Shape Memory Alloy Research and Development at NASA Glenn
Current and Future Progress

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Shape Memory Alloys: An Introduction

- Alloys that have a “memory.” These materials have the ability to remember and recover their original shapes with load or temperature.
- SMAs exhibit a solid-to-solid, reversible phase transformation

**How?**

1. Bain strain $\rightarrow$ (lattice deformation)
2. Lattice invariant shear $\rightarrow$ (accommodation)
Shape Memory Alloys: An Introduction

- SMA actuators can generate motion in one dimension (wire form), two dimensions (bending of a bar) or even motion in a more complex three dimensions (springs, honeycombs).

- Functionality: Tension (e.g., wires, springs), compression (e.g., rods, springs), bending (e.g., beams, plates), torsion (e.g., rods, tubes, and springs).
Research and Understanding of Shape Memory Alloys

1. Applied Research
2. Alloy Processing & Development
3. Testing and Modeling
4. Applications

ATOMIC SCALE
(NANOMATERIALS)

MICRO-SCALE
(MICROSTRUCTURES)

STRUCTURAL SCALE
(COMCOMPONENTS)

Å 10^{-10}

nm 10^{-9}

µm 10^{-7}

mm 10^{-6}

10^{-5}

10^{-4}

10^{-3}

10^{-2}

10^{-1}

10^{0}

m

10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0}

Å nm µm mm

10^{-7} 10^{-6}

10^{-5} 10^{-4}

10^{-3} 10^{-2}

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NiTiHf Alloys
Dynalloy
Commercial NiTi Alloys
New Alloys Being Used for Demonstrations
Recent alloys look promising for further gains
Development of Shape Memory Alloys: 
**NiTi –Based HTSMAs**

![Graph showing NiTiHf strain vs. temperature](image)

- Temperature (°C)
- Strain (%)
Processing and Workability of HTSMAs

NiTiPt

Induction Melt + Homogenization

Extrusion

Wire Grinding

44 & 5 mil NiTiPt

Wire Drawing

5 mil NiTiPt wire

Multiple-Pass Extrusion

60 mil NiTi-20Pt rod
Processing and Workability of HTSMAs

NiTiHf

High temperature extrusion proved to be problematic (C. Wojcik 2008)

Successful hot rolled button (C. Wojcik 2008)

Successful hot extrusion (rods and tubes)
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Thermomechanical Testing

Uniaxial (tension/compression)

- Isothermal monotonic
- Isothermal cyclic
- Isobaric cyclic
- Isostrain cyclic

Multiaxial

- Proportional/non-proportional loading
- 3D strain measurement
- Torque/force/twist/displacement control capability

Geometries

Torsion

Durability

- New frames for durability testing are underway
- Durability analysis of sample and components
- Generate data for existing materials

Hot grip testing
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SMA Existing and Potential Applications

Automotive

Aerospace

Robotics

Biomedical

Space

Home goods

Energy harvesting

Toys

Source: J. Mohd Jani et al. / Materials and Design 56 (2014) 1078–1113
Shape Memory Alloy Applications

**Space**

**SMA Bellows**
- Dynamic sealing
- Fluid handling
- Flexibility (structure alignment)

**SMA Spring Tire**
- Superelastic technology
- Lunar rovers
- Terrestrial tires

**SMA Docking Coupling**
- Cryogenic transfer coupling
- Orbital propellant depots
- Propellant handling/protection

**SMA Thermal Switch**
- Thermal management
- Clean & spark-free operation
- Passive or active control

**SMA Bearings**
- Corrosion resistant
- Non-galling properties
- High yield
Shape Memory Alloy Applications

Aeronautics

Adaptive Fan Blade
- Embedded SMA actuators
- Aerodynamic efficiency
- Specific fuel consumption reduction

SMA Cellular Structures
- Airframe and engine components
- Morphing airfoils
- Lightweight trusses

The Mars Atmosphere and Volatile Evolution (MAVEN) mission.
- SMA Pinpullers (From TiNi Aerospace) were used to secure and release deployables

Variable Area Nozzle
- High bypass turbofan
- SMA torque tubes provide flap rotation
- Engine noise reduction
Shape Memory Alloy Applications
Non-Aerospace Potential

Oil and Gas Industry
- SmartRAM™ actuators (LMP)
- SMA couplings (Aerofit Inc)
- Deep-water valves/shut off valves
- Self-torquing fasteners

Medical Industry
- Surgical tools
- Stents and implants
- Glasses frames

Other Applications
- Home appliances
- Electronics
- Transportation
- Air conditioners

Automotive Industry
- Louvers
- Quiet actuators
- Door handle
Development of Shape Memory Alloys: Challenges

High transformation temperatures
- Above 100 °C
- Good work output
- Thermal stability

Durability
- Loading history
- Functional fatigue
- Structural fatigue

Workability/Processing
- Ductility
- Composition control
- Heat treatment
- Large scale

Design Tools
- Testing standards
- Design handbooks
- Database

Modeling
- Micromechanics
- Phenomenological
- Evolutions/transients

Dimensional stability
- Cyclic stability
- Stress-strain relationship

Challenges in:
- Microstructures
- Micromechanics
- Design
- Applications
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