Auxetic Enhancement of Vibration Energy Harvesting

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Abstract: We have developed an auxetic energy harvester to increase the power output available from small tensile strain excitations (<300 με at 1–20 Hz). We found that this produced around 11 times more power than an equivalent plain harvester under the same excitation.

Introduction

A thin piezoelectric element (PZT: PIC151) bonded atop an auxetic substrate, shown in Figure 1, can be simultaneously stretched axially and laterally by the same applied strain[1].

The auxetic region is more flexible than the rest which also concentrates that applied strain into the piezo.

These factors combined lead to greater stress in, and thus power from, the piezo compared to an equivalent plain harvester subjected to the same strain excitations.

Using a single re-entrant hexagonal unit as our auxetic region, we investigated this novel enhancement of energy harvesting with FE modelling and experiments.

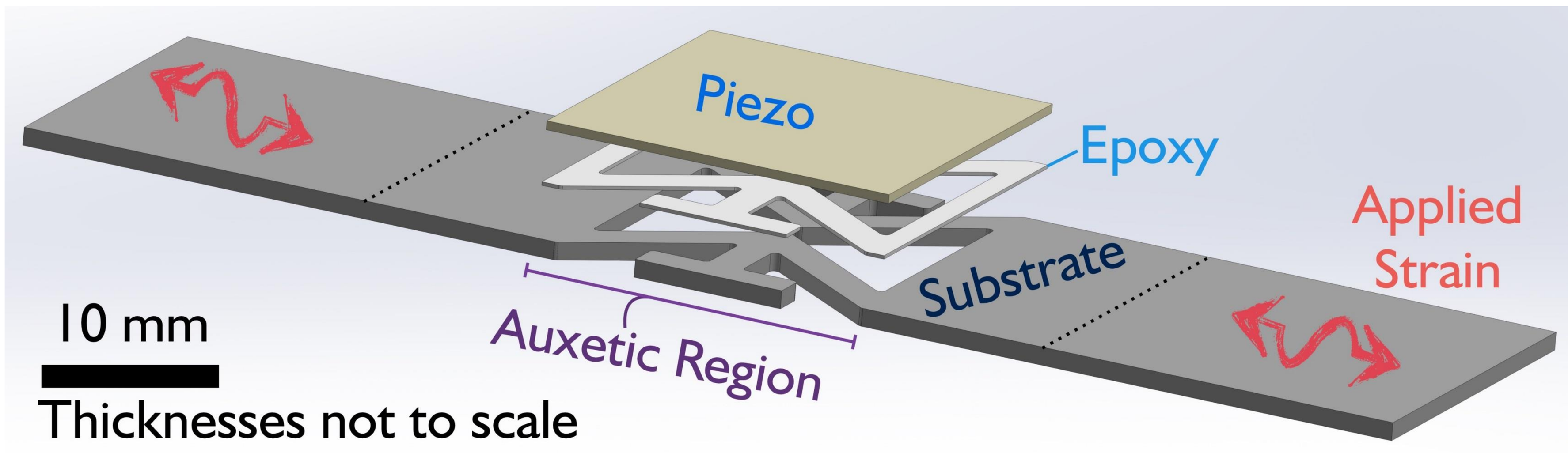

Figure 1: Exploded Auxetic Harvester model, showing where tensile strain is applied, and its components: substrate (80×20×1.2 mm), piezoelectric element (20×20×0.2 mm) and bonding epoxy.

Results

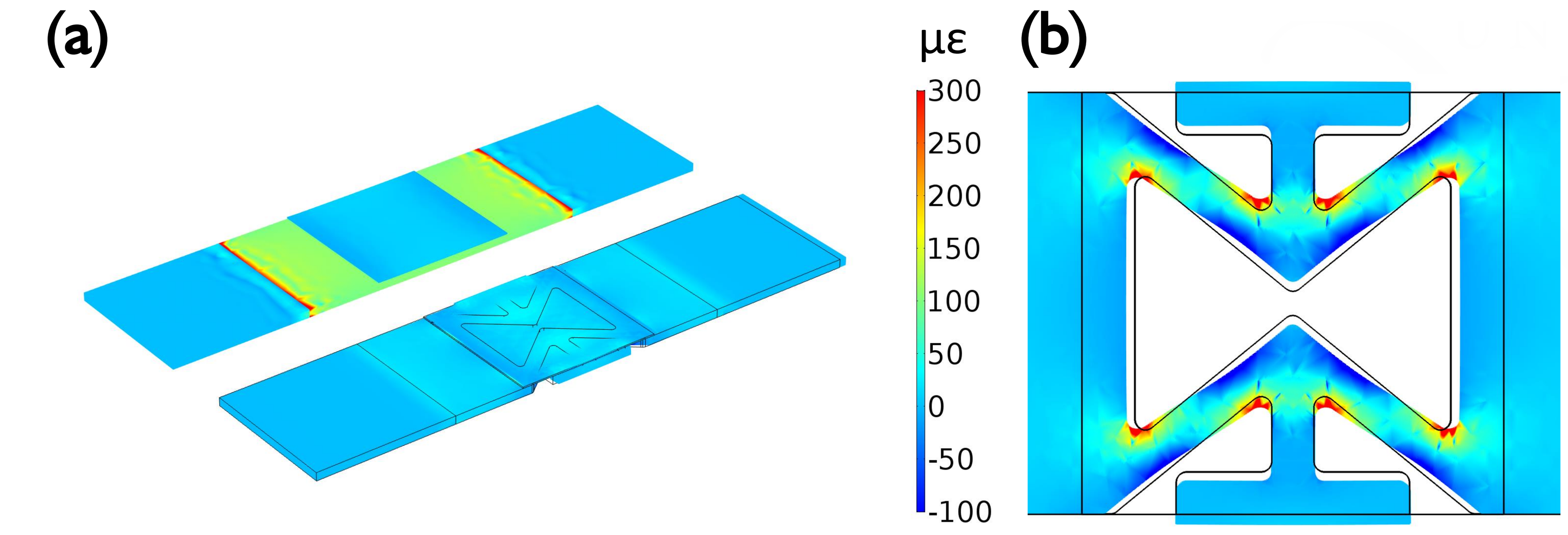

Figure 2: (a) Simulated strain in Plain & Auxetic harvesters.
(b) Isolated Auxetic region slice through substrate.

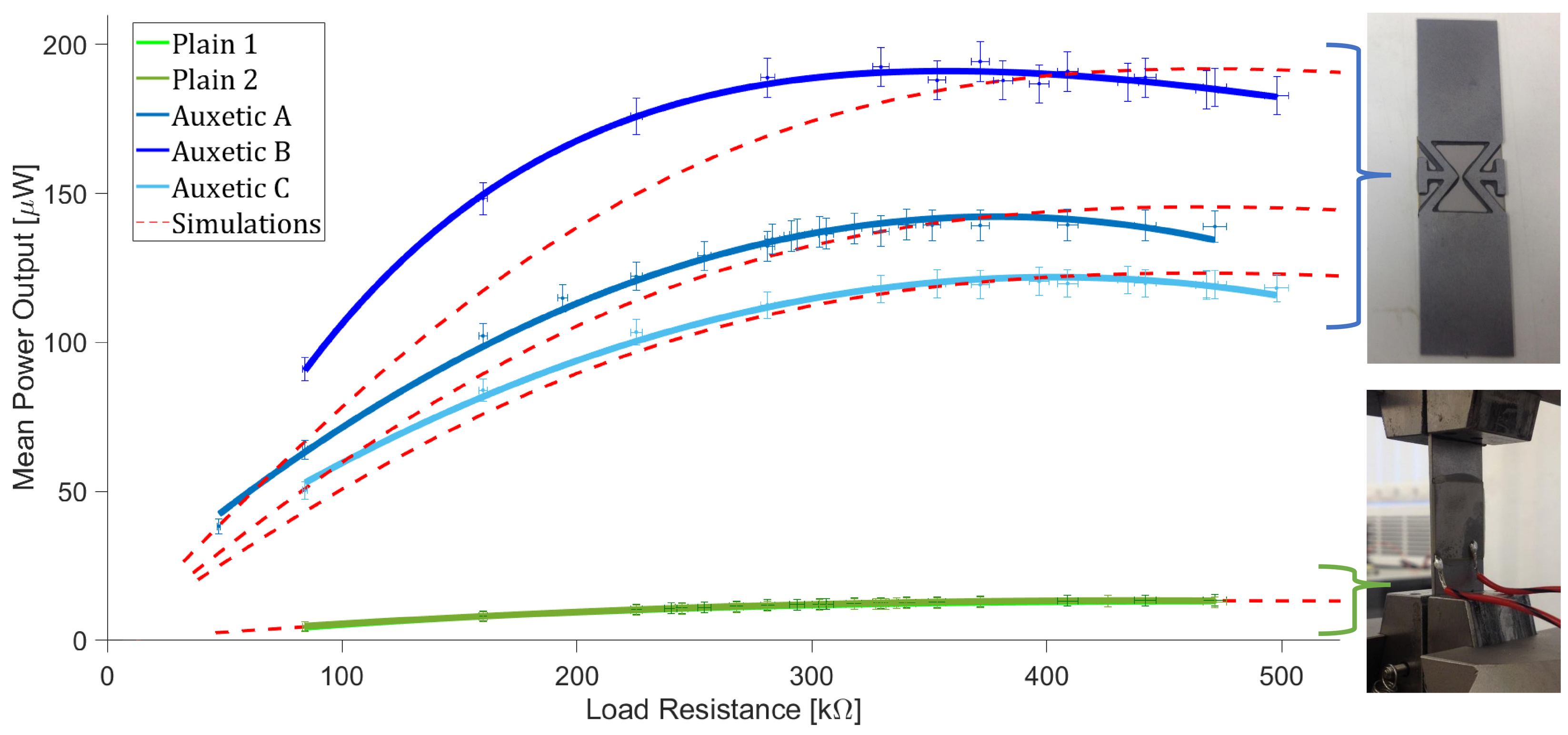

Figure 3: Experimental power obtained from a 250 με, 10 Hz excitation for Plain & Auxetic harvester samples, compared to equivalent simulations (dashed red). Variation between auxetic samples due to excess epoxy stiffening the corners.

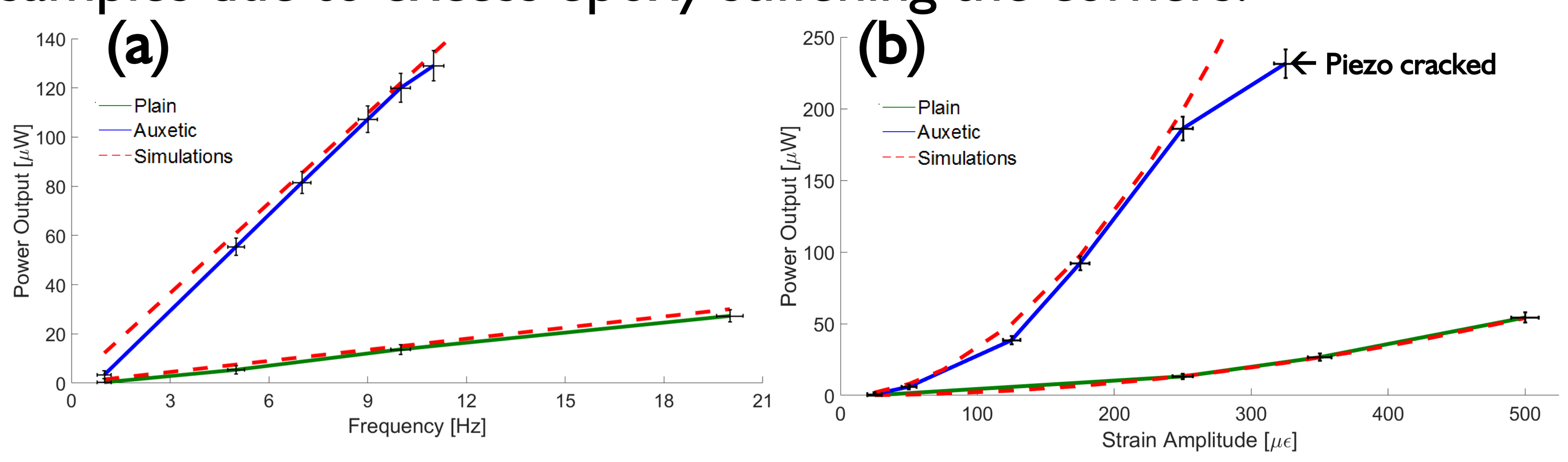

Figure 4: (a) Effect of varying frequency of applied excitation.
(b) Effect of varying strain amplitude of excitation.

Discussion

Our results show a significant power gain of ~11 times on average by using auxetics in energy harvesting. Under the same excitation, from Figure 3, auxetic harvester: 191 μW; plain equivalent: 13 μW. Figure 4 shows this gain is consistent over a range of different excitation. This gain comes with increased stress in the brittle piezo however; directing us to low-strain environments for applications.

There has been interest in self-powering Structural Health Monitoring and other Internet of Things devices[2,3], but harnessing enough energy from their environs is a limitation; auxetic enhancements could power such devices in future.

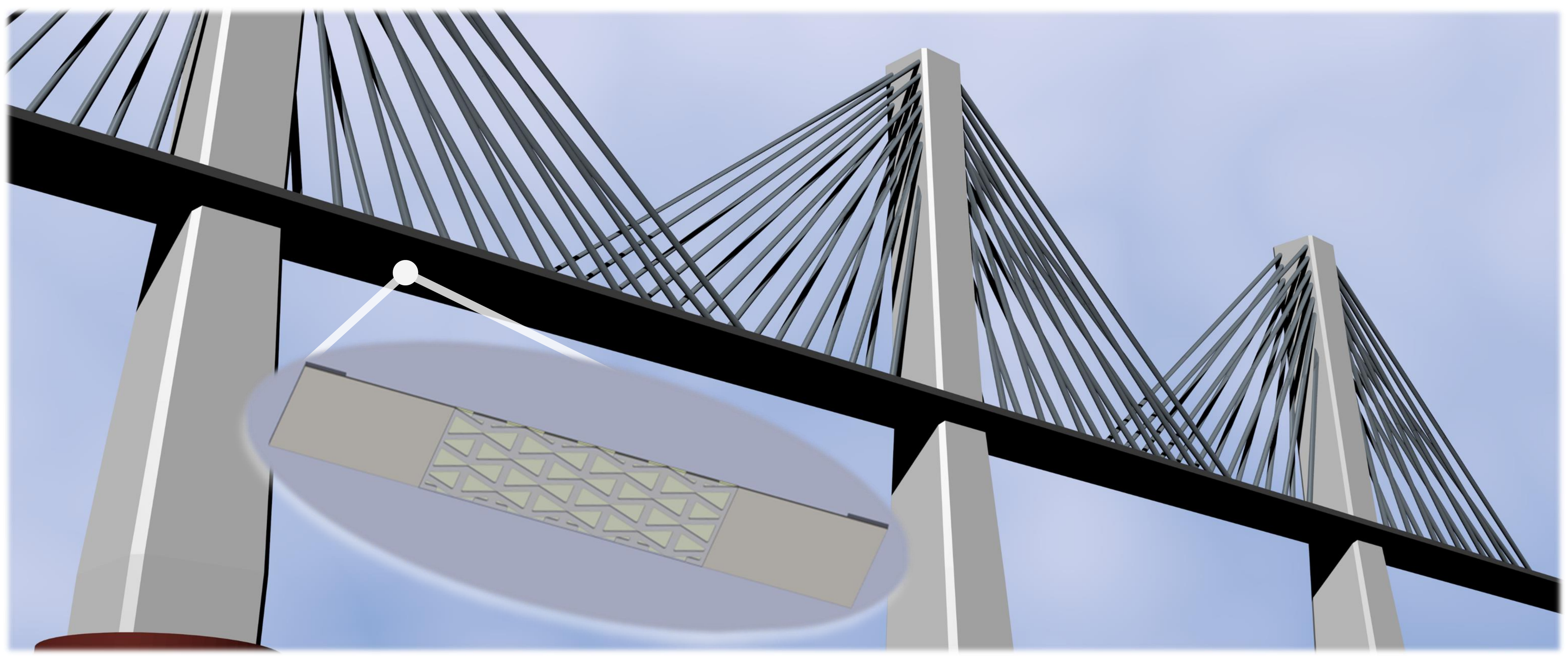

Figure 5: Example potential application of larger scale auxetic vibration energy harvester in situ under a bridge.

References

[1] Q. Li, Y. Kuang, & M. Zhu, "*Auxetic piezoelectric energy harvesters for increased electric power output*" AIP Adv., 2017.

[2] F. Shaikh & S. Zeadally, *"Energy Harvesting in wireless sensor networks: A comprehensive review"* RSER 2016

[3] N. Bonessio, et al., *"Structural Health Monitoring of Bridges Via Energy Harvesting Sensor Nodes"* Bentham Open, 2016

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