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EPSRC Centre for Doctoral Training in Metamaterials XM^2

Auxetic Design in Vibration Energy Harvesting

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Abstract: We have developed a piezoelectric vibration energy harvester with an auxetic design (a re-entrant honeycomb array) to increase the power output from tensile strain excitations (<300 με at 1–30 Hz). We compared ceramic PZT and composite MFC as the piezo element, and found they produced 6.2 and 11.8 times more power, respectively, than their equivalent plain harvesters under the same excitations. These gain factors are constant under all matching excitations tested. Absolute MFC output remained less than PZT.

Introduction

Auxetic metamaterials have a negative Poisson's ratio due to their structure: they expand laterally under tension.
A piezoelectric element bonded atop an auxetic substrate can be stretched in both in-plain axes at once[1,2].
This auxetic region is more flexible than the remaining substrate, concentrating applied strain into the piezo.

These factors lead to more power from the piezo, compared to an equivalent plain harvester design under the same excitation.

Using a re-entrant honeycomb array as our auxetic region, we optimised the auxetic design using finite element modelling.
We experimentally compared two piezoelectric materials on each substrate design: Ceramic PZT and Composite MFC.

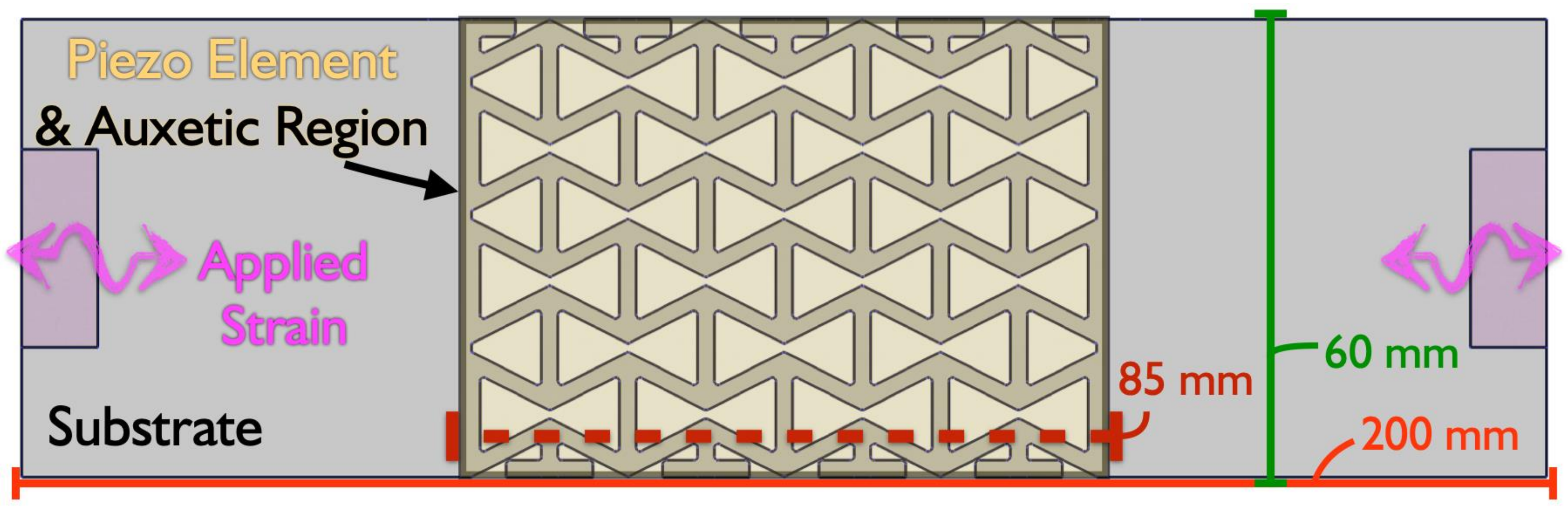

Figure 1: Auxetic Harvester design plan, showing components: substrate (with laser cut auxetic region) and piezoelectric element, and where tensile strain is applied.

Results

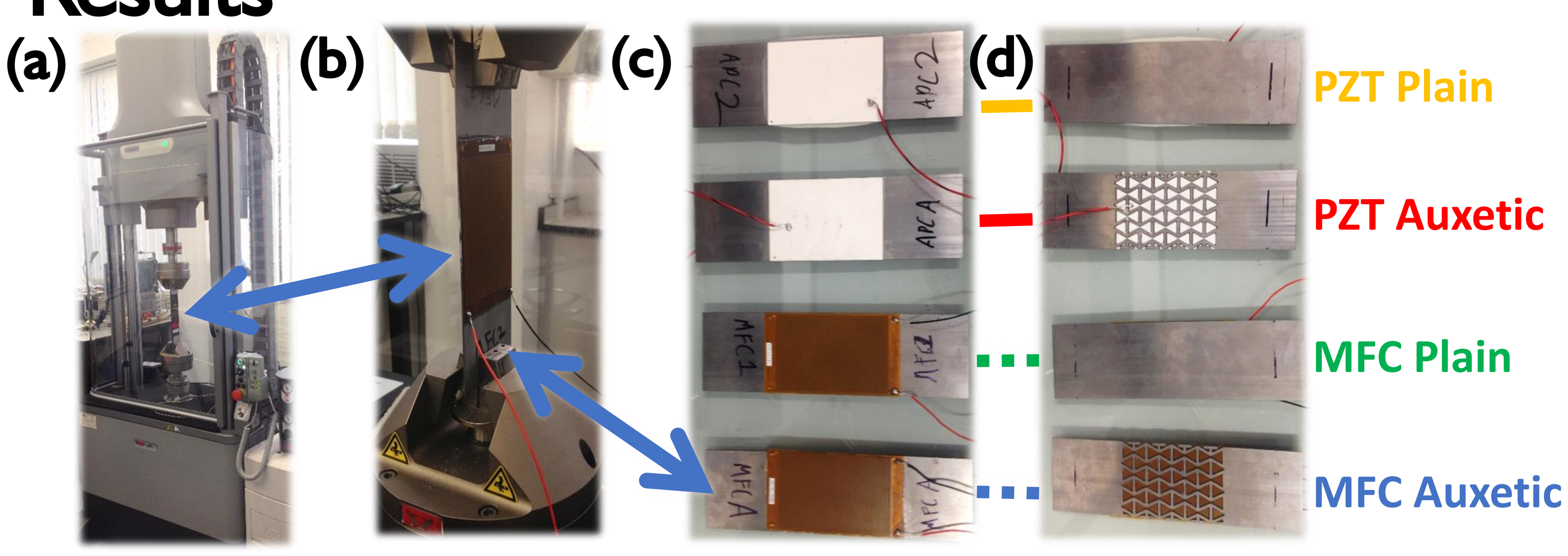

Figure 2: (a) Instron E10000 (b) Harvester Clamped into Instron (c) All Harvesters Front (d) All Harvesters' Reverse Side

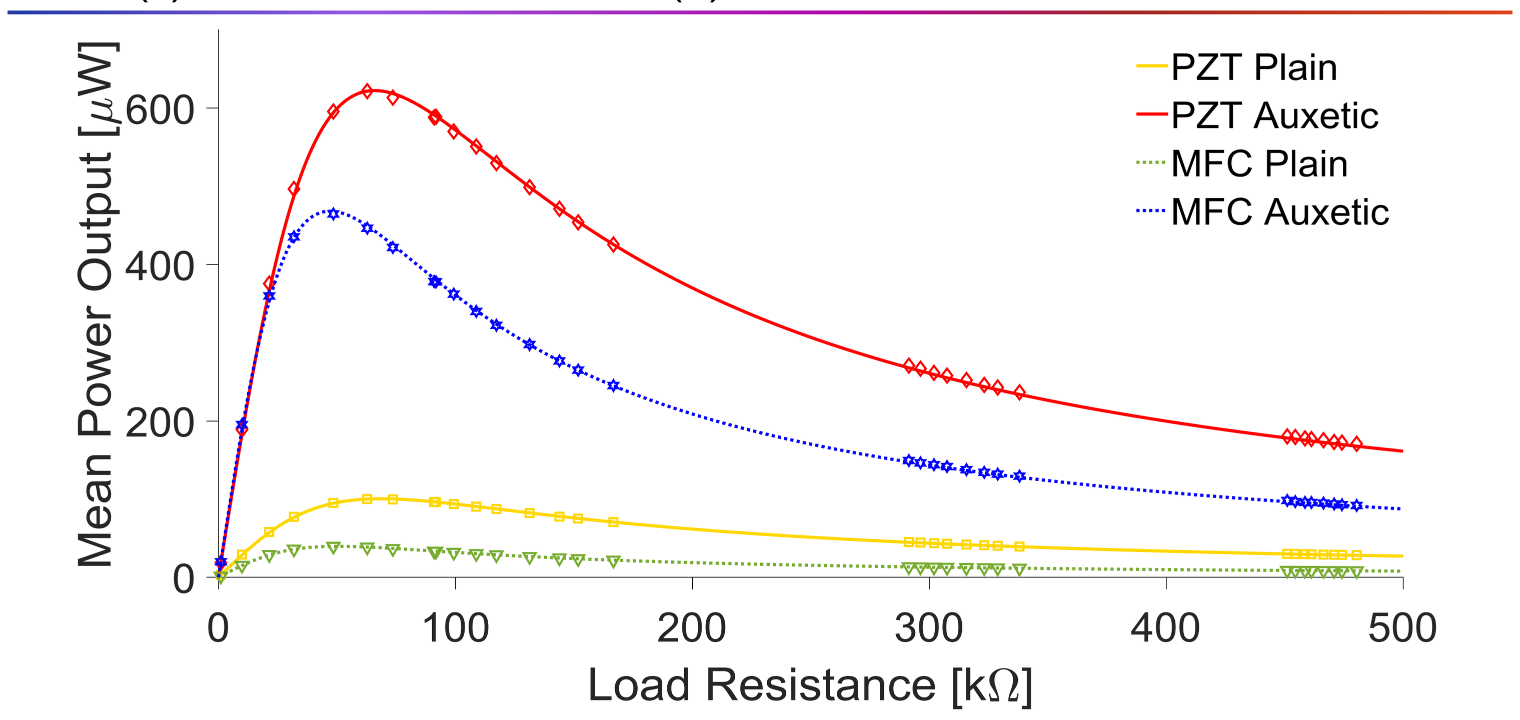

Figure 3: Experimental power obtained from a nominal 100 με peak-to-peak at 10 Hz excitation for Plain & Auxetic harvester samples.

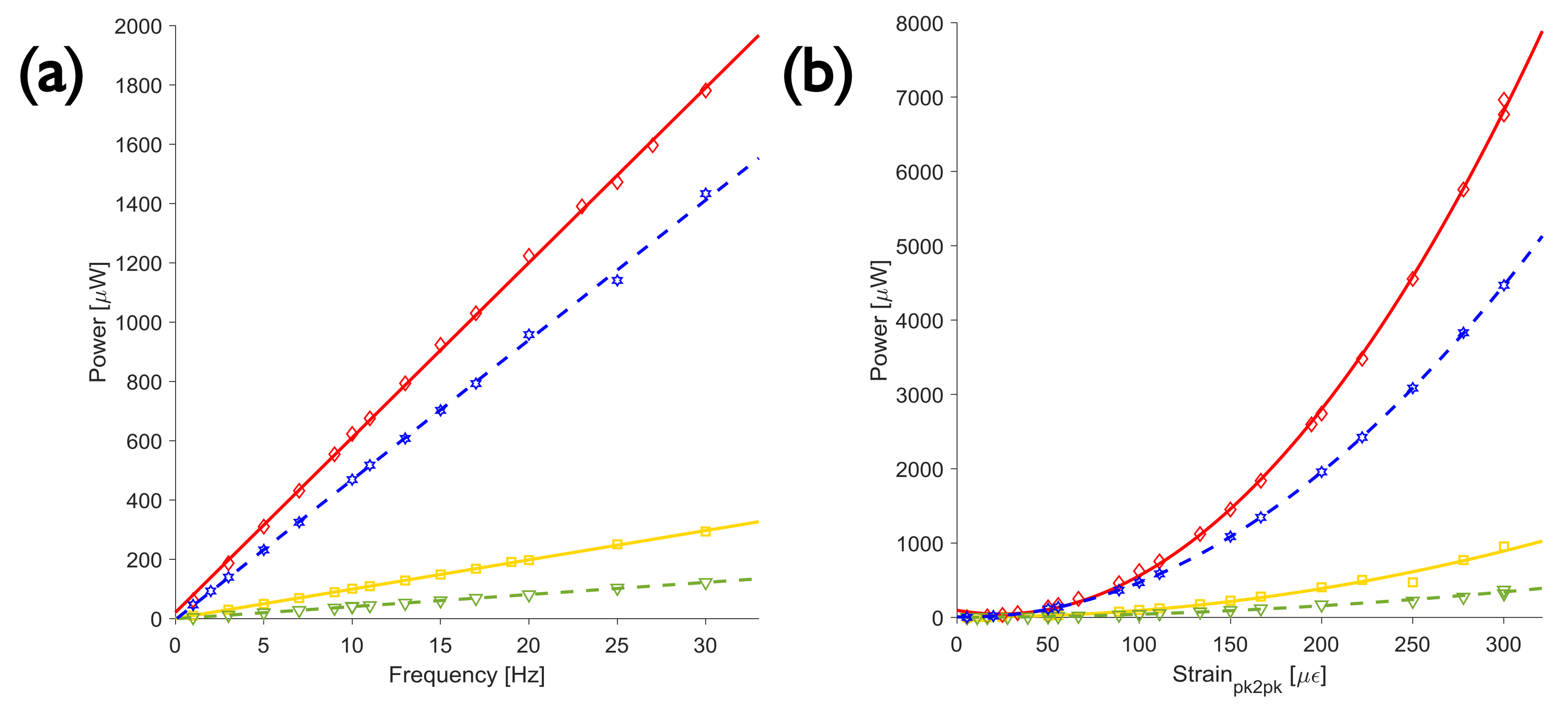

Figure 4: (a) Effect of varying frequency of applied excitation (nominal 100 με). (b) Effect of varying strain amplitude of excitation (10 Hz).

Discussion

Our results show a significant power gain by using auxetics:
6.2 times for PZT and **11.8** for MFC, at peak power outputs.

Figure 4 shows these gains are consistent over a range of excitations.

The gain between MFC samples is much larger, due to its flexibility. However, the MFC produced less absolute power; this is due to it being thinner than the available PZT (0.3 vs. 0.5 mm), as well as its reduced piezoelectric constants.

There is room for even further improvements with MFC, as the lower strength of PZT was a constraint on the auxetic region.

There has been interest in developing self-powered Structural Health Monitoring and wireless Internet of Things devices[3,4], but accumulating enough ambient energy has always been a limitation. Auxetic designs could increase power output from these low-strain environments and make harvesting here practical.

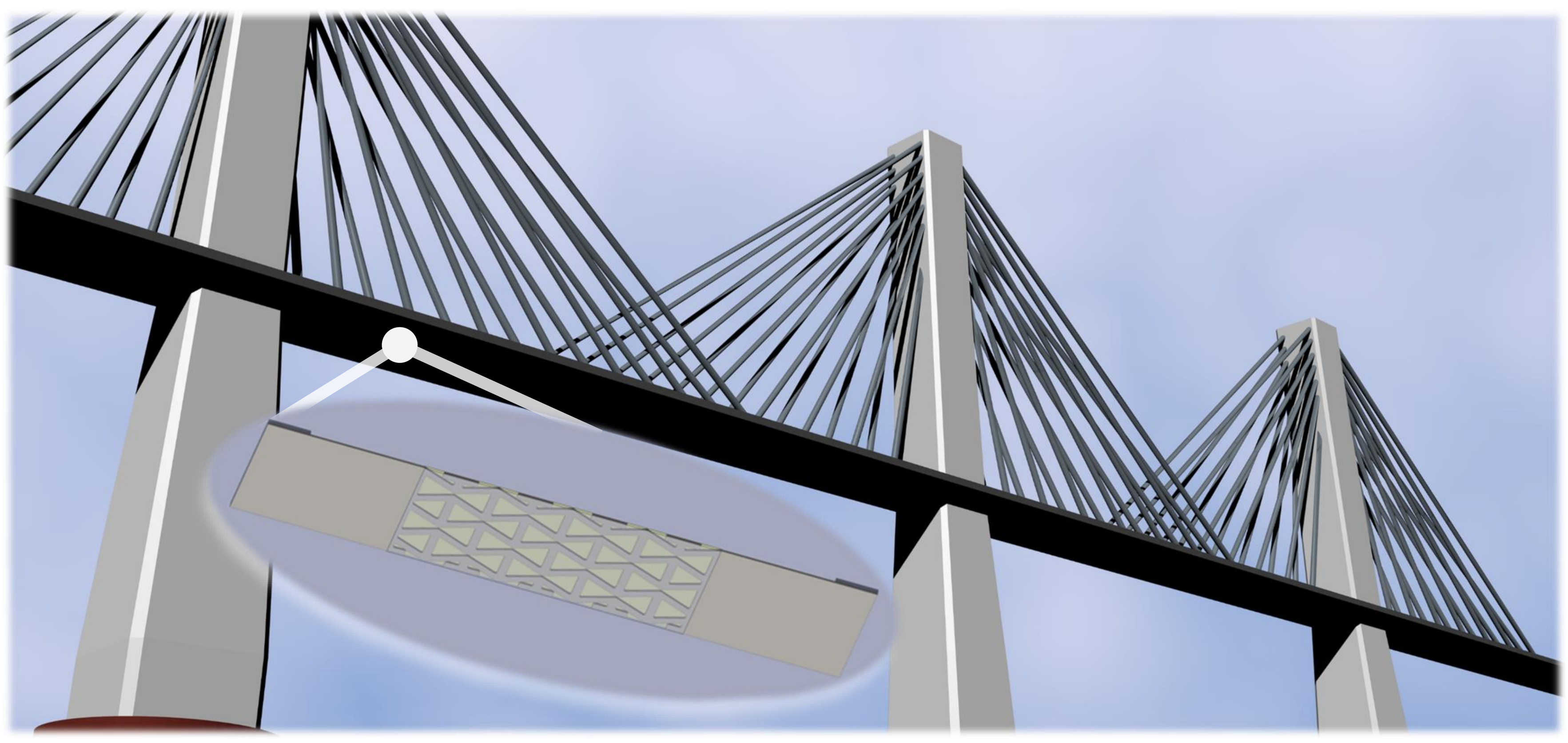

Figure 5: Potential application of an auxetic vibration energy harvester.

References

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[3] F. Shaikh & S. Zeadally, "*Energy Harvesting in wireless sensor networks: A comprehensive review*", RSER, 2016
[4] N. Bonessio, et al., "*Structural Health Monitoring of Bridges Via Energy Harvesting Sensor Nodes*", Bentham Open, 2016

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