

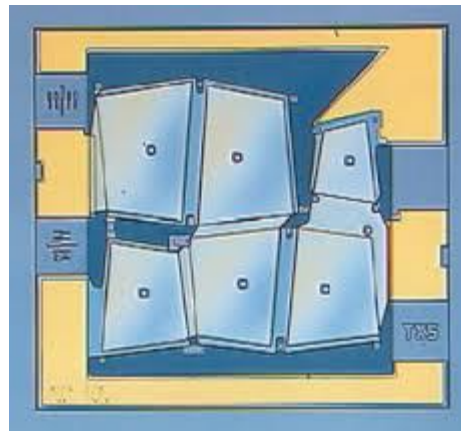
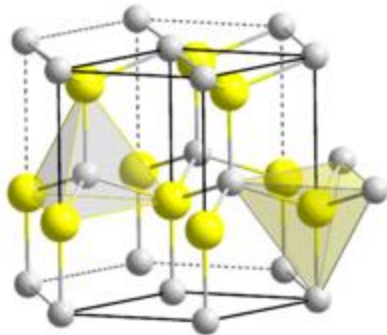
AIN FOR THICK PIEZOELECTRIC FILMS AND THERMAL CONDUCTIVITY

Shad Roundy



Aluminum Nitride (AlN)

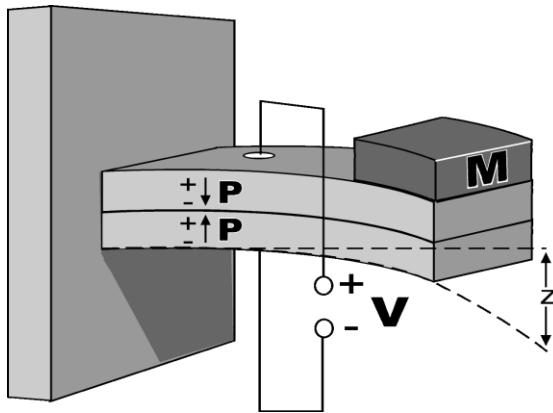
- Piezoelectricity
 - Wurtzite crystal with inherent piezoelectricity
 - Very high temperature operation (no Curie temperature)
Stable up to 1300 C in air
 - High Q material
- Very high thermal conductivity
 - 70 – 285 W/m/K



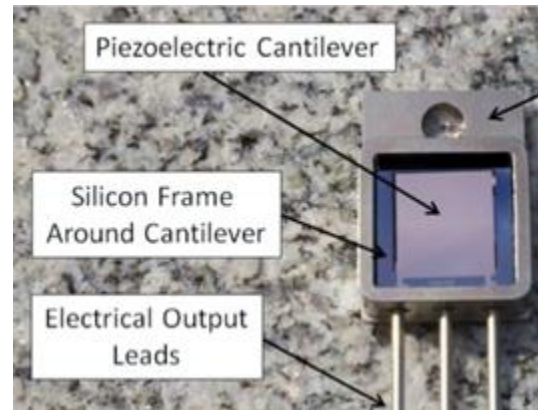
Agilent FBAR datasheet



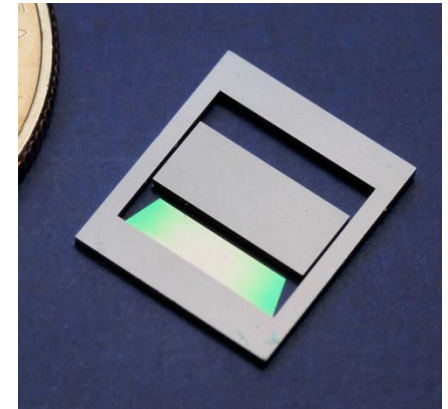
MEMS Scale Vibration Energy Harvesting



Vibration Energy Harvesting
Piezo Structure

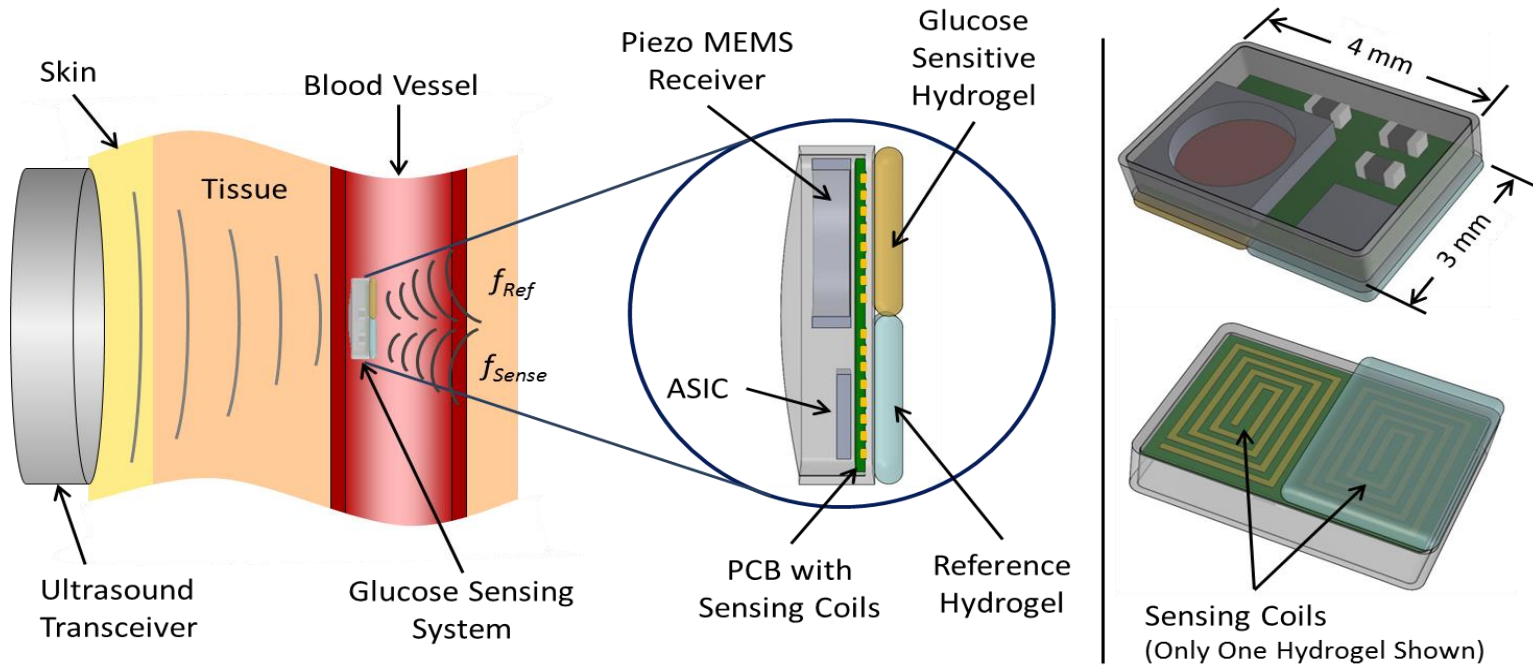


AlN Based Vibration Energy Harvester
MicroGen Inc.



- Microscale vibration energy harvesting has typically not been very successful partly due to thin and low quality piezo materials
- The most common material, PZT, is less compatible than AlN for fab processes and cannot operation at extreme temperatures

Ultrasonic Power Transfer for Implants



- At very small sizes ($\sim \text{mm}^2$) and large implant depths ($> 1 \text{ cm}$) acoustics can be much more efficient than inductive coupling or RF power transfer
- PZT presents biocompatibility issues

Power for Energy Harvesting

$$P_{rms} = \frac{1}{4} \omega k^2 c^E V S^2$$

volume

$$FOM = k^2 c^E = \frac{d^2 c^{E2}}{\epsilon^T} = \frac{e^2}{\epsilon^T}$$

ω = frequency

k^2 = material coupling coefficient

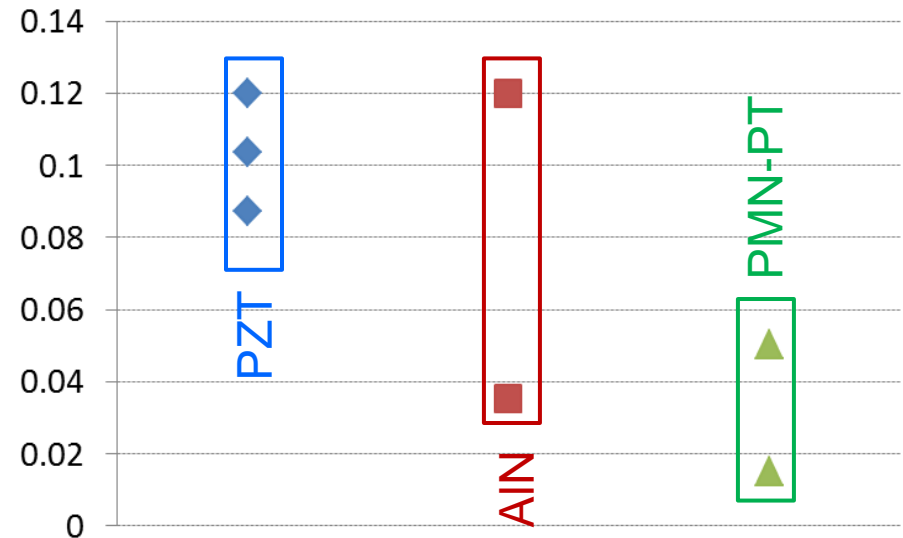
c^E = material stiffness at zero electric field

V = volume of material

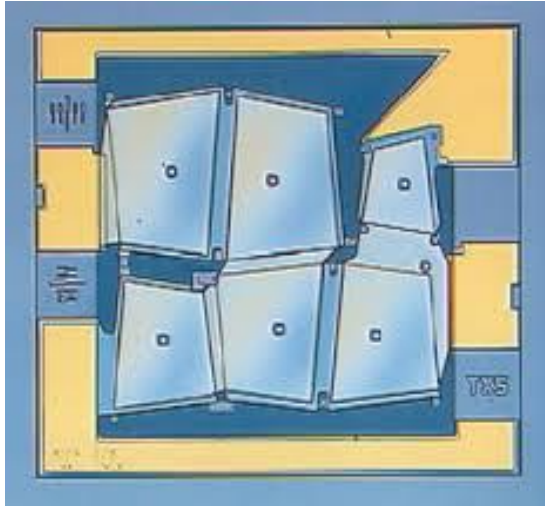
S = maximum strain in material

ϵ^T = dielectric constant at zero stress

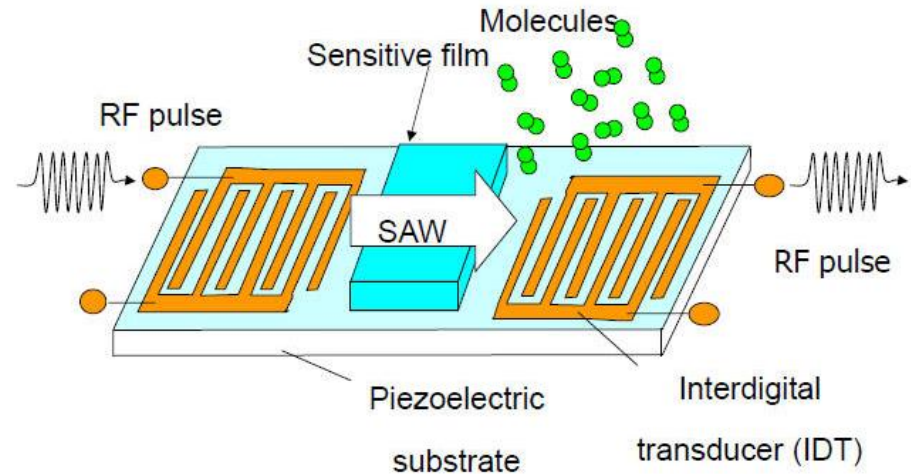
Material Figures of Merit (C^2/m^4)



Resonators / Resonant sensors



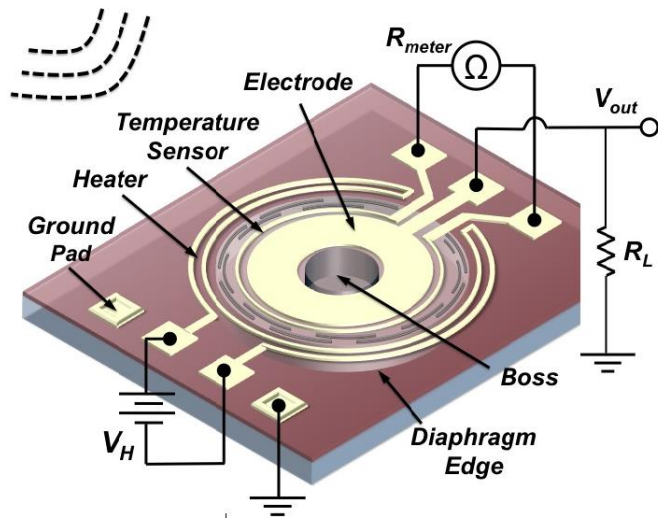
Agilent Film Bulk Acoustic Resonator (FBAR)



SAW Gas Sensors
Tohoku University

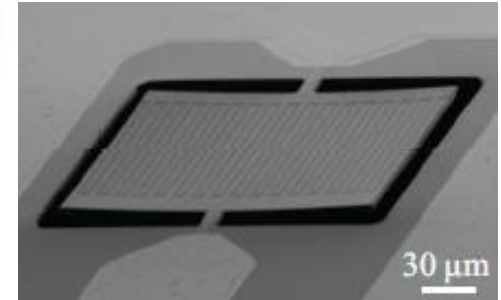
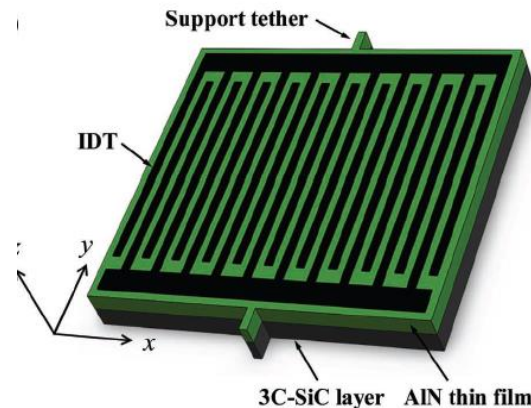
- AlN can be used for Bulk Acoustic Wave (BAW) and Surface Acoustic Wave (SAW) devices
- Applications
 - Oscillators and filters for communication systems
 - Untethered chemical, strain, pressure, acceleration sensors

Harsh Environment Applications



High temperature Energy Harvesters
Lai et. al. Transducers 2013

- Material is non-ferroelectric
- Maintains piezoelectric properties up to at least several hundred degrees C



High temperature GHz Resonator
Li et. al., Adv. Mater. 2012, 24, 2722-2727

Endeavor AT AlN Tool from OEM Group



OEMGROUP **tegal**

- Up to 6 um thick AlN
- 100 – 200 mm wafers
- ~\$695k