Other Types of MEMS Actuators

**Definition:** Actuator: A device that converts an electrical signal into a nonelectrical quantity.

1) Piezoelectric Actuators (review from earlier)
   - Applying a voltage across a piezoelectric crystal results in a small deformation proportional to the electric field strength and very small range of motion.

2) Thermal Actuators
   - Consider a MEMS electric heating element:

   ![Diagram](image)

   - Power in $R$: $P = I^2R$ → dissipated as heat → Joule heating
   - Electricity → Heat: an actuator

   a) Thermal Bimorph Actuator

   ![Diagram](image)
Let $\text{CTE}_2 > \text{CTE}_1$, $\text{CTE}$ = Coefficient of Thermal Expansion.

$\rightarrow$ heat the structure through the resistive heater

result:

\[ \text{it bends up} \]

$\rightarrow$ requires high power: $P > I^2$

\[ 6. \text{ Shape Memory Alloys (SMA)} \]

$\rightarrow$ a material that has a rigid state above a certain temperature ($T_c$) called Austenite phase, and a pliable state (Martensite phase) below $T_c$.

$\rightarrow$ Whatever the shape initially was in the Austenite phase, it will forcefully return to that shape when temperature rises above $T_c$.

Note: $T_c$ is the phase transition temperature.

Nitinol is commonly used MEMS SMA material

- up to a 5% strain
- $T_c$ tailorable between -100°C to +100°C

$\rightarrow$ One macro SMA application is for replacing explosive bolts

\[ 3. \text{ Magnetic Actuators} \]

$\rightarrow$ Fabricate movable MEMS structures with ferromagnetic materials such as Ni or Fe.

$\rightarrow$ Use an external magnetic field to actuate the device.
# A Comparison of MEMS Actuator Technologies

<table>
<thead>
<tr>
<th>Actuator:</th>
<th>Electrostatic</th>
<th>Piezoelectric</th>
<th>Shape Memory Alloy</th>
<th>Magnetic (External)</th>
<th>Thermal Bimorph</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power Requirements</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Fabrication</td>
<td>Easy</td>
<td>More Difficult</td>
<td>More Difficult</td>
<td>More Difficult</td>
<td>More Difficult</td>
</tr>
<tr>
<td>Speed</td>
<td>Fast</td>
<td>Fast</td>
<td>Slow to Fast</td>
<td>Slow</td>
<td></td>
</tr>
<tr>
<td>Bi-Directional Motion</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Maybe</td>
<td>Possibly</td>
</tr>
<tr>
<td>Ruggedness</td>
<td>Sensitive to Contamination</td>
<td>High</td>
<td>High</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Size</td>
<td>Small to Large</td>
<td>Small to Large</td>
<td>Small to Large</td>
<td>Large</td>
<td>Small to Large</td>
</tr>
<tr>
<td>Range of Motion</td>
<td>Large</td>
<td>Small</td>
<td>Small</td>
<td>Large</td>
<td>Large</td>
</tr>
</tbody>
</table>
Other types of MEMS actuators

1. Steam engines on a chip
2. Internal combustion engines on a chip
   ex: Wankel engine → show photo
3. Micro-fluidic MEMS
   → actuator or pump to move a liquid through micro-plumbing
   a. PCB-pump → show photo
   b. Flow FET
Fig. 7: Micropump in PCB technology

Lienhard Pagel, Univ. Rostock, Germany
4) **FlowFET** → a microfluidics actuator

**Working principle:**
Electro-osmotic flow in a channel

- Fluid flows through the channel.
- Opposite charge in fluid attracts to channel wall charge.

- Fluid motion

V → Voltage across 2 electrodes (V = 100V)
causes fluid to flow by attracting charged fluid particles.

Adding a 3rd electrode on the other wall allows the fluid flow to be controlled like current in a MOSFET.