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Structure and wear properties of laser gas nitrided NiTi surface

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Abstract

The laser gas nitriding process is an efficient technique for modification of materials. Composite coatings with a microstructure consisting of dendritic TiN/NiTi were fabricated on a substrate of NiTi by the laser gas nitriding process. Different nitrogen flow rates were supplied during the laser process in order to detect the influence of the TiN on the wear resistance. The wear resistance of the TiN/NiTi coatings was evaluated under sliding wear test conditions in 5% NaCl aqueous solution at room temperature. The results indicate that the TiN/NiTi coatings have excellent abrasive and adhesive wear resistance because of the high hardness and the proportion of the TiN.

Keywords: Laser gas nitriding; Wear resistance; NiTi shape memory alloy; TiN coating

1. Introduction

Within the past 5 years, equiatomic NiTi alloy has become widely used in a variety of mainstream biomedical applications [1] because of its unique shape memory effect (SME) around the room temperature and superelasticity[2]. From a product point of view, several candidate applications require good wear resistance. For example, the medical industry is very interested in the high compliance of NiTi alloys for use in joint replacement, where wear plays an important role.

Recent studies have demonstrated that the equiatomic NiTi alloy exhibits a high wear resistance [3]. The wear behaviour of NiTi alloy was expected to improve further if hard particles were embedded in the alloy [4]. The hard-phase particles may withstand the external load and the pseudoelastic matrix can absorb impact energy and accommodate a relatively large strain. Ye et al. [5] demonstrated a high wear resistant of TiNi-based TiC or TiN reinforced composites by using the vacuum sintering process.

TiN as a modified layer to improve the corrosion resistance of the NiTi has been reported by Fu et al. [6], Endo et al. [7], Wu et al. and Lin et al. [8,9], Starosvetsky et al. [10], etc. The process for obtaining the TiN is concerned with the ion nitriding [9], arc ion plating [7], pulsed high-energy density plasma [6] and power immersed reaction assistant coating nitriding method [10]. However, published results concerning the effects of TiN/NiTi on wear resistance, especially to the coating made by laser gas nitriding on NiTi shape memory alloys were sparse.

The laser gas nitriding process (LGN) is an efficient technique for the modification of materials [11]. Our previous work on the NiTi has shown that an alloyed layer with TiN on the NiTi substrate will be formed during the LGN treating [12]. To our knowledge, no investigation of the wear behaviour of LGN NiTi has been reported yet. The present study obtained TiN/NiTi coatings by the laser gas nitriding process in different nitrogen flow rates. The purpose of this work is to investigate the effects of the

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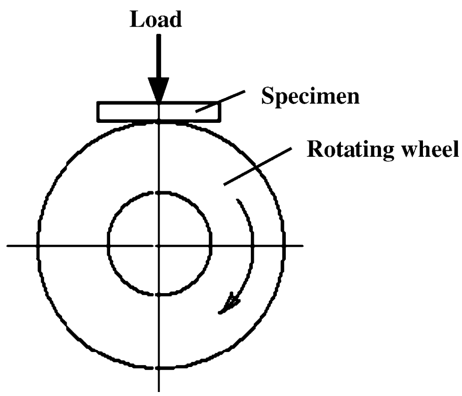

Fig. 1. Schematic of the block-on-wheel dry sliding wear tester.

laser nitriding process on the microstructure and the wear resistance of the TiN/NiTi coating.

2. Experimental materials and methods

2.1. Materials

The material used for the experiment was a binary nickel-rich NiTi alloy with a nominal composition of 50.8 at.% Ni.

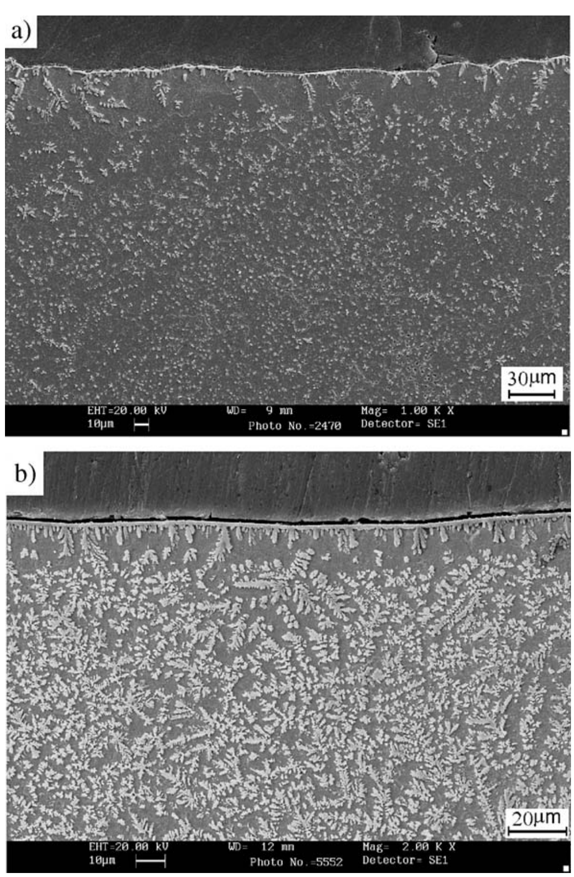

Fig. 2. SEM images of the microstructure of the cross-section of LGN NiTi specimens nitrided by nitrogen flow rate of 10 l/min (a) and 40 l/min (b).

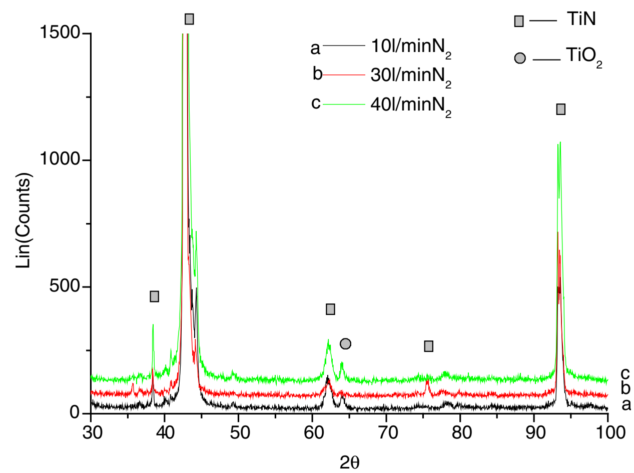

Fig. 3. The XRD charts of LGN treated NiTi surface, a) 10 l/min N_2 flow rate, b) 30 l/min N_2 flow rate, c) 40 l/min N_2 flow rate.

The hot rolled as-received NiTi alloy was as plate metal with a thickness of 4 mm. The specimens of 25 × 8 × 4 mm were cut for the experiment. A continuous wave 2-kW Nd-YAG laser was used to irradiate the specimen surface with a peak power intensity of 500 W. The laser beam was defocused to a 2-mm spot size. High purity nitrogen gas (99.9%) N_2, was blown onto the specimen molten pool through a nozzle with ϕ5 mm diameter. The nitrogen gas flow rate was changed from 10 to 40 l/min for investigating its influence on the NiTi microstructure. The scanning speed was kept as 5 mm/s. The overlap neighboring tracks was 0.5 mm (25% overlap).

2.2. Characterization methods

Scanning electron microscopy (SEM) was performed using a Leica Stereo Scan 440 for investigating the microstructure of the LGN coatings. The microstructures of the composite layer were also studied by optical

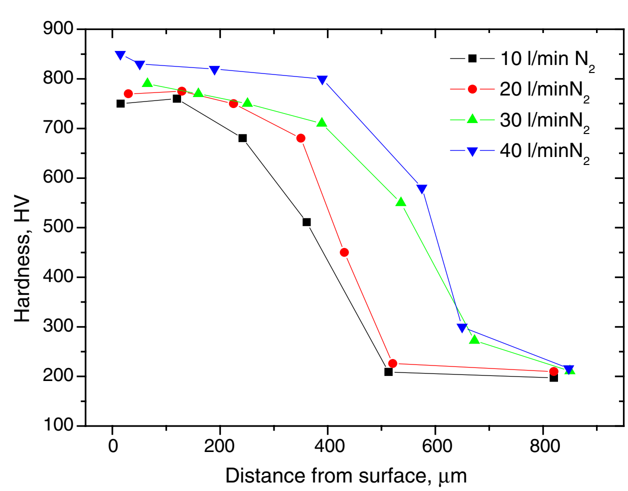

Fig. 4. Profile of the microhardness of the LGN NiTi samples.