

# Pulsed-Laser Annealing of NiTi Shape Memory Alloy Thin Film

S.K. Sadrnezhaad<sup>1,2)†</sup>, E. Rezvani<sup>1)</sup>, S. Sanjabi<sup>1,3)</sup> and A.A. Ziaei Moayed<sup>2)</sup>

1) Materials and Energy Research Center, P.O. Box 14155-4777, Tehran, Iran

2) Department of Materials Science and Engineering, Sharif University of Technology, P.O. Box 1156-9466, Tehran, Iran

3) Department of Materials Science and Engineering, Tarbiat Modarres University, P.O. Box 14115-143, Tehran, Iran

[Manuscript received September 11, 2007, in revised form February 11, 2008]

Local annealing of amorphous NiTi thin films was performed by using an Nd:YAG 1064 nm wavelength pulsed laser beam. Raw samples produced by simultaneous sputter deposition from elemental Ni and Ti targets onto unheated Si (100) and Silica (111) substrates were used for annealing. Delicate treatment with 15.92 W/mm<sup>2</sup> power density resulted in crystallization of small spots; while 16.52 and 17.51 W/mm<sup>2</sup> power densities caused ablation of the amorphous layer. Optical microscopy, scanning electron microscopy, X-ray diffraction and atomic force microscopy were performed to characterize the microstructure and surface morphology of the amorphous/crystallized spot patterns.

**KEY WORDS:** Local heat treatment; NiTi thin film; Pulsed laser annealing; Amorphous/crystallized spot composite

## 1. Introduction

Considerable research has recently been devoted to thin film NiTi shape memory alloys (SMA) for development of micro-electro-mechanical (MEMS) devices<sup>[1-6]</sup>. NiTi helps development of stents, medical infusion pumps, microneedles for trans-dermal and sub-dermal fluid transport, microvalves, microgrippers and micropositioners<sup>[1-7]</sup>. Potential future applications of the NiTi alloy include medical microdevices such as micropumps to promote fluid circulation<sup>[8]</sup> and artificial heart valves<sup>[9]</sup>.

Two-way NiTi thin films can simplify the sensor/actuator mechanisms used in production of the above systems. Local laser annealing can induce two-way shape memory effect with the non-annealed regions demonstrating elastic behavior and the annealed spots showing shape memory behavior<sup>[10,11]</sup>. Furnace annealing is not a feasible option for bio-MEMS consisting of low melting point polymers. The as-deposited NiTi amorphous film may, however, locally be crystallized by laser heating to a composite-like pattern. Rapid laser heating can reduce the exposure time to the oxidizing atmosphere<sup>[2,3]</sup> and reduce the risk of oxidation for the SMA layer. Direct crystalline film-deposition onto a heated substrate is not so beneficial because of film cracking<sup>[12]</sup> and coarse crystallographic texture that produce high surface roughness<sup>[13]</sup>.

Previous investigators have studied continuous-laser treatment of the NiTi thin layers. Bellour *et al.*<sup>[12]</sup> have, for example, treated the NiTi thin film with a continuous-wave (CW) laser system for an application in a micro-gripper<sup>[12]</sup>. They utilized a zero-contact line-scan approach to provide a flexible inexpensive technology. He *et al.*<sup>[4]</sup> used CO<sub>2</sub> laser annealing to achieve a crystalline structure induced on films for IC applications. They demonstrated capability of local annealing achievable with alternative line scans. Wang *et al.*<sup>[13]</sup> reported selec-

tive crystallization *via* diode laser annealing of amorphous NiTi thin films. They reported homogenous nucleation with random crystallographic textures leading to a uniform microstructure across the annealed area. They observed a significant stress recovery of their laser annealed layer<sup>[13]</sup>.

Properties of ultra high vacuum (UHV) furnace-annealed films have also been investigated before<sup>[14]</sup>. No information is, however, on pulsed-laser treatment of NiTi thin films available in the literature. Present investigation is devoted to the pulsed-laser heat treatment (PLH) as an alternative novel method for creation of local shape-memory crystals embedded in amorphous NiTi thin layers.

## 2. Experimental

Infrared (IR) pulsed-laser beam was used to investigate the localized crystallization of the as-deposited NiTi thin films. The films were deposited by sputter deposition from separate elemental Ni and Ti targets onto unheated Si (100) and Silica (111) substrates<sup>[14]</sup>. Samples 1 and 2 were deposited on silicon substrate, while sample 3 was precipitated on silica. Total area of all samples was 5 mm×10 mm.

Laser heating was carried out under atmospheric condition. The pulse duration was 200  $\mu$ s. A Q-switch solid-state Nd:YAG laser with a wavelength of 1064 nm (Baublys Co., Germany) was used for heat treatment. The position of the specimens and the laser optical parameters were software controlled. The sample X-Y stage had an accuracy of 0.1  $\mu$ m. Sample No. 1 (Si substrate) had a laser spot diameter of 0.8 mm. The optical parameters of the laser were changed from one spot to another. The laser power changed from 8 to 8.5 W for this sample; changed from 8.2 to 8.3 for sample 2 and between 8 and 8.3 W for sample 3.

Microstructures of the spots were studied by optical microscopy and scanning electron microscopy (SEM, LEO 440i, England). Crystallographic studies were done by X-ray Diffraction (XRD) using a Philips Xpert, Netherland (CuK $\alpha$ , 40 kV, 40 mA). Grazing

† Corresponding author. Prof., Ph.D.; Tel.: +98 21 66165215; E-mail address: sadrnezh@sharif.com, sadrnezh@yahoo.com (S.K. Sadrnezhaad).