Manufacturing & Prototyping

Thermo-Mechanical Methodology for Stabilizing Shape Memory Alloy Response

This innovation is directly applicable to actuator applications employing shape memory alloys.

John H. Glenn Research Center, Cleveland, Ohio

This innovation is capable of significantly reducing the amount of time required to stabilize the strain-temperature response of a shape memory alloy (SMA). Unlike traditional stabilization processes that take days to weeks to achieve stabilized response, this innovation accomplishes stabilization in a matter of minutes, thus making it highly useful for the successful and practical implementation of SMA-based technologies in real-world applications. The innovation can also be applied to complex geometry components, not just simple geometries like wires or rods.

SMAs are being developed for use as actuators, switches, and other devices in aerospace, automotive, and many other industries. An important aspect of developing a useful SMA technology is the ability to achieve a stabilized material response. Most SMAs exhibit dimensional instability when thermally cycled in the presence of applied stress. In order to mitigate the need for the design to deal with such issues, "training" or stabilization of the materials response must be achieved prior to utilizing the material under service conditions.

The process of stabilizing an SMA for actuator response is generally thought of as a stabilization of the strain during thermal cycling under conditions of fixed stress (the so-called isobaric response). Although this formulation is entirely appropriate, the underlying reason for the strain stabilization is governed by the internal states that the combination of stress and temperature produce (in this case, one of the drivers being transient and one being fixed). Hence, any combination of stress and temperature that would produce the same strain state could also stabilize the material for the intended service condition. In general, thermal cycling under fixed stress is commonly used to achieve stabilized behavior, but this process is not only time-consuming but costly.

The current innovation replaces this process with an alternate method utilizing mechanical cycles under conditions of fixed temperature (the so-called isothermal response), since mechanical cycling takes far less time than thermal cycling. The current innovation describes a process for determining this link, followed by achieving stabilization by a rapid and efficient mechanical cycling treatment. To begin, the stabilization point for the material (the absolute strain levels achieved after stabilization) is established by performing an isobaric experiment under conditions identical to those that will be used during service. Once known, a set of isothermal mechanical cycling experiments is performed using different levels of applied stress. Each of these mechanical cycling experiments is left to run until the strain response has stabilized. Once the stress levels required to achieve stabilization under isothermal conditions are known, they can be utilized to train the material in a fraction of the time that would be required to train the material isobarically. Once the strain state is achieved isothermally, the material can be switched back under isobaric conditions, and will remain stabilized for the service conditions.

The advantage of approaching the problem via this technique is that it is now possible to reduce the amount of time required to achieve a stabilized material response from days to weeks, down to a matter of minutes. The significant reduction in time translates into a more cost-effective solution for SMA-based technologies that in turn improves the viability of SMA device utilization.

This work was done by Santo Padula of Glenn Research Center. Further information is contained in a TSP (see page 1).

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Innovative Partnerships Office, Attn: Steven Fedor, Mail Stop 4–8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-18594-1.

Hermetic Seal Designs for Sample Return Sample Tubes

Prototype sample tube seals prevent material loss and maintain sample integrity.

NASA's Jet Propulsion Laboratory, Pasadena, California

Prototypes have been developed of potential hermetic sample sealing techniques for encapsulating samples in a ≈1-cm-diameter thin-walled sample tube that are compatible with IMSAH (Integrated Mars Sample Acquisition and Handling) architecture. Techniques include a heat-activated, finned, shape memory alloy plug; a contracting shape memory alloy activated cap; an expanding shape memory alloy plug; and an expanding torque plug.

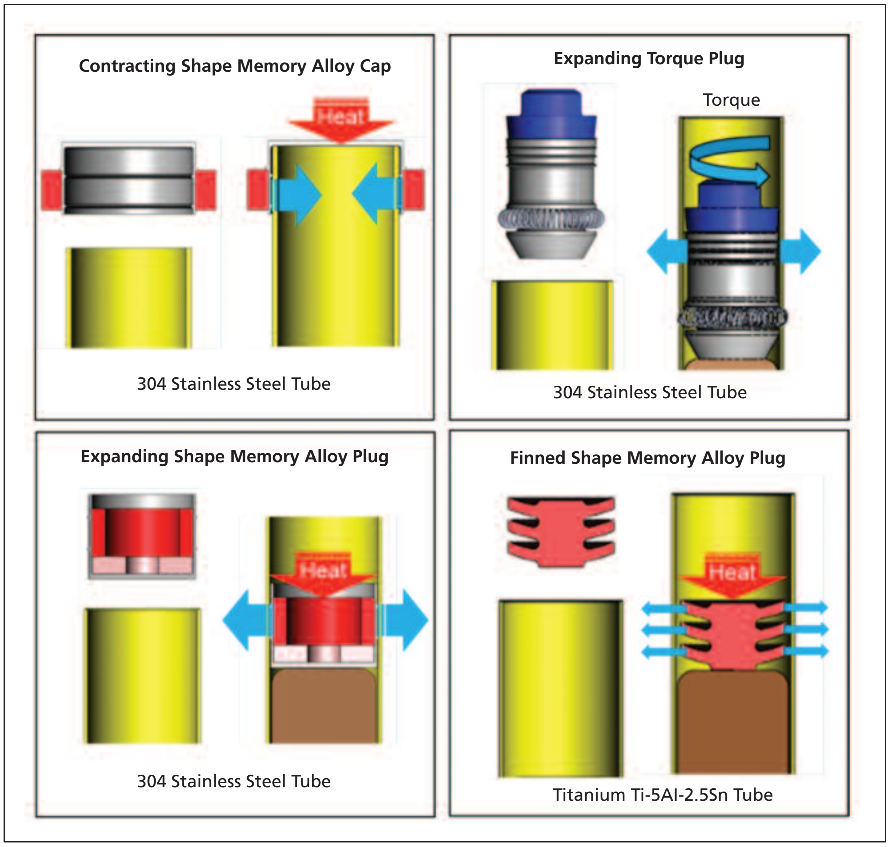
Initial helium leak testing of the shape memory alloy cap and finned shape memory alloy plug seals showed hermetic-seal capability compared against an industry standard of $<1\times10^{-8}$ atm-cc/s He. These tests were run on both clean tubes and dirty tubes dipped in MMS (Mojave Mars Simulant). The leak tests were also performed after thermal cycling between –135 and +55 ºC to ensure seal integrity after Martian diurnal cycles. Developmental testing is currently being done on the expanding torque plug, and expanding shape memory alloy plug seal designs.

The finned shape memory alloy (SMA) plug currently shows hermetic sealing capability based on preliminary tests. The finned SMA plug sealing technique requires a heater to actuate the plug. Materials have been selected to comply with current sample compatibility, contamination control, and planetary protection concerns. Various Nitinol SMA chemistries are currently being investigated that allow the seal to start activating at temperatures as low as 45 °C (if low-temperature sealing is required for sample integrity), and as high as 135 °C (if planetary protection dry heat microbial reduction is required).

The contracting shape memory alloy cap requires a heater to actuate an SMA ring that swages the toothed cap onto the outside of the tube. The expanding SMA plug also requires a heater to actuate a ring that swages the toothed cap into the inside of the tube.

The benefit to the expanding torque plug is that no heat is required to create a seal. All that is needed is a rotating actuator to actuate the plug.

This work was done by Paulo J. Younse of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1). NPO-48927



Potential hermetic **Sample Sealing Techniques** include a contracting shape memory alloy cap, expanding torque plug, expanding shape memory alloy plug, and a finned shape memory alloy plug.

Silicon Alignment Pins: An Easy Way To Realize a Wafer-to-Wafer Alignment

Etched pockets and silicon pins are used to align two wafers together.

NASA's Jet Propulsion Laboratory, Pasadena, California

Submillimeter heterodyne instruments play a critical role in addressing fundamental questions regarding the evolution of galaxies as well as being a crucial tool in planetary science. To make these instruments compatible with small platforms, especially for the study of the outer planets, or to enable the development of multi-pixel arrays, it is essential to reduce the mass, power, and volume of the existing single-pixel heterodyne receivers.

Silicon micromachining technology is naturally suited for making these submillimeter and terahertz components, where precision and accuracy are essential. Waveguide and channel cavities are etched in a silicon bulk material using deep reactive ion etching (DRIE) techniques. Power amplifiers, multiplier and mixer chips are then integrated and the silicon pieces are stacked together to form a supercompact receiver front end. By using silicon micromachined packages for these components, instrument mass can be reduced and higher levels of integration can be achieved.

A method is needed to assemble accurately these silicon pieces together, and a technique was developed here using etched pockets and silicon pins to align two wafers together. Each silicon piece is patterned with the pockets on both sides of the wafer, front and back, which are then etched down to ≈130 μm.

Meanwhile, the silicon pins are etched in a 200-μm thick wafer. By etching a C-shaped pin, the pin can be compressed to fit into the alignment pocket by an appropriate choice of the pin wall thickness. When released, the pin expands to fill the pocket. A tight fit is ensured by choosing the relaxed pin diameter to be greater than the pocket diameter. This approach reduces the misalignment tolerance to the positional variation between the photolithographically defined pockets, which is typically under 3 μm.

During assembly, the silicon compression pins are placed on the etched pockets of the first wafer, and the wafer to be aligned will find the right location using its own "back" etched pockets. The two wafers are therefore quickly and easily aligned. If more wafers need to be stacked, one can place additional layers, each time using the pins and the etched pockets as alignment features.

Using this method, one can align several wafers, if needed, by only han-