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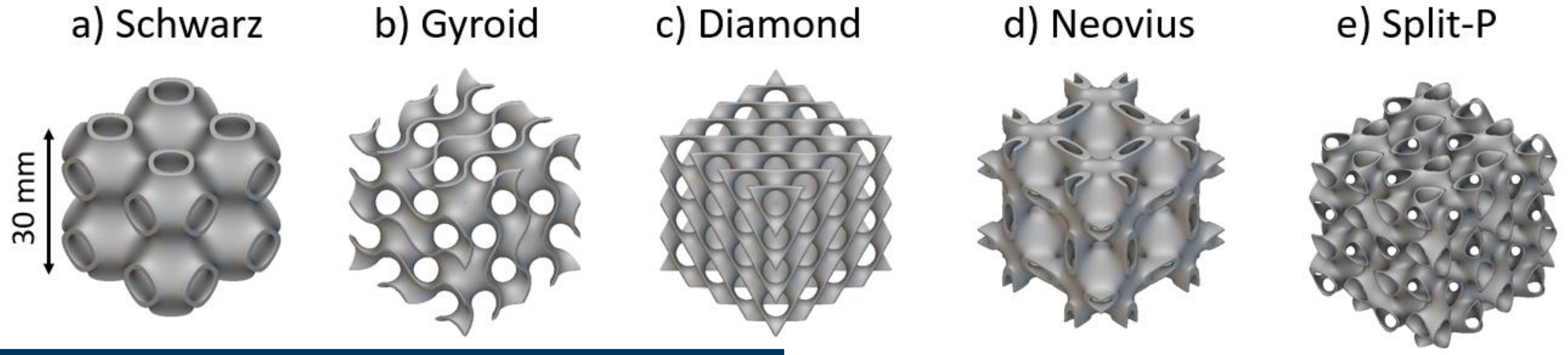
SELF-SENSING BEHAVIOUR OF TRIPLY PERIODIC MINIMAL SURFACE LATTICES ENABLED BY ADDITIVE MANUFACTURING



Project Aim

To develop and characterise the mechanical properties of self-sensing metamaterial lattice structures for damage and structural health monitoring through piezoresistive properties.

Advances in additive manufacturing have enabled the production of complex geometries unattainable from traditional methods. One type of such geometry is that derived from triply periodic minimal surfaces (TPMS). This project explores the properties of five such lattice structures; namely the schwarz, gyroid, diamond, neovius and split-p. The structures were printed in poly-ether-imide, an amorphous thermoplastic polymer with excellent mechanical properties, thermal resistance and chemical resistance. Making it suitable and safe for use in components which may be prone to damage.

However, the neat polymer itself lacks self-sensing abilities. Carbon nanotubes (CNTs) can be used to provide electrical conductivity together with an increase in mechanical performance. CNTs create an electrical percolation network through the composite at low weight percentages. However, the production of high-quality filament from PEI/CNT composites is challenging. Instead, a conductive CNT coating was applied to the architected structures produced using an epoxy/CNT composite with 1wt.% CNT.

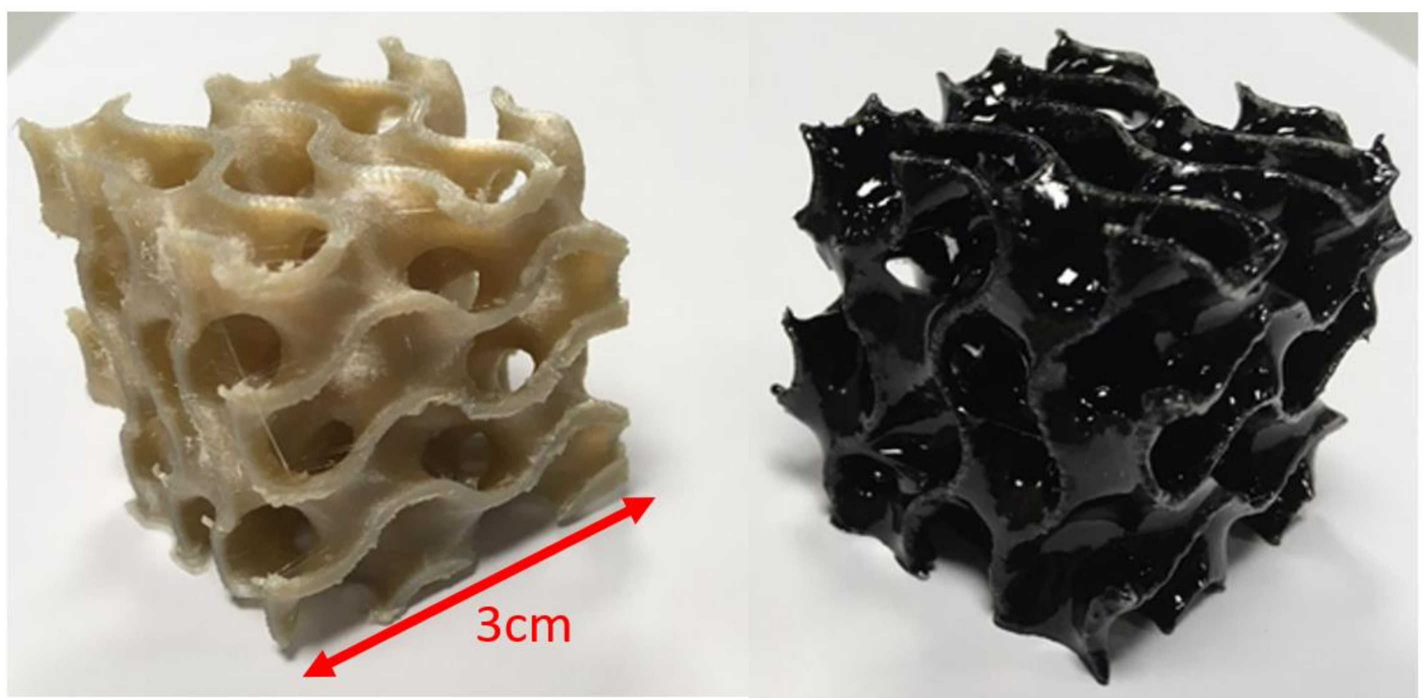


Figure 1: Printed nest PEI gyroid and epoxy/CNT coated gyroid samples

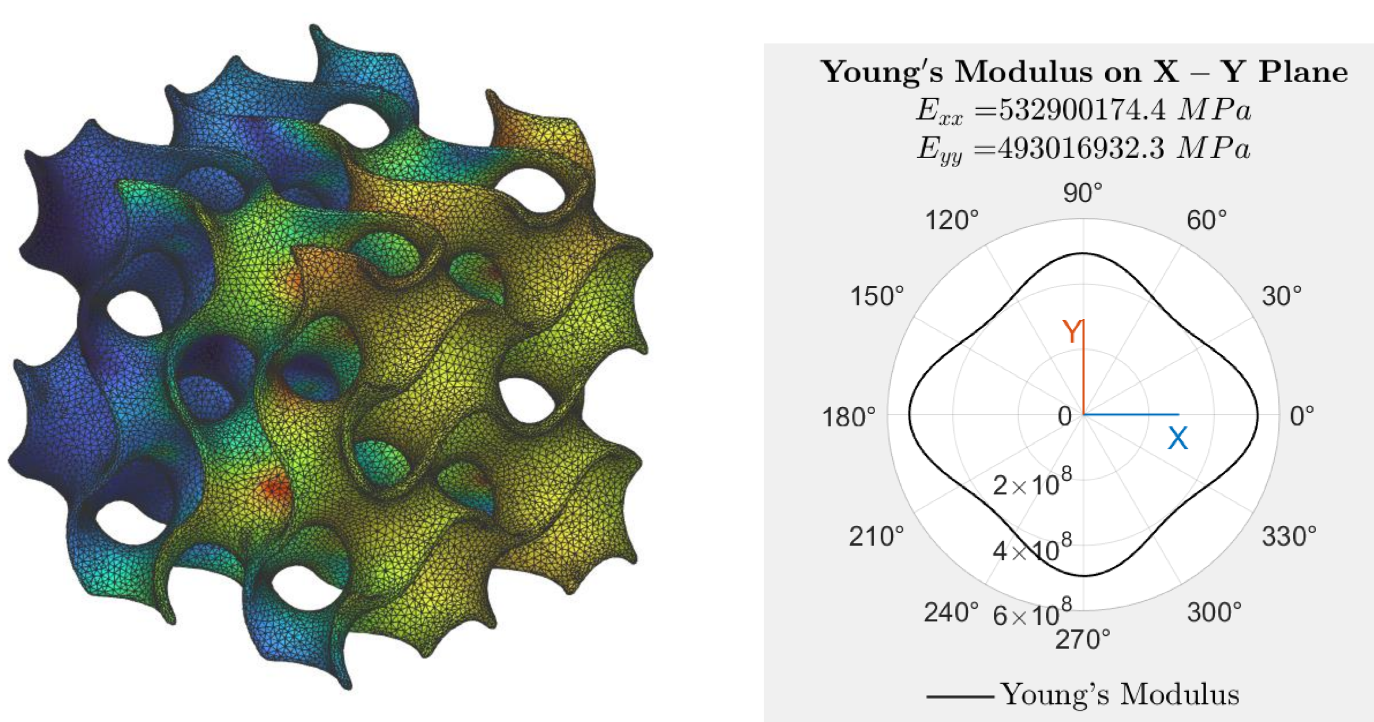


Figure 2: FE simulation of gyroid sample and resulting polar elastic modulus diagram

Mechanical response

The mechanical response of these lattices was tested at varying degrees of porosity. The optimal response was obtained from the split-p lattice which provided the best energy absorption characteristics. The distribution of ligaments across the cross-sectional area of the structure reduced the brittle fracture effect other samples suffered from and proved the hypothesized energy absorption abilities of the material which can increase by over 10-fold during failure.

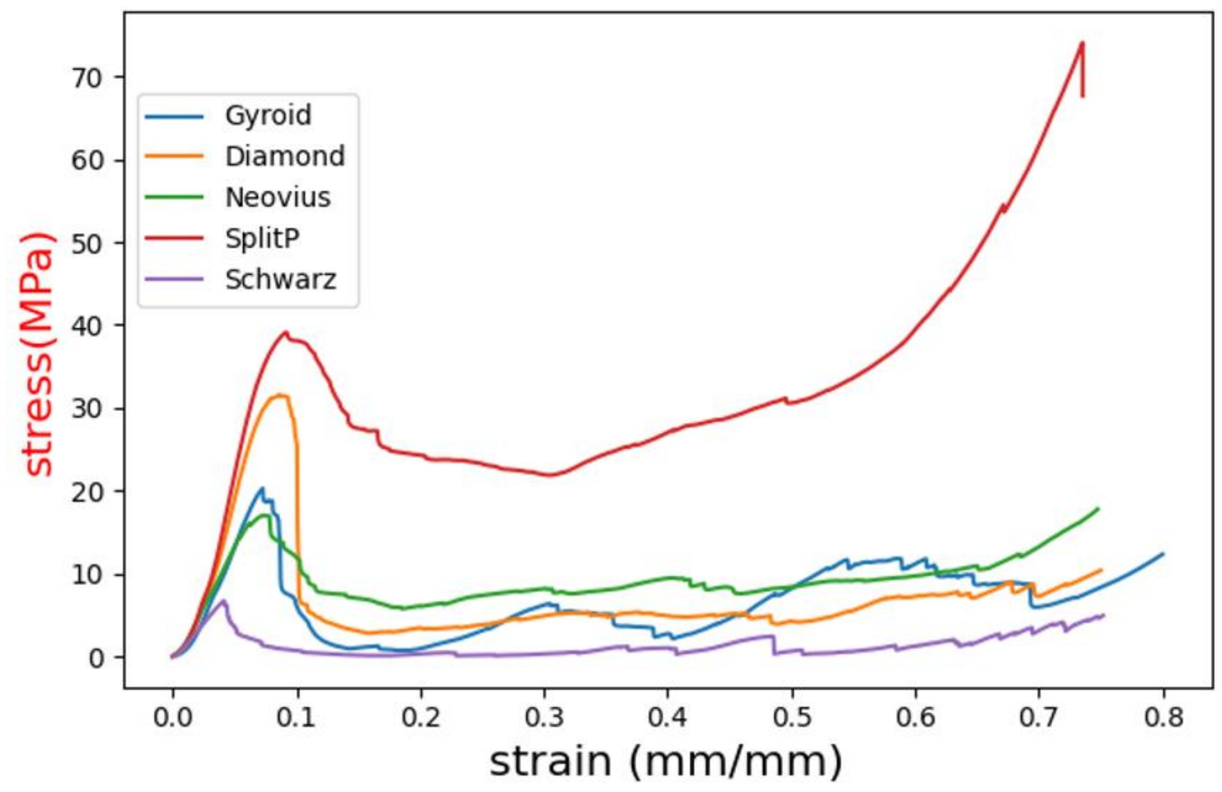


Figure 3: Stress strain response of lattice shapes at 75% porosity

Piezoresistive response

The piezoresistive response was plotted as a function of normalized change in resistance (ΔR/R0) as a function strain. Observed changes in resistance under elastic compression are due to reduction in distance between CNTs in the conductive network. Fluctuations during the collapse densification phase of the porous structure are attributed to failure of members and reductions in contact resistances.

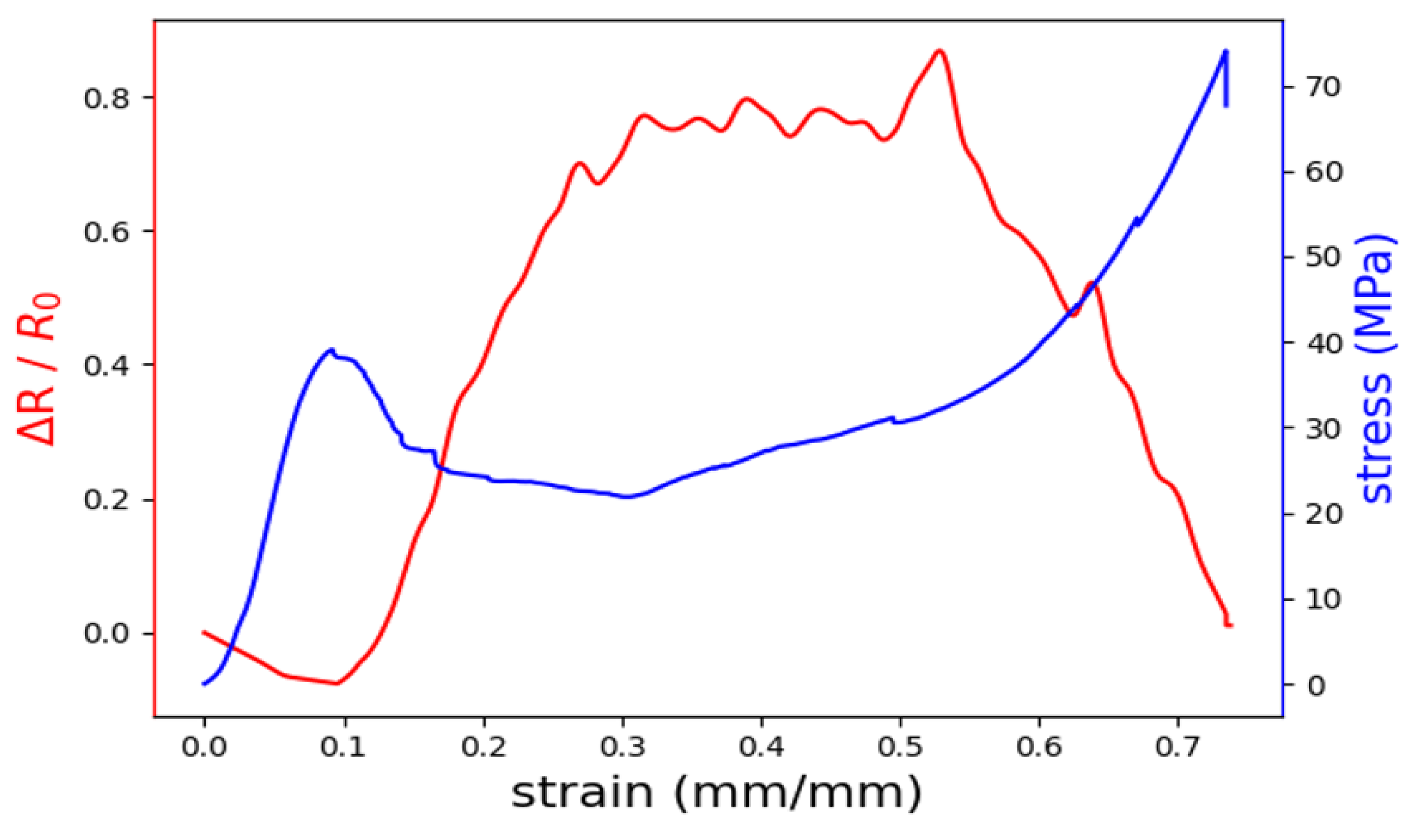


Figure 4: Piezoresistive strain response of Split-P lattice shapes at 75% porosity

Conclusions

By monitoring the piezoresistive response we are able to determine the strain and damage state of the structure, providing its 'sensing' abilities which allow us to detect and quantify damaged components through a non-invasive method.