Electronics and Computer Science

FLEXIBLE LOW TEMPERATURE PIEZOELECTRIC FILMS FOR HARVESTING FROM TEXTILES

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Abstract **This poster reports new flexible low temperature PZT-polymer composites used for energy harvesting from textiles. They are screen-printable which gives the advantage of low-cost and suitability for mass-production. The PZT powder content was varied in three polymer binders and the resulting composites were denoted ECS-PolyPZT 1, 2 and 3. ECS-PolyPZT 2 with 45% and 60% PZT was found to be the most flexible materials that achieved an initial d_{33} of 22 and 25 pC/N, respectively. Following optimization of the poling parameters, the d_{33} improved to 27 pC/N and 36.7 pC/N for ECS-PolyPZT with 45% and 60%, respectively. These materials are suitable for energy harvesting from fabrics enabling applications to be explored in the future.**

Introduction

This poster presents the optimization of screen-printable, low temperature piezoelectric composite materials with respect to their piezoelectric activity and flexibility. The piezoelectric, dielectric and mechanical properties are investigated for a variety of formulations. The materials are formed by mixing PZT ceramic powder with a polymer binders. Two different PZT powders (2 and 0.8µm particle sizes) were blended with a ratio of 4:1 [1]. Three different polymer binders were evaluated and the piezoelectric composites have been denoted ECS-PolyPZT 1, 2 and 3. The optimum weight percentages of PZT powder and poling process have been investigated. The proposed materials satisfied all the conditions for suitability in energy harvesting from textiles.

Experimental

The materials were mixed, triple-roll milled and printed in a capacitive structure for testing piezoelectric properties and film flexibility. All the materials were thermally cured at the temperature and time shown in table 1, which are suitable for fabric.

Material	Temp. (ºC)	Time (min)
ECS-PolyPZT 1	130	10
ECS-PolyPZT 2	125	10
ECS-PolyPZT 3	130	10
ELX 30 Silver/polymer	125	5

Table 1: Curing conditions

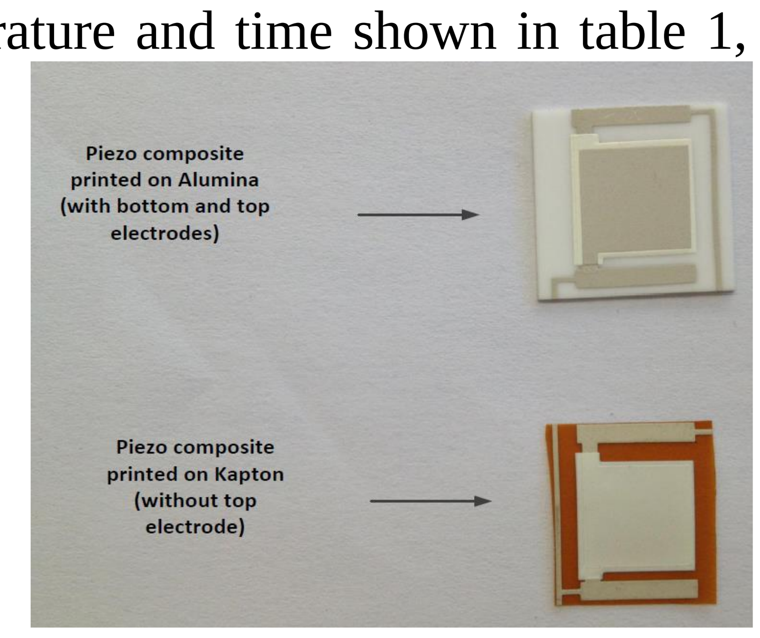

Fig. 1: Test capacitive devices

Results

Permittivity vs. PZT Content

The permittivity was measured against PZT content for each composite. The permittivity was calculated with the aid of previously measured capacitances, electrode areas and thickness of the active material of every composite.

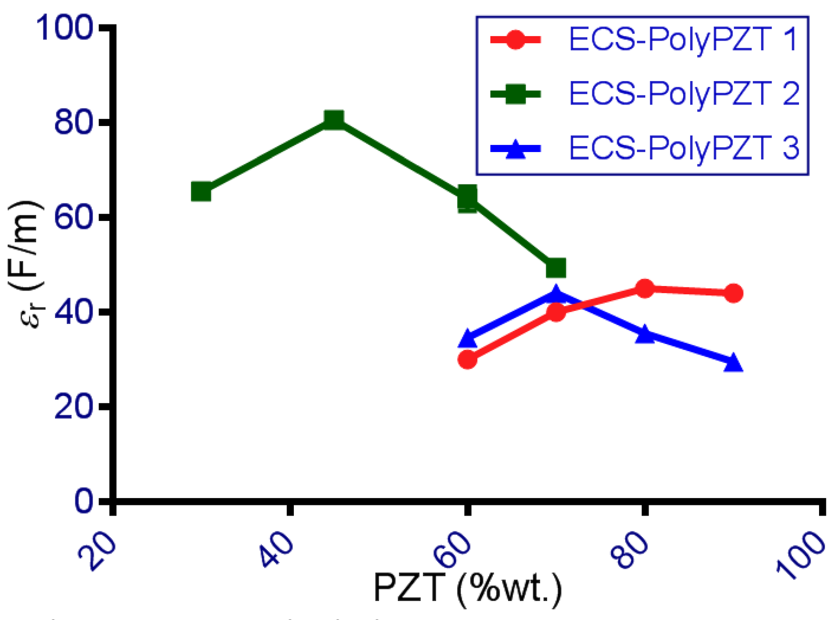

Fig. 2: Permittivity versus PZT content in the composites

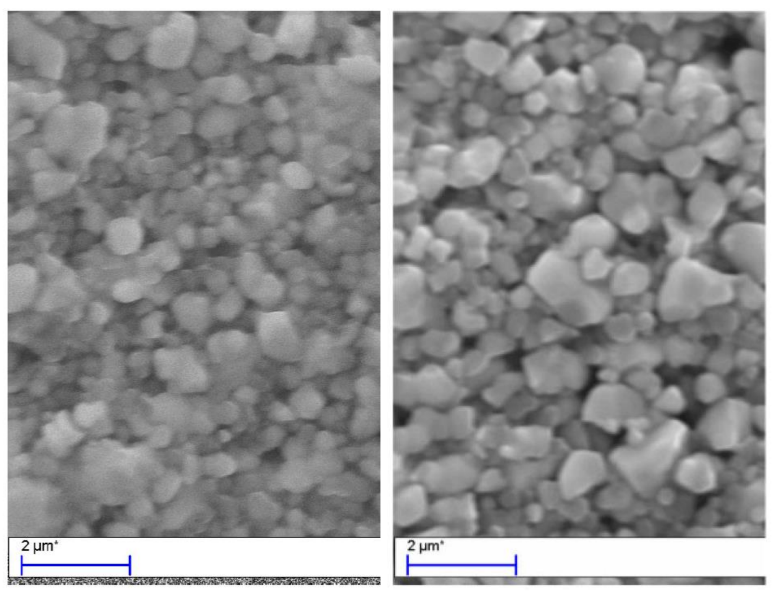

Fig. 3: SEM images of ECS-PolyPZT 2 with 45 % (left) and 70% (right) PZT

The permittivity of each film was found to fall after certain percentage of PZT content. This is because the porosity of the film was found to increase with concentration of PZT and the trapped voids reduce the measured permittivity.

d_{33} vs. PZT Content

The d_{33} coefficient was measured using samples were initially poled using poling conditions (E = 6MV/m, T=160ºC and t=10 min).

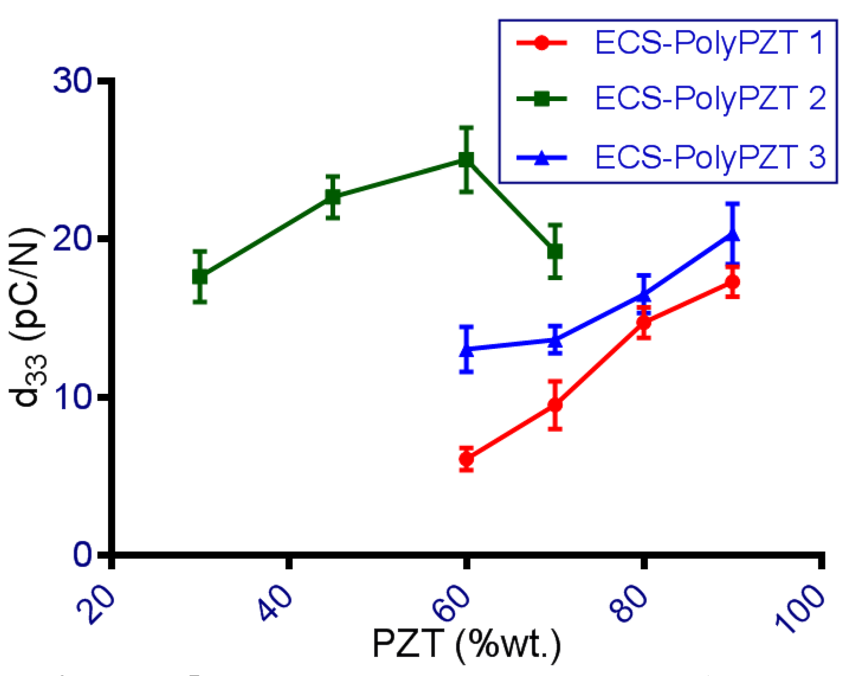

Fig. 4: d_{33} versus PZT content (E=6MV/m, T=160ºC & t=10min)

Material/PZT %wt.	d_{33} (pC/N)
ECS-PolyPZT 1/90	17
ECS-PolyPZT 2/60	25
ECS-PolyPZT 3/90	20

Table 2: The materials which gave maximum d_{33}

Table 2 shows the best PZT content that gives the highest piezoelectric properties for each composite and their d_{33} coefficient values.

Flexibility Test of The Selected Materials

Flexibility of the Kapton devices was tested by bending around different diameter formers and observing the minimum radius of curvature the film can withstand before failure (wrinkles or cracks). The number of complete bending cycles the materials can withstand was observed without a former.

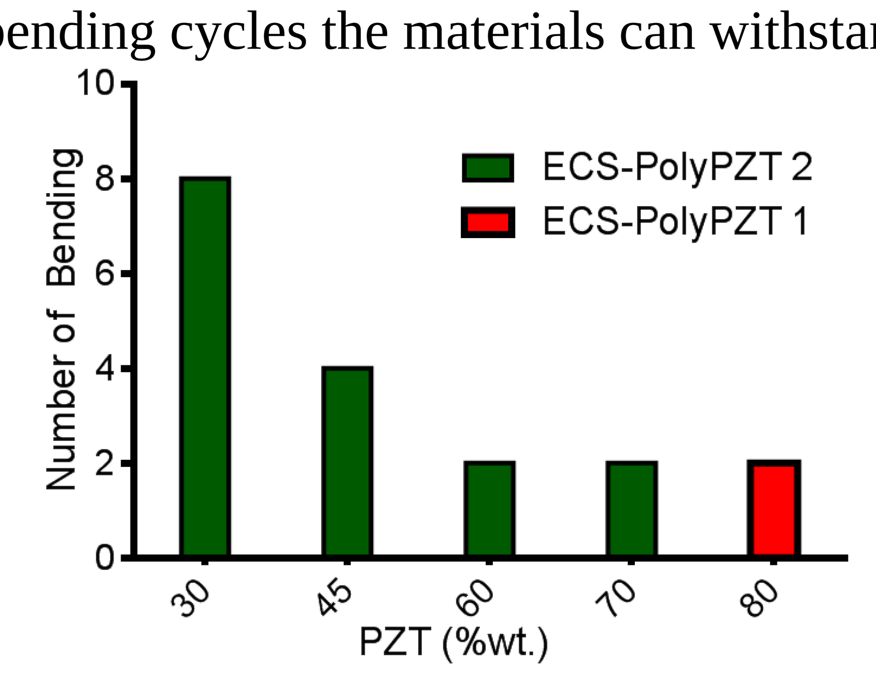

Fig. 5: Number of complete bending test

Fig. 6: Showing the flexibility of ECS-PolyPZT 45%PZT

ECS-PolyPZT 2/45 and 60 PZT provided the best combination of piezoelectric activity and film flexibility. Poling optimisation was investigated for ECS-PolyPZT 2/45. The optimised poling conditions were then applied to ECS-PolyPZT 2/60.

Poling Parameter Optimization

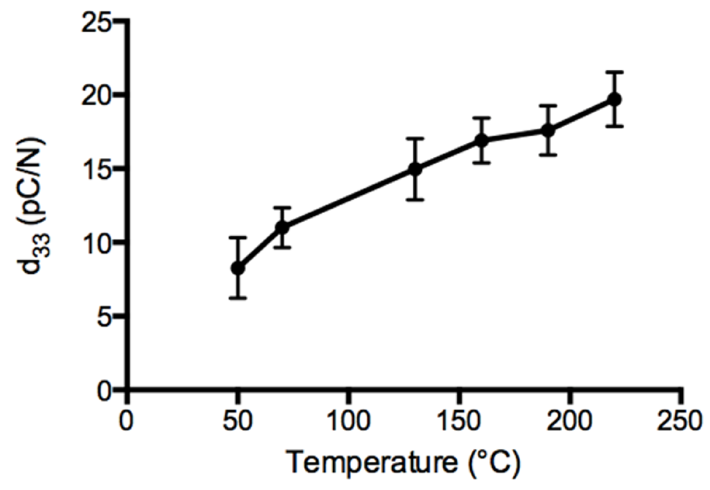

Fig. 7: Poling temperature optimization (E=4MV/m & t=10min)

T= 160ºC for fabric suitability

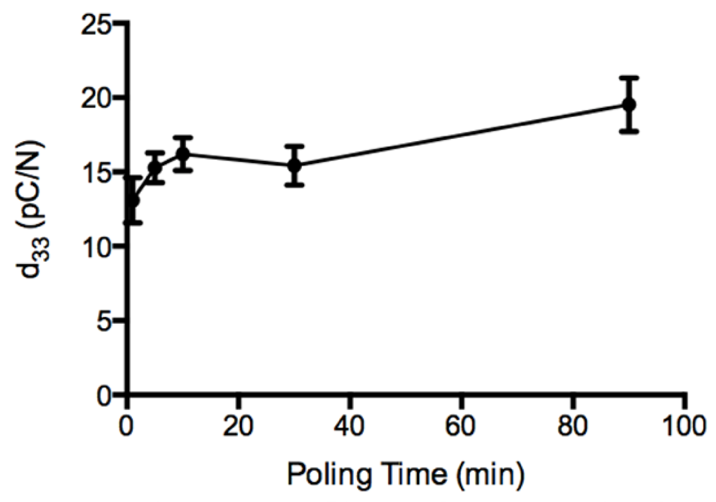

Fig. 8: Poling time optimization (E=4MV/m & T=160ºC)

T = 10min for good mass production

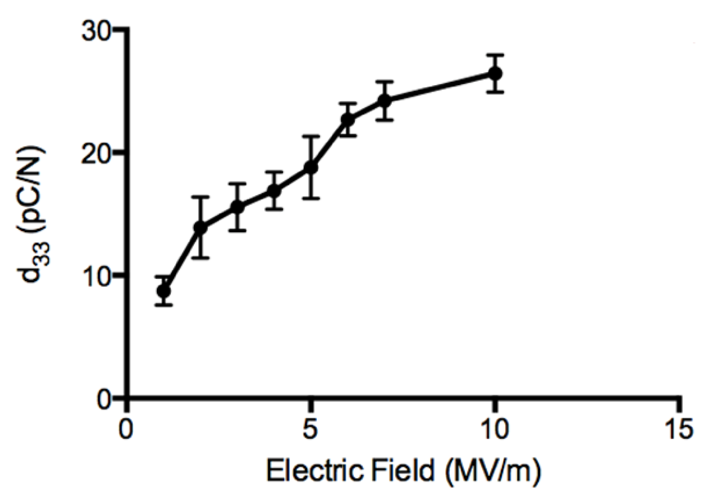

Fig. 9: Poling field optimization (T=160ºC & t=10min)

Optimum poling parameters : E=10 MV/m, T=160ºC & t=10min

After poling optimisations, ECS-PolyPZT 2/45 gave a d_{33} of 27pC/N. d_{33} was again measured for ECS-PolyPZT 2/60 with the optimized poling parameters giving a d_{33} of **33.5** pC/N. With the temperature increased to 200ºC, a d_{33} value of **36.7** pC/N was measured which is greater than PVDF (20-30 pC/N).

Conclusion

PZT content were varied to investigate piezoelectric properties and film flexibility. ECS-PolyPZT 2/45 and 60 PZT demonstrated d_{33} values of **27** and **36.7** pC/N with a good level of flexibility. These materials are suitable for use on a wide range of fabrics and will now be used to develop fabric based energy harvesters.

References [1] Torah R, Beeby S P and White N M 2005 An improved thick-film piezoelectric material powder blending and enhanced processing parameters *IEEE transactions on ultrasonics, ferroelectrics, and frequency control*, **52(1)**, 10-16