SCREEN-PRINTED PIEZOELECTRIC SHOE-INSOLE ENERGY HARVESTER USING AN IMPROVED FLEXIBLE PZT-POLYMER COMPOSITES

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Introduction

This poster reports improvements to a composite polymer piezoelectric material ECS-PolyPZT [1] that can be printed onto flexible substrates. The promising piezoelectric and mechanical properties have been exploited in an energy harvesting shoe-insoles. Improved performance have been achieved by blending different PZT particle sizes. The composite material can be processed at low temperature and screen printed onto flexible substrates, e.g. Kapton or textiles. A capacitive piezoelectric structure was printed on the top of shoe-insoles. The proposed piezoelectric shoe-insoles have been simulated using ANSYS APDL and also practically tested.

Improved Piezoelectric Composites

Paste Formulations

The composites are mixtures of PZT-5H powder of 2 µm particle size and smaller particles (0.15, 0.3 and 0.8 µm) which were used as the filler particles. The 2 µm PZT powder was mixed with various ratios of each filler powder and then blended with a polymeric binder with 60% overall PZT powder by weight. Table 1 shows the formulations investigated. The materials were first printed in a capacitive structure (CS) on Alumina substrates to test the piezoelectric coefficient d_{33} of the material.

Particle Size (µm)	Formulation Ref. #	Large Particle Percentage (%)
0. 8	08-1	90
	08-2	82
	08-3	75
	08-4	62
0.3	03-1	98.6
None	02-1	100
0.15	015-1	90
	015-2	82
	015-3	75
	015-3	62

Table 1: The ECS-PolyPZT (with 60% PZT) composites investing formulations

Poling the devices and d_{33} Measurements

The CS devices were poled with an electric field of 8 MV/m, poling temperature of 160 ºC and poling time of 10 min. The d_{33} coefficient measurements were taken using a PM35 piezometer from PiezoTest. The d_{33} for each formulation was measured 25 times (i.e. 5 devices x 5 d_{33} measurements each).

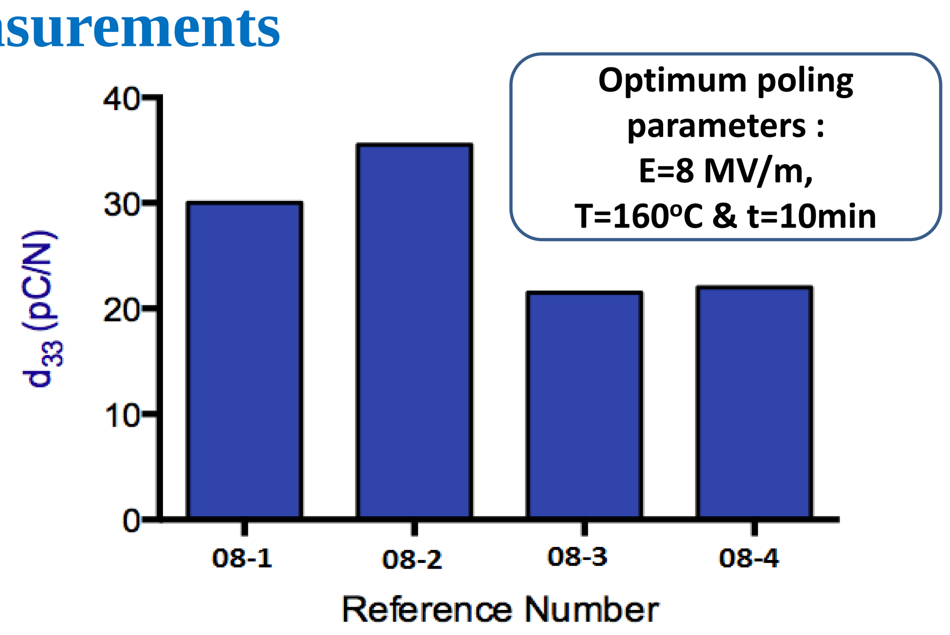

Fig. 1: d_{33} values for materials with 0.8 µm filler

The formulations with 0.3 and 0.15 µm filler particles gave lower d_{33} values. Figure 1 shows formulation 08-2 provided a d_{33} 36 pC/N. This is a 25% increase in activity compared to our pervious version material and is 10% better than PVDF.

Piezoelectric Shoe-Insole (PSI)

Design of PSI

The CS was printed at the stress – active parts of the insoles (see figure 2) to harvest energy from foot force. The top electrode of the sole part at the device was divided into 8 elements which enables force mapping and future design optimisation. Four layers were printed onto these two locations of the PSI.

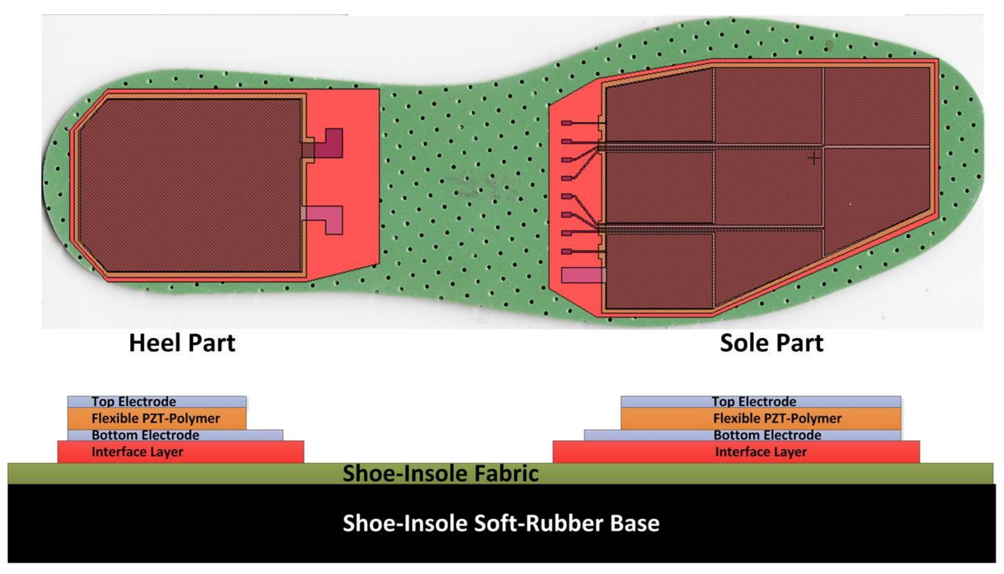

Fig. 2: Schematic of top (top) and cross-sectional (bottom) views of PSI

Fabrication of the Device

Screen-printing was used for fabricating the PSI devices. Figures 3 and 4 show the complete printed PSI device and the mechanical flexibility of the PSI. Table 2 lists the materials that were screen-printed and also their curing conditions.

Material	Curing Type	Curing Conditions
Interface Layer (UoS-IF#4; Smart Fabric Inks)	UV cured	8 layers (60 sec for every layer)
Bottom Electrode (ELX30, Electra)	Thermally cured	125 °C for 10 min
Piezoelectric Material (ECS-PolyPZT)		130 °C for 10 min
Top Electrode (DuPont 5000)		125 °C for 5min

Table 2: Curing Conditions of the materials

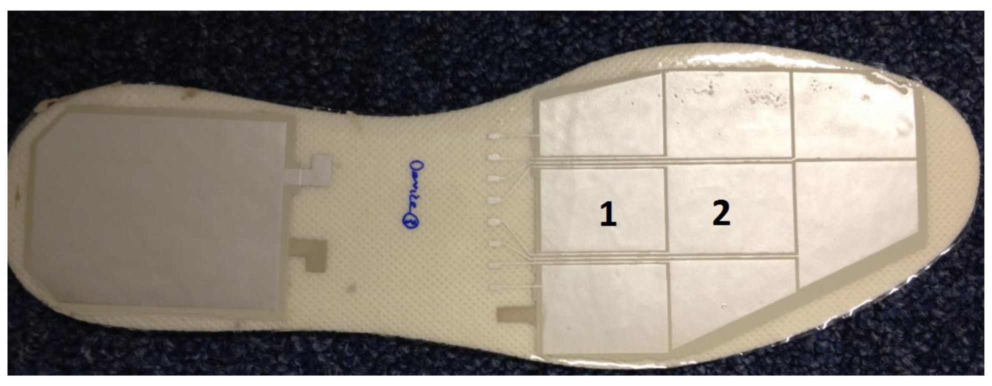

Fig. 3: Top view of the printed PSI showing elements 1 and 2

Fig. 4: Showing the flexibility of the device

ANSYS APDL Simulation

The ANSYS results in figure 5 predict an open-circuit voltage of 3V from element 1 in the sole part of the insole from a foot strike from a 70 kg man.

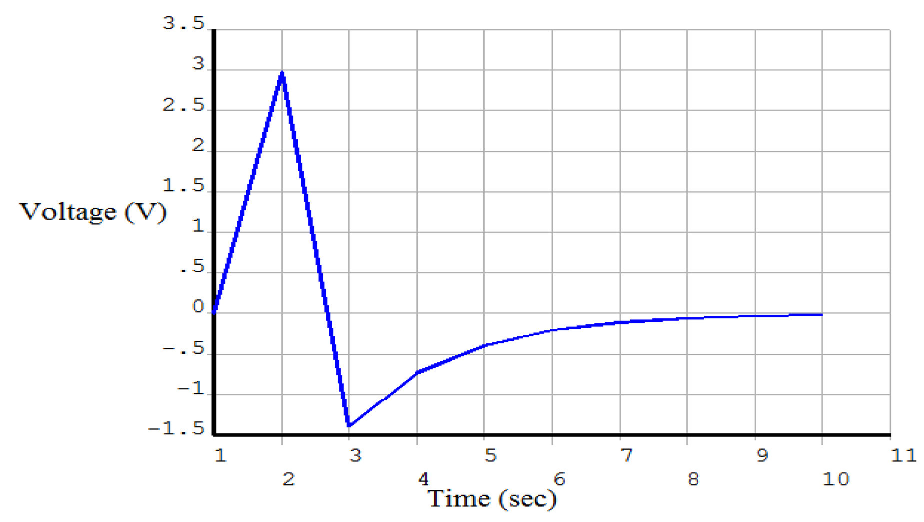

Fig. 5: The open-circuit output voltage for strike for one element of the sole part

Experimental Results

The practical PSI was tested by measuring the open-circuit voltage at the sole part of the insole. The material was poled with an applied electric field of 4 MV/m which is lower than the typical one (8 MV/m). This explains the reduced open-circuit voltage (see figure 6) compared to the ANSYS APDL results in figure 5.

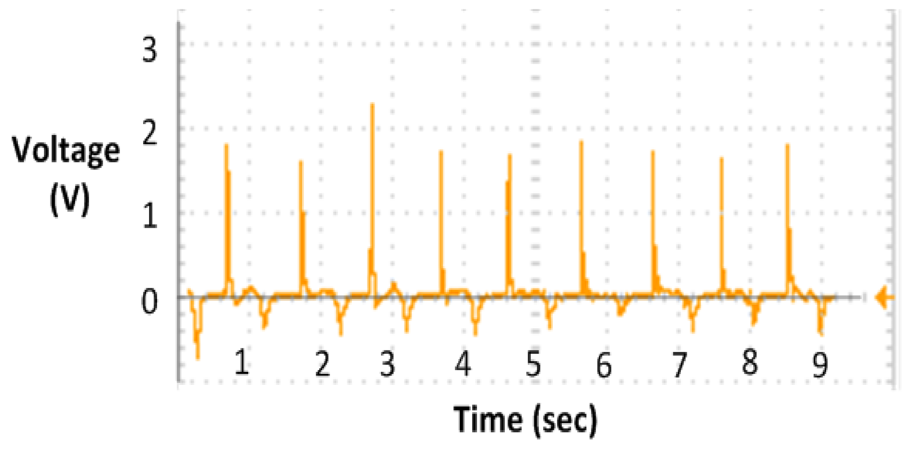

Fig. 6: The open-circuit output voltage of one element of normal gait (1 strike/sec)

Conclusion

It was found by changing the filler particle size and particle weight ratios, the d_{33} can be increased. The d_{33} of the new version of ECS-PolyPZT was improved to reach 36 pC/N. Also, a new piezoelectric shoe-insole (PSI) was investigated. The sole part of the insole was divided into 8 elements; each element can provide a 2 V open-circuit voltage.

References

[1] Almusallam A, Torah R N, Yang K, Tudor J and Beeby S P 2012 Flexible Low Temperature Piezoelectric Films for Harvesting from Textiles presented at the PowerMEMS 2012, December 3-6, Atalanta, USA, Atalanta, USA

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