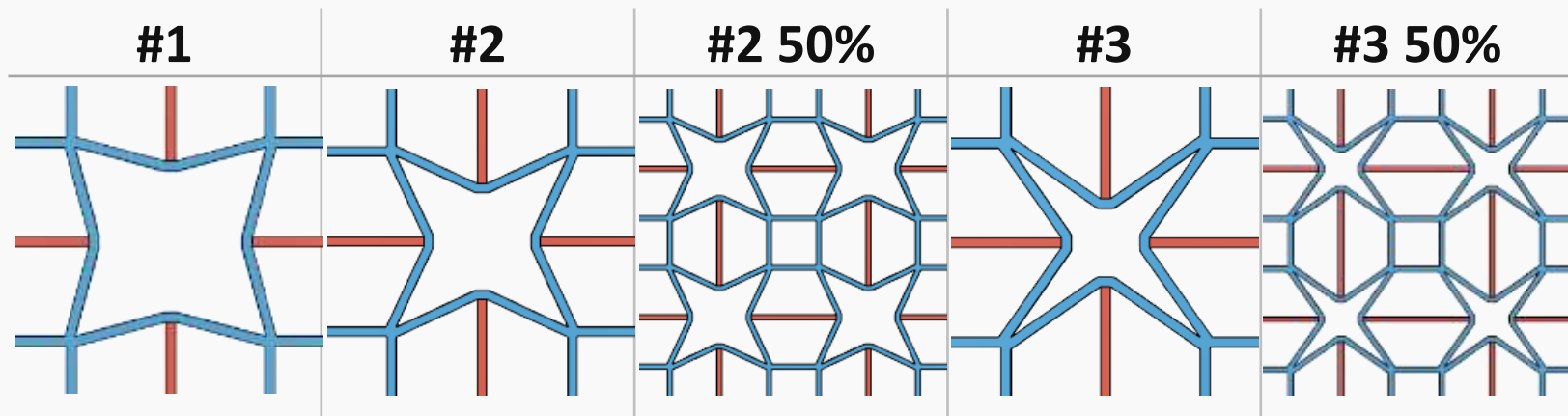
↑ Young's Modulus

• **Red**

↑ CTE

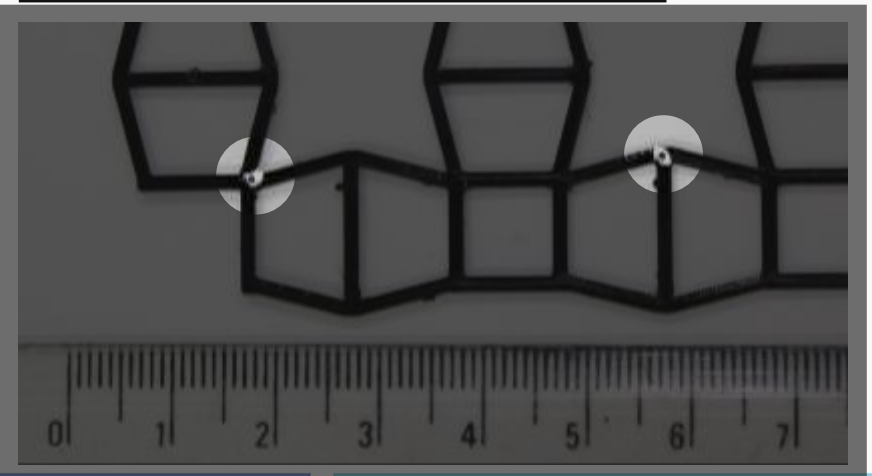
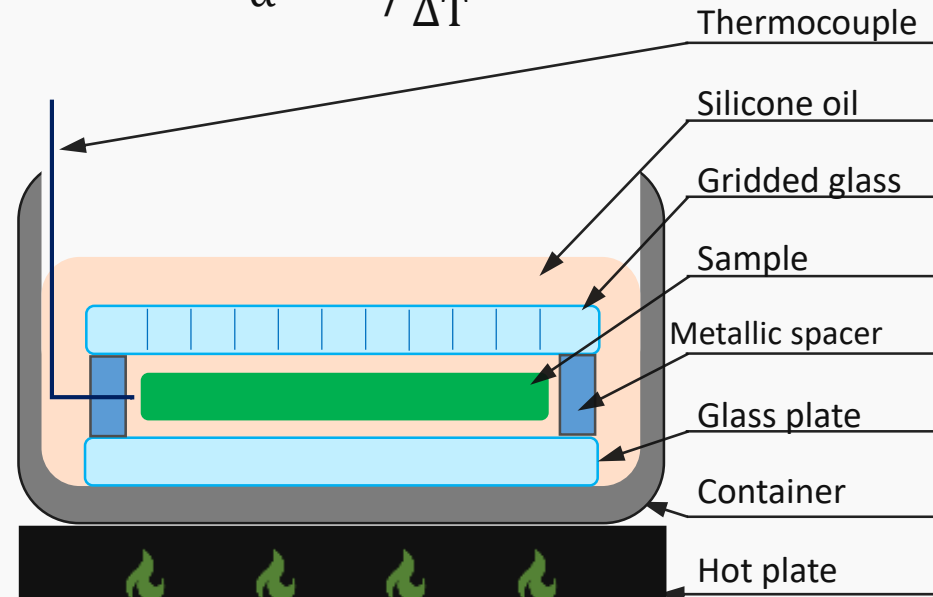
↓ Young's Modulus

Mesh	H <sub>1</sub> (mm)	H <sub>2</sub> (mm)	θ (°)	t (mm)
#1	10	10	15	1,0
#2	10	10	25	1,0
#2 50 %	5,0	5,0	25	0,5
#3	10	10	35	1,0
#3 50%	5,0	5,0	35	0,5



- **Anepectic behaviour:**  
 1 photo/°C      4h/trial

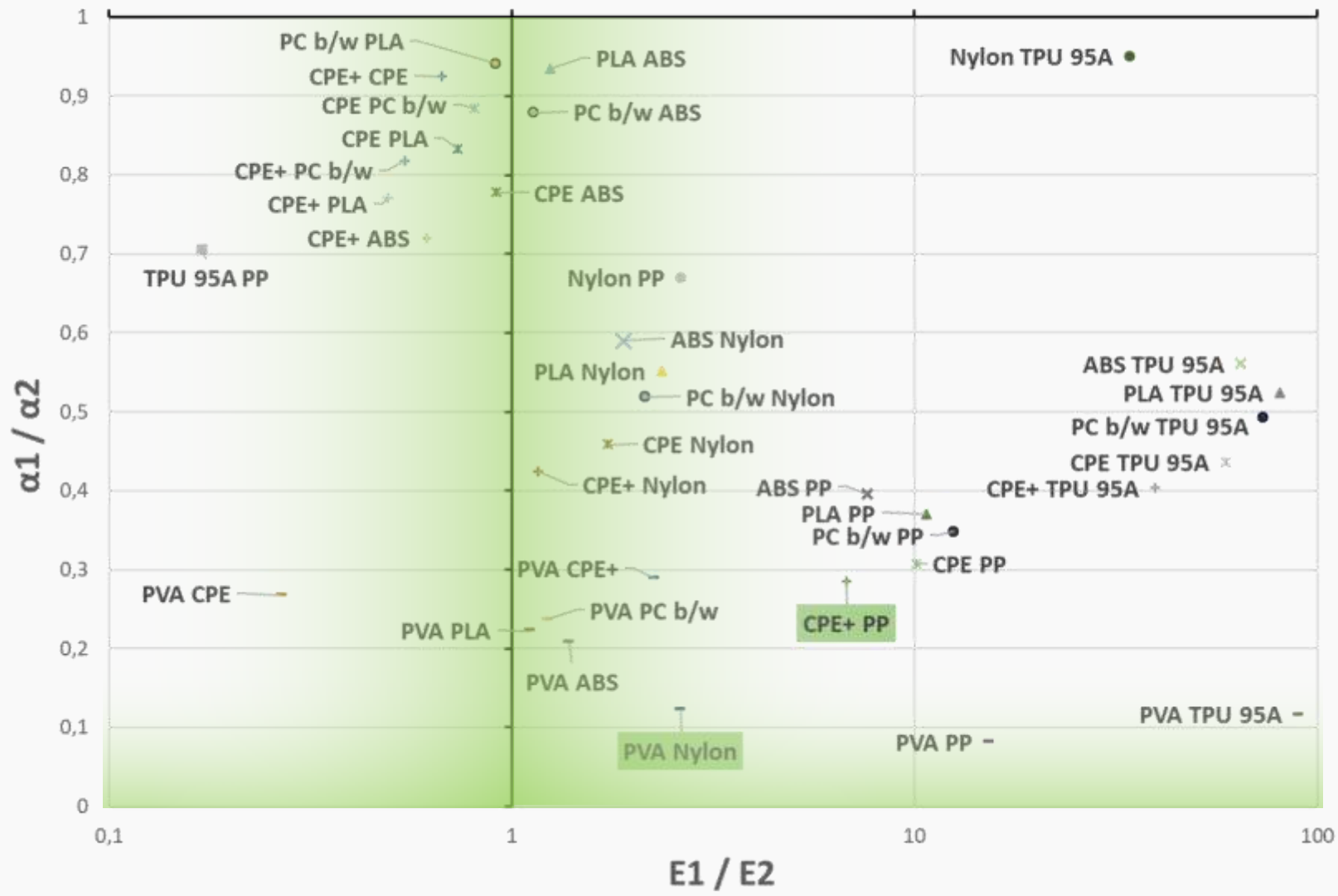
$$\alpha = \frac{\frac{\Delta L}{L_0}}{\Delta T}$$



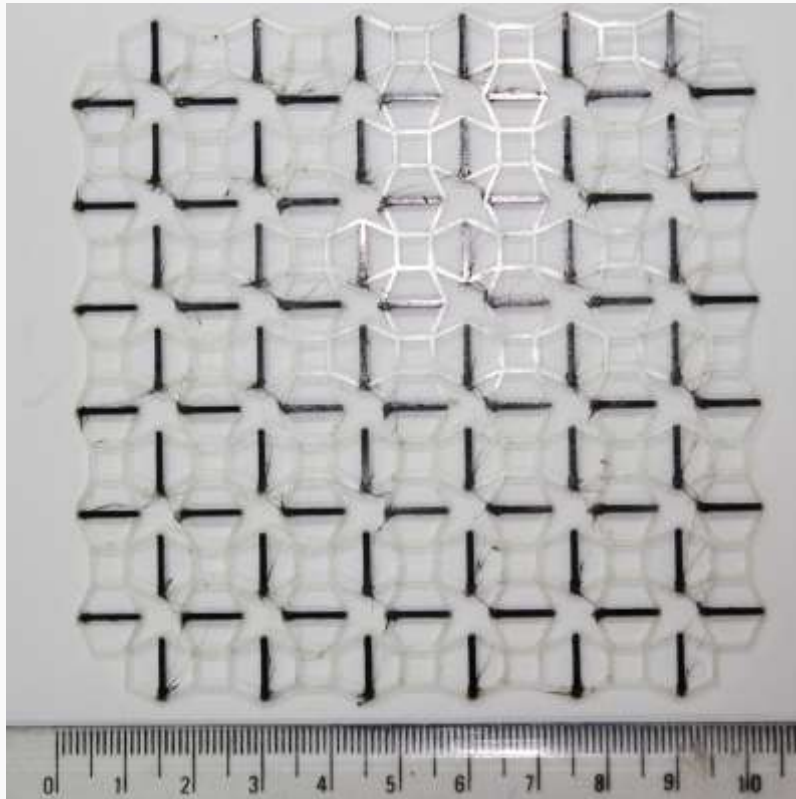
**Additive Fabrication of Anepectic Meshes**

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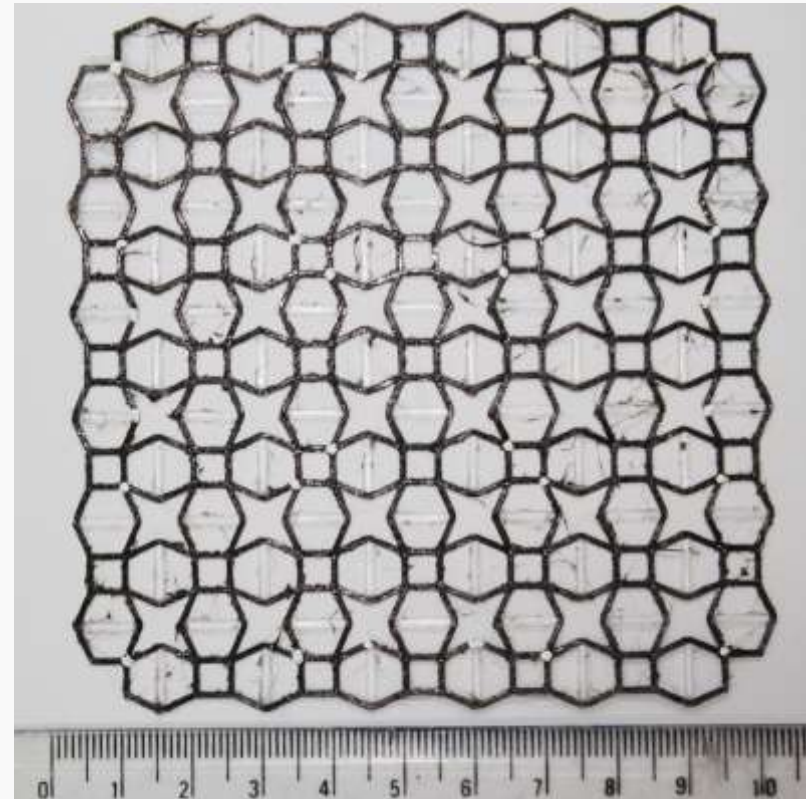
Material	Young's Modulus (MPa)	CTE ( $\times 10^{-6} \text{ }^\circ\text{C}^{-1}$ )	Tg ( $^\circ\text{C}$ )
<b>CPE+</b>	1031	71	105
<b>Nylon</b>	889	166	35
<b>PP</b>	152	248	-25
<b>PVA</b>	2328	21	35



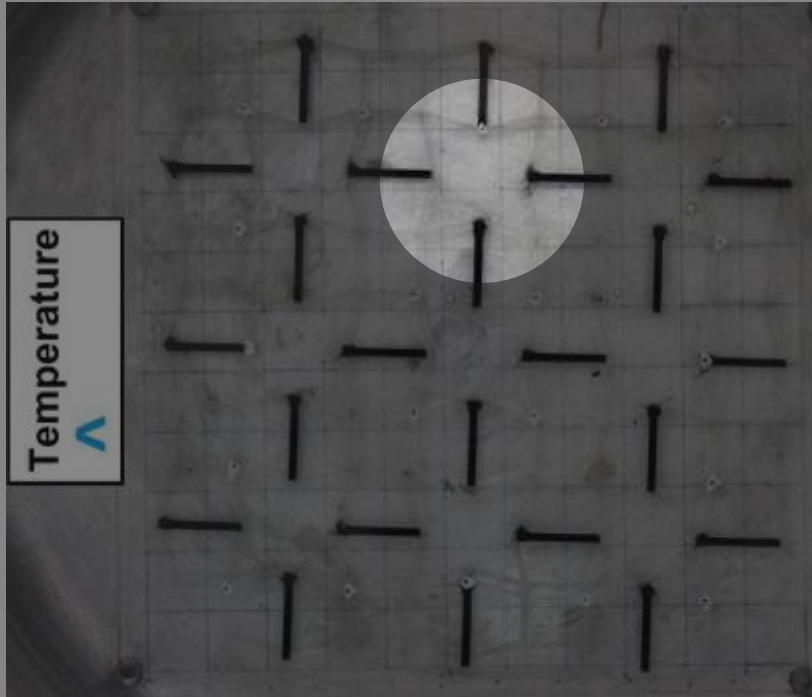
- Nylon-PVA



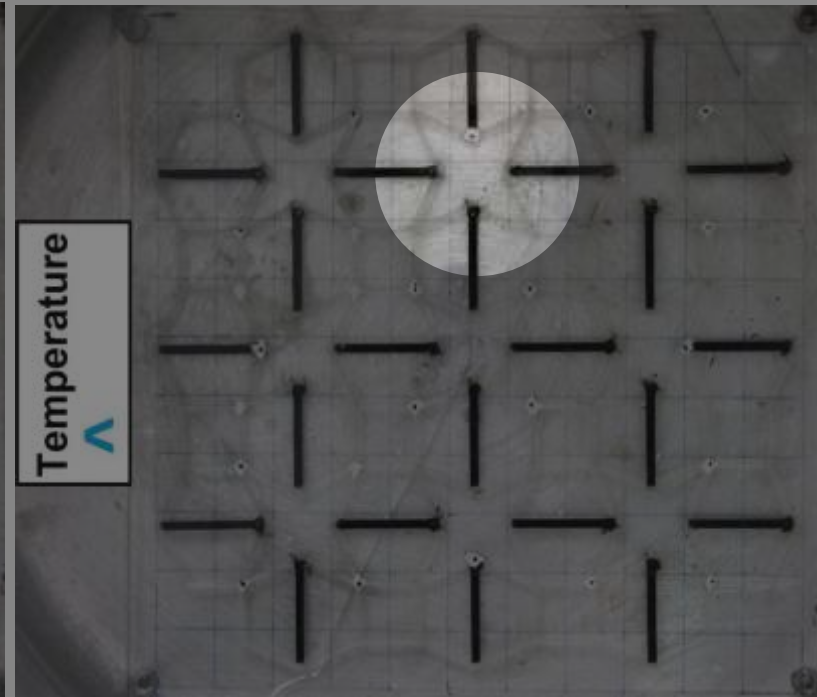
- PP-CPE+



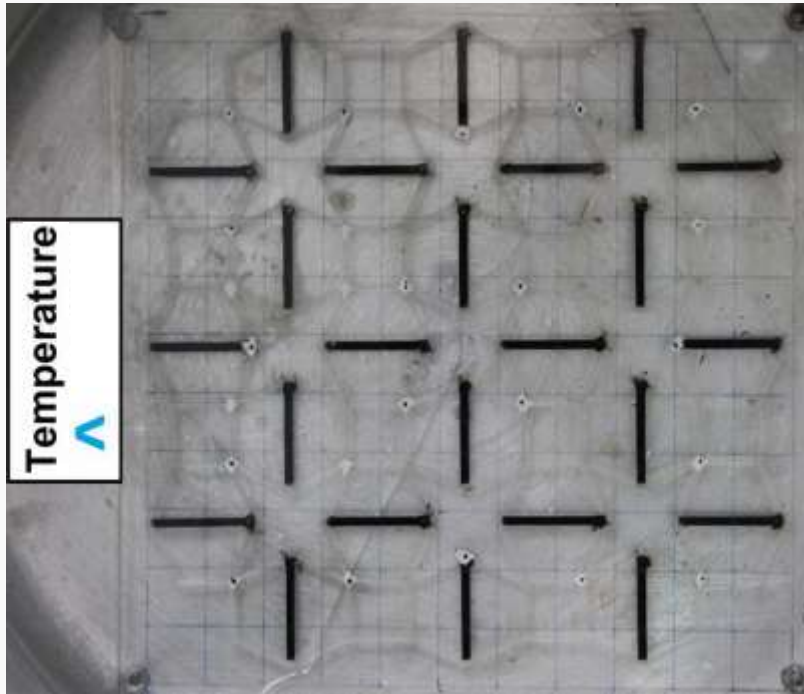
- Mesh #1 Nylon-PVA



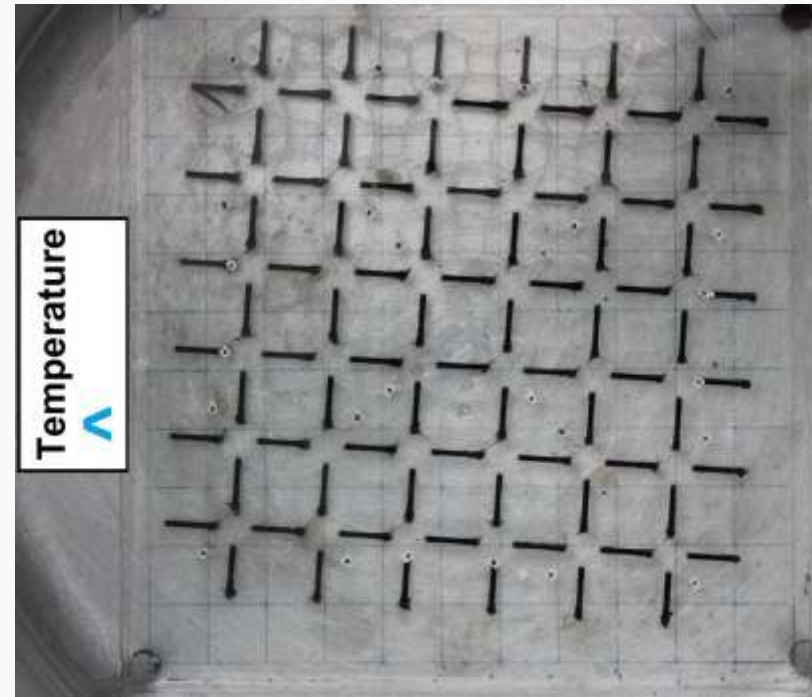
- Mesh #2 Nylon-PVA



- Mesh #2 Nylon-PVA



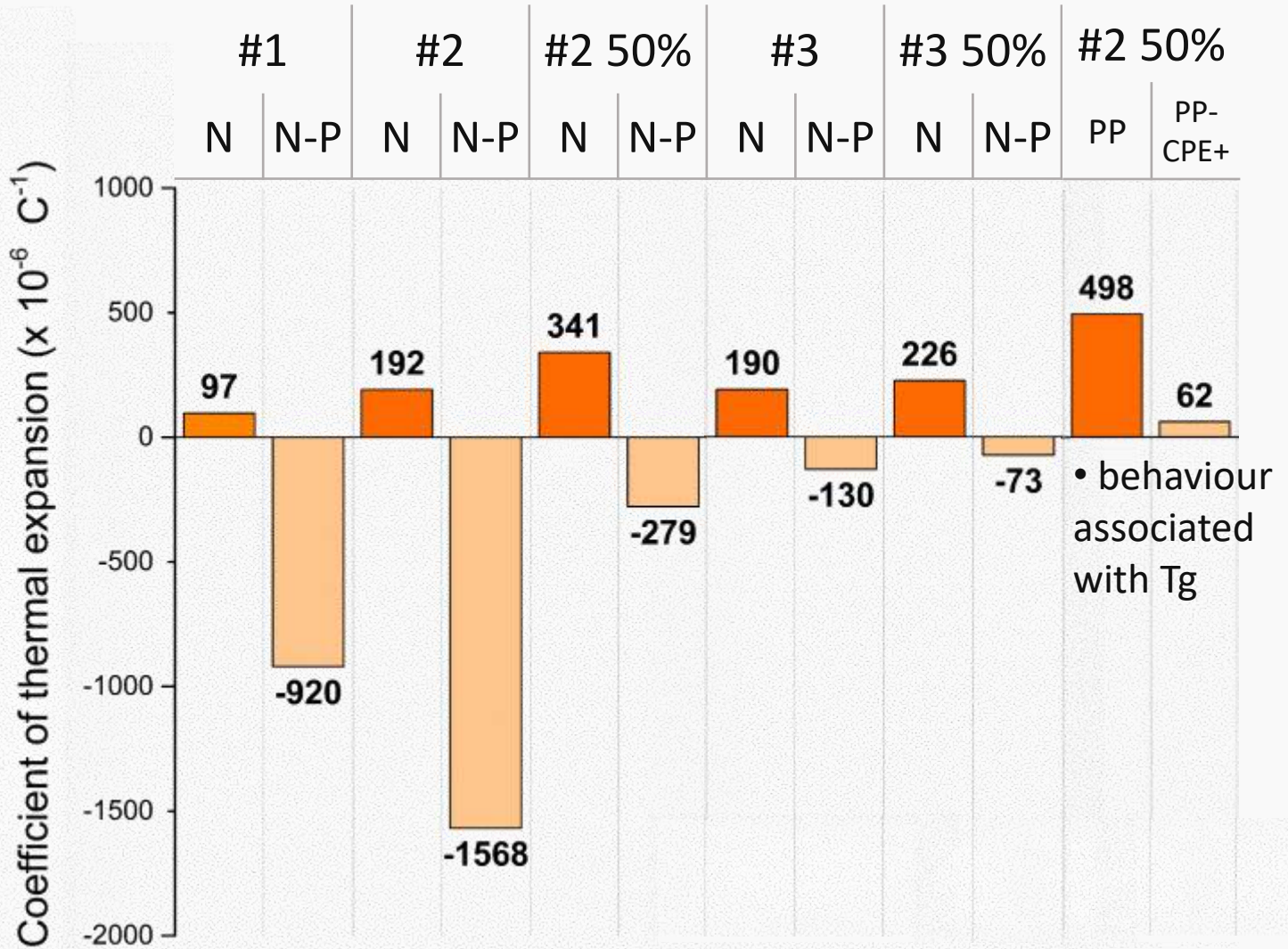
- Mesh #2 50% Nylon-PVA



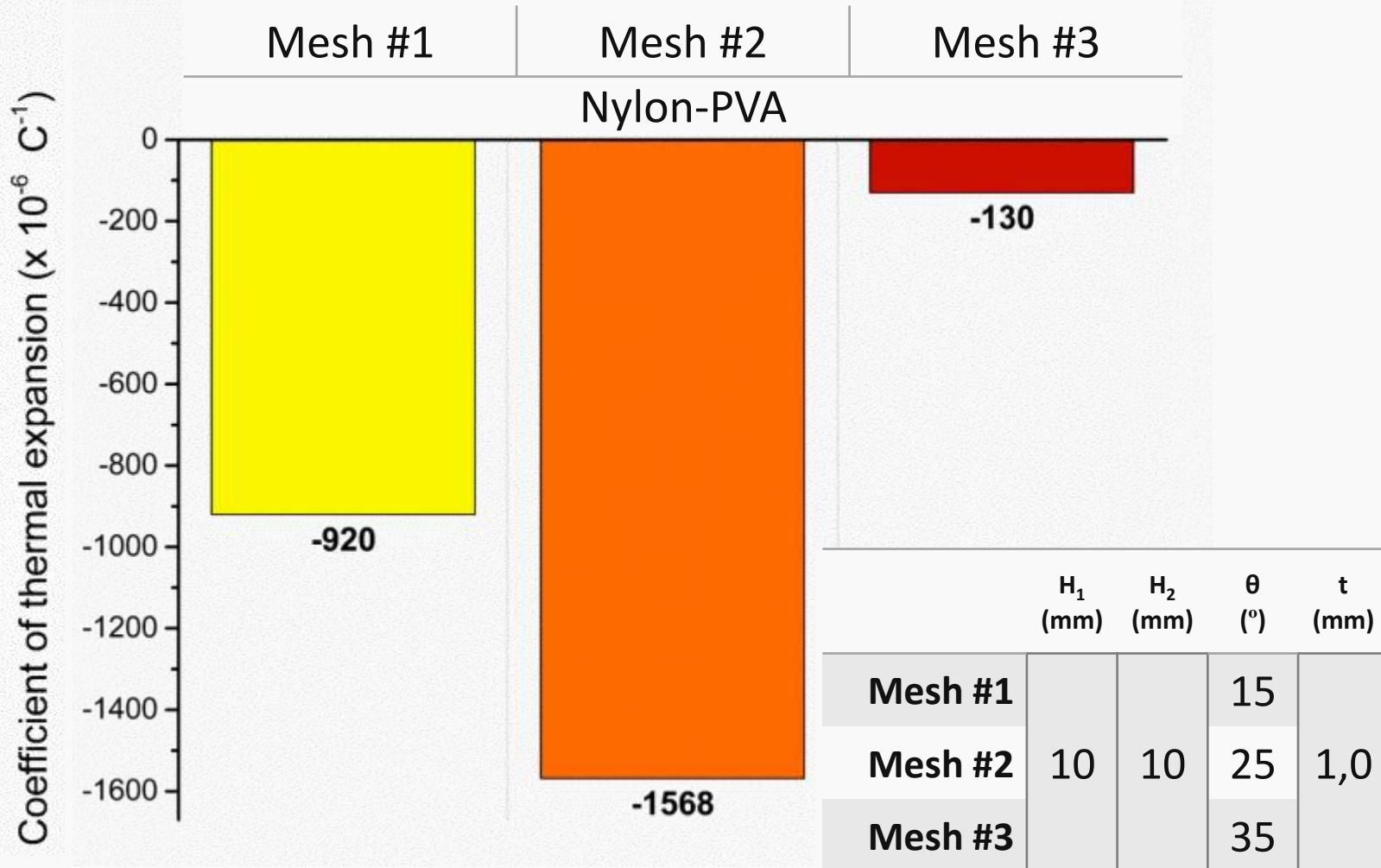
Mesh	Poisson's ratio
Mesh #2 Nylon	-0,37
Mesh #2 Nylon-PVA	-0,056



# Anepectic behaviour – effect of material combination

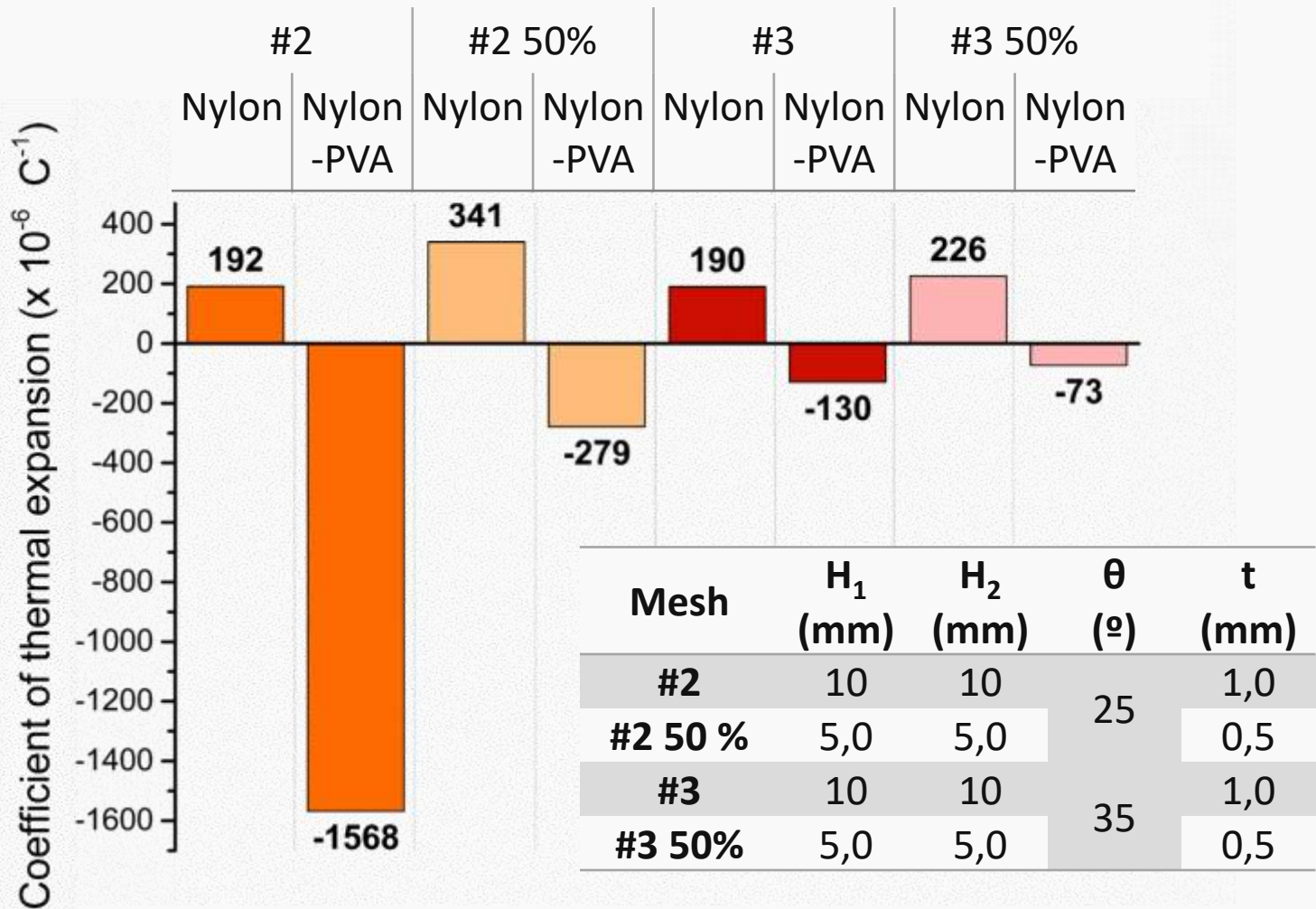


# Anepectic behaviour – effect of architecture

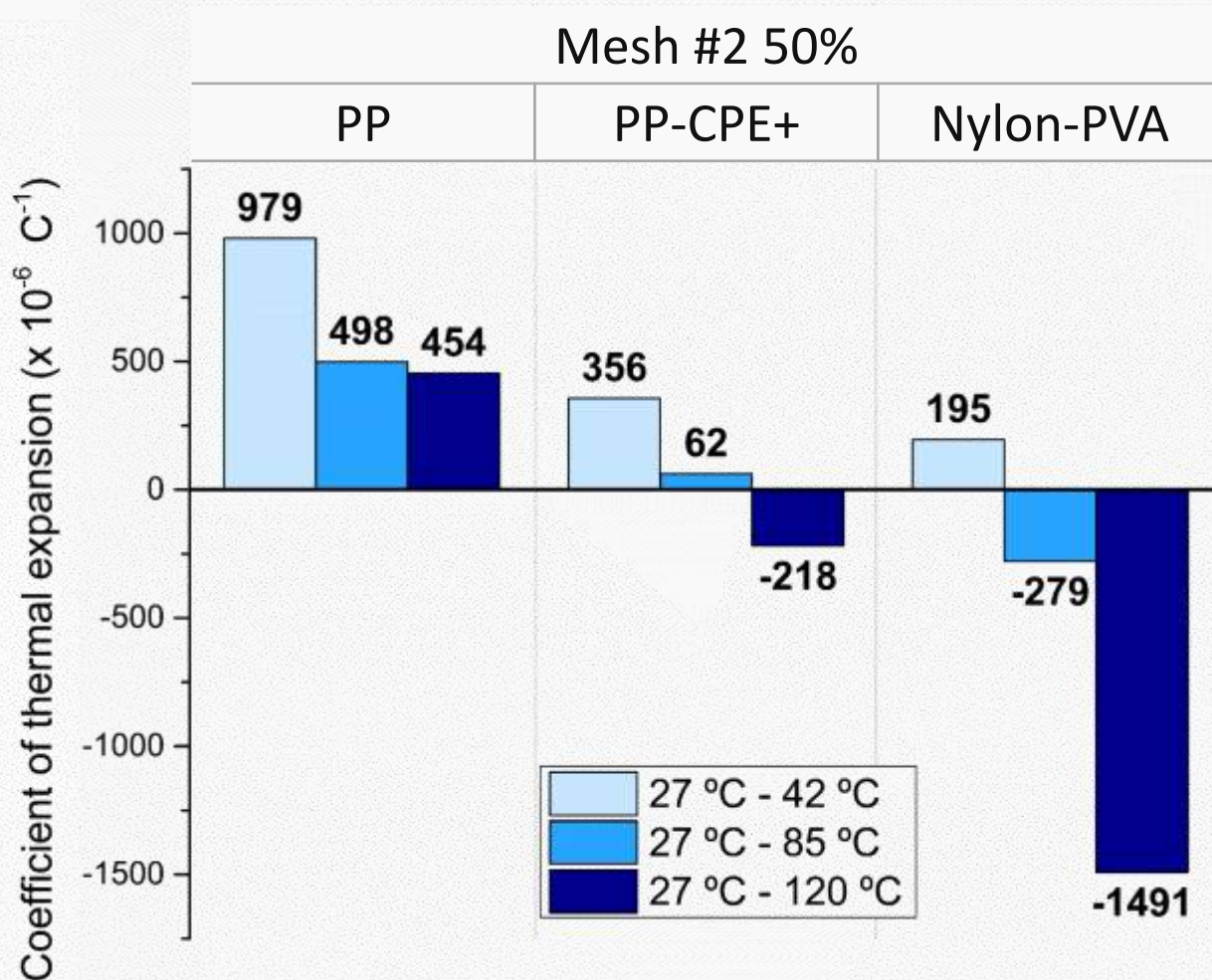


# Anepctic behaviour – effect of scale

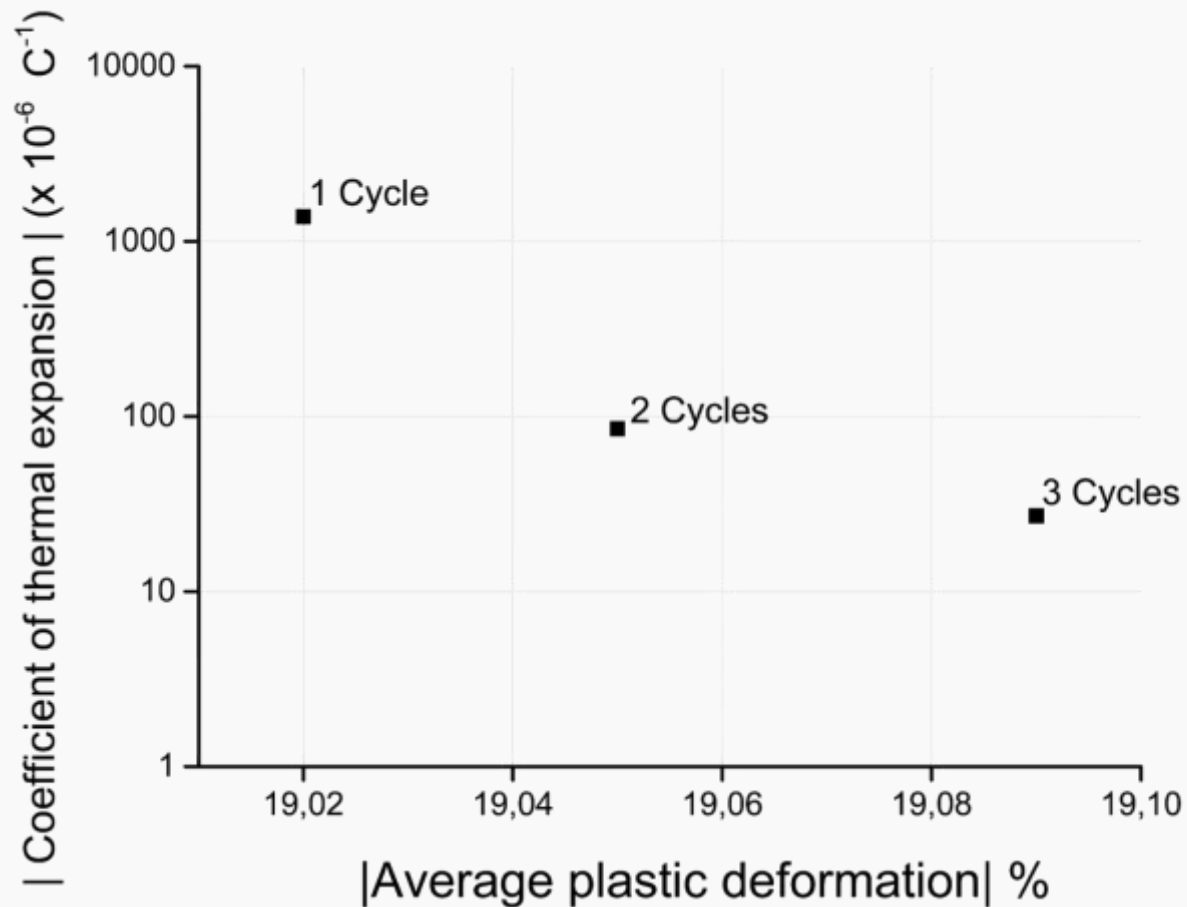
- Size reduction of unit cell



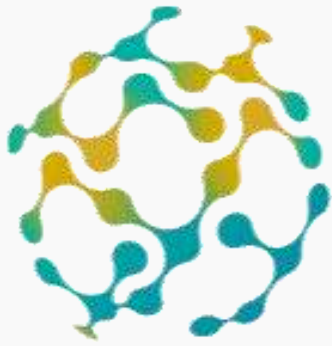
# Anepectic behaviour – plastic flow



# Anepectic behaviour – heating cycles



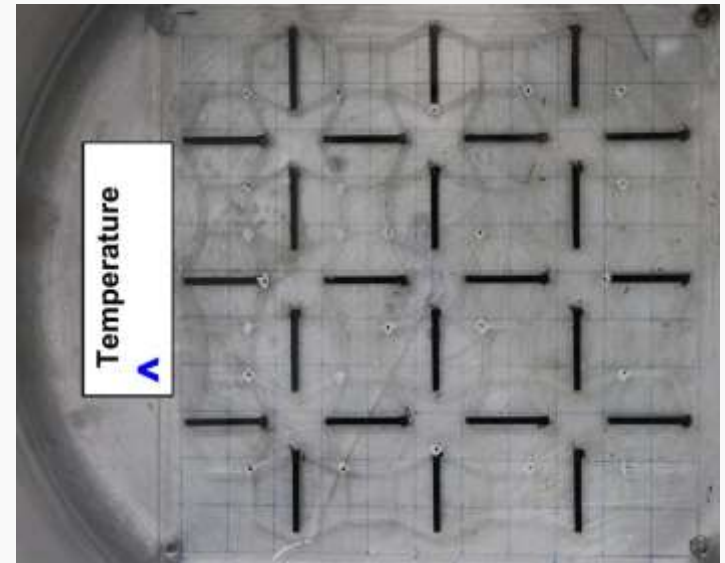
- Accomplished **objective**:
  - **Fabricate** anepectic meshes
  - Understand ways to **optimize** in the future
- Anepectic effect observable after **carefully picking material properties**:
  - CTE ; Young's Modulus
  - Glass transition temperature
- **Mesh architecture**:
  - $\theta$  of  $25^\circ$
  - $H_1, H_2 \approx 10$  mm
  - Nylon-PVA



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# Additive Fabrication of Anepectic Meshes

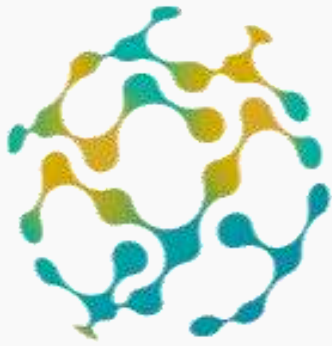
Thank you!



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Soft and Biofunctional Materials Group

16 de Abril de 2019

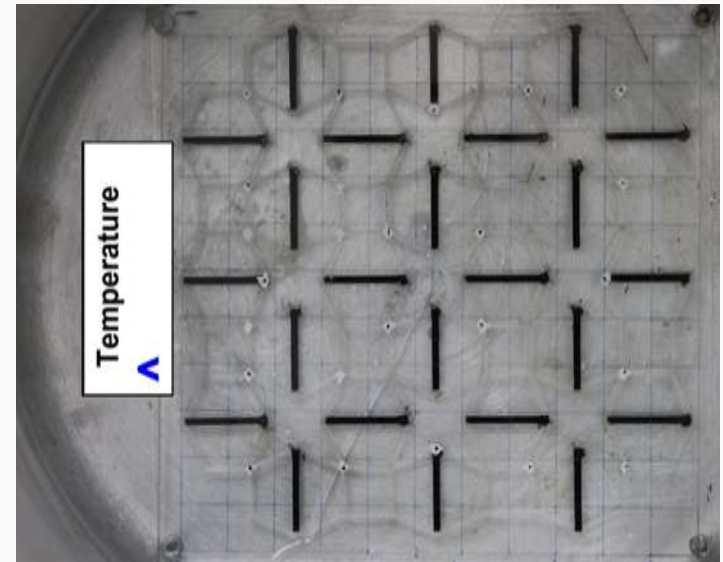
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# Additive Fabrication of Anepectic Meshes

## Thank you!



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