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Evolution of auxetics: multiphysics gradient composite configurations and their manufacturing

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ADVANCED COMPOSITES CENTRE FOR INNOVATION & SCIENCE

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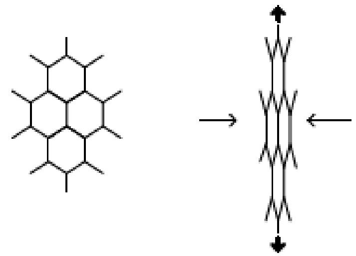
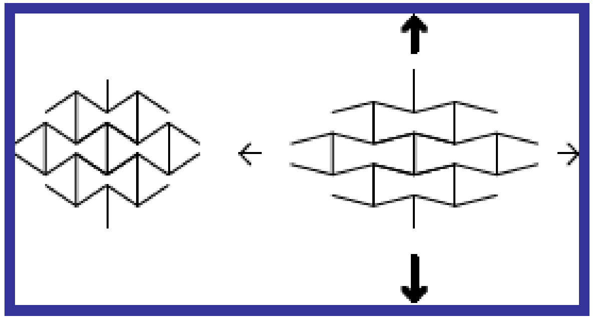
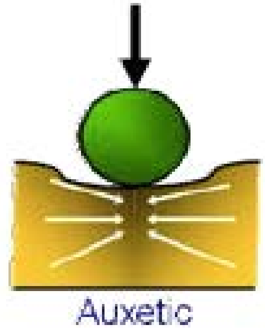
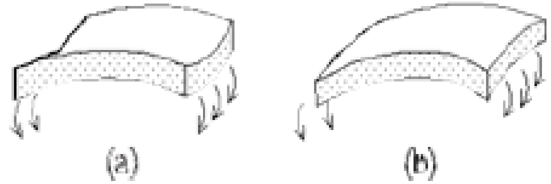
Auxetics and gradient concepts

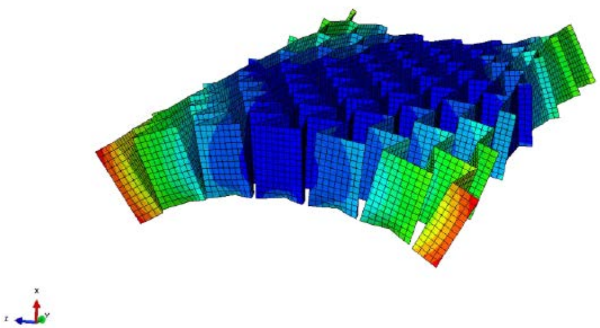


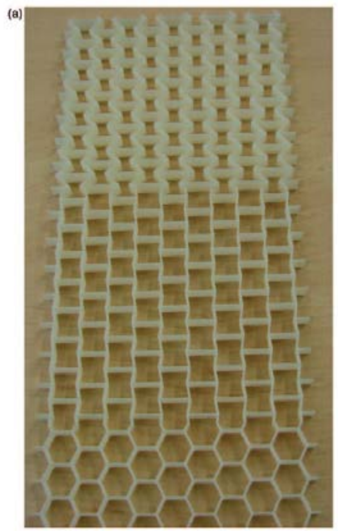






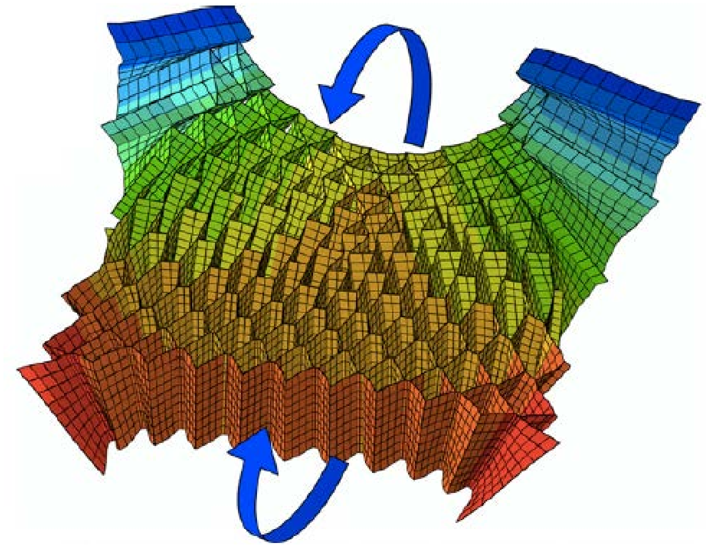
- Auxetics is synonymous of Negative Poisson's Ratio (NPR)
- NPR leads to enhancement of several mechanical and physical properties
- Currently manufactured into foams, CFRP, elastomeric composites, cellular and microporous materials

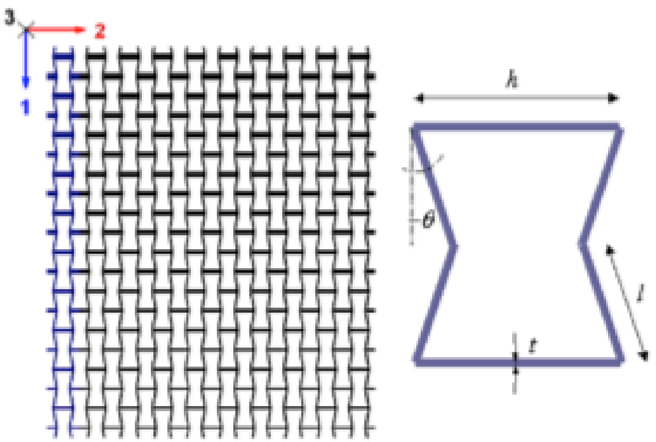




Gradient structures provide continuous variation of the mechanical and multiphysics behaviour of the material

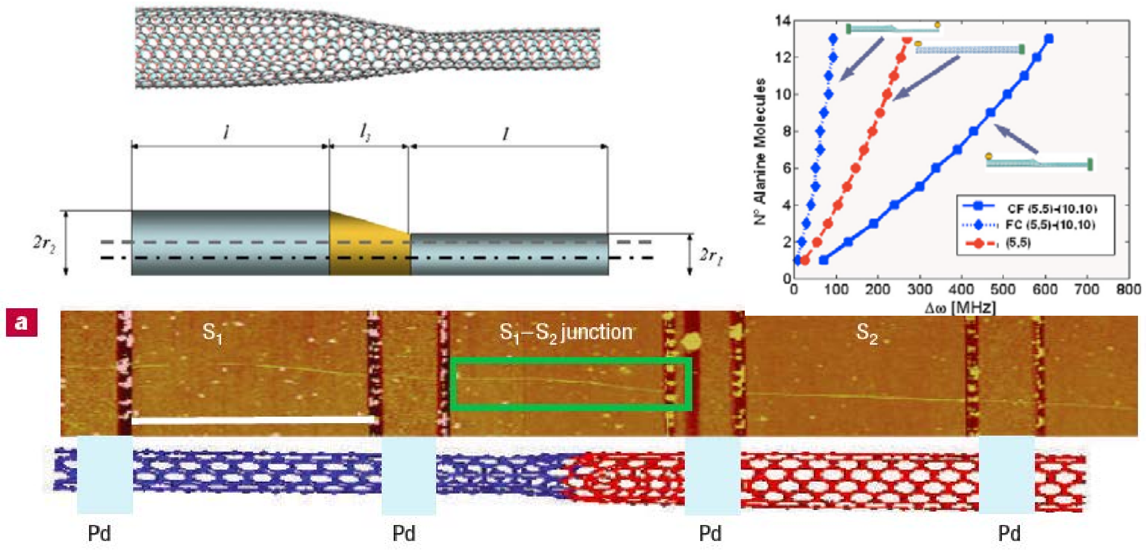
Why gradient?





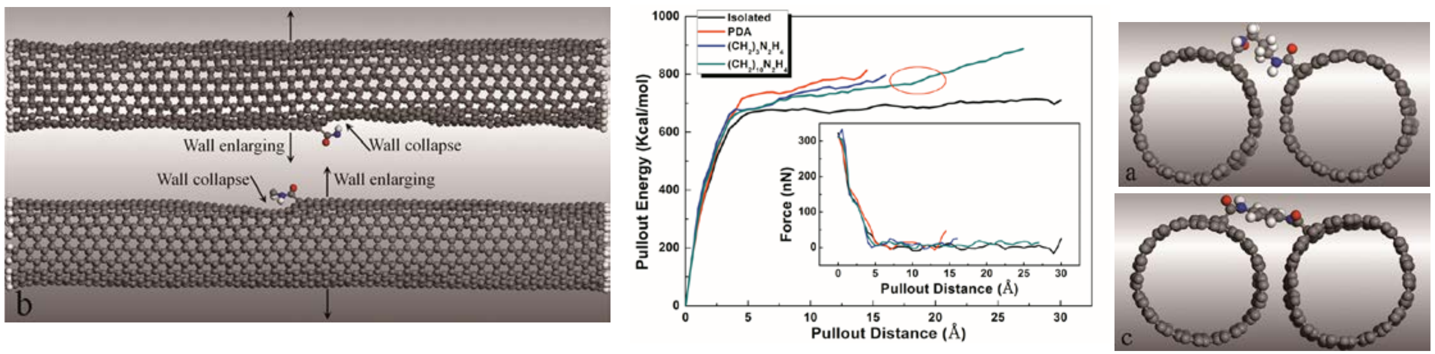
- ➢ Effective continuous variation of Poisson's effect over the surface → multiple curvature during the deformation
- Adaptation to sandwich structures with complex surfaces
- Shape morphing applications
- ➢ Variation of density provides non-uniform distribution of thermal and electrical conductivities across the same surface
- ➢ Non-uniform distribution of the mechanical properties induces localised structural responses to global loading → possible mechanisms to engineer customised local onset of failure
- ➢ Different strain energy distributions in the same structures under loading → non-usual energy dissipation mechanisms

Nanoscale gradient



- CNT heterojunctions show auxetic effects for short tube lengths
- Mechanical response under nonlinear loading depending on the position over the CNT-HT
- Dynamic behaviour strongly dependent over the geometry of BCs
- Can be manufactured by temperature oscillations during CVD

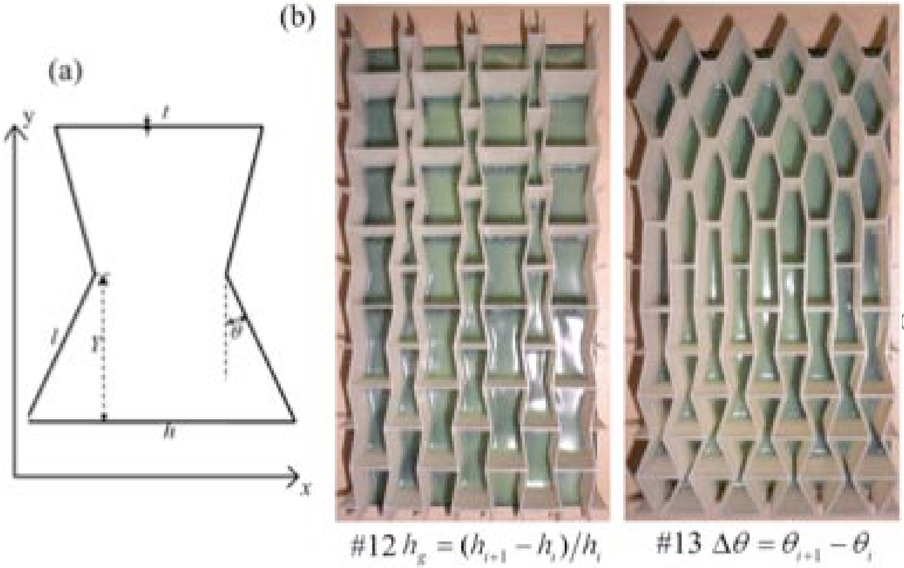
(Scarpa F, Narojczyk J W, Wojciechowski K W, 2011. Phys. Stat. Solidi B 248(1), 82)
(Scarpa F, Narojczyk J W, Wojciechowski K W, Inman D J 2011. Nanotechnology 22, 465501)

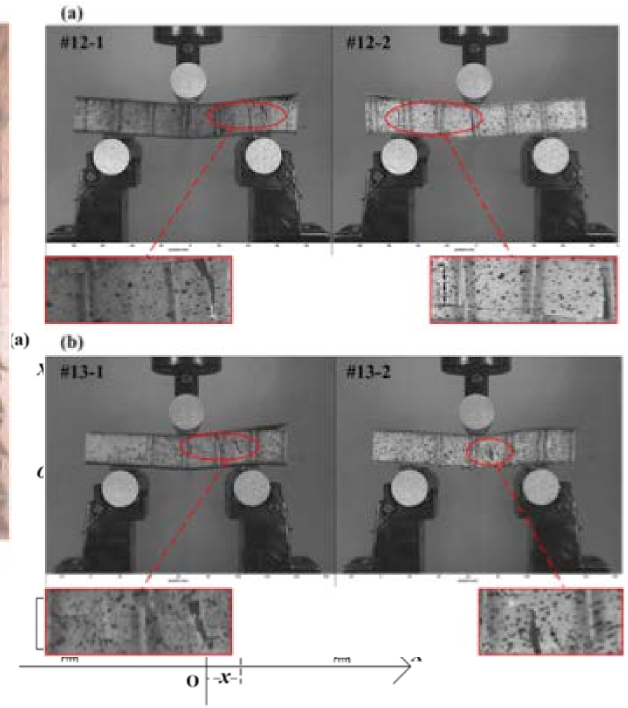


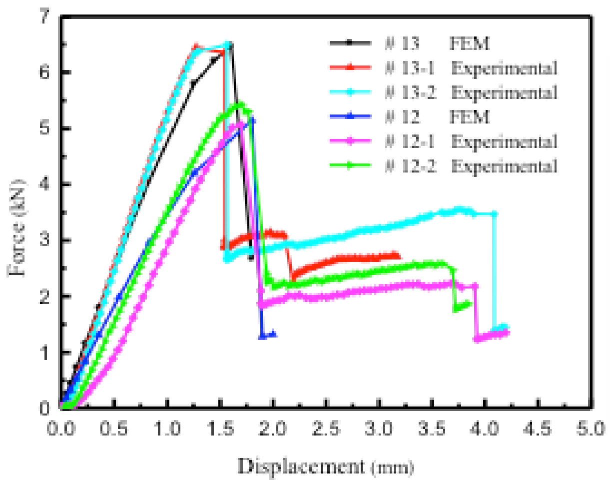
- Bridger links between CNT provide localised auxetic effect
- Significant increase in pullout energy in CNT/PE composites

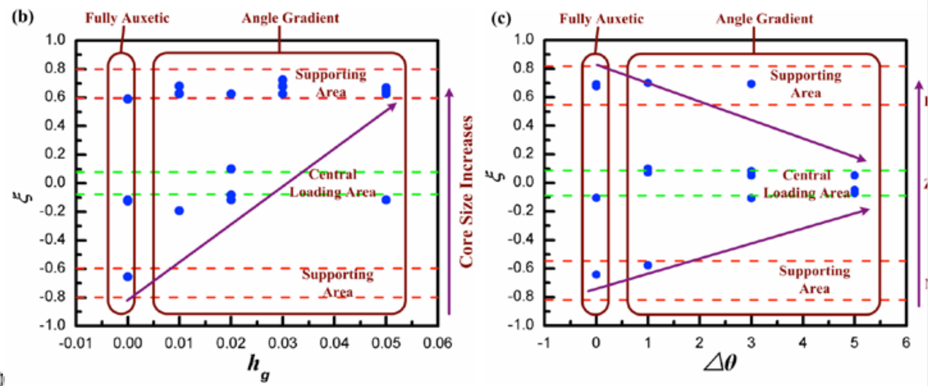
(Zhang J, Jiang D, Scarpa F, Peng H X, 2013. Comp. A, In press)

Gradient cores





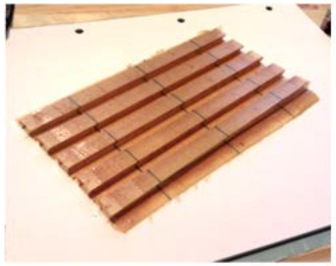


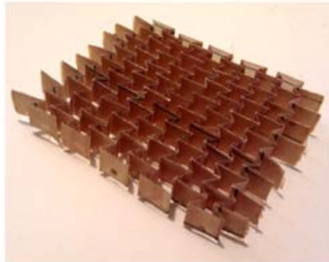


- Gradient core with auxetic configurations manufactured using RP techniques
- Subjected to transverse shear and 3-point bending tests
- Peak loads per weight higher than similar configurations with hexagonal cores
- Onset and location of core failure strongly dependent on the core geometry

(Y Hou, YP Tai, C Lira, F Scarpa, JR Yates, B Gu, 2013. Compo. A 49, 119-131)
(C Lira, F. Scarpa, 2010. Comp. Sci. Tech. 70, 930)

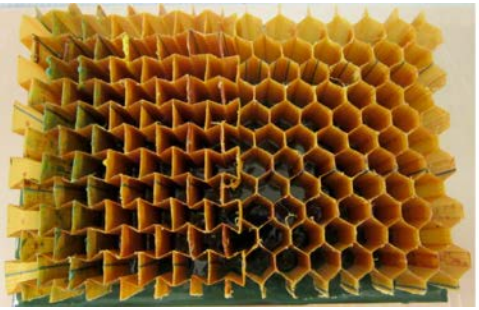
Kirigami to manufacture complex structures

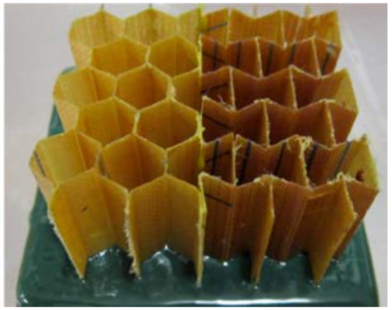


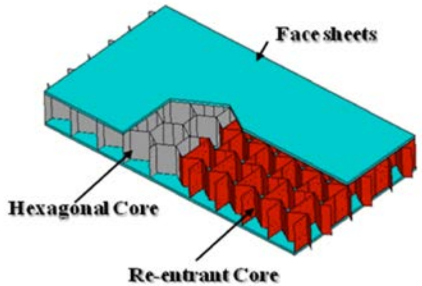


- Kirigami = Origami + cut patterns
- Compatible with thermoset and thermoplastic core materials
- Patterns of valleys/fold cuts created on flat prepregs
- Structures folded in modular moulds and autoclaved or thermoformed
- Possibility of building large sets of 3D cellular configurations
- Compatible with printed electronics/embedding of sensors/actuators

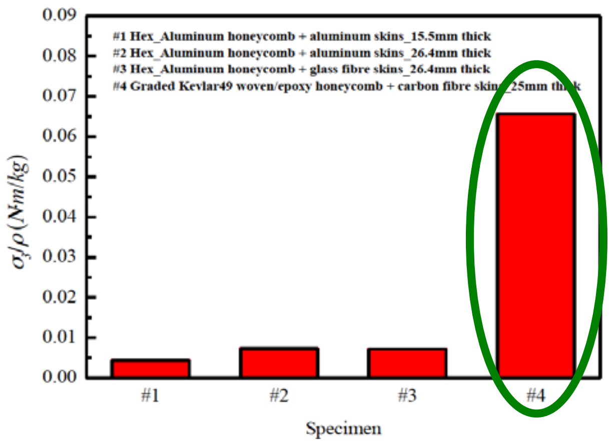
Graded CFRP/Kevlar sandwich structures

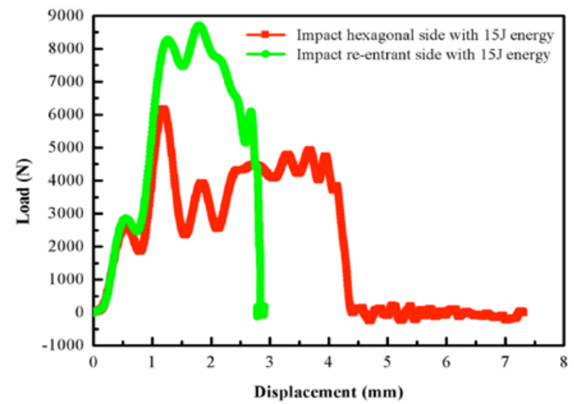


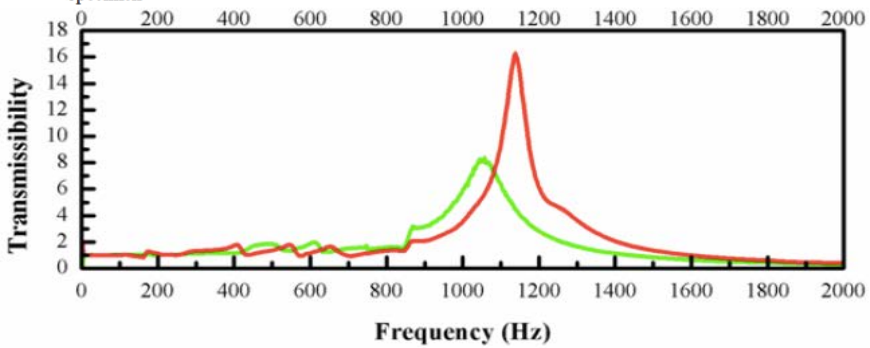




- Graded Kevlar/914 conventional/auxetic sandwich structures with T800/2020 skins manufactured using the Kirigami process
- Samples subjected to flatwise compression and edgewise impact loading
- 6-fold increase in specific compressive strength compared to sandwich panels available off-the-shelf
- Impact on the auxetic side reduces significantly the residual deformations
- Dynamic loading on the auxetic side reduces the vibration transmissibility through the whole structure

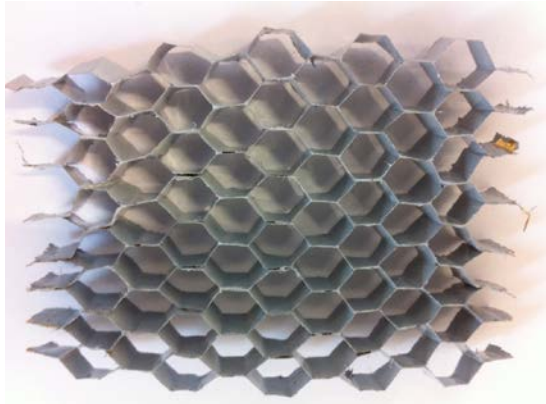


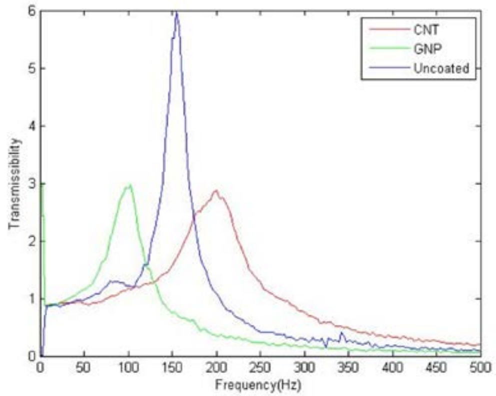




(Y Hou, R. Neville, F Scarpa, C Remillat, B Gu, M Ruzzene, 2013. Comp. B. Subm.)
(Y. Hou, R. Neville, G. Mouly, F Scarpa, C Remillat, M Ruzzene, B Gu, 2013. Comp. Sci. Tech. Subm)

Adding multifunctionality

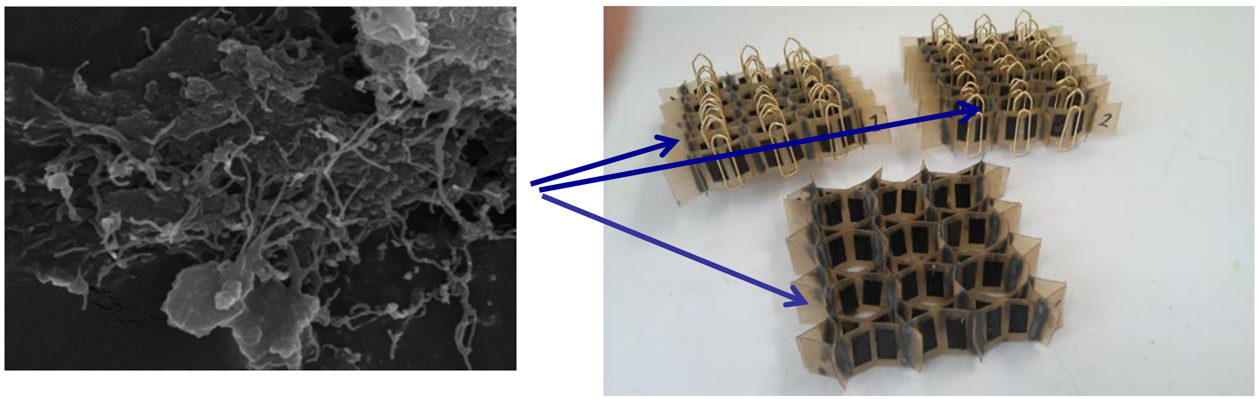




(K. Chatzipanagis, F Scarpa, H X Peng, 2012)

PU / CNT / GNP coatings in Kirigami-assembled structures

- Coatings increase electric conductivity
- Strong increase in damping and energy absorption compared with undoped sample



(FP7 M-RECT Project. Collaboration with Victrex plc and MTM KU Leuven)

PEEK / CNT films in PEEK Zero-ν Kirigami cores

- PEEK/CNT films for high energy absorption under high-amplitude dynamic loading
- Films assembled in PEEK Kirigami cores

Conclusions

- Gradient auxetics can be developed at different scales
- Experimental evidence of enhancement in strength, impact resistance, damping and vibration transmissibility
- Fabrication of gradient composite cores can be achieved using Kirigami techniques.
- Added multifunctionality through nanocoatings/nanofilms/ embedded electronics via Kirigami process

Thanks for your attention