



UNIVERSITÀ  
DEGLI STUDI  
FIRENZE  
**DIEF**  
DIPARTIMENTO  
DI INGEGNERIA  
INDUSTRIALE

October 17th–18th, 2022

# MECHANICAL DESIGN OF AUXETIC META-BIOMATERIALS FOR VERTEBRAL IMPLANTS

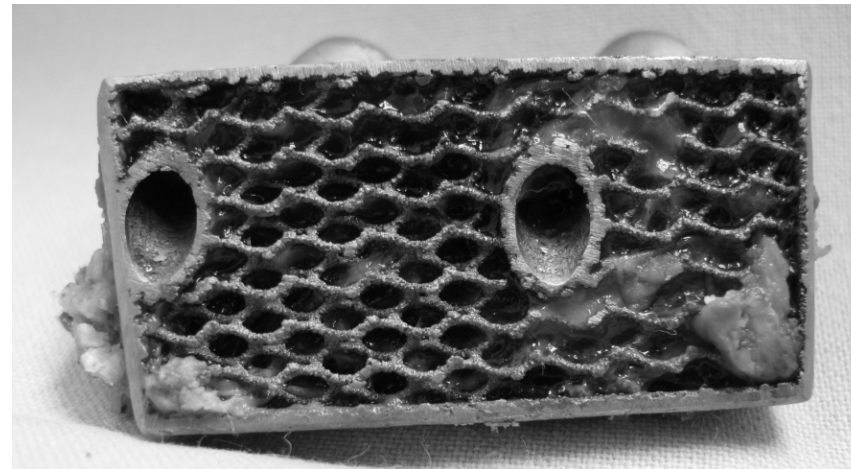
A. Sorrentino, D. Castagnetti

📍 Plesso Didattico Morgagni, Viale  
Morgagni, 44-48, 50134 Firenze

ADDITIVE 4 BIOMEDICAL



# VERTEBRAL BODY REPLACEMENT (VBR)



$P \uparrow \uparrow$

$E \uparrow \uparrow$

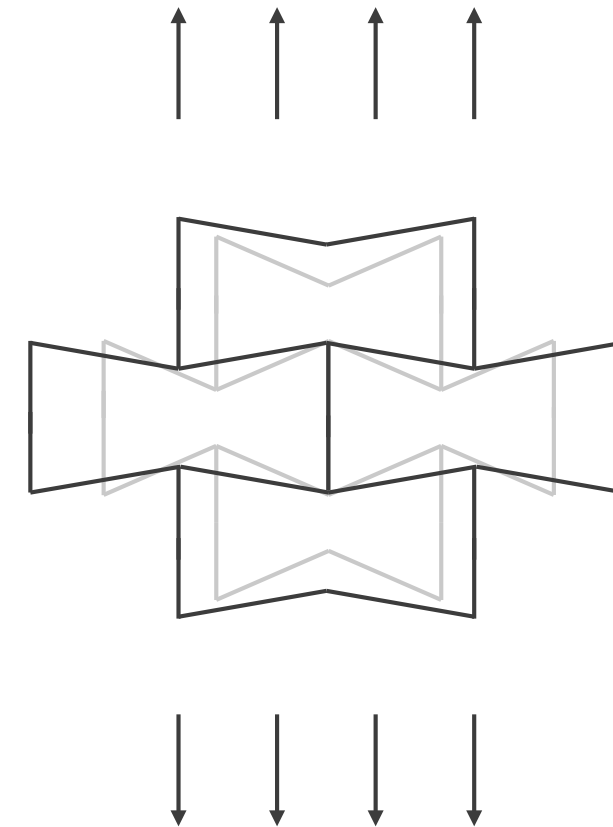
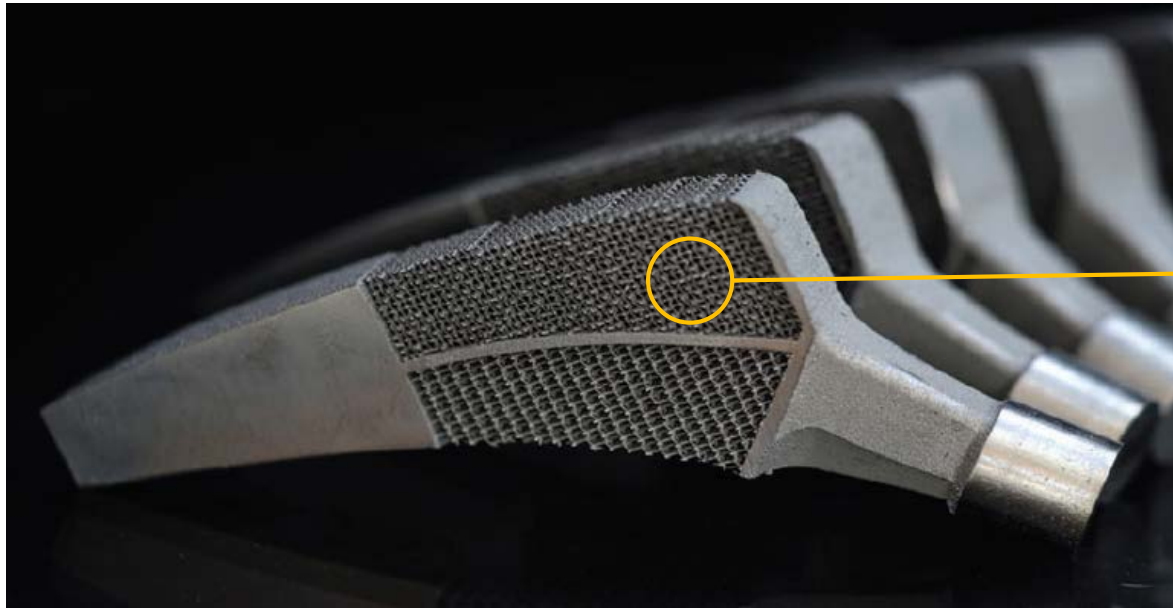
$\epsilon_e \downarrow \downarrow$

Istituto Ortopedico Rizzoli – Bologna (Italia)

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# AUXETIC META-BIOMATERIALS



NPR

Kolken *et al.*, Rationally designed meta-implants: a combination of auxetic and conventional meta-biomaterials, 2018

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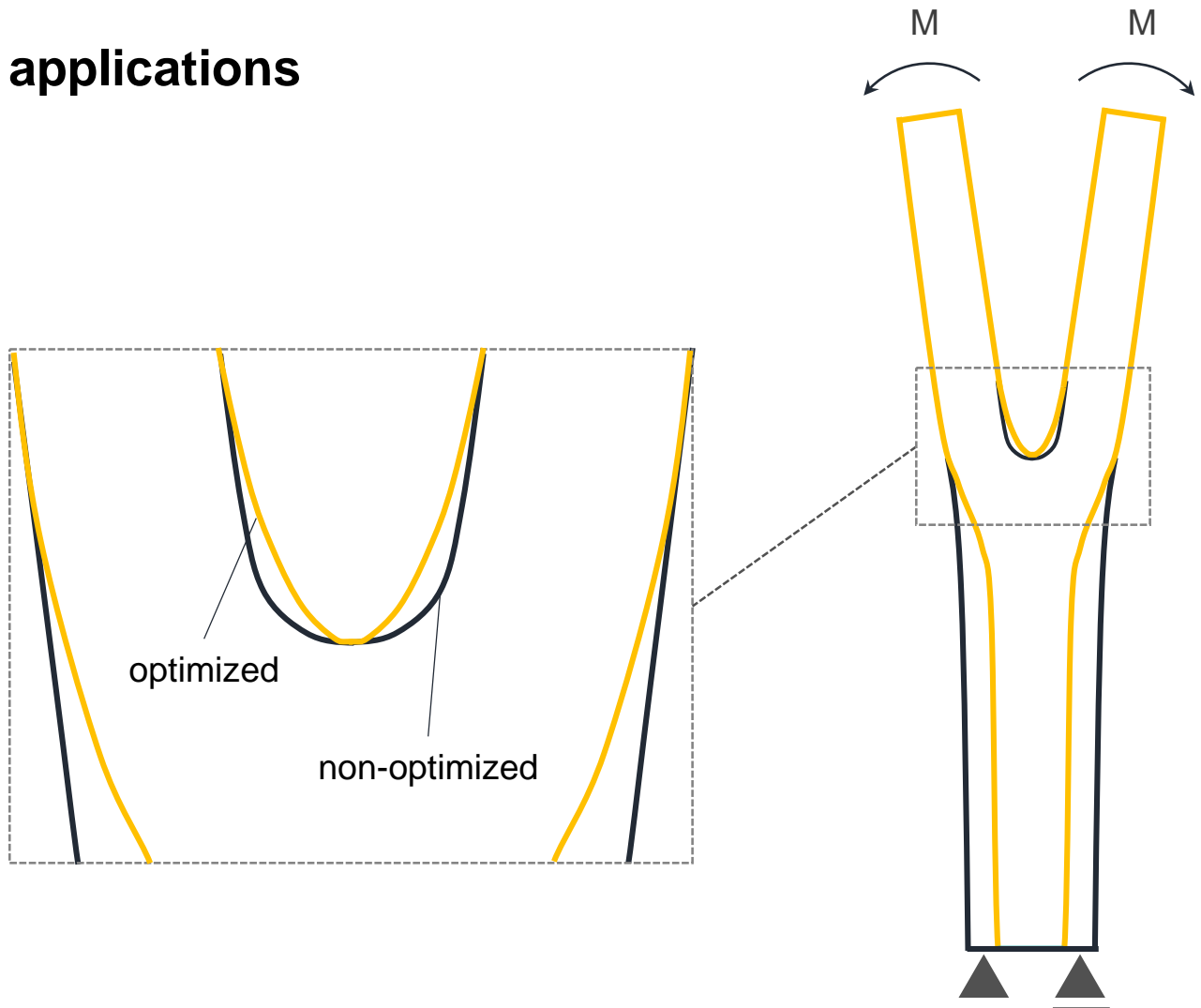


# OBJECTIVES AND MOTIVATIONS

Novel meta-structures for VBR applications

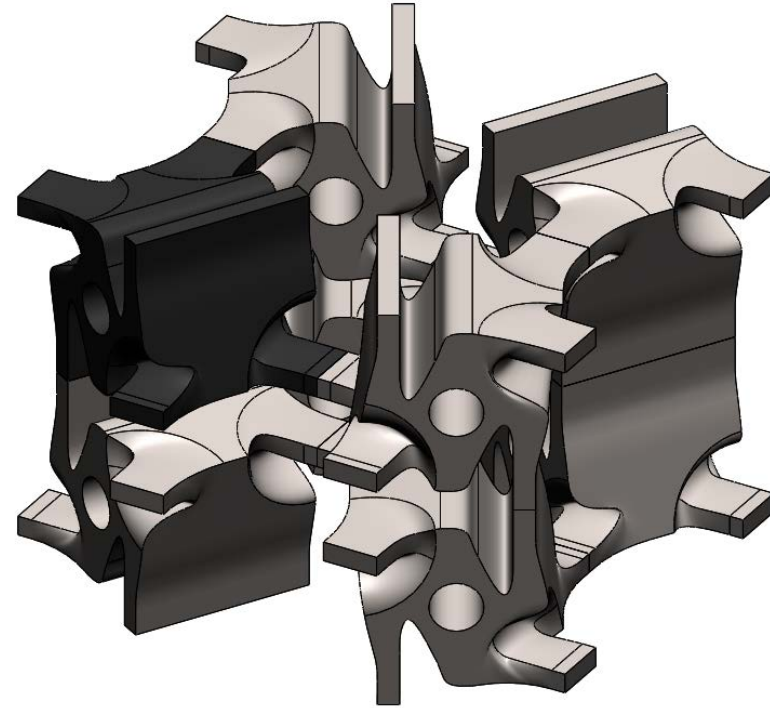
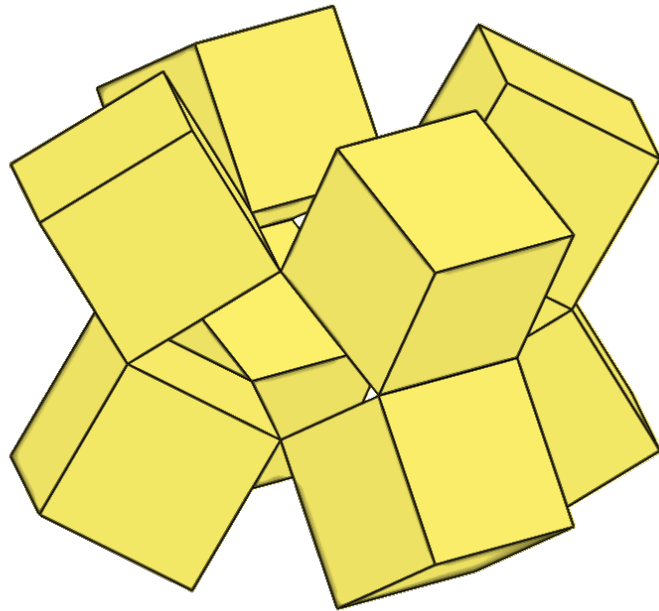
Auxetic metamaterials

Bio-inspired approaches



# NEGATIVE POISSON'S RATIO (NPR) LATTICE

Vertebral cancellous bone



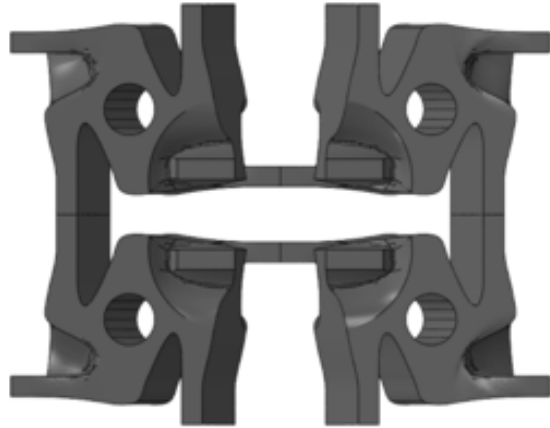
**Patent:** Metmateriale auxetico ad elementi rotanti in titanio o tecnopolimero realizzato mediante stampa 3D - (2021)  
*A. Sorrentino, D. Castagnetti, A. Pasquali, M. Celesti, R. Manzo*

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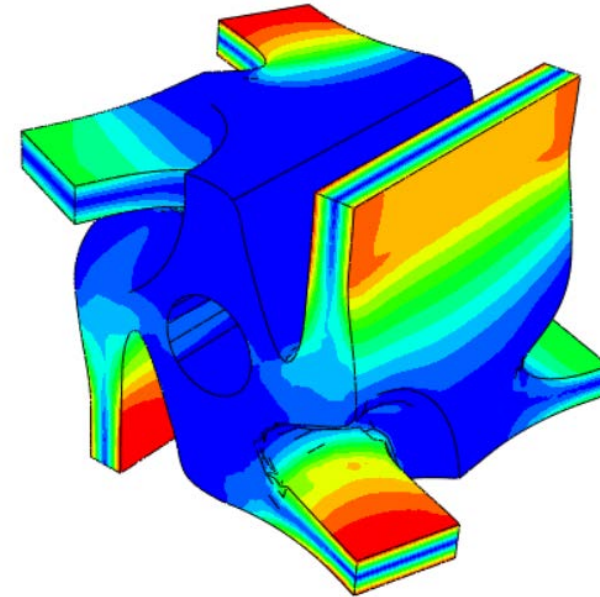
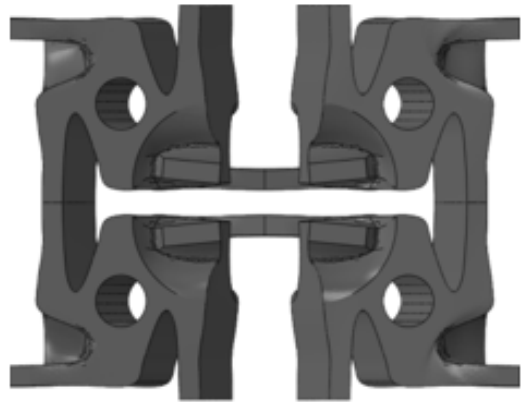


# NPR LATTICE: FE ANALYSES

$\varepsilon = 0\%$



$\varepsilon = 3\%$



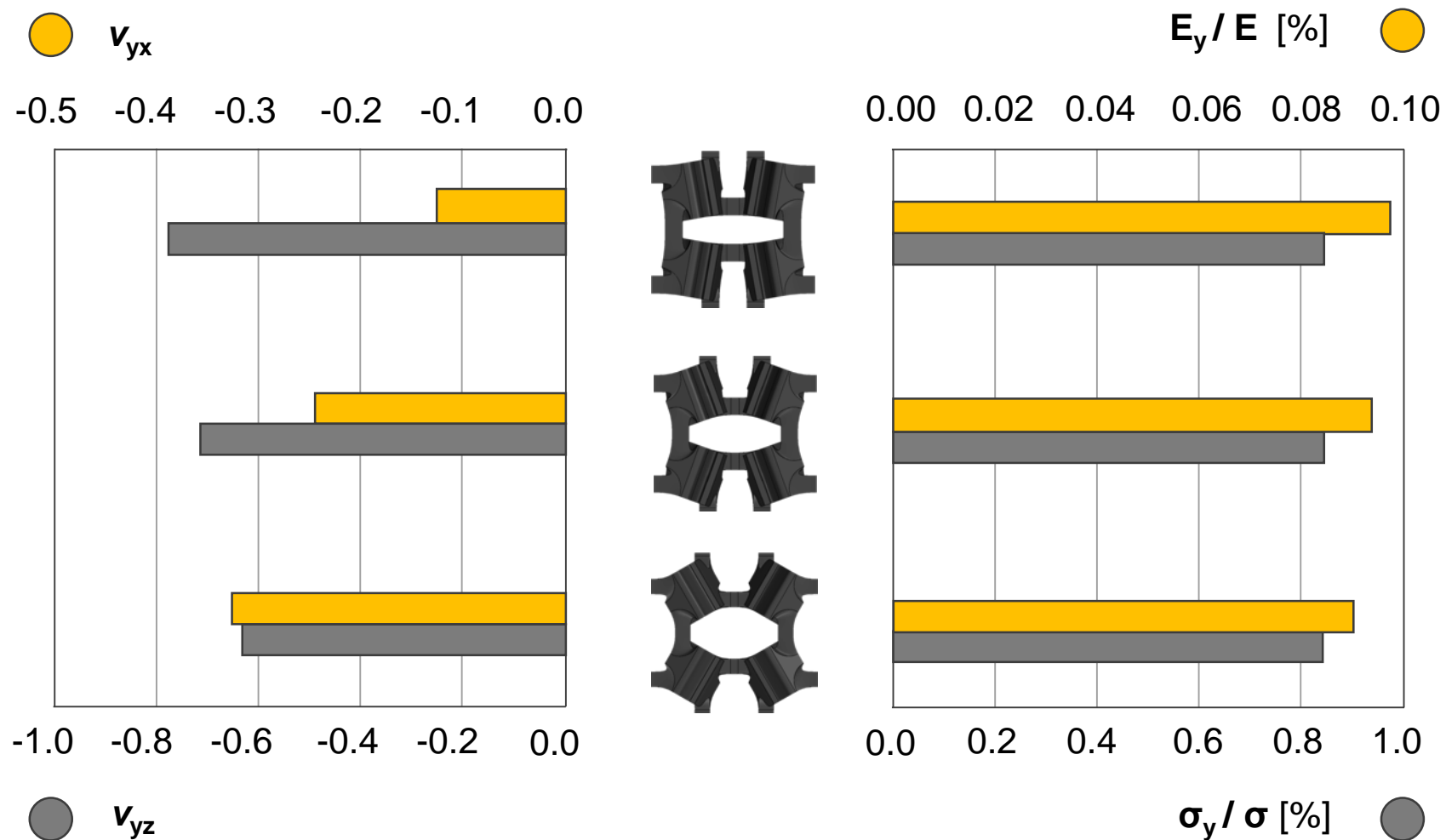
0.5  870

von Mises

Sorrentino *et al.*, Negative Poisson's ratio lattice for designing vertebral biomaterials, 2021

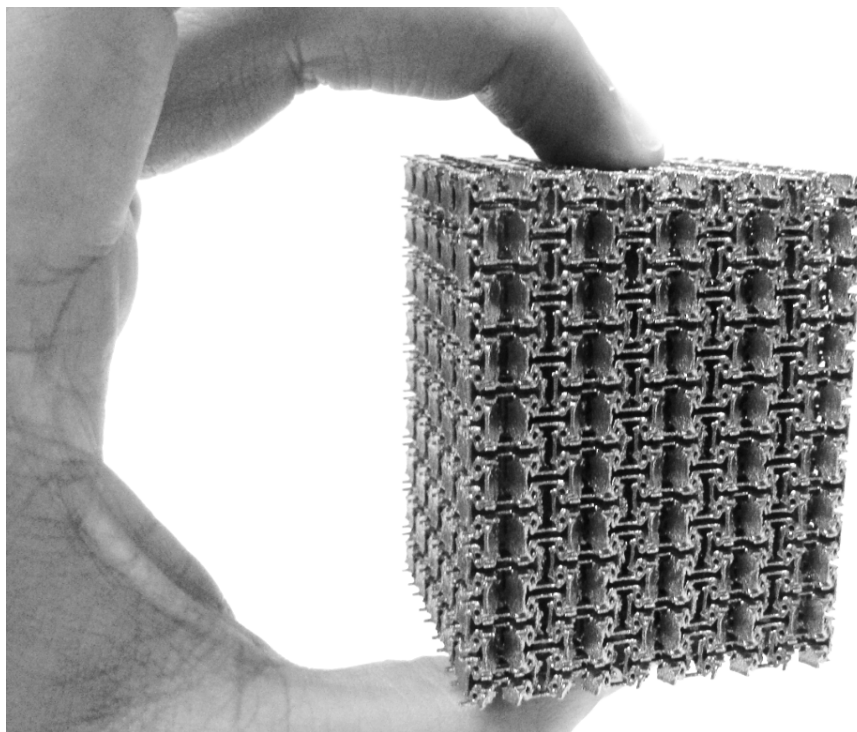
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# NPR LATTICE: MECHANICAL PROPERTIES



# NPR LATTICE: AM AND EXPERIMENTAL VALIDATION

SLM - Ti6Al4V ELI

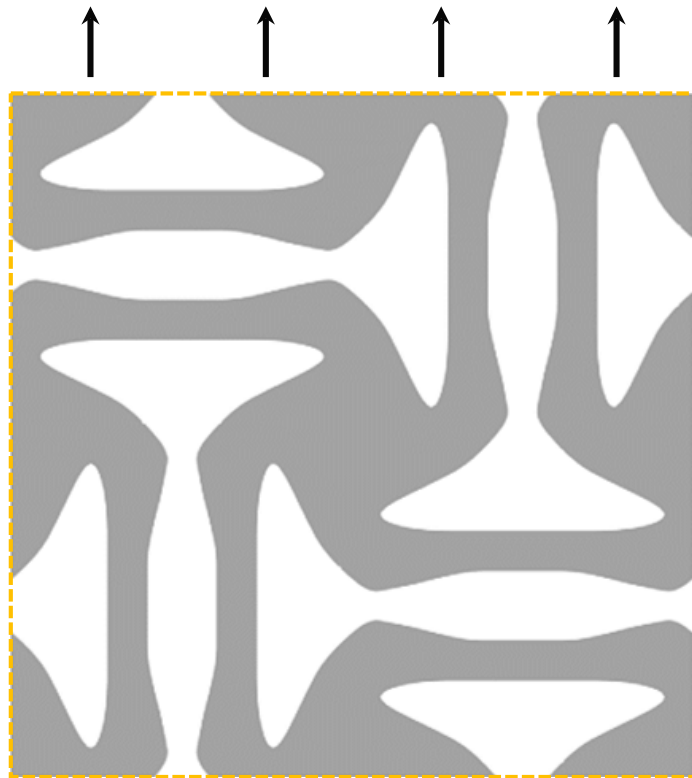


	FE	Exp.
<b>P</b> [%]	76	74
$\epsilon_e$ [%]	3.5	> 3
<b>E<sub>y</sub></b> [MPa]	90-100	116
<b>v<sub>yx</sub></b>	-0.636	-0.615
<b>v<sub>yz</sub></b>	-0.329	-0.325





# 2D AUXETIC CHIRAL HONEYCOMB



$\varepsilon = 0\%$



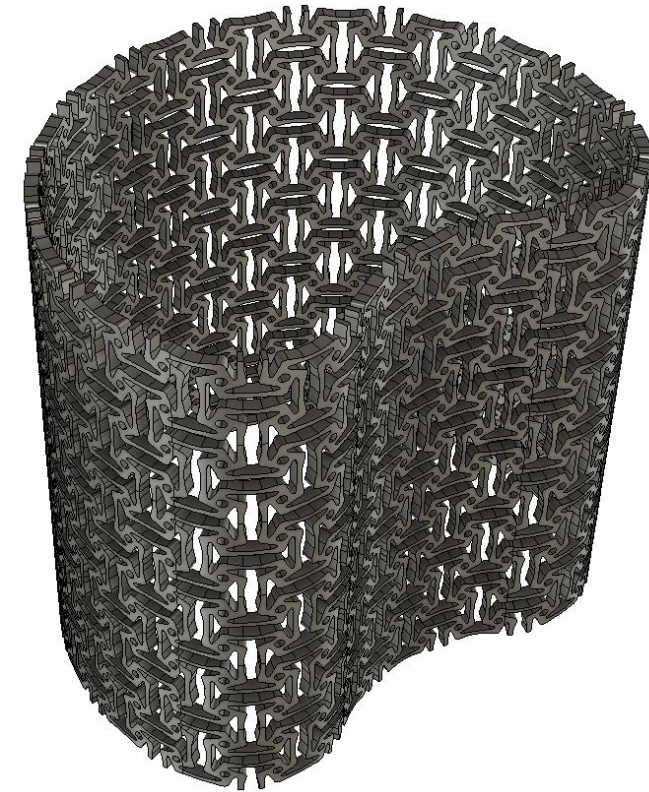
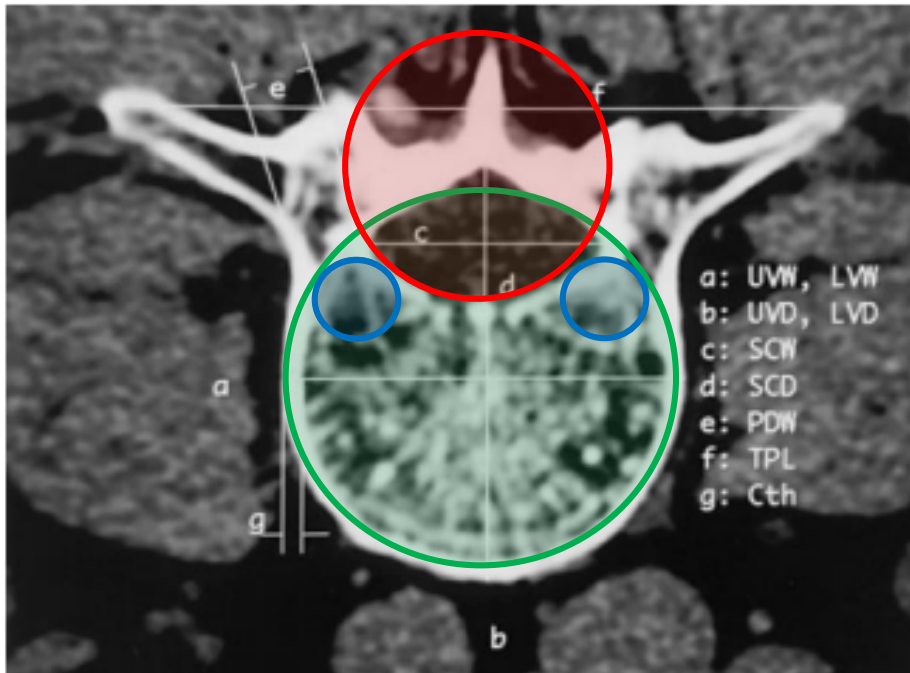
$\varepsilon = 3\%$

**NPR**



# VERTEBRAL META-SHELL WITH NPR BEHAVIOR

Vertebral **cortical** bone

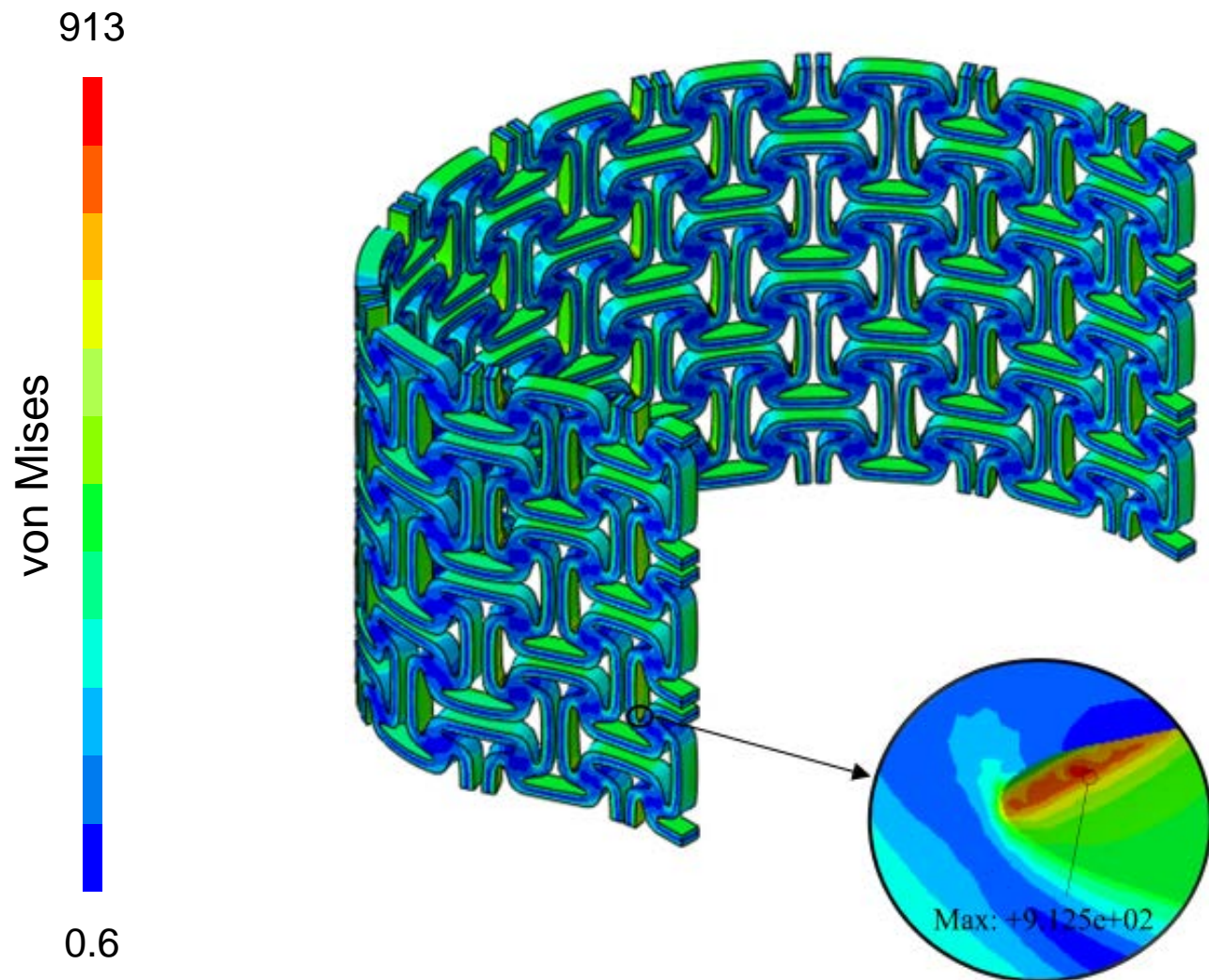


**Patent:** Struttura vertebrale in parete sottile in metamateriale auxetico - (2022)  
*A. Sorrentino, D. Castagnetti, A. Pasquali, M. Celesti, R. Manzo*

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# VERTEBRAL META-SHELL: FE ANALYSES



$$\nu = -0.89$$

$$E = 540 \text{ MPa}$$

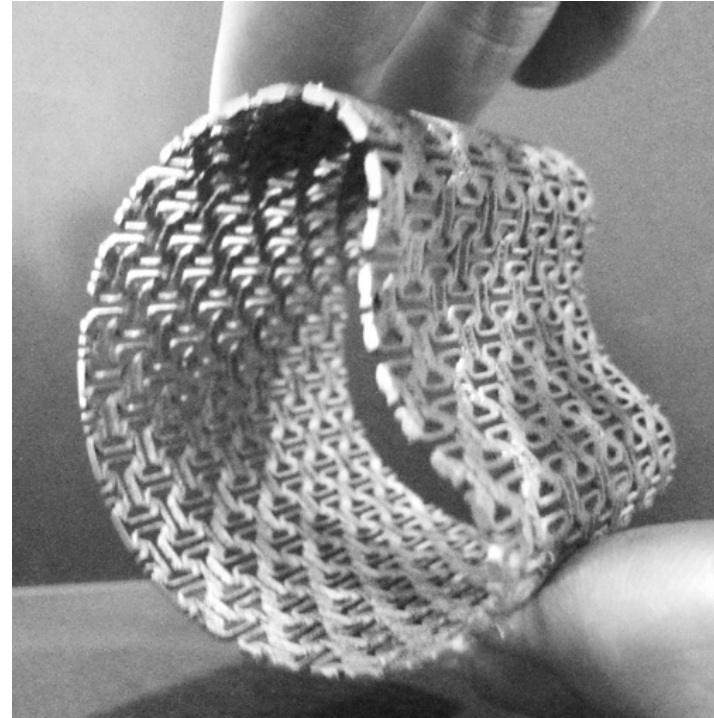
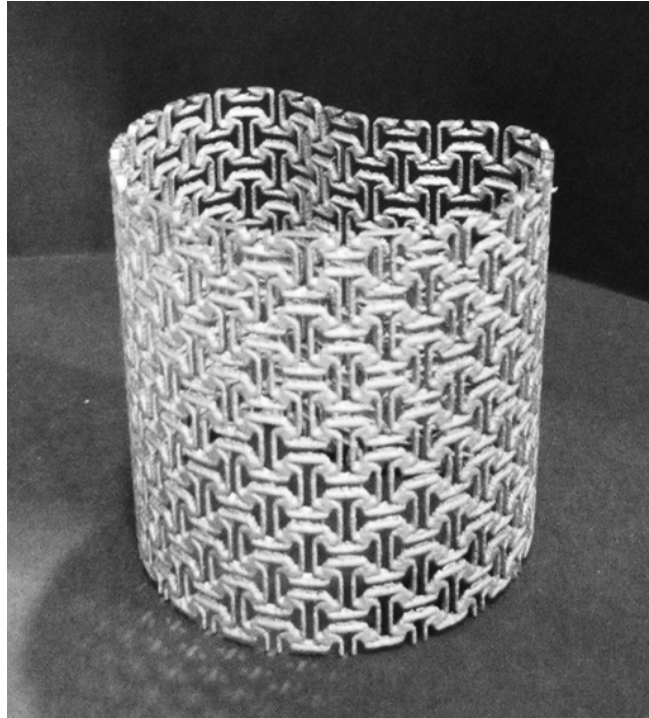
$$\epsilon_e \approx 3\%$$





# VERTERBAL META-SHELL: AM

SLM - Ti6Al4V ELI



$$t_{\text{shell}} = 1 \text{ mm}$$

$$t_{\text{ligament}} = 0.5 \text{ mm}$$

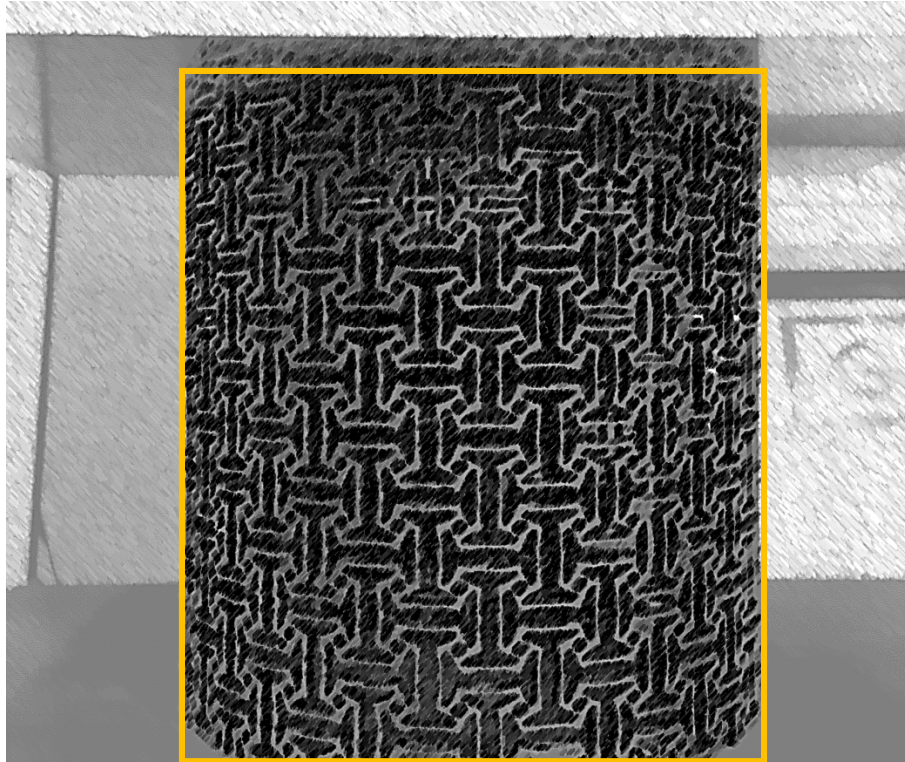
Zare – BEAMIT

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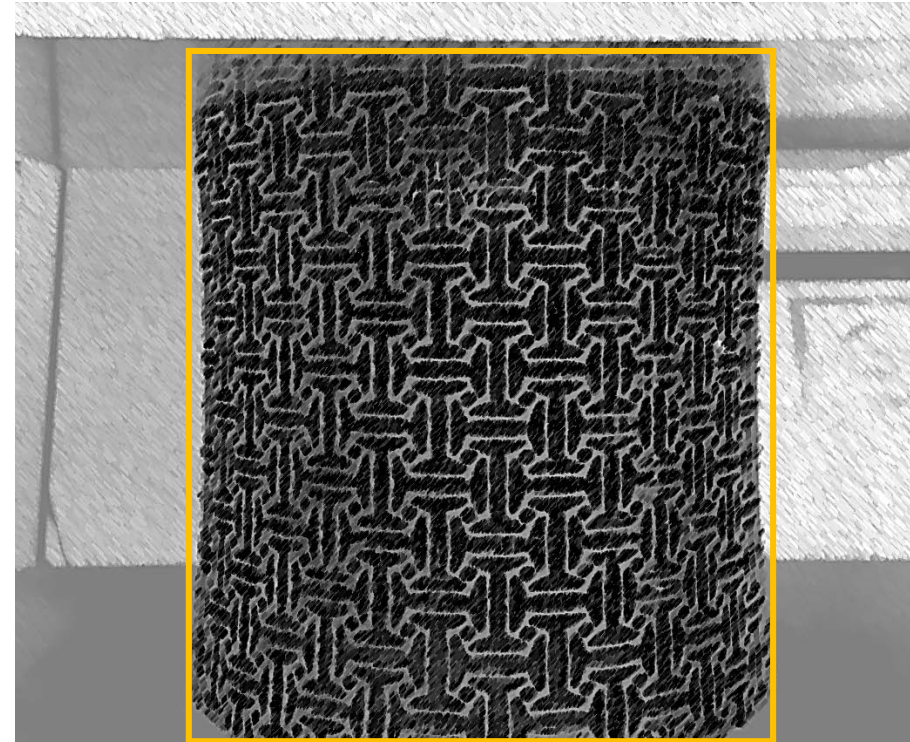


# VERTERBAL META-SHELL: EXPERIMENTAL VALIDATION

In progress



$\varepsilon = 0\%$



$\varepsilon = 3\%$





# CONCLUSIONS



**UNIMORE**  
UNIVERSITÀ DEGLI STUDI DI  
MODENA E REGGIO EMILIA

Dipartimento di Scienze e Metodi  
dell'Ingegneria

Novel vertebral **meta-biomaterials**

Negative Poisson's ratio behavior (**auxetics**)

**Tailored** mechanical properties

