

## **INTRODUCTION TO SHAPE MEMORY ALLOYS**

Shape Memory Alloys (SMA's) are novel materials which have the ability to return to a predetermined shape when heated. When an SMA is cold, or below its transformation temperature, it has a very low yield strength and can be deformed quite easily into any new shape--which it will retain. However, when the material is heated above its transformation temperature it undergoes a change in crystal structure which causes it to return to its original shape. If the SMA encounters any resistance during this transformation, it can generate extremely large forces. This phenomenon provides a unique mechanism for remote actuation.

The most common shape memory material is an alloy of nickel and titanium called Nitinol. This particular alloy has very good electrical and mechanical properties, long fatigue life, and high corrosion resistance. As an actuator, it is capable of up to 5% strain recovery and 50,000 psi restoration stress with many cycles. By example, a Nitinol wire 0.020 inches in diameter can lift as much as 16 pounds. Nitinol also has the resistance properties which enable it to be actuated electrically by joule heating. When an electric current is passed directly through the wire, it can generate enough heat to cause the phase transformation. In most cases, the transition temperature of the SMA is chosen such that room temperature is well below the transformation point of the material. Only with the intentional addition of heat can the SMA exhibit actuation. In essence, Nitinol is an actuator, sensor, and heater all in one material.

Shape memory alloys, however, are not for all applications. One must take into account the forces, displacements, temperature conditions, and cycle rates required of a particular actuator. The advantages of Nitinol become more pronounced as the size of the application decreases. Large mechanisms may find solenoids, motors, and electromagnets more appropriate. But in applications where such actuators can not be used, shape memory alloys provide an excellent alternative. There are few actuating mechanisms which produce more useful work per unit volume than Nitinol.

Nitinol is available in the form of wire, rod and bar stock, and thin film. Examples of SMA products developed by TiNi Alloy Company include silicon micro-machined gas flow microvalves, non-explosive release devices, tactile feedback device (skin stimulators), and aerospace latching mechanisms. If you are considering an application for shape memory alloys, TiNi Alloy Company can assist you in the design, prototyping, and manufacture of actuators and devices.

## Physical Properties of Nitinol

- Density: 6.45gms/cc
- Melting Temperature: 1240-1310° C
- Resistivity (hi-temp state): 82 uohm-cm
- Resistivity (lo-temp state): 76 uohm-cm
- Thermal Conductivity: 0.1 W/cm-° C
- Heat Capacity: 0.077 cal/gm-° C
- Latent Heat: 5.78 cal/gm; 24.2 J/gm
- Magnetic Susceptibility (hi-temp): 3.8 uemu/gm
- Magnetic Susceptibility (lo-temp): 2.5 uemu/gm

## Mechanical Properties of Nitinol

- Ultimate Tensile Strength: 754 - 960 MPa or 110 - 140 ksi
- Typical Elongation to Fracture: 15.5 percent
- Typical Yield Strength (hi-temp): 560 MPa, 80 ksi
- Typical Yield Strength (lo-temp): 100 MPa, 15 ksi
- Approximate Elastic Modulus (hi-tem): 75 GPa, 11 Mpsi
- Approximate Elastic Modulus (lo-temp): 28 GPa, 4 Mpsi
- Approximate Poisson's Ratio: 0.3

## Actuation

- Energy Conversion Efficiency: 5%
- Work Output: ~1 Joule/gram
- Available Transformation Temperatures: -100 to +100° C

## Stress-Strain Characteristics of Nitinol at Various Temperatures

