SMART MATERIALS

- Materials which can think on their own & have
  - Mental alertness,
  - quick perception,
  - speedy activity,
  - effectiveness,
  - spirited liveliness
  - intelligence …
- Smart materials can respond to a change & are
  - able to receive information(sensing the problem)
  - able to analyze & decide(processing the information)
  - able to act on the decision(actuating the process)

- Three basic components of a smart system are
  - ♦SENSOR
  - ♦ PROCESSOR
  - ♦ ACTUATOR

- Example: Smart concrete building
  (suitable to earth quake areas)

  Sensor : optical fibers(embedded in concrete)

  Processor: smart wires(automatic shrink/expand)

  Actuator :chemically active smart materials
  (fillers preventing crack propagation)

SMART MATERIALS….!!!!

Smart materials are the materials that can significantly alter one or more of their inherent properties owing to the application of an external stimuli in a controlled fashion.

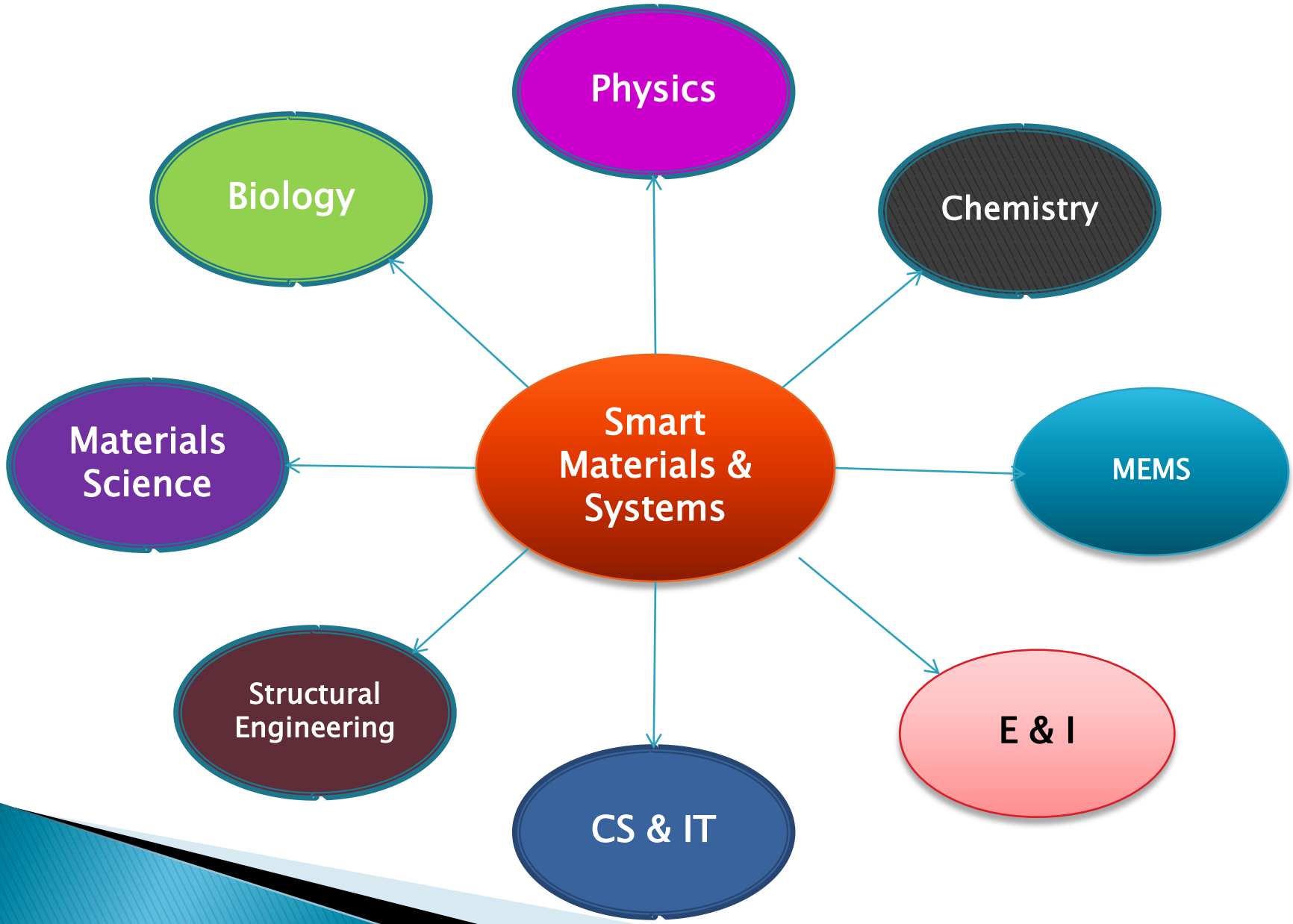
The several external stimulus to which the SMART Materials are sensitive are :

- ***Stress;***
- ***Temperature;***
- ***Moisture;***
- ***pH;***
- ***Electric Fields;***
- ***Magnetic Fields……***

CLASSIFICATION OF SMART MATERIALS

- Structural materials– (Stress–Strain Relation)
- Electrical materials – (R–T relation)
- Bio compatible materials– (Biomimics)
  (Recognition, analysis & growth characteristics)
- Intelligent biological materials – (Biomimics)
- Dynamically tunable materials – versatile

Inter disciplinary nature of smart materials



SPECIFIC TYPES OF SMART MATERIALS

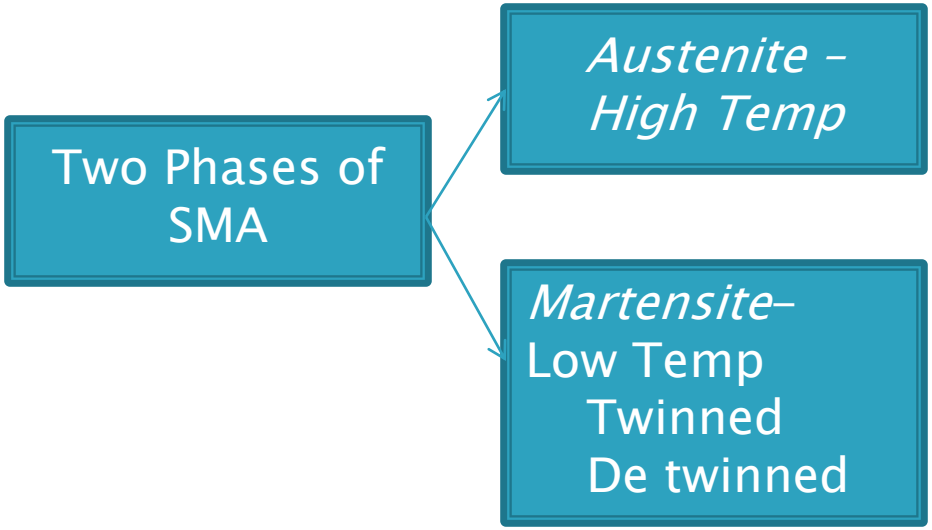
- Shape Memory Alloys
- Piezoelectric Materials
- Magnetostrictive Materials
- Magneto-Rheological Fluids
- Electro-Rheological Fluids

Shape memory alloys

- An alloy that “remembers” its original, cold-forged shape. By heating it returns back to the re-deformed shape.
- SMAs are materials which can revert back to original shape & size on cooling by undergoing phase transformations.
- Examples: NiTiNOL (thermal),
  NiMnGa, Fe-Pd, Terfenol-D (Magnetic)
  CuZnSi, CuZnAl, CuZnGa, CuZnSn (actuator)

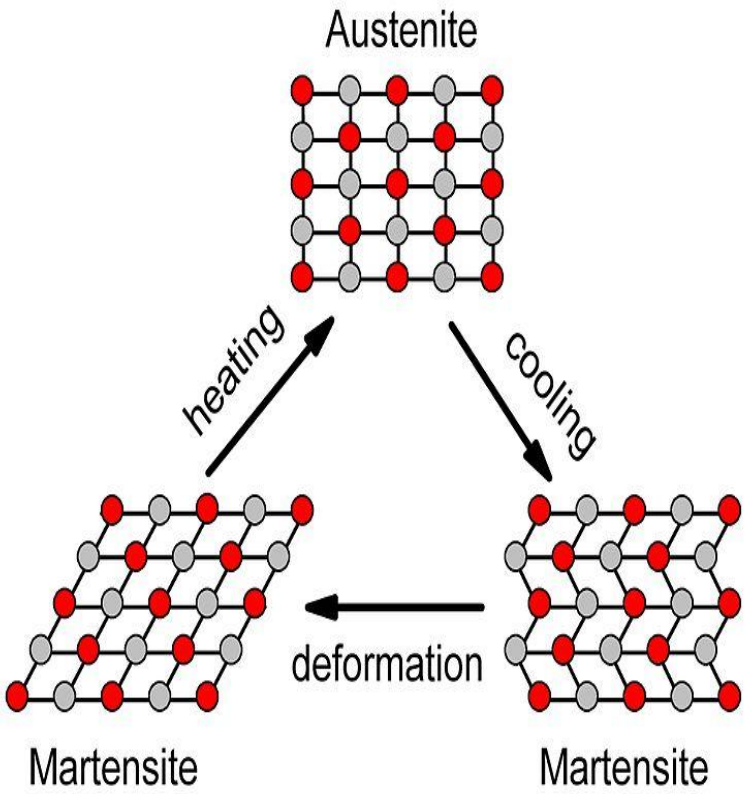
Shape Memory Alloys

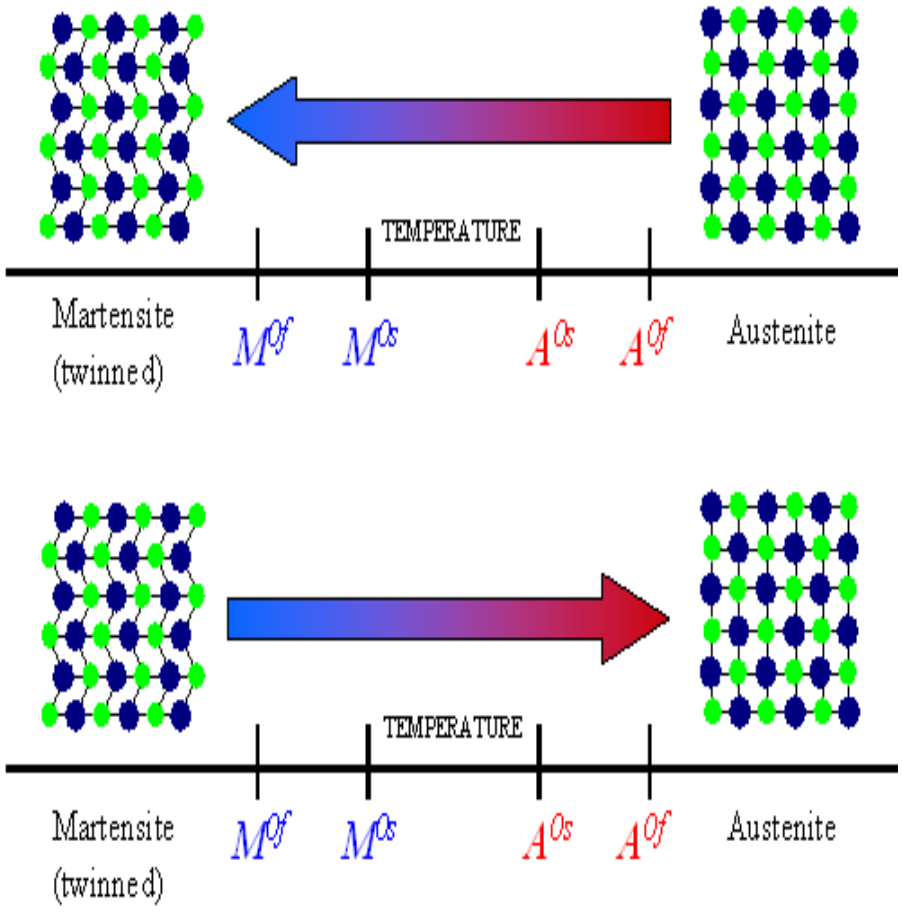
- Shape Memory Alloys (SMAs) are a unique class of metal alloys that can recover apparent permanent strains when they are heated above a certain temperature.



- A phase transformation which occurs between these two phases upon heating/cooling is the basis for the unique properties of the SMAs.

SHAPE MEMORY EFFECT

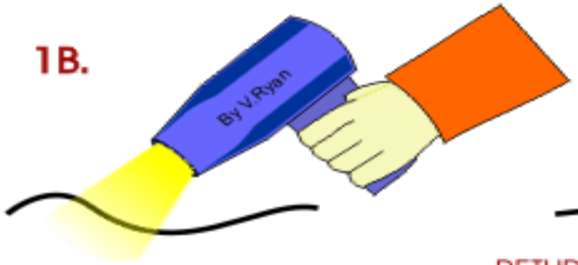




1A.

ORIGINAL WIRE SHAPE

1B.

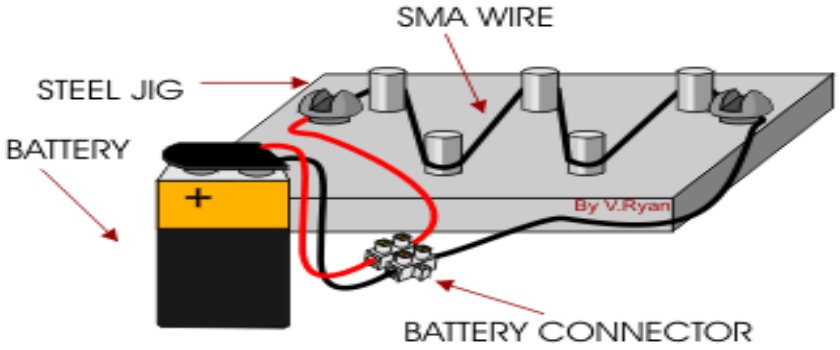


TWISTED SMA WIRE.
HEATED ABOVE 90 DEGREES

1C.

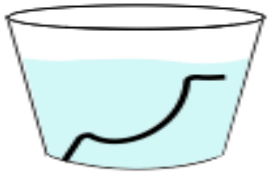
RETURNS TO ORIGINAL SHAPE

1. FOLD SMA WIRE ROUND STEEL JIG AND PASS CURRENT THROUGH IT

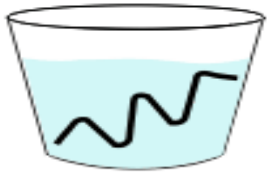


2. CHANGE SHAPE OF SMA WIRE

3. PLACE IN HOT WATER



4. SMA RETURNS TO PROGRAMMED SHAPE



SMA– NiTiNOL (SE508 Wire)

PHYSICAL PROPERTIES

Melting Point:	2390°F	1310°C
Density:	0.234 lb/in^3	6.5 g/cm^3
Electrical Resistivity:	32 µohm-in	82 µohm-cm
Modulus of Elasticity:	6-11 x 10^6 psi	41-75 x 10^3 MPa
Coefficient of Thermal Expansion:	6.1 x 10^{-6}/°F	11 x 10^{-6}/°C

MECHANICAL PROPERTIES

Ultimate Tensile Strength (UTS):	160-200 x 10^3 psi	1100-1150 MPa
Total Elongation (min):	10%	10%

SUPERELASTIC PROPERTIES

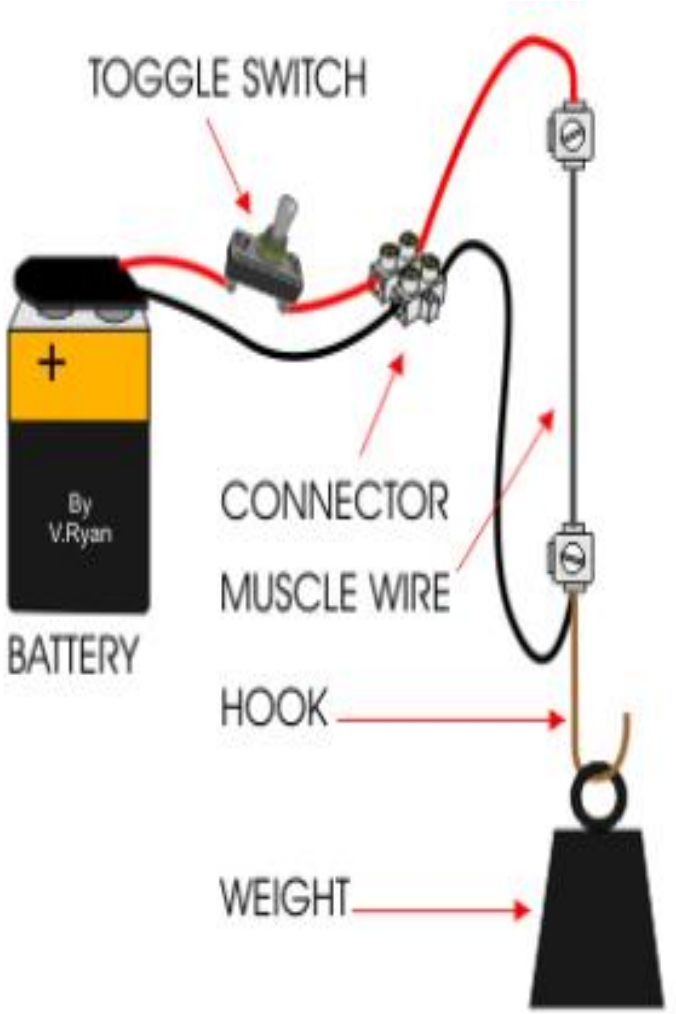
Loading Plateau Stress @ 3% strain (min):	65 x 10^3 psi	450 MPa
Permanent Set (after 6% strain) (max):	0.2%	0.2%
Transformation Temperature (A_f):	41 to 64° F	5 to 18° C

COMPOSITION (Meets ASTM F2063 requirements)

Nickel (nominal):	55.8 wt.%
Titanium:	Balance
Oxygen (max):	0.05 wt.%
Carbon (max):	0.02 wt.%

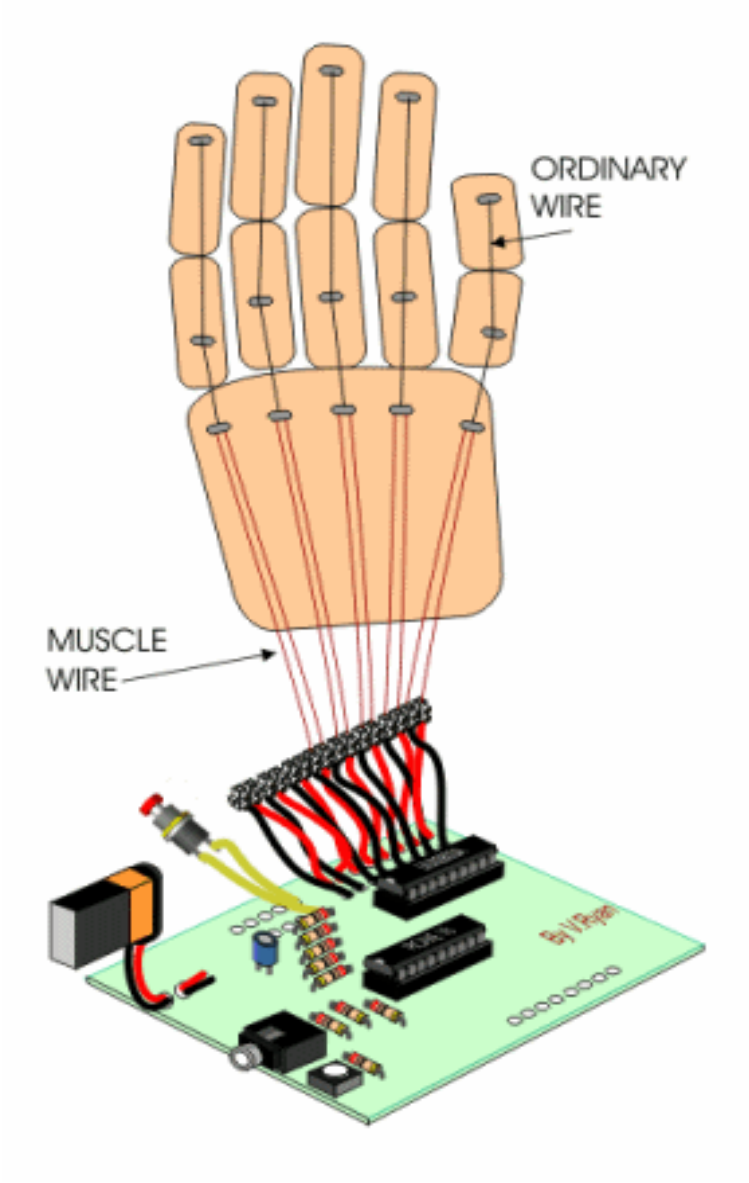
SMA in ROBOTICS– Muscle wire

- Muscle wire is NiTi alloy which can be stretched up to 8 % of its length and still recover. (at room temp 3 to 5 % stretch is possible)
- When a small current is passed through the wire it becomes much harder and returns to its original length with a reasonable force.
- A battery and switch are connected to muscle wire & a small weight stretches the muscle wire.
- The cycle of turning on and off the current has the effect of lifting and lowering of the weight.



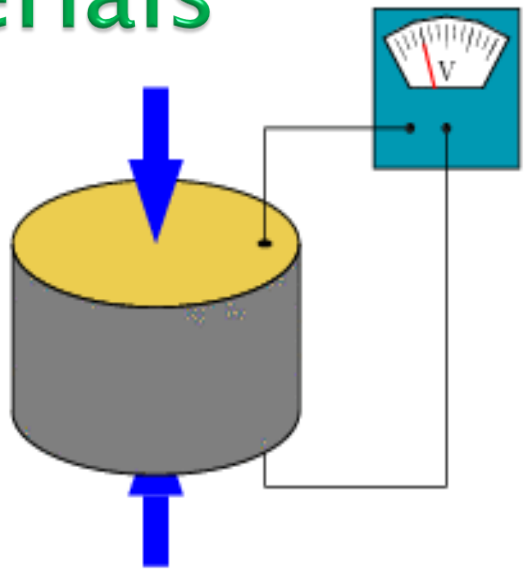
SMA in ROBOTICS– Robotic hand

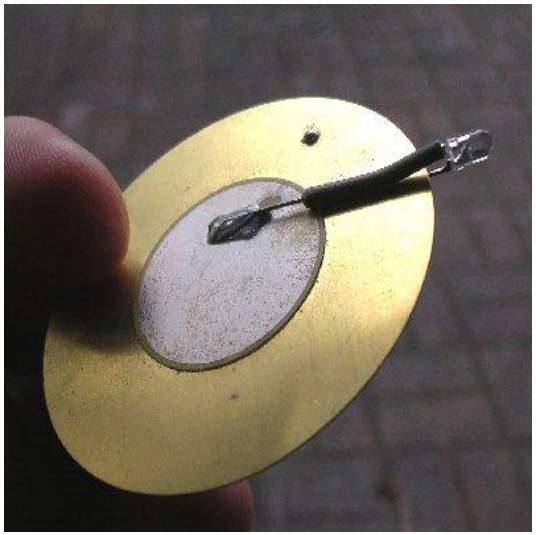
- A clever **use of muscle wire** and a micro-controller circuit is a **robotic hand**.
- A robotic hand has ‘stretched muscle wires’ attached to the base of each finger
- When current is applied to the muscle wire it contracts to its ‘natural’ length by pulling on the ordinary wire.
- The micro-controller is programmed to give five of the outputs with switch on and off options.
- This makes the fingers of the hand move.



Piezoelectric Materials

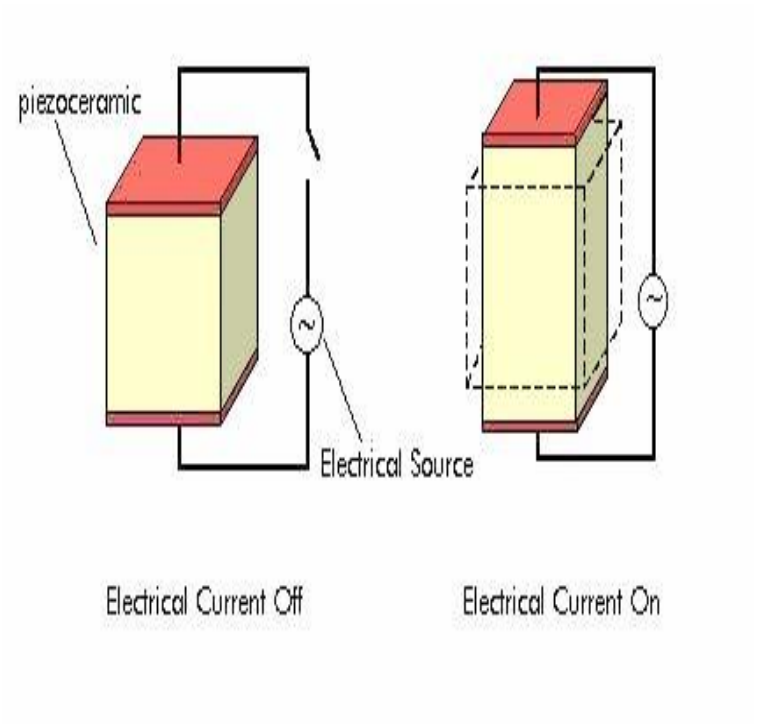
- Materials that produce a voltage when stress is applied.(An applied mechanical stress will generate a voltage)
- Example:Quartz,$BaTiO_3$,$GaPO_4$
- The piezoelectric effect describes the relation between a mechanical stress and an electrical voltage in solids.
- In physics, the piezoelectric effect can be described as the the link between electrostatics and mechanics.
- An LED is wired to a piezoelectric transducer. The LED briefly lights when the device is flicked & shows that electricity has been generated by stress and strain.





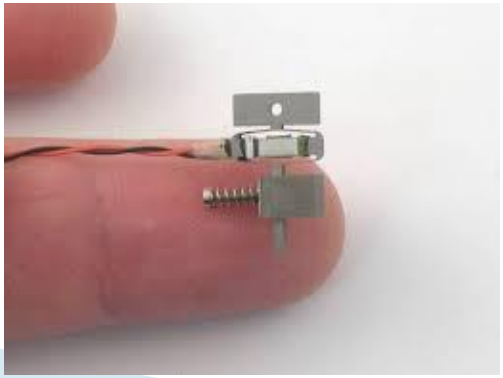
Reverse Piezo electric effect

- An applied voltage will change the shape of the solid by a small amount (up to a 4% change in volume).
- Quartz watches, Piezo electric US oscillator



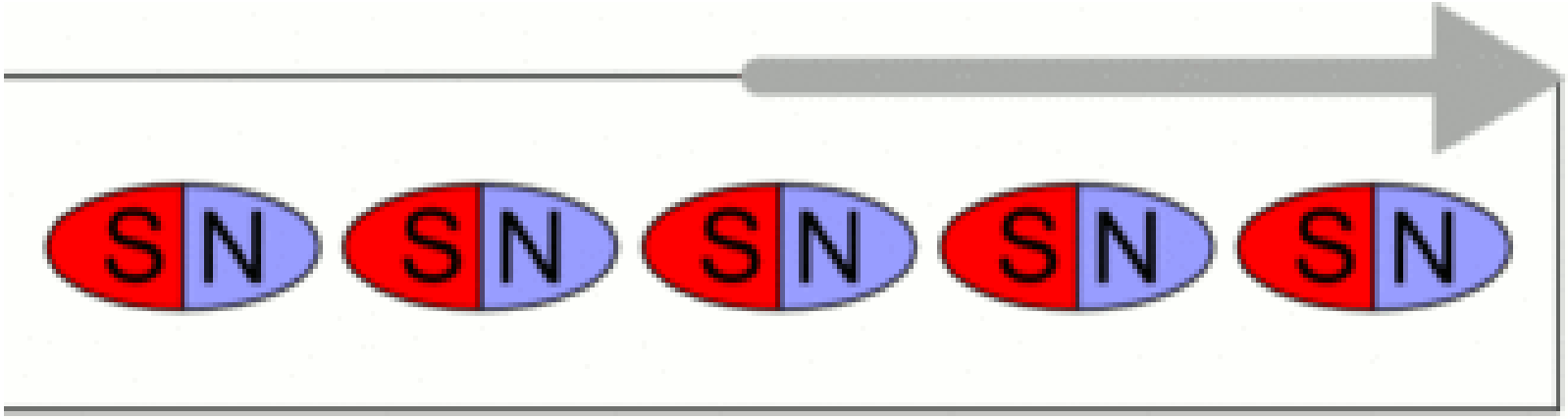
Applications of piezo electric effect

- In lighters or portable sparkers with a piezo fuze a sudden and strong pressure is used to produce a voltage. The spark then ignites the gas.
- A piezo motor is based on the change in mechanical shape of a piezoelectric material when an tension is applied. The material produces ultrasonic or acoustic vibrations and produces a linear or rotary motion.
- Piezo elements are used in music for acoustic instruments. They are inserted in stringed instruments such as guitar, violin or Mandoline. The dynamic deformation/vibration of the cords is converted into a small alternating voltage.



Magnetostrictive Materials

- Magneto striction is a property of ferro magnetic materials that causes them to change their shape or dimensions during the process of magnetization.
- The effect was first identified in 1842 by James Joule when observing a sample of iron.
- Ex: Fe, Co, Terfenol – D (US transducers, sonar, sound bug



Magnetostrictive Materials–Applications

- **Actuators and Sensors**

  Magnetostrictive transducers – Convert magnetic energy in to mechanical energy

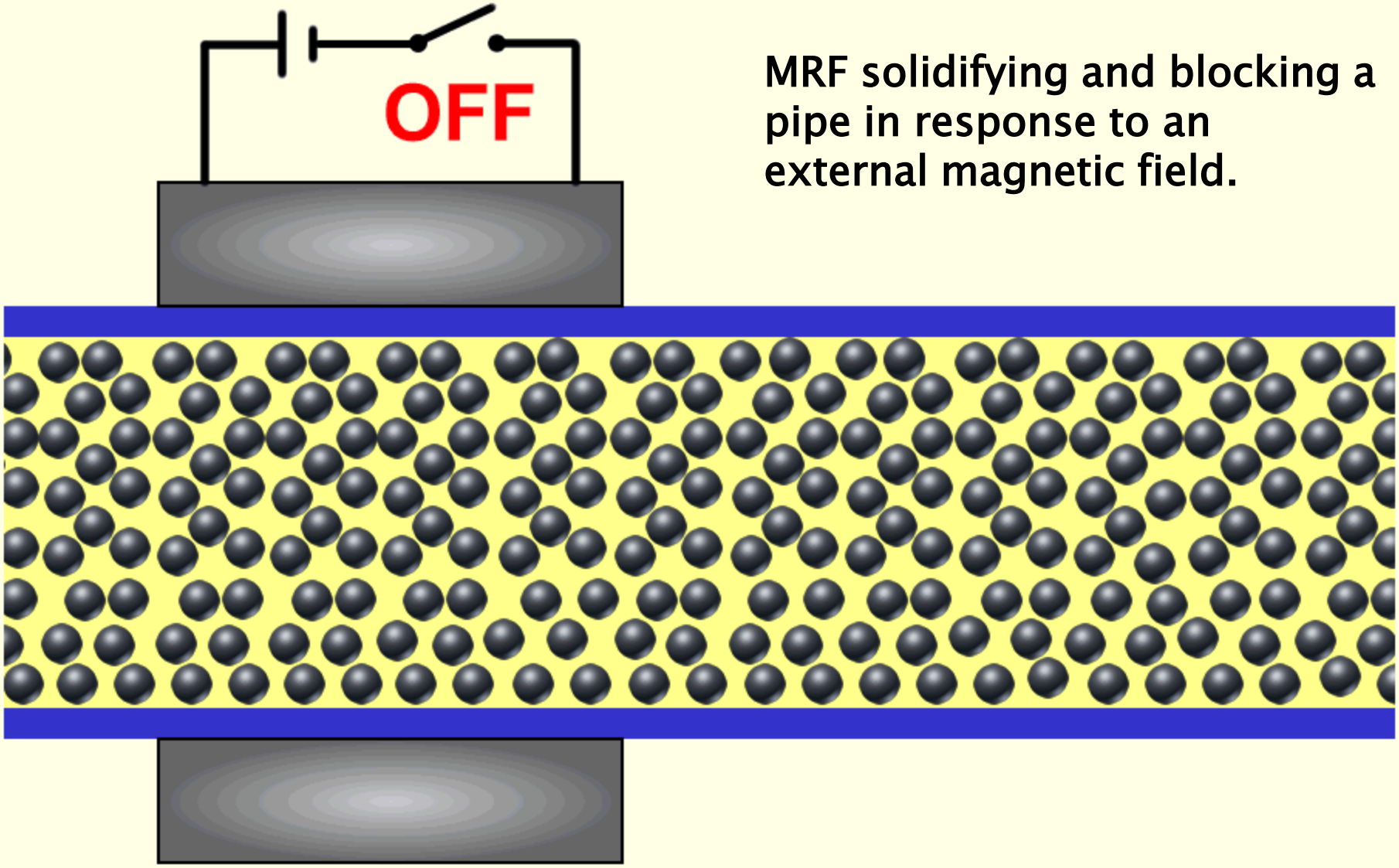
- **Vibration Speaker Technology**

  using the highest power Smart Material . Install in seconds – peel and stick – no screws or mounting issues

  High quality sound without design compromise. No wires, no boxes, no grilles.

Magneto-Rheological Fluids (MRFs)

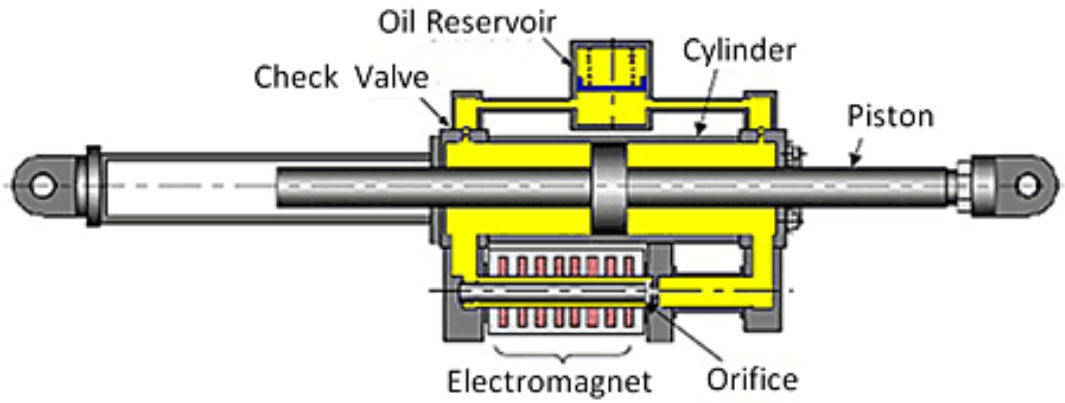
- A MR fluid is a smart fluid which usually consists of 20-40 percent iron particles, suspended in mineral oil, synthetic oil, water or glycol.
- MRF also contains a substance which prevents the iron particles from setting.
- When subjected to a magnetic field, the magnetic particles inside increase the fluid's viscosity, rendering it viscoelastic solid.



MRF solidifying and blocking a pipe in response to an external magnetic field.

"OFF" position – the MR fluid is not magnetized & the particles inside, distributed randomly, allow the fluid to move freely, acting like a damper fluid.
"ON" position – the particles become energized and align into fibrous structures and restricts the movement of the fluid

MRF – Applications



Applications of Smart Materials

- Smart switches & actuators(NiTi –long life)
- Safety device, fuse, alarms (CuZnAl –reliability)
- Artificial limbs, blood vessels & muscles (SM Polyurethane –bio compatibility)
- Adhesive tapes/bands (time bound adhesive property /painless removal/healing property)
- Food packaging industry–wrappers(adoptability)
- Smart spoons (Temperature sensitive polymers)
- Smart nose & tongue (recognition characteristics)
- Smart clothes (Adaptive to temperature changes)

Applications of Smart Materials

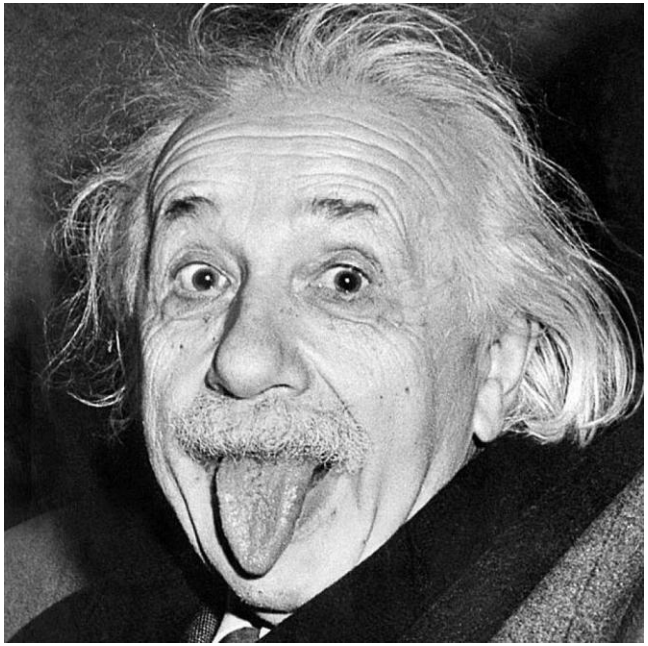
- An “animated lamp” designed by Romolo Stanco that uses shape-memory alloy to change its shape whenever it’s turned on and off.
- NiTi NOL wire- diameter in mm

Applications of Smart Materials

- Aircraft which will incorporate "smart materials" that will allow the wings of a craft to change shape for optimal flying conditions.
- "Stealth Bombers" have ferro fluids on their outer "skin" to make them harder to spot with radar.

Smart sensors – Smart Spoons

Smart sensors – Smart Tongue & Nose



THANK YOU