Materials Letters 138 (2015) 29–32

Contents lists available at ScienceDirect

Materials Letters

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

Nano-quasi-grating of optical diffraction on special stainless steel by a femtosecond-pulsed laser

Chen-Kuan Kuo [a], Shao-Wei Luo [b], Hung-Yin Tsai [b], Shing-Hoa Wang [a,*], Rudder T. Wu [c], Min-Chieh Chou [d], Tsong-Ru Tsai [e], Ming-Chan Shieh [e], Ya-Ching Yang [f], Kent Huang [f]

[a] Department of Mechanical Engineering, National Taiwan Ocean University, Keelung 20224, Taiwan
[b] Department of Power Mechanical Engineering, National Tsing-Hua University, Hsinchu 30071, Taiwan
[c] National Institute for Materials Science, Tsukuba 305-0047, Japan
[d] Mechanical and Systems Research Laboratories, Industrial Technology Research Institute, Hsinchu 31040, Taiwan
[e] Institute of Optoelectronic Sciences, National Taiwan Ocean University, Keelung 20224, Taiwan
[f] Bruker Taiwan Corporation, Xizhi Dist, New Taipei City 22101, Taiwan

ARTICLE INFO

Article history:
Received 5 August 2014
Accepted 13 September 2014
Available online 22 September 2014

Keywords:
Laser processing
Metals and alloys
Optical properties

ABSTRACT

The optical grating on the special stainless steels can be faithfully processed by a femtosecond pulsed laser. At the heat inputs of 0.05 mJ/mm and 0.2 mJ/mm, the optical diffraction illustrated that symmetric double peaks occurred at the diffracted angles of approximately $\pm 13.4^{\circ}$ and $\pm 6^{\circ}$ for the single phase of 254 SMO. As for the duplex phase of SAF 2205, the optical diffraction only appeared at the diffracted angle of $\pm 13.8^{\circ}$ under the heat input of 0.05 mJ/mm, whether a clear periodic structure or a new compound formation is the main factor that influences their optical diffraction.

1. Introduction

Laser induced periodic surface structures can be observed on a wide range of materials, such as metals, semiconductors and dielectrics [1,2] and these have dimensions in periodicity and amplitude which are comparable to, or smaller than, the wavelength of the laser radiation. The rapid development of advanced femtosecond-pulsed laser (FS-pulsed laser) manufacturing using an ultra-short-pulse provides a new promising means by which the surface or bulk can be modified with micrometer precision by the mechanism of multi-photon absorption [3]. Unlike conventional laser micromachining, the FS-pulsed laser supports grating micromachining without heat generation at the focus of the laser beam. Femtosecond-pulse studies have pointed to stainless steel and other metals, such as titanium and aluminum, as a surface treatment to change the microstructure of the metal surface in order to reflect a variety of color changes [4]. This approach to surface modification using an FS-laser is versatile and attractive for a variety of solid-state materials [5]. The metallic shallow microgratings absorb light and contribute to changes in the color of the stainless steel surfaces. The self-organized nanogratings are formed by the interaction of the high-intensity incident laser beam and the laser induced plasma waves. The interaction of laser pulses with metals undergoes several processes: melting, spallation, and phase explosion [6]. A phase explosion takes place above a certain threshold energy, which is considered to be the primary mechanism for the formation of self-organized nanogratings [7]. Optical gratings with good diffraction properties by the nano-imprinting of bulk metallic glass [8] and various glass materials [9] by ArF excimer laser ablation have been reported. The aims of this study are to investigate the feasibility of optical diffraction in the metal optical components, and the effect of the grating period associated with an FS-pulsed laser process on the surface of single phase of 254 SMO superaustenitic and duplex phase of SAF 2205 stainless steel applied to a harsh corrosive environment.

2. Experimental procedures

The superaustenitic stainless steel of 254 SMO (containing key elements of Ni 17.9, Cr 20.1, Mo 5.82, in wt%) with a single γ phase exhibits great resistance to chloride pitting and crevice corrosion because of high molybdenum content. The other is duplex ($\alpha+\gamma$) stainless steel of SAF 2205 (containing key elements of Ni 5.41, Cr 21.5, Mo 2.95, in wt%) with improved corrosion resistance. The diffraction-grating-like structure was embedded by an all-in-one femtosecond regenerative amplifier system (UC-1035-2000; High Q Laser Production GmbH), which integrated a Yb:Ytterbium laser as the irradiation source [10]. As a direct writing beam, the wavelength

* Corresponding author.
E-mail address: shwang@ntou.edu.tw (S.-H. Wang).

http://dx.doi.org/10.1016/j.matlet.2014.09.062
0167-577X/

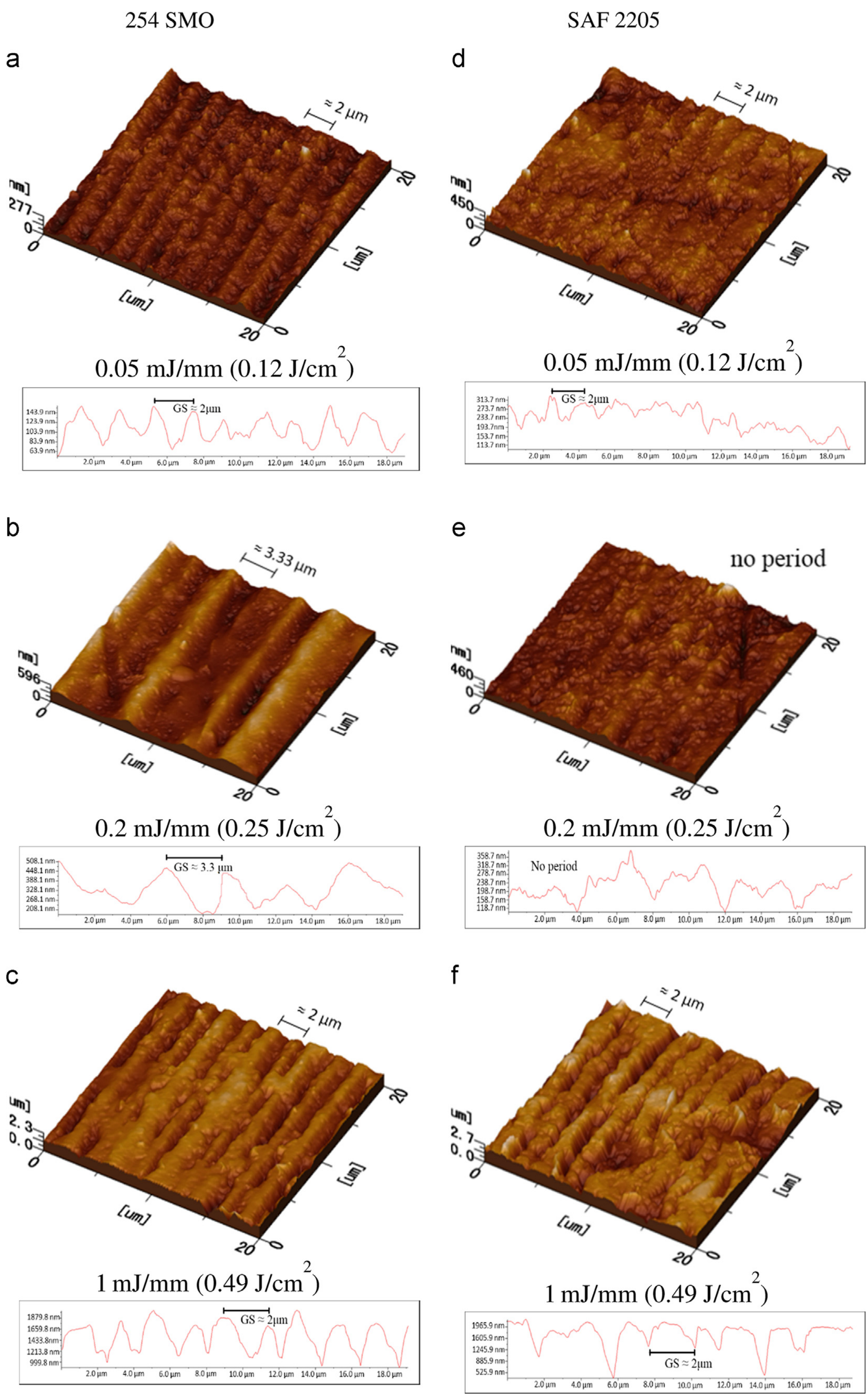

Fig. 1. AFM image ($20 \times 20\ \mu m^2$) and the depth profile of gratings in 254 SMO steel [(a)–(c)] and SAF 2205 steel [(d)–(f)]. Heat input/unit length (laser fluence) (GS grating space).