Designation: F2005 – 05 (Reapproved 2015)

Standard Terminology for Nickel-Titanium Shape Memory Alloys[1]

This standard is issued under the fixed designation F2005; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This terminology is a compilation of definitions of terms used in ASTM documents relating to nickel-titanium shape memory alloys used for medical devices. This terminology includes only those terms for which ASTM either has standards or which are used in ASTM standards for nickel-titanium shape memory alloys. It is not intended to be an all-inclusive list of terms related to shape memory alloys.

1.2 Definitions that are similar to those published by another standards body are identified with abbreviations of the name of that organization; for example, ICTAC is the International Confederation for Thermal Analysis and Calorimetry.

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E7 Terminology Relating to Metallography

E473 Terminology Relating to Thermal Analysis and Rheology

F2004 Test Method for Transformation Temperature of Nickel-Titanium Alloys by Thermal Analysis

F2082 Test Method for Determination of Transformation Temperature of Nickel-Titanium Shape Memory Alloys by Bend and Free Recovery (Withdrawn 2015)[3]

3. Terminology

active austenite finish temperature, *n*—term used to denote austenite finish temperature of a finished wire, tube, or component as determined by a bend and free recovery method rather than by DSC.

alloy phase, *n*—*in a shape memory alloy*, the crystal structure stable at a particular temperature and stress.

anneal, *v*—to heat treat in order to remove the effect of cold-working.

austenite, *n*—the high temperature parent phase in Ni-Ti shape memory alloys with a B2 crystal structure. This phase transforms to R-phase or martensite on cooling.

austenite finish temperature (A_f), *n*—the temperature at which the martensite to austenite transformation is completed on heating in a single-stage transformation (Fig. 1) or the temperature at which the R-phase to austenite transformation is completed on heating in a two-stage transformation (Fig. 2).

austenite peak temperature (A_p), *n*—the temperature of the endothermic peak position on the differential scanning calorimeter (DSC) curve upon heating for the martensite to austenite transformation in a single-stage transformation (Fig. 1) or the temperature of the endothermic peak position on the DSC curve upon heating for the R-phase to austenite transformation in a two-stage transformation (Fig. 2).

austenite start temperature (A_s), *n*—the temperature at which the martensite to austenite transformation begins on heating in a single-stage transformation (Fig. 1) or the temperature at which the R-phase to austenite transformation begins on heating in a two-stage transformation (Fig. 2).

bend and free recovery (BFR), *n*—a test method for determining austenite transformation temperatures on heating.

DISCUSSION—The test involves cooling a wire or tube specimen below the M_f temperature, deforming the specimen in a controlled fashion, then heating through the austenite transformation. By measuring the shape memory response of the specimen A_s and A_f, temperatures can be determined. This test method is covered in Test Method F2082.

differential scanning calorimeter (DSC), *n*—a device that is capable of heating a test specimen and a reference at a controlled rate and of automatically measuring the difference in heat flow between the specimen and the reference both to the required sensitivity and precision.

differential scanning calorimetry (DSC), *n*—a technique in which the difference in heat flow into or out of a substance and an inert reference is measured as a function of temperature while the substance and the reference material are subjected to a controlled temperature program. This test

[1] This terminology is under the jurisdiction of ASTM Committee F04 on Medical and Surgical Materials and Devices and is the direct responsibility of Subcommittee F04.12 on Metallurgical Materials.

Current edition approved March 1, 2015. Published May 2015. Originally approved in 2000. Last previous edition approved in 2010 as F2005 – 05 (2010). DOI: 10.1520/F2005-05R15.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

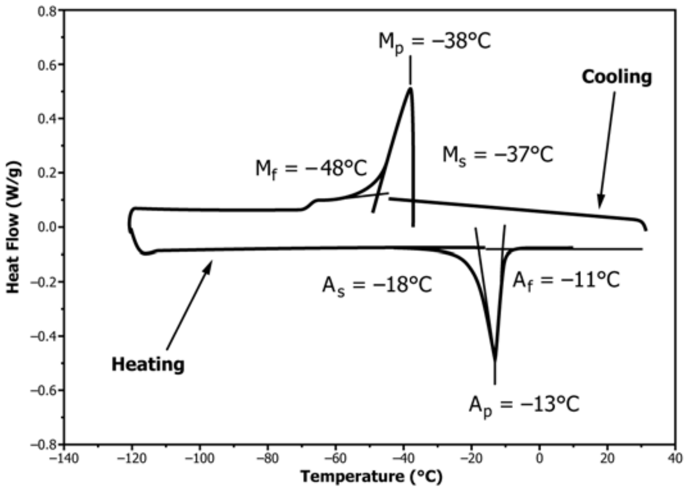

FIG. 1 DSC Graph for a Single-Stage Transformation

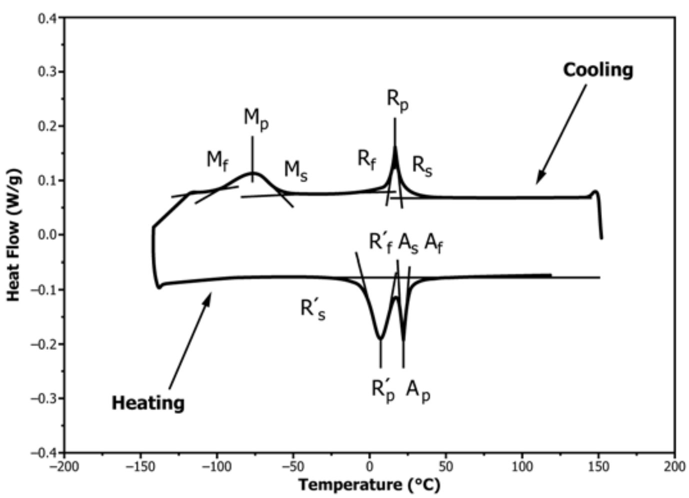

FIG. 2 DSC Graph for a Two-Stage Transformation

method, as it applies to Ni-Ti shape memory alloys, is covered in Test Method F2004.

(E473) (ICTAC (International Confederation for Thermal Analysis and Calorimetry)) (1993)

free recovery, *n*—unconstrained motion of a shape memory alloy upon heating and transformation to austenite after deformation below the austenite phase.

linear elasticity, *n*—linear recoverable deformation behavior.

DISCUSSION—No significant phase transformation event occurs while straining the material and the tensile load-extension or stress-strain plot is linear upon loading and unloading.

lower plateau strength (LPS), *n*—the stress at 2.5 % strain during tensile unloading of the sample, after loading to 6 % strain.

martensite, *n*—the lowest temperature phase in Ni-Ti shape memory alloys with a B19' (B19 prime) monoclinic crystal structure.

martensite deformation temperature (M_d), *n*—the highest temperature at which martensite will form from the austenite phase in response to an applied stress.

martensite finish temperature (M_f), *n*—the temperature at which the transformation from austenite to martensite is completed on cooling in a single-stage transformation (Fig. 1) or the temperature at which the transformation from R-phase to martensite is completed on cooling in a two-stage transformation (Fig. 2).

martensite peak temperature (M_p), *n*—the temperature of the exothermic peak position on the DSC curve upon cooling for the austenite to martensite transformation (Fig. 1) or the R-phase to martensite transformation (Fig. 2).

martensite start temperature (M_s), *n*—the temperature at which the transformation from austenite to martensite begins on cooling in a single-stage transformation (Fig. 1) or the temperature at which the transformation from R-phase to martensite begins on cooling in a two-stage transformation (Fig. 2).

nitinol, *n*—a generic name for a Ni-Ti alloy.

pseudoelasticity, *n*—See **superelasticity**.

R-phase, *n*—the intermediate phase which may form between austenite and martensite.

DISCUSSION—This occurs in Ni-Ti shape memory alloys under certain conditions. The crystal lattice of the R-Phase is a rhombohedral distortion of the cubic austenite crystal lattice structure, hence the name "R-phase."

R-phase finish temperature (R_f), *n*—the temperature at which the transformation from austenite to R-phase is completed on cooling in a two-stage transformation (Fig. 2).

R-phase peak temperature (R_p), *n*—the temperature of the exothermic peak position on the DSC curve upon cooling for the austenite to R-phase transformation (Fig. 2).

R-phase start temperature (R_s), *n*—the temperature at which the transformation from austenite to R-phase begins on cooling in a two-stage transformation (Fig. 2).

R'-phase finish temperature (R'_f) , *n*—the temperature at which the martensite to R-phase transformation is completed on heating in a two-stage transformation (Fig. 2).

R'-phase peak temperature (R'_p), *n*—the temperature of the endothermic peak position on the DSC curve upon heating, for the martensite to R-phase transformation in a two-stage transformation (Fig. 2).

R'-phase start temperature (R'_s) , *n*—temperature at which the martensite to R-phase transformation begins on heating in a two-stage transformation (Fig. 2).

residual elongation (El_r[%]), *n*—the strain after tensile loading to 6 % strain and unloading to 7 MPa.

shape memory alloy, *n*—a metal which, after an apparent plastic deformation in the martensitic phase, undergoes a thermoelastic change in crystal structure when heated through its transformation temperature range, resulting in a recovery of the deformation.

solution anneal, solution heat treatment, *v*—to heat treat in order to remove precipitates.

superelasticity, *n*—nonlinear recoverable deformation behavior of Ni-Ti shape memory alloys at temperatures above the austenite finish temperature (A_f). Pseudoelasticity is sometimes used for superelasticity.

DISCUSSION—The nonlinear deformation arises from the stress-induced formation of martensite on loading and the spontaneous reversion of this crystal structure to austenite upon unloading.

thermoelastic martensitic transformation, *n*—a diffusionless thermally reversible phase change characterized by a change in crystal structure.

DISCUSSION—This is a process in which an incremental change in temperature produces a proportionate increase or decrease in the amount of phase change.

transformation temperature range, *n—in a shape memory alloy*, the temperature range in which a change of phase occurs. **(E7) (1988)**

upper plateau strength (UPS), *n*—the stress at 3 %strain during tensile loading of the sample.