Feasibility of Piezoelectric Transducers for Energy Harvesting in Implantable Micro Devices

CLINTON AUL

4803 DEVICES FOR RENEWABLE ENERGY

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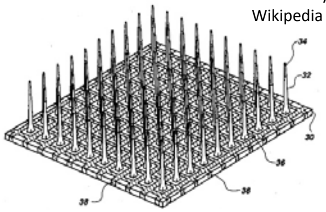
Implantable Devices: Background

- Electronic Devices
  - Smaller
  - Faster
  - More Processing Power
  - Less Power Consumption
- Variety of Implantable Devices
  - Nervous System
  - Retinal
  - Cochlear
  - Brain

MRI-Safe Pacemaker
University of Colorado, Denver



Utah Array Brain Implant
Wikipedia

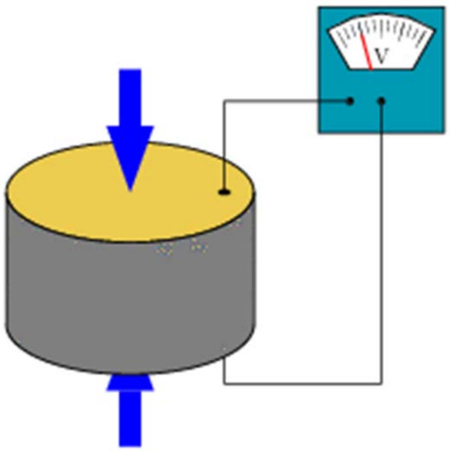
Power Requirements

- Pacemaker – 0.3 µW [1]
- Cochlear Implant – 4 mW [2]
- Retinal Implant with sensor and microchip – 10 mW [3]
- Full feature wireless microcontroller – 60 mW [4]

References.
[1] C. Dagdeviren, et al, "Conformal Piezoelectric energy harvesting and storage from motions of the heart, lung, and diaphragm," Proc. Nat. Academy of Sciences, Dec 16, 2013
[2] M. Baker, 'A low-power cochlear implant system," MIT, accessed [4/8/2015], http://dspace.mit.edu/handle/1721.1/40494
[3] retina-implant.de, "Subretinal Implant Technology"
[4] BLE113 Specifications, BlueGiga.com

Why Piezoelectric

- Advantages
  - Kinetic energy transducer
  - Free Energy (Parasitic)
  - Few/no moving parts
  - Cheap
- Disadvantages
  - Low power output



GIF Source: http://en.wikipedia.org/wiki/Piezoelectricity

Piezoelectric Power

- Common Materials
  - Lead Zirconate Titanate (PZT)
  - Aluminum Nitrate (AlN)a
  - Zinc Oxide (ZnO)
- Parameters
  - Size
  - Proof Mass
  - Resonant Frequency
- Power Output [1]
  - MEMS – 1.2 to 2 μW
  - Nanowire – 10-20 pW/wire
  - 1x1x1.8 cm^3 – 4.8 mW

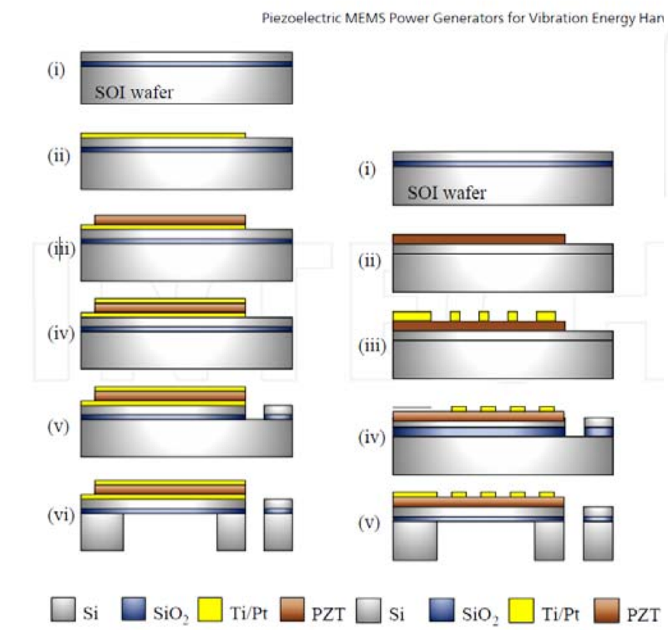
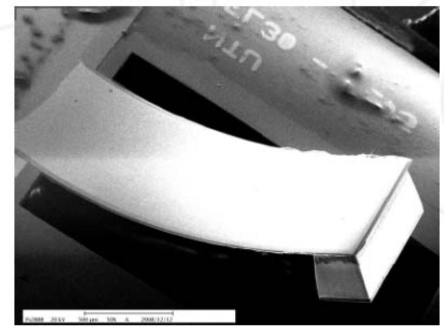
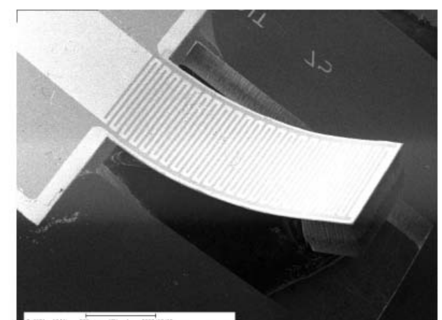


Figure 19. Fabrication processes of d31 (left) and d33 (right) devices

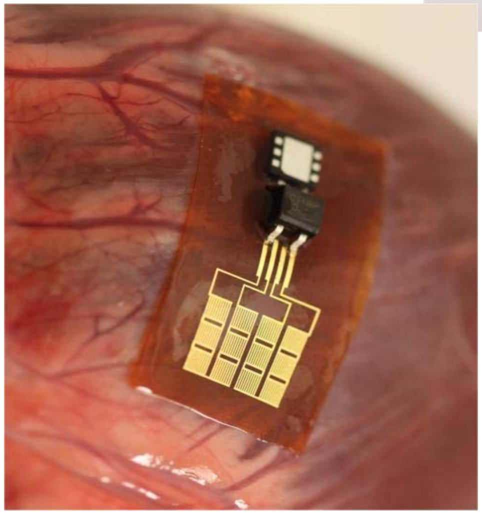




[1, Images] W. Wu, B. Lee, "Piezoelectric MEMS Power Generators for Vibration Energy Harvesting," Dpt. Eng. Science and Ocean Eng., National Taiwan University, Taipei, Taiwan, Oct, 2012

Example: Cardiac Pacemaker

- Totally self powered
- Arrays of elements connected in parallel and series.
- Power Density = 1.2 $\mu W/cm^2$
- Efficiency of 1.7%
- Material capable of 20 million physical manipulations



C. Dagdeviren, et al, “Conformal Piezoelectric energy harvesting and storage from motions of the heart, lung, and diaphragm,” Proc. Nat. Academy of Sciences, Dec 16, 2013

Conclusions

- Successes
  - Piezoelectric energy harvesting successfully powers pacemaker
- Challenges
  - Increase efficiency
  - Biocompatibility
  - Further reduce power consumption

Questions?