

Energy Harvesting with Piezoelectric Actuators

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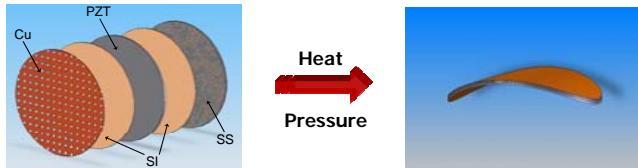


Motivation and Objective

- Scaling of IC technology is far outpacing that of power supplies.
- Example: At an average power consumption of 100 mW, you need more than 1 cm³ of lithium battery volume for 1 year of operation.
- Goal:** To study energy harvesting with piezoelectric devices using vibration energy.

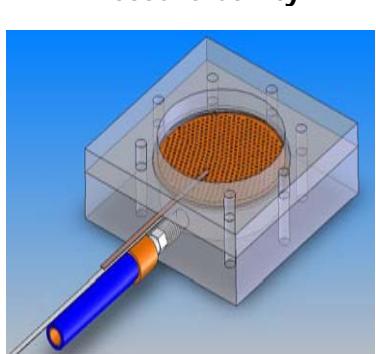
Materials and Method

Piezoelectric Diaphragm - Thunder®



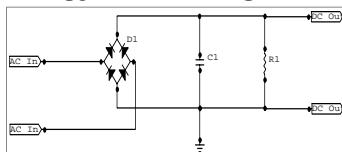
- Pre-stressed laminated wafer using thermal CTE mismatch
- Robust and high out of plane displacement

Experimental Parameters



Frequency	2.5Hz 3.25Hz 5.0Hz
Pressure	138kPa (20.0psi) 206.85kPa (30.0psi) 275.8kPa (40.0psi) 344.75kPa (50.0psi)
Temperature	20°C 40°C 60°C 80°C 100°C
Resistance	470kΩ 1MΩ 2MΩ

Energy Harvesting Circuit

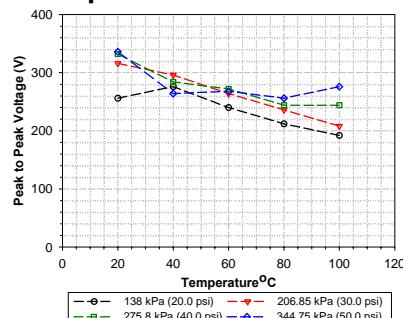


Experiments Table

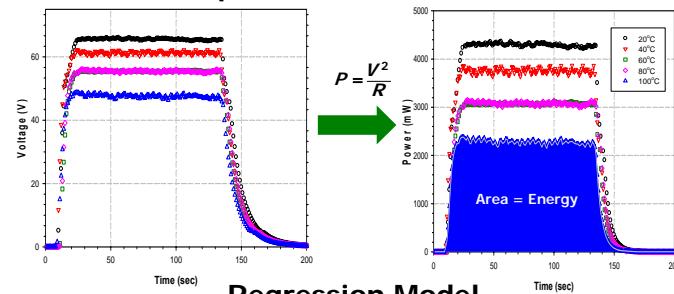
	Pressure	Frequency	Temperature	Load Resistance	Output
Experiment 1	X	X	X		ACV
Experiment 2 (measured over time)	X	X	X	X	DCV

Results

Experiment 1 ACV Results



Experiment 2 DCV Results

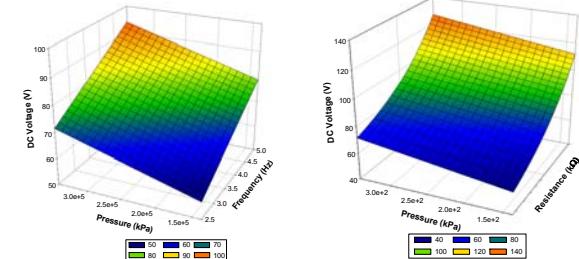
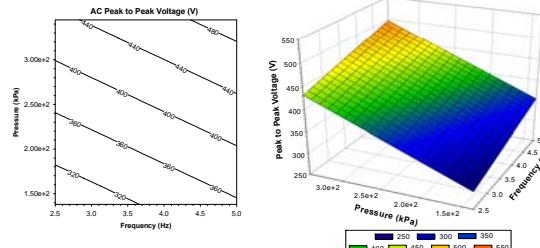


Regression Model

$$V(DC) = 28.41 + 8.98 \cdot f + 3.61 \times 10^{-5} \cdot r + 7.18 \times 10^{-5} \cdot p - 3.12 \times 10^{-6} \cdot (fr) - 9.60 \times 10^{-7} \cdot (fT) - 4.33 \times 10^{-5} \cdot (fp) - 1.18 \times 10^{-7} \cdot (rT) + 4.71 \times 10^{-7} \cdot (fpT)$$

Regression Model

$$V(AC) = 242.18 + 26.14 \cdot f + 6.85 \times 10^{-4} \cdot p - 2.58 \times 10^{-4} \cdot (fp) - 0.59 \cdot (fr) - 5.88 \times 10^{-6} \cdot (pT) + 3.19 \times 10^{-6} \cdot (fpT)$$



Conclusions

- Pressure and frequency are significant factors
- Temperature is not a main factor but is important in combination with other factors

	Voltage (V)	Power Density (μW/mm ³)	Energy (J)
Experiment 1 (ACV)	336		
Experiment 2 (DCV)	107.89	15.32	1.36



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