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Short Communication

Fabrication of porous NiTi-shape memory alloy objects by partially hydrided titanium powder for biomedical applications

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A B S T R A C T

Porous NiTi-shape memory alloy (SMA) is a promising biomaterial with desirable mechanical property and appropriate biocompatibility for human implant manufacturing. In this research, porous NiTi-SMAs have been successfully produced by using thermohydrogen process (THP). This process has capability of production of homogenous structures, appropriate pore-size distributions and short sintering times. The THP-SMA samples produced in this research have a low Young's modulus (19.8 GPa) and a high tensile strength of 255 MPa. These properties are close to those of the natural bone and can meet the mechanical property demands of the hard-tissue implants for heavy load-bearing applications. The samples produced exhibit sufficient thermoelastic effect distinguished by a 1.2% mean recoverable strain.

1. Introduction

Nickel–titanium alloy near the equiatomic concentration is well known for its shape memory effect (SME). Due to its unique physical and mechanical properties like room temperature ductility, damping effect, corrosion resistance and biocompatibility, this material can be used for numerous smart engineering and biomedical applications [1,2]. Porous NiTi-shape memory alloy has, for example, been considered as a promising biomedical material for orthopedics and bone implant surgeries in recent years [3]. Its porous structure allows the ingrowth of the human tissue, firm fixation of the bone implant and comprehensive transmission of the body fluid [3]. Furthermore, variation of the porosity by changing of the production parameters results in adjustability of the NiTi elastic modulus for matching of the human bone.

Several powder metallurgical methods including self-propagating high-temperature synthesis (SHS), hot isostatic pressure (HIP), spark plasma sintering (SPS) and conventional sintering (CS) are used for fabrication of porous NiTi parts. Conventional sintering is a simple and inexpensive way. Disadvantages of this method are a lengthy sintering time (72 K s), intermetallic compound formation, contamination with atmospheric elements and non-homogenous pore-size distribution [4]. These drawbacks lead to a weak shape memory effect (SME) and a low mechanical strength [4].

From previous investigations [5–7], it can be inferred that hydrogen as a temporary alloying element can become a powerful resource for improvement of the microstructure and mechanical properties of the NiTi alloy and its production method. Hydrogen can be incorporated in the structure by a mechanism called thermohydrogen processing (THP) [5]. The hydrogenated powder can be consolidated with less energy than virgin powder. This can be translated to a pressure reduction of 34–67 MPa or a temperature decrease of 110–140 °C [5]. The hydrogen can be removed from the structure by a simple vacuum annealing of the specimen. Hydrogen release cleans the powder surface, promoting better bonding to the adjacent particles [8].

In this research, porous NiTi specimens with homogenous structures, appropriate pore-distribution and relatively high strength were obtained by sintering of partially hydrided titanium powder together with elemental nickel powder. The sintering time was lower than that of the virgin powders reported by previous authors [9–11]. The specimens revealed good shape memory effect and low Yong's modulus suitable for orthopedic and biomedical applications.

2. Experimental procedure

Partially "hydrided" Ti powder being crushed under hydrogen to absorb <4 atom% hydrogen [12] with purity of 99.99% and size of <50 μm (Jonhson Matthey Company, USA) and Ni powder with purity of 99.5% and size of <10 μm (Merck Company, Gmbh) were employed to produce porous NiTi specimens. Fig. 1 shows the elemental morphology of the powders. Ti had a wide range of size distribution and irregular shape. This supported preparation of a good compactable mixture.

The powders with the nominal composition of Ti–50 atom% Ni were blended in a cylindrical mixer for 3.6 K s to become

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