DSC Characterization of Shape Memory Metal Alloys

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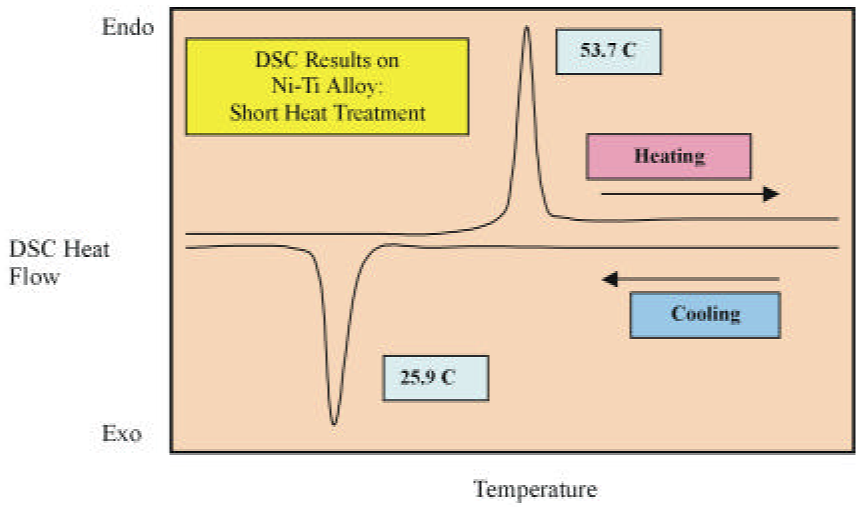
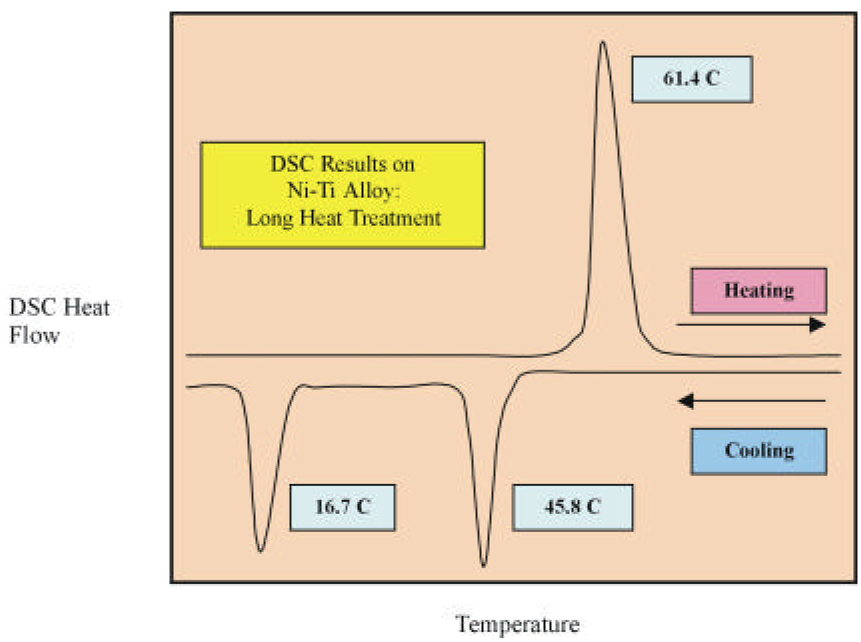
Shape memory alloys exhibit an unusual characteristic of yielding changes in their shape at a certain temperature range. This property has brought about commercialization of these alloys for certain applications, such as high performance hydraulic pipe joints, frames for eyeglasses, and household appliances. Of the most common shape memory alloys is a nickel – titanium (Ni-Ti) system that has high durability and reliability.

The shape memory alloy can be set into a certain configuration or geometry when a large load exceeding the alloy's elastic limit is applied. This inelastic deformation cannot be removed or reversed even when the load is removed from the alloy. This produces a permanent set state or configuration into the alloy. By processing the alloys at certain temperatures and loads, the desired configurations or shapes can be set or locked into the alloy. Even if the alloy is then deformed at lower temperatures, the original set or memorized configuration can be regenerated when the alloy is heated. This is termed the 'shape memory effect' or SME.

For the Ni-Ti shape memory alloys, the SME properties are based upon the thermoelastic martensite transformation observed during cooling and the reverse transformation measured during heating. Differential scanning calorimetry (DSC) provides an ideal means of characterizing the cooling and heating transformations associated with the shape memory alloys such as the Ni-Ti system.

The PerkinElmer Pyris 1 DSC is an excellent instrument for analyzing the





thermal properties of shape memory alloys based on its outstanding performance characteristics.

- high sensitivity for the detection of weak transitions
- outstanding resolution for better separation of overlapping transitions, which can be obtained for certain alloys
- platinum resistance thermometer (PRT) for the best accuracy and reproducibility of sample temperature measurements
- ability to heat and cool quickly (up to 500 C/min)
- well defined, symmetrical peaks due to short time constant associated with power compensated design of the Pyris 1 DSC
- easy to use Pyris for Windows software™

The resolution provided by the Pyris 1 DSC is outstanding such that even at a fast heating rate of 40 C/min, the resolution is equivalent to other heat flux designed DSC instruments operating at the slower rate of 20 C/min. The ability of the Pyris 1 DSC to resolve or separate the overlapping transitions can be important for the Ni-Ti shape memory alloys which frequently exhibit closely occurring transformations during cooling or heating, or both.

Displayed in the following figure are the DSC results obtained on a Ni-Ti alloy processed at 400 C for a period of 10 minutes. The data is presented for the cooling and the subsequent heating segments for this particular alloy.

If the Ni-Ti alloy is now processed with extensive heat treatment at 400 C, its physical properties will change significantly. Displayed in the following figure are the DSC results obtained when the alloy is held at 400 C for 17 hours and then cooled and heated.

After the prolonged heat treatment at 400 C, the Ni-Ti alloy yields two exothermic peaks during cooling as compared to the single peak obtained during the shorter heat treatment. When the alloy is heated, a single, intense endothermic peak is observed at 61.4 C.

Summary

Differential scanning calorimetry (DSC) yields valuable characterization information on shape memory alloy systems, such as Ni-Ti. The transformations occurring during cooling and heating are readily observed using DSC. The PerkinElmer Pyris 1 DSC is ideally suited for the analysis of these alloys given its outstanding resolution and its ability to resolve or separate closely occurring transitions.

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