Title

Piezoelectric Vibrational Energy Scavenging for Autonomous Wireless Sensor Networks

Permalink

https://escholarship.org/uc/item/7xk4f3kk

Authors

Reilly, Elizabeth
Ramesh, R.
Wright, Paul

Publication Date

2007

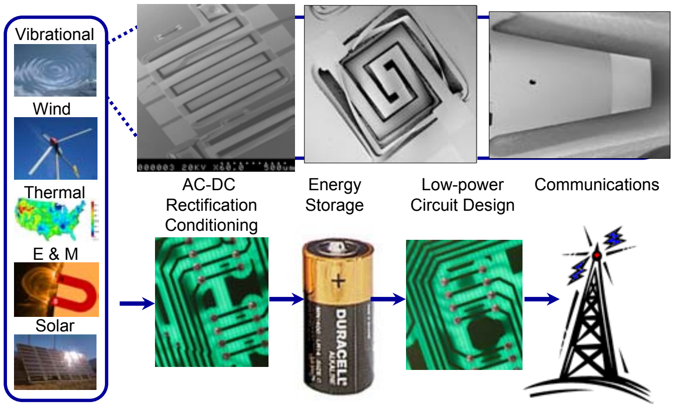
Piezoelectric Vibrational Energy Scavenging for Autonomous Wireless Sensor Networks

Lindsay Miller
Padraic Shafer
Elizabeth Reilly
R. Ramesh
Paul Wright

Vision

Ubiquitous wireless sensor networks have extraordinary potential for use in demand response, environmental monitoring, manufacturing & medical device applications. Realization of these networks for wide-spread market use requires that the sensor nodes be miniaturized & maintenance free. A microscale energy scavenger addresses these needs by harnessing environmental vibrations to provide a replenishable source of power for the sensor node while simultaneously reducing the volume occupied by the power generator.

Piezoelectric vibrational energy scavenging is an ideal energy source for indoor applications where solar & wind are not feasible, & thermal, pressure & field gradients are usually negligible. Piezoelectric scavengers can be fabricated as MEMS devices without requiring an external power source or complex three-dimensional designs as electrostatic & electromagnetic vibrational scavengers do.



Research Questions

How can power output be increased?

- How can high *f* MEMS & low *f* vibration sources be reconciled?
- How can % of material undergoing strain be maximized?
- What are the materials for optimal device performance?

How can fab process be scaled for mass production?

- Can fab-friendly processes produce high quality piezoelectric films?

How can stability/robustness be ensured for lifetime?

- How can electromechanical domains be engineered to prevent fatigue?

Methods

Maximize power output

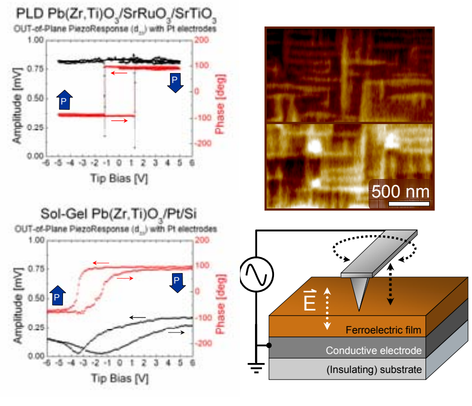
- Innovative geometries: ↓ resonant *f*, ↑ % material strained
- Alternative piezoelectric materials ↑ electromechanical coupling (d_{31}): PZT, PMN-PT, PVDF

Scalable fabrication

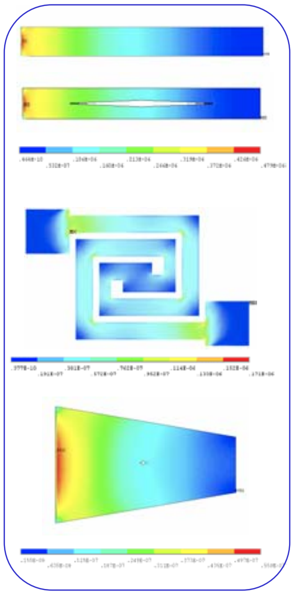
- Replace pulsed laser deposition with sol-gel, sputtering, or chemical vapor deposition

Maximize stability/robustness

- Vary growth parameters (temp, pressure, orientation)
- Strain engineering (biaxial tensile/compressive layers)
- Encourage formation of single domain materials
- Pin motion of domain walls: ↓ energy loss, ↑ cyclical fatigue life



Polarization domains in $Pb(Zr,Ti)O_3$ revealed by piezo-force microscopy (Contrast indicates polarization direction)



Findings

Power output

- Approx 1 μW/cm³ empirical output, 100 μW/cm³ predicted Multiple domains reducing efficiency?
- PMN-PT has d_{31} ≈1200 pC/N, about 5X that of PZT
- Modeling shows alternate geometries can increase % strain

Scalability

- Sol-gel can coat entire 4” wafer uniformly
- Poly-granularity reduces remnant piezoresponse
- Sol-gel process optimization is needed

Stability/Robustness

- Sol-gel fatigues faster (10^5 cycles) than PLD ($>10^9$ cycles) May improve with quality of bottom electrode
- Substrate orientation can suppress multiple, competing domains

Geometry	Resonant Frequency (Hz)	% Area Strained	% Increase
Cantilever	1000	40.4	0
Slit Cantilever	1113	50.2	29.2
Trapezoid	5583	55.6	37.7
Spiral	6247	74.5	87.0

UC Berkeley | CBE | BMI | CEC