



AUXETIC MATERIALS

- 'the positive side of being negative'

Presentation By,
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CONTENT

- Introduction
- Mechanical Properties
- Natural Auxetic Materials
- Man-Made Auxetic Materials
- Applications
- Conclusion

INTRODUCTION

- Meta Materials
 - Auxetic Materials- become thicker width-wise when stretched along its length.
 - Become thinner when compressed lengthwise.

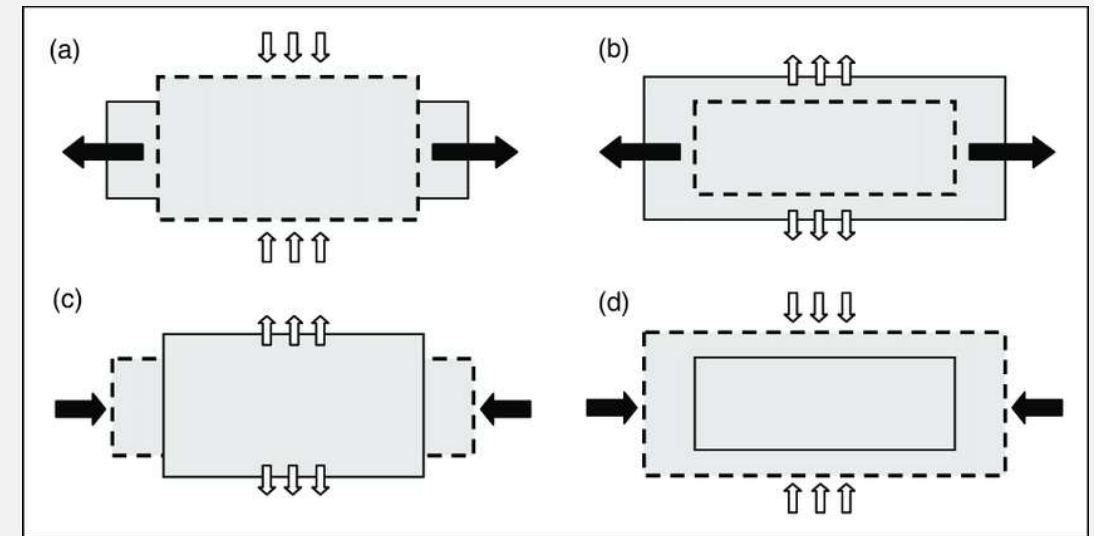
Why??

Negative Poisson's Ratio

$$\text{Poisson's Ratio: } \nu = \frac{-\varepsilon_y}{\varepsilon_x}$$

ε_y : tensile strain perpendicular to the stretching direction.

ε_x : tensile strain in the stretching direction



Source: ResearchGate

MECHANICAL PROPERTIES

A negative Poisson's ratio is associated with:

- Increased shear modulus, $G = \frac{E}{2(1+\nu)}$ than conventional materials
- Indentation resistance, $H \propto (1 - \nu^2)^{-x}$

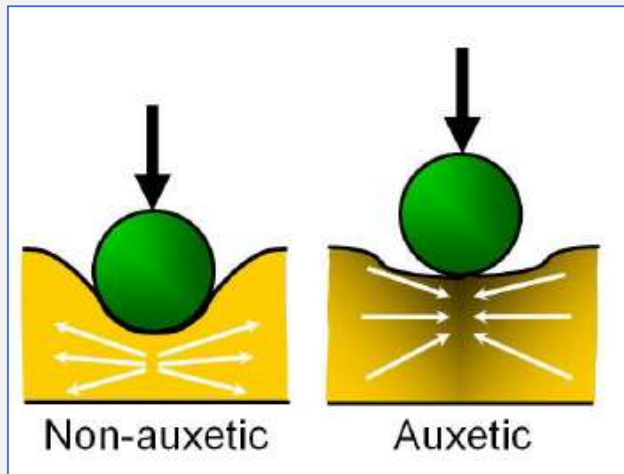


Fig: Indentation response of auxetic and non-auxetic materials, Source: [3]

- Fracture toughness
- High energy absorption capability

Poisson's ratio of isotropic materials :

$$-1 \leq \nu \leq 0.5$$

In 1987, first man-made cellular polyurethane foam with a Poisson's ratio of -0.7, by Lakes.

MECHANICAL PROPERTIES

- Lower Young's modulus, $E = \frac{\sigma}{\epsilon}$
- Young's modulus E and bulk modulus K for isotropic materials,

$$E=2G (1+\nu)=3K (1-2\nu)$$

- Synclastic Behaviour



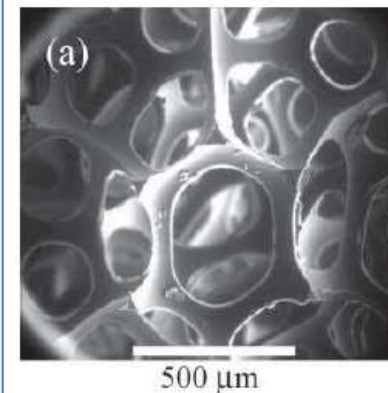
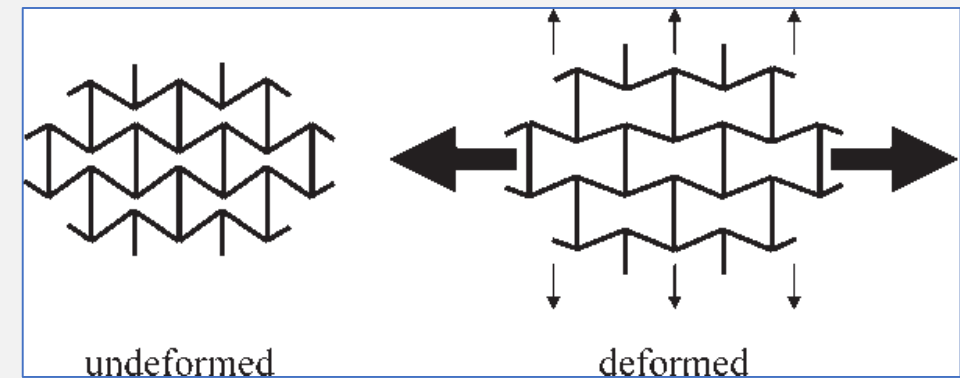
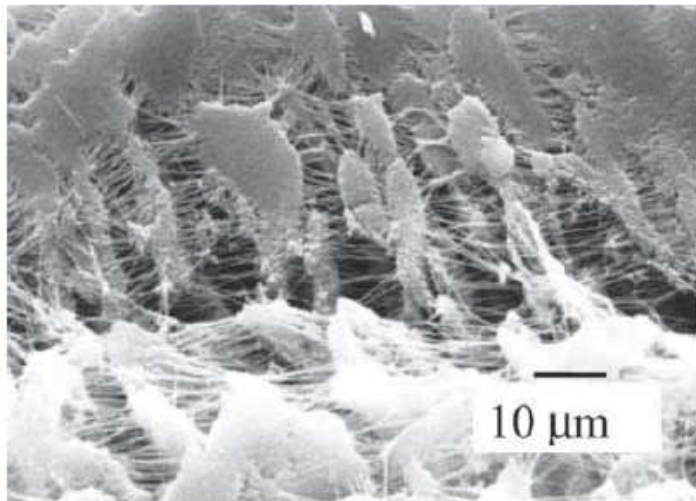
Source: [3]

Natural Auxetic Materials

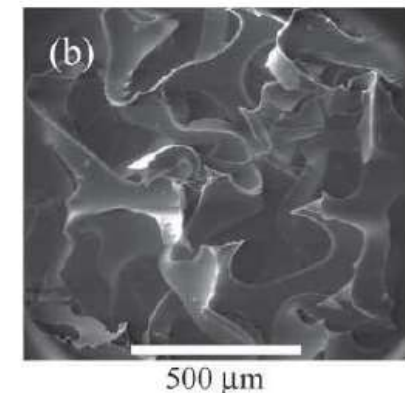
- certain rocks
- single crystals of arsenic, cadmium, α -cristobalite, iron pyrites
- cat skin
- salamander skin
- cow teat skin [2]
- load-bearing cancellous bone from human tibia
- soft tissues
- early stage embryonic tissue [4]

Man-Made Auxetic Materials

- Honeycomb Structures
- Polymeric and metal foams
- Auxetic microporous polymers
- Long fibre composites



Positive Poisson's ratio PU foam



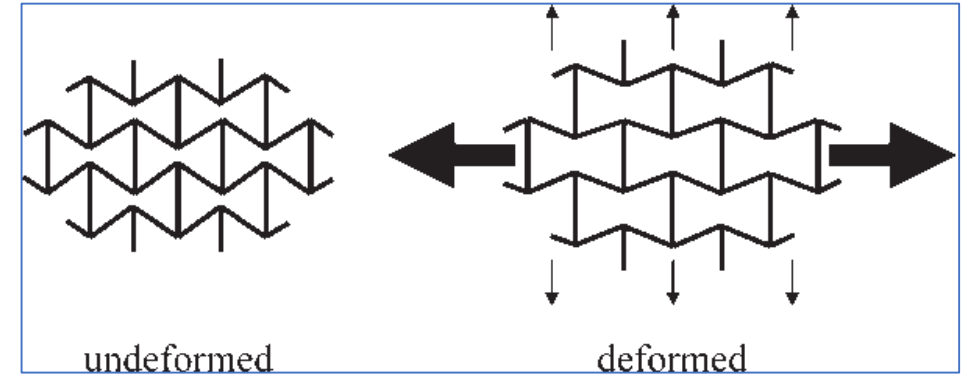
Auxetic PU foam

HONEYCOMB STRUCTURES

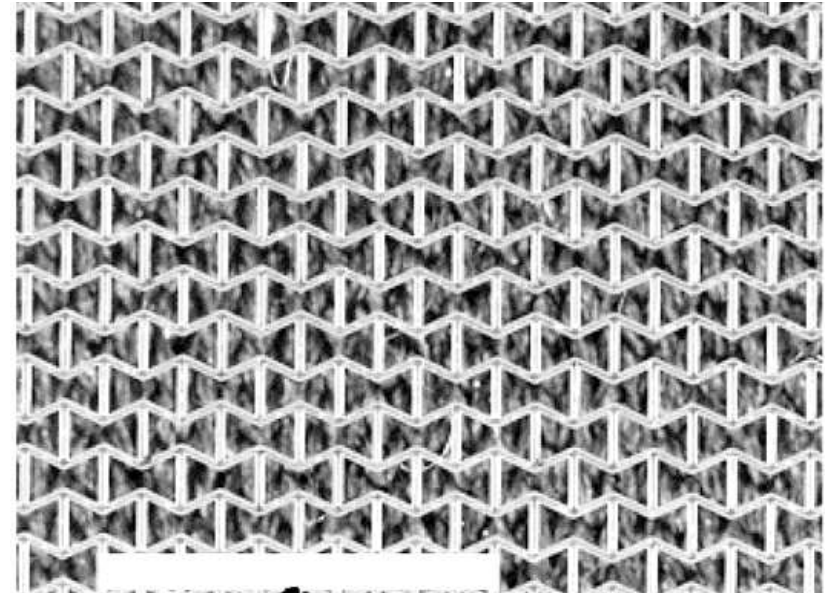
- Tessellating re-entrant hexagon topology- first honeycomb structure, 1980s. [5]
- direction alignment of diagonal ribs → movement of ribs along the vertical direction
- laser ablation for fabrication

Application:

- Improved membrane filter cleaning and particulate size selectivity capabilities.
- As core material in a curved body part for aerospace.



Source: [5]



Source: [5]

FOAM

- Thermoplastic- silicone rubber, and metallic- copper.
- Transformation method of thermoplastic:
triaxial compression → heating above softening point → cooling.
- Application of magnetic or electric fields to change the stiffness of the foams.

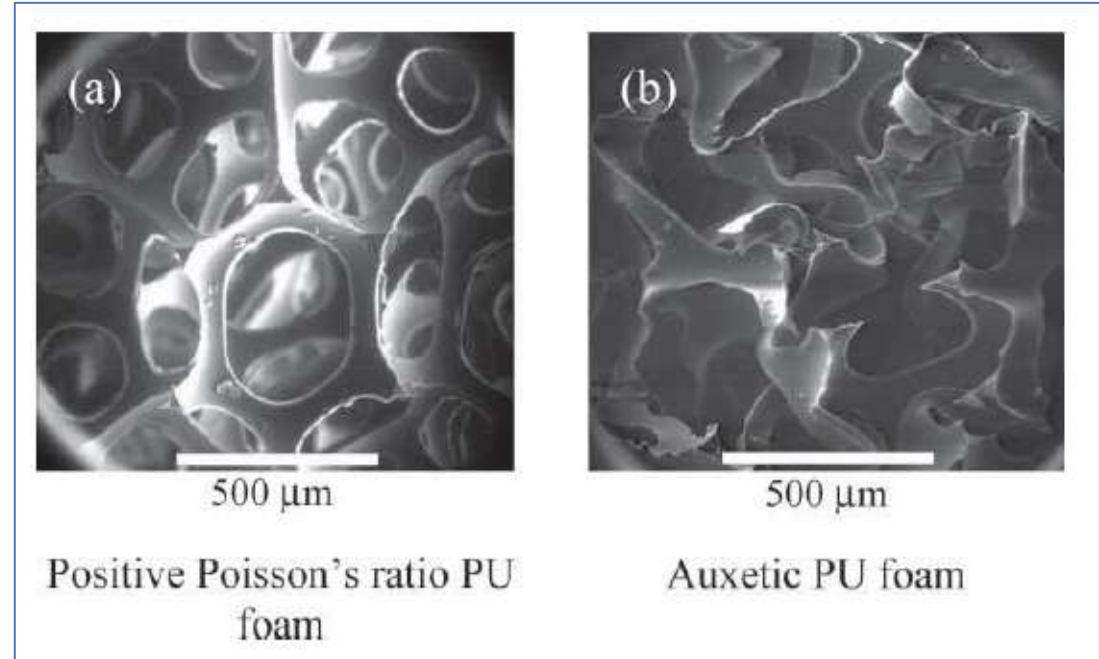


Fig: Polyurethane form before and after conversion
Source: [5]

FOAM

- Transformation in ductile metal foams:

uniaxial compression until yielding occurs → compression in each of the three orthogonal directions.

- Applications:

packaging, sound insulation, air filtration, shock absorption, sponges, development of seat cushions.

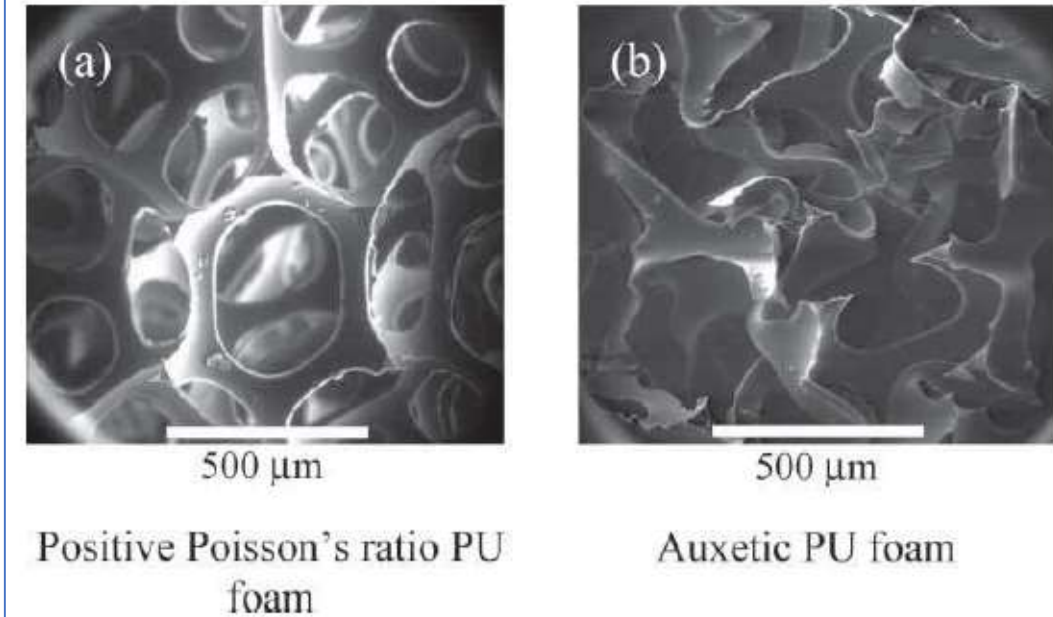


Fig: Polyurethane form before and after conversion
Source: [5]

POLYMERS

1. Microporous polymer cylinders-

- Process: compaction, sintering, and extrusion
- Ultra high molecular weight polyethylene, polypropylene, and nylon
- Enhancements in indentation resistance
- Very good ultrasound absorption

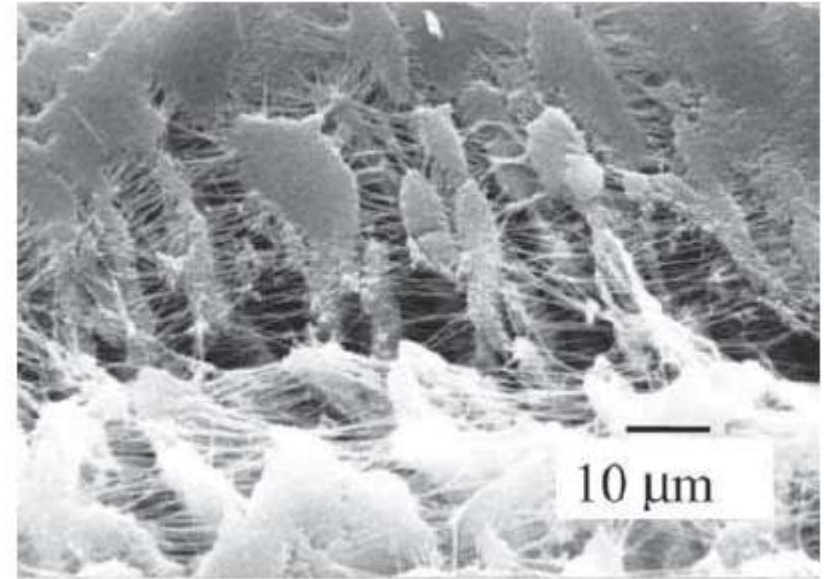


Fig: Nodule–fibril microstructure of auxetic PTFE
Source: [5]

POLYMERS

2. Microporous polymer fibres-

- Fabrication- using partial melt spinning technique in 2001
- Polypropylene, polyester, and nylon fibres
- 'Smart bandage'- potential textile application
- Auxetic fibres containing a wound healing drug within the fibre micropores

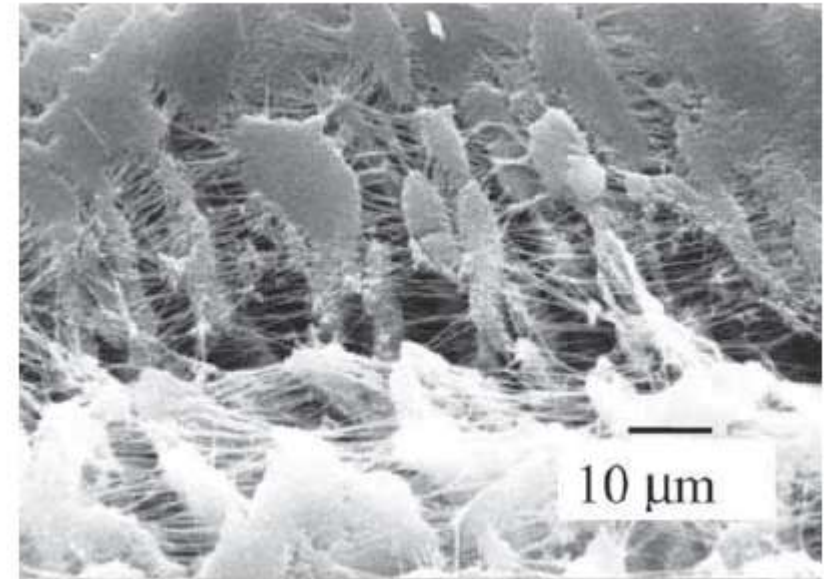


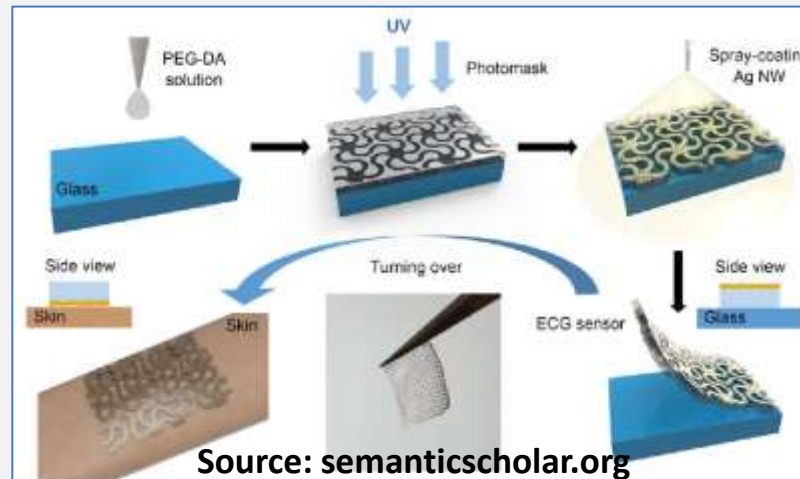
Fig: Nodule–fibril microstructure of auxetic PTFE
Source: [5]

APPLICATIONS

- Applications are based on the Poisson's ratio, superior toughness, tear resistance, or on the acoustic properties of the materials.

General:

- Robust shock absorbers
- Air filters
- Electrodes in piezoelectric sensors
- Auxetic cushions
- Auxetic mattresses



APPLICATIONS

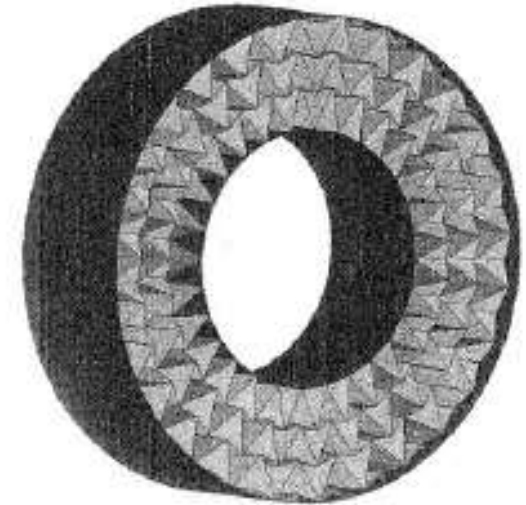
- Earphone with ear cushion made of auxetic foam- reduce air leaks
- Aircraft nose-cones, wing panel
- Auxetic Seat Belts
- Lightweight wheels and run-flat tires
- 'Sisma Calce' auxetic sheets- earthquakes.



Source: [9]

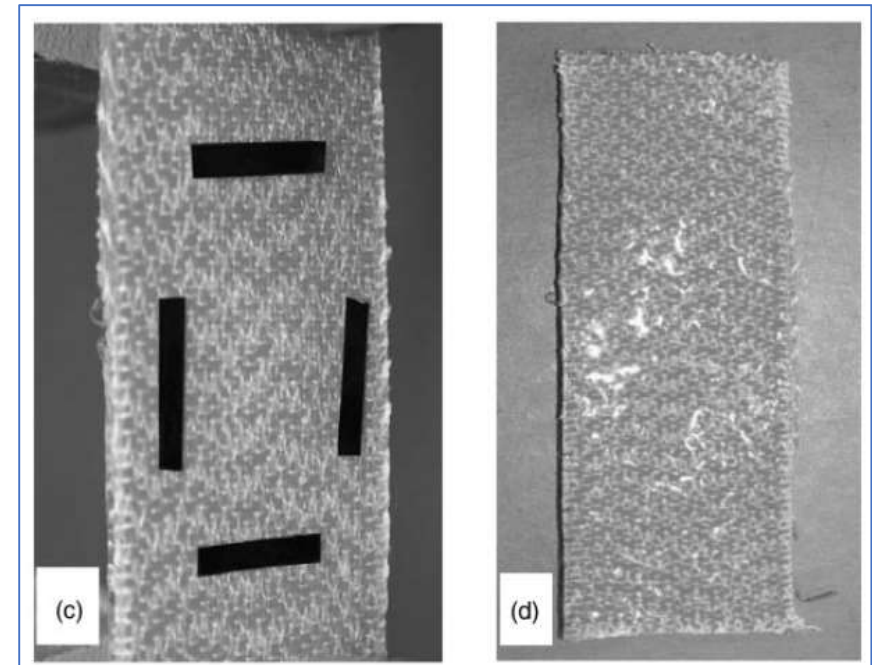


Source: [2]



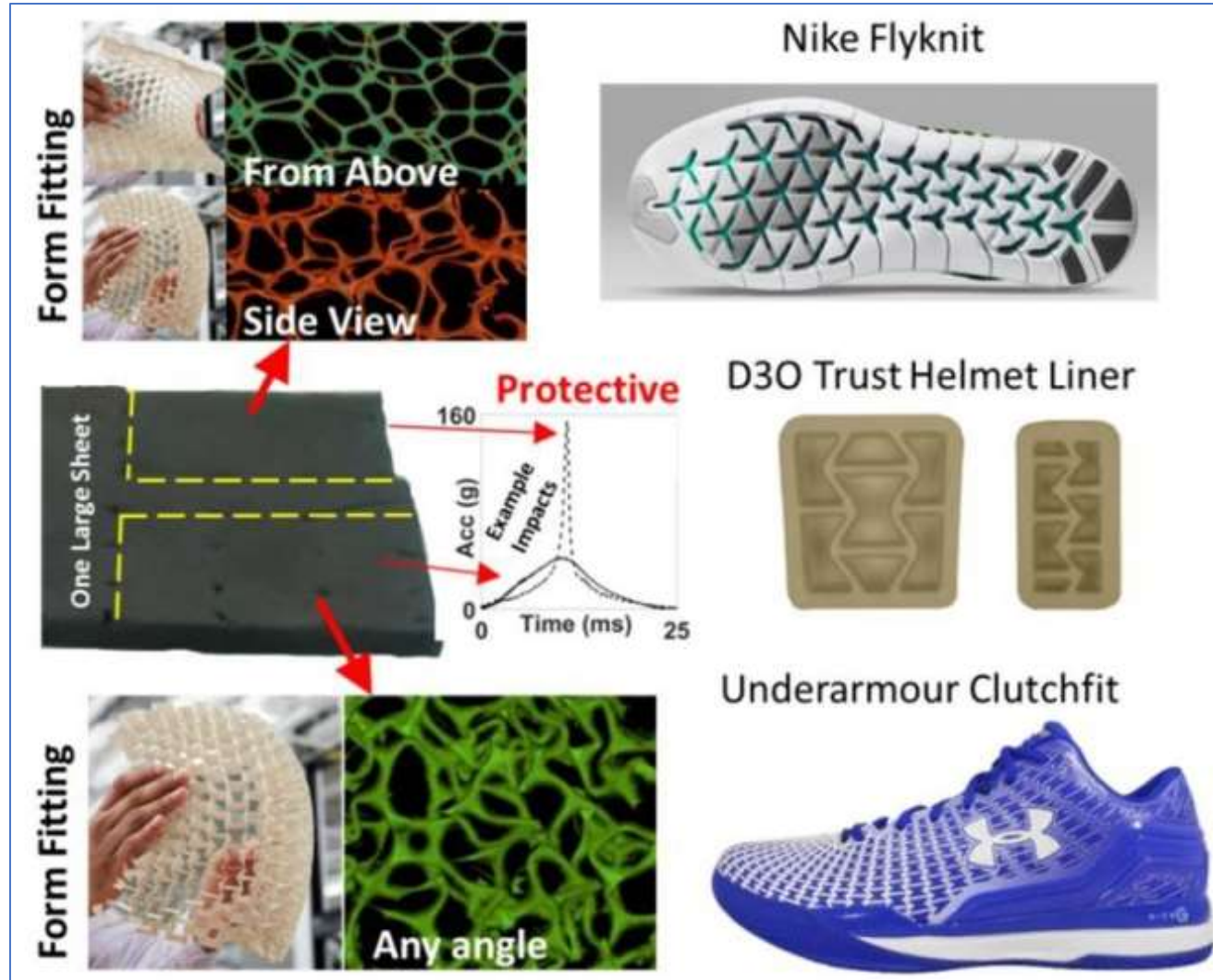
DEFENCE APPLICATIONS

- Improved toughness, resilience, shear resistance, improved acoustic properties
- Tents, canopies, buildings, military vehicles, gloves, bulletproof vest.
- Synclastic curvature- Helmets, Knee-pads
- Ideal press-fit fasteners and rivets



source: [1]

SPORTS APPLICATIONS



source: engineering sport.co.uk

TEXTILE APPLICATIONS

- Mostly used in the fibre or yarn form.
- Maternity clothes
- Dental floss- expands to fit into the wide gaps in between teeth.
- Summer wear and functional sportswear- increased air permeability under extension
- Medical textiles- smart bandage- shape memory ability

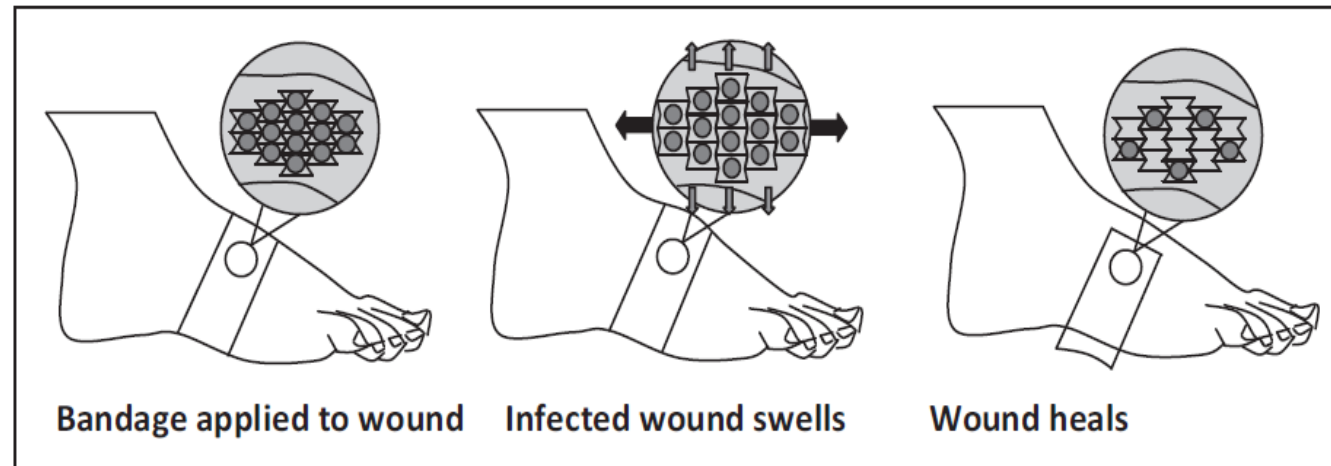


Source: [9]



Source: mdpi.com₁₇

TEXTILE APPLICATIONS



Source:
thepanoptik.co.uk

Source: [8]

BIOMEDICAL APPLICATIONS

1. Arterial Prostheses

- Expanded polytetrafluoroethylene (ex-PTFE).
- Unique deformation mechanism → becomes thicker in response to the blood flow → favourable factor to minimise wall thinning.
- Fracture toughness → Decreases ruptures of blood vessel prosthesis

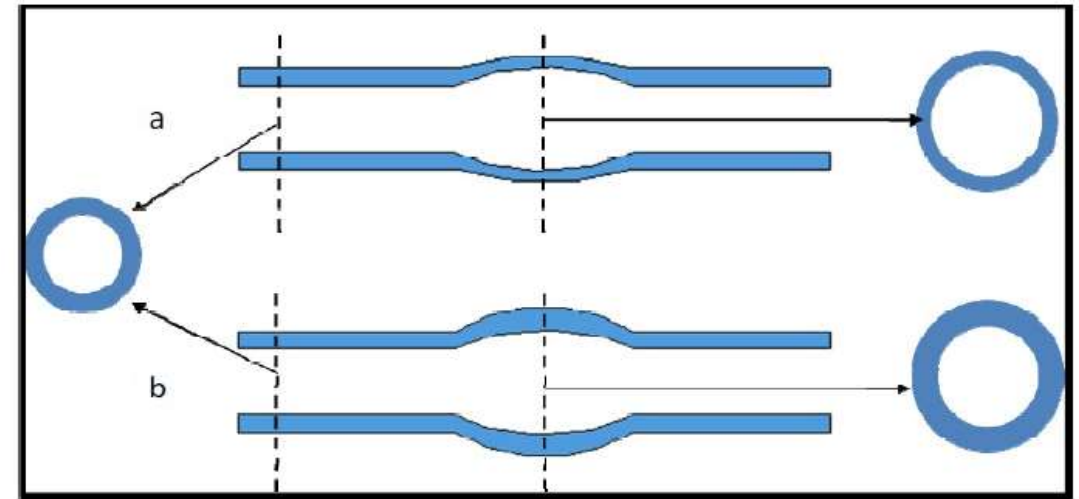


Fig: pulse of blood flowing through (a) non-auxetic arterial prosthesis; (b) an auxetic arterial prosthesis

Source: [2]

BIOMEDICAL APPLICATIONS

2. Implants

- Knee, hip and intervertebral disc replacement
- Candidature for implant linings by improving wear resistance
- 3D FEA model using ANSYS - cellular structures such as periodic regular hexagonal, auxetic re-entrant hexagonal and honeycombs

BIOMEDICAL APPLICATIONS

3. Auxetic Stents

- Overcomes the drawback of current stents
- Enhanced mechanical properties
- Tuned Geometrical Structures
- High circumferential strength in expanded configuration
- Low flexural rigidity in crimped configuration



Fig: Polyurethane auxetic oesophageal stents
Source: [2]

BIOMEDICAL APPLICATIONS

4. Dilators

- Auxetic expansion sheath over conventional balloon catheters
- Auxetic dilator employs expanded UHMWPE, including auxetic variant as a liner component.
- UHMWPE is stronger than PTFE
- UHMWPE – high lubricity, flexibility, abrasion resistance and lower processing temperature
- UHMWPE based devices- catheter sterilisation by gamma rays or electron beam
- PTFE based devices- gas sterilisation.

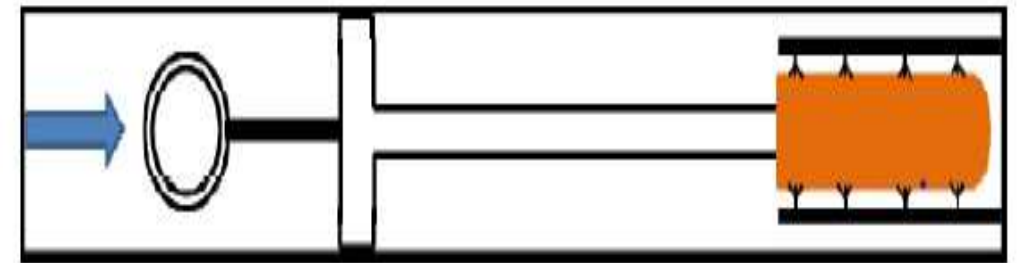


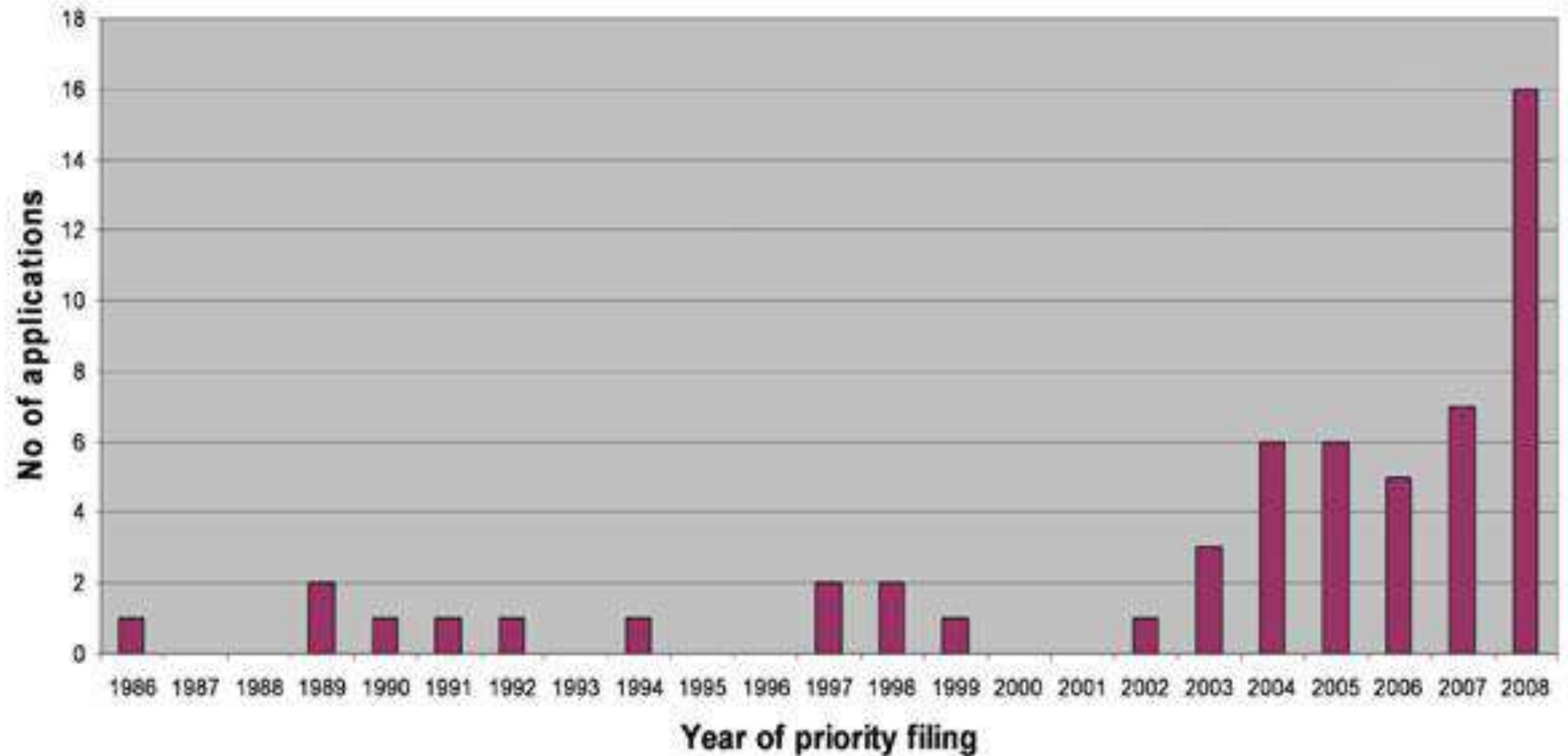
Fig: Auxetic Dilator
Source: [2]

*UHMWPE- ultra-high molecular-weight
polyethylene

CONCLUSION

- Advantages- mechanical properties like higher shear modulus, enhanced indentation resistance, synclastic curvature, better crack resistance.
- Potential in the development of new and improved structural and functional materials.
- Mechanical properties can be changed by changing component's proportions.
- Attracting increasing interest in auxetic nano-materials.
- However, yet to develop better cost effective methods of manufacturing.

RESEARCH PROGRESS



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Thank you for your attention