Piezoelectric and Piezoresistive Instrumentation

By: Kris Hyblova, Abby Covrig, Kyron Heinrich

Direct Piezoelectric Effect
Inverse Piezoelectric Effect

![Diagram of sound wave and electrical signals]

Piezoelectric Materials

**Materials**
- **Single Crystal:**
  - Quartz, Lithium Niobate (LiNbO3), and Lithium Tantalate (LiTaO3)
  - Surface Acoustic Wave devices (SAWs), dynamic pressure sensors
- **PolyCrystal:**
  - Barium titanate (BaTiO3), Piezoelectric Pb(Ti,Zr)O3 solid solutions (PZT) ceramics
- **Polymers:**
  - Polyvinylidene difluoride (PVDF)
  - Drawn and stretched to polar phase
Piezoelectric properties

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Quartz</th>
<th>BaTiO₃</th>
<th>PZT 4</th>
<th>PZT 5H</th>
<th>(Pb,Sm) TiO₃</th>
<th>PVDF-TrFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>$d_{33}$ (pC/N)</td>
<td>2.3</td>
<td>190</td>
<td>289</td>
<td>593</td>
<td>65</td>
<td>33</td>
</tr>
<tr>
<td>$g_{33}$ ($10^{-3}$ Vm/N)</td>
<td>57.8</td>
<td>12.6</td>
<td>26.1</td>
<td>19.7</td>
<td>42</td>
<td>380</td>
</tr>
<tr>
<td>$k_l$</td>
<td>0.09</td>
<td>0.38</td>
<td>0.51</td>
<td>0.50</td>
<td>0.50</td>
<td>0.30</td>
</tr>
<tr>
<td>$k_p$</td>
<td>0.33</td>
<td>0.58</td>
<td>0.65</td>
<td>0.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\varepsilon_{33}/\varepsilon_0$</td>
<td>5</td>
<td>1700</td>
<td>1300</td>
<td>3400</td>
<td>175</td>
<td>6</td>
</tr>
<tr>
<td>$Q_M$</td>
<td>&gt;10⁵</td>
<td>500</td>
<td>65</td>
<td>900</td>
<td>3–10</td>
<td></td>
</tr>
<tr>
<td>$T_C$ (°C)</td>
<td>120</td>
<td>328</td>
<td>193</td>
<td>355</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

General Purpose Pressure Sensor

- Measurement Range: 200 psi (1379 kPa)
- Sensitivity: (±15%) 25 mV/psi (3.6 mV/kPa)
- Low Frequency Response: (-5%) 0.5 Hz
- Resonant Frequency: >=500 kHz (>=500 kHz)
- Electrical Connector: 10-32 Coaxial Jack
- Weight: 0.21 oz (6.0 gm)
Sensors

• Piezoelectric sensors are required for specific applications
  • turbulence, blast, ballistics, and engine combustion
  • (Not good for static pressure applications)

What is Piezoresistive Effect?

• Material: semi-conductors (mainly silicon)
• A stress changes the resistivity of the material

The Piezoresistive Effect: Change in the electrical resistivity of a semiconductor or metal when mechanical strain is applied.
Example

- Strain Gauge
  - Silicon
    - adding various elements -> Regions with more or less electrons
    - Changes resistivity in certain areas
  - N and P sections create sensing 'wires'

DMP333 High Range Precision Pressure Transmitter

(incorporates a silicon piezoresistive sensing element)

- pressure sensor designed for high pressure applications
- Temperature range: –40 to 125 degC
- Pressure range: 60 to 600 bar (870 psi to 8700 psi)

## Advantages

- Robust
- Calibration and performance doesn't change over time
- Simple construction
- Large output signal
- Integrated circuits for signal processing
- Stable over time

## Disadvantages

- Consume more power
- Requires constant temperature
- Junction leakage

## References

- [https://www.autodesk.com/products/eagle/blog/piezoelectricity/](https://www.autodesk.com/products/eagle/blog/piezoelectricity/)
- [https://www.pcb.com/resources/technical-information/introduction-to-pressure-sensors](https://www.pcb.com/resources/technical-information/introduction-to-pressure-sensors)
Questions