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

This standard is issued under the fixed designation F 2005; 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.

1.3 A definition is a single sentence with additional information included in a discussion. This standard is reviewed every five years, and the year of the last revision is appended.

2. Referenced Documents

2.1 *ASTM Standards:*

E 7 Terminology Relating to Metallography[2]

E 473 Terminology Relating to Thermal Analysis[3]

3. Terminology

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 effects of cold-working or aging heat treatments, or both.

DISCUSSION—Annealing shall be at a minimum temperature of 800°C for a minimum time of 15 min followed by rapid cooling by water quenching, gas quenching, or air cooling.

austenite, *n*—the highest temperature phase in Ni-Ti shape memory alloys.

DISCUSSION—In Ni-Ti the high-temperature phase has the B2 body-centered cubic crystal structure.

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).

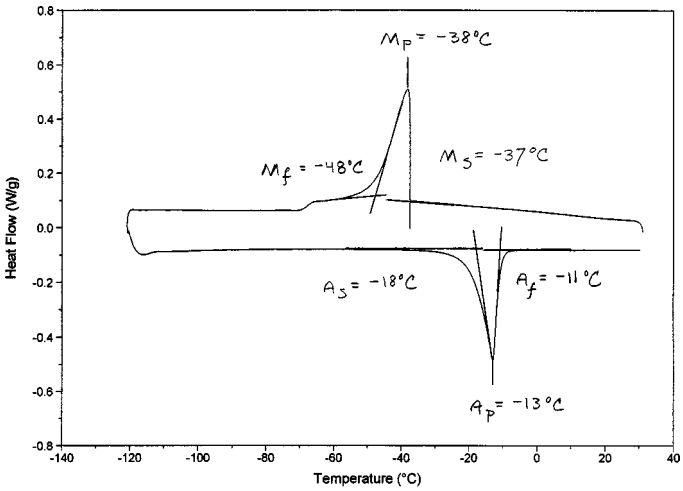

FIG. 1 DSC Graph for Single-Stage Transformation

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).

differential scanning calorimeter (DSC), *n*—a device which 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.

(E 473) (ICTAC) (1993)

martensite, *n*—the lowest temperature phase in Ni-Ti shape memory alloys.

DISCUSSION—In Ni-Ti the lowest temperature phase has the B19

[1] This terminology is under the jurisdiction of ASTM Committee F-4 on Medical and Surgical Devices and is the direct responsibility of Subcommittee F04.12 on Metallurgical Materials.

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[2] *Annual Book of ASTM Standards*, Vol 03.01.

[3] *Annual Book of ASTM Standards*, Vol 14.02.

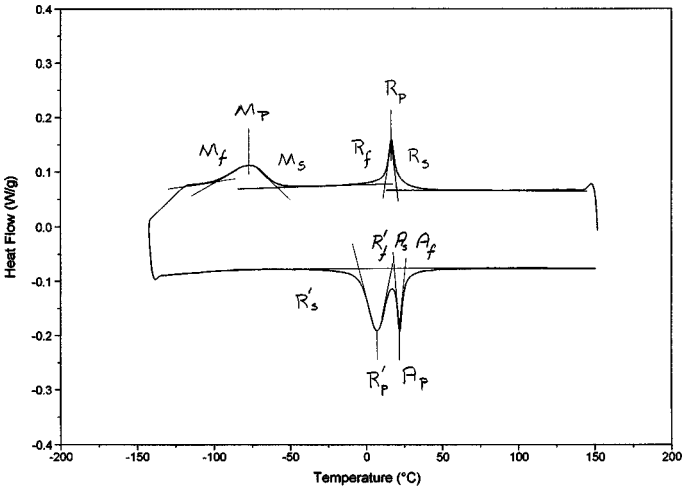

FIG. 2 DSC Graph for a Two-Stage Transformation

monoclinic crystal structure.

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 (see 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—a generic trade name for a Ni-Ti alloy.

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

R-phase, *n*—the intermediate phase which forms from austenite prior to martensite formation.

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).

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.

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

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. **(E 7) (1988)**