Materials Science and Engineering C 29 (2009) 2203–2207

Contents lists available at ScienceDirect

Materials Science and Engineering C

journal homepage: www.elsevier.com/locate/msec

Phase transformation behavior of porous NiTi alloy fabricated by powder metallurgical method

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ARTICLE INFO

Article history:
Received 2 November 2008
Received in revised form 29 April 2009
Accepted 6 May 2009
Available online 19 May 2009

Keywords:
Porous NiTi
Phase transformation temperature
Aging
Shape memory effect

ABSTRACT

Nickel titanium shape memory alloys (NiTi-SMAs) were successfully produced from elemental Ni/Ti powders by powder metallurgical method and then subjected to age treatment. Microstructure was examined by SEM and XRD and phase transformation temperatures were measured by dilatometric method. The phase transformation temperatures increased with both duration and temperature of the age treatment. The porous product exhibited desirable shape memory effect.

1. Introduction

NiTi-SMAs have proved the most applicable shape memory compound introduced during recent years. Shape memory effect (SME), superelasticity, self-healing tribological surfaces, mechanical strength, biocompatibility and corrosion resistance are advantageous properties substantiating NiTi for biomedical applications [1–5]. According to previous authors [5,6], porous NiTi having cellular structure can be used as bone implant and dental root. Porosity permits ingrowths of body tissue into implant to create strong fixation in implant–bone interface [7–9]. Young's modulus of the implant decreases with porosity to approach that of the bone. Similarity of implant–bone stiffness prevents stress-shielding behavior and osteoporosis diseases [10].

NiTi shape memory vs. superelasticity effects are both strongly correlated with the phase transformation temperatures. Controlling the phase transformation temperatures is, therefore, an important task required for practical utilization of NiTi-SMAs. Near equiatomic NiTi alloy shows thermoelastic martensitic transformation from high-temperature BCC phase (B2) to low-temperature monoclinic martensitic phase (B19′) in a single cooling step. Ni-rich NiTi alloys may endure rhombohedral phase (R) transformation at the intermediate temperatures (B2 → R → B19′) [11]. All start and finish phase transformation temperatures depend on the chemical composition, Ni content, heat treatment and thermomechanical processes [11–14]. Aging is a convenient tool for adjustment of the transformation temperatures. Aging temperature, aging time and the cooling rate of the heat treated specimens affect the transformation temperatures of the SMAs [14,15]. Formation of such precipitates as Ni_4Ti_3 during aging reduces the Ni content of the matrix and affects the transformation temperatures. Stress fields around the precipitates can vitally be influenced [11,15]. A set of predesigned values can thus be determined and associated with each compositional range and application.

Various methods are devised by researchers to investigate the phase transformation temperatures of the shape memory specimens. Differential scanning calorimetery (DSC), resistivity measurement, mechanical testing and dilatometric measurements are well-known examples. Dilatometric measurement is a simple way to reveal the shape memory behavior of NiTi specimens [16].

Porous NiTi samples were successfully produced in this research from fine elemental materials by powder metallurgical procedure. Effects of aging on austenitic transformation temperatures and shape memory properties were then evaluated by dilatometric method. The specifications reported seem of considerable practical significance.

2. Materials and methods

Ten NiTi samples were fabricated, heat treated and aged. Titanium powders (99.99% purity) with particle size of less than 50 µm (Johnson Matthey Company, USA) and nickel (99.10% purity) with particle size of ~10 µm (Merck Company, Gmbh) were mixed together in a cylindrical mixer. An equiatomic powder ratio was selected. Eight grams of the mixture was compacted into a rigid die by applying uniaxial compression stress of about 750 MPa. Dimensions of the compacts were $40 \times 6 \times 1.5$ mm. Green compacts were sintered at 1050 °C for 2 h in a vacuum chamber assembled by the authors having 10^{-6} Torr pressure. The sample was then furnace cooled to the ambient temperature. To

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doi:10.1016/j.msec.2009.05.006