Smart Nanocomposite Paint Sensors For Infrared Detecting And Energy Harvesting

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Abstract

This research explores and presents the functionality of nanocomposite Paint/PLZT films for use in pyroelectric infrared sensors and piezoelectric energy harvesting devices. Smart Paint Lead Lanthanum Zirconate Titanate (Paint/PLZT) nanocomposite films have been fabricated by the conventional paint-brushing technique on copper substrate. The pyroelectric and dielectric properties were measured for their use in uncooled and thermal conversion devices. The material's properties investigated include the dielectric constants (ε', ε'') and pyroelectric coefficient (*p*) as a function of temperature. Using foregoing parameters, the material's Figure-of-Merit for infrared detections and thermal conversion were calculated. The results indicated that composite films are functional. Based on the preliminary results obtained, it has been found that Paint/PLZT films are attractive for use in uncooled thermal conversion devices and piezoelectric energy harvesting, especially in applications where curved surface sensors are required.

Figures-of-merit

$F_I = p/c'$ High Current Detectivity

$F_V = p/\varepsilon' c'$ High Voltage Responsivity

$F_D = p/c'\sqrt{\varepsilon''}$ High Detectivity

$F_E = p^2/\varepsilon'$ Thermal Energy Conversion of Pyroelectric Material

Where *p* is the pyroelectric coefficient, *c'* is the volume specific heat, *ε'* is the dielectric constant, and *ε''* is the imaginary part of dielectric constant (dielectric loss constant).

Experimental setup



Fig. 1. Piezoelectric harvester testing setup: (1) oscilloscope, (2) waveform generator, (3) multimeter, (4) programmable resistor, (5) power amplifier, (6) vibrometer, (7) laser displacement meter, (8) cantilever, and (9) shaker

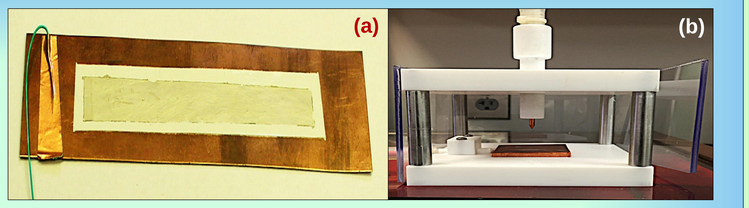


Fig. 2. (a) Nanocomposite films on copper substrate, (b) poling setup

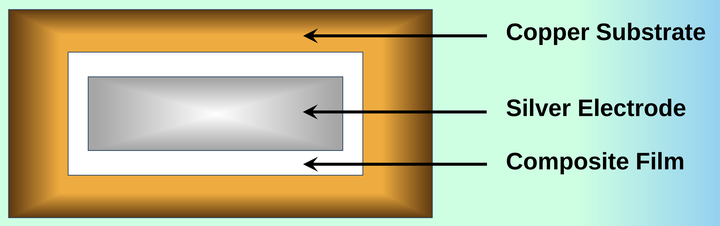


Fig. 3. Diagram of nanocomposite films on copper substrate

Results

Table 1. Summary of Performance of Harvesters with Temperature Gradient

Sample	Mode	ΔT	Resonance Frequency (Hz)	Resistance (MΩ)	Output Voltage (mV)	Output Power (nW)
Paint: PLZT	Piezoelectric	0	101	2.2	11.3	0.0585
Paint: PLZT	Piezo + Pyro	3.8	101	2.2	16	0.117

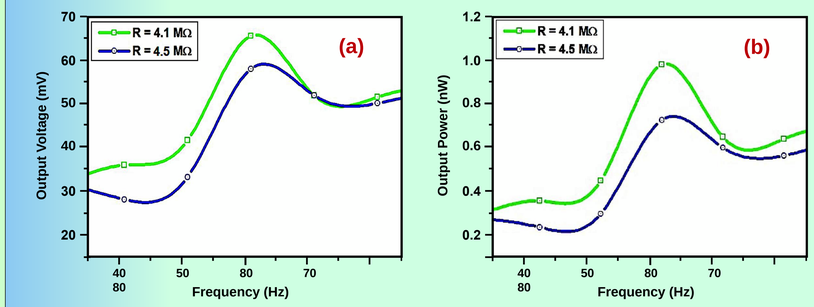


Fig. 5. PLZT frequency vs. output (a) voltage and (b) power

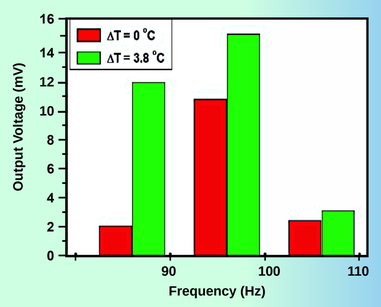


Fig. 6. ΔT results: freq. vs. output voltage of Paint/PZLT

Table 2. Summary of Pyroelectric Performance of Harvesters

Sample	Temp. (° C)	Pyroelectric Coeff. (p); F_I (nC/cm² ° C)	$F_V = p/\varepsilon'$ (nC/cm² ° C)	$F_D = p/(\varepsilon'')1/2$ (nC/cm² ° C)	$F_E = p^2/(\varepsilon')$ (pC/cm² ° C)²
PVDF	45	0.43	0.03	0.42	0.012
Paint: PLZT	45	0.114	0.011	0.13	0.0011

Conclusions

The preliminary experimental results obtained for nanocomposite films (PVDF, Paint-PLZT, films) can be summarized as follows:

- Functional piezoelectric harvesters on copper substrate based Paint/PLZT films have been fabricated using the conventional paint brushing method. This technique is a very useful and inexpensive for the manufacturing of nanocomposite pyroelectric sensors and energy conversion devices due to the process requiring less energy, time, and effort as compared to ceramic and single crystal fabrication processes.
- The calculated pyroelectric materials *figure-of-merits* (FI and FE) of the composite films were found to be lower than pristine PVDF films.
- It is demonstrated that a temperature gradient of about 3° C results in an increase in output voltage and power. The maximum output voltage at a frequency value of 101Hz and a load resistance of 2.2MΩ was increased from 11.3mV to 16mV for the Paint/PLZT based harvester, exhibiting enhanced performance.

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