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September 16–21, 2012, Minsk, Belarus

Edited by V.I. Arkhipenko, V.S. Burakov and V.K. Goncharov

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16–21 сентября 2012 г., Минск, Беларусь

Под редакцией В.И. Архипенко, В.С. Буракова и В.К. Гончарова

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CONTENTS

INVITED LECTURES

POSTER SESSION

LASER ABLATION AND STRUCTURING OF HARD COATING WITH ULTRA-SHORT LASER PULSES

B. Gaković[1], B. Radak[1], C. Radu[2], M. Zamfirescu[2], M. Trtica[1], S. Petrović[1], J. Stasic[1], P. Panjan[3] and I. Mihailescu[2]

[1]Vinča Institute of Nuclear Sciences, University of Belgrade, POB 522, 11001 Belgrade, Serbia
[2]National Institute for Lasers, Plasma and Radiation Physics, POB MG-36, Magurele, Ilfov, Romania
[3]Jožef Stefan Institute, Jamova 39, 1000 Ljubljana, Slovenia
e-mail: biljagak@vinca.rs

Abstract. For material processing one of the main advantages of using ultra short laser pulses, comparing to long pulses, is the highly localized modification. Ultra short pulse laser modification of materials is valuable for their application in nanotechnology, tribology, microelectronics, medical application, etc. In this paper, special attention is paid to experimental investigations of femtosecond laser surface modification of hard protective coating. The sample has been processed by a Ti:sapphire laser with pulse duration of 200 fs and wavelength of 775 nm. Single and multi pulse irradiation were performed in air. Various analytical techniques were used for characterization. The damage threshold for the examined coating, irradiated by 200 fs pulses, was determined.

Introduction

Protective surface coatings, espacially titanium based are important in many applications. Titanium-aluminium-nitride (TiAlN) obtained by incorporation of Al in titanium nitride (TiN) is a material with excellent hardness and thermal stability. In addition, multilayered coatings have mechanical advantages over single layer composed of either TiN or TiAlN /1,2/. Conventional mechanical micro-structuring of such hard materials is difficult and application of lasers is often the solution. Irradiations of multilayered TiAlN/TiN coating deposited on steel by nanosecond and picoseconds laser pulses were studied recently /3/. It was found that laser induced periodical surface structures (LIPSS) readily form on this coating under certain combinations of parameters with those lasers. Formation of LIPSS was accompanied by more or less pronounced thermal effects. It has been demonstrated that fs laser pulses can be easily adjusted to induce little or no collateral damage and thermal effects on materials, in case of proper choice of number of pulses-energy combinations. The present paper deals with effects of 200 fs laser pulses upon a TiAlN/TiN multilayer deposited on steel – from damage thresholds to structures formed.

Experimental

The experimental sample was a multilayered TiAlN/TiN hard coating deposited on the steel substrate. The TiAlN/TiN multilayer was prepared with a commercial device (CemeCon 800). The layered structure of the coating was achieved by sequential depositions of TiN and TiAlN. Details and conditions of the procedure have been given elsewhere /3/. The total thickness of the coating was 2.17 μm and consisted of 45 alternating layers. The first layer next to the steel substrate was TiN, about 40 nm thick, followed by a TiAlN layer of nearly the same thickness, and so on. The top layer was TiAlN about 500 nm thick.

Irradiation was done with a Ti:sapphire laser equipped with a chirped pulse amplification (CPA) system (Clark-MRX 2101). The laser wavelength was 775 nm, pulse duration 200 fs and a repetition rate 2 kHz /4/. The pulse energy ranged from 5 to 350 μJ and the spatial profile of the beam was nearly Gaussian with with a ($1/e^2$) beam radius ω_0 =16.6 μm . The linearly polarized beam was focused and directed perpendicular to the target surface. All irradiations were performed in air. The procedure was computer controlled using dedicated software.To determine the damage threshold a series of laser pulse energies (E) and pulse counts (N=1,2,3,4,5,7,10,15,20,50,100,200 and 400) were used (Fig. 1.)

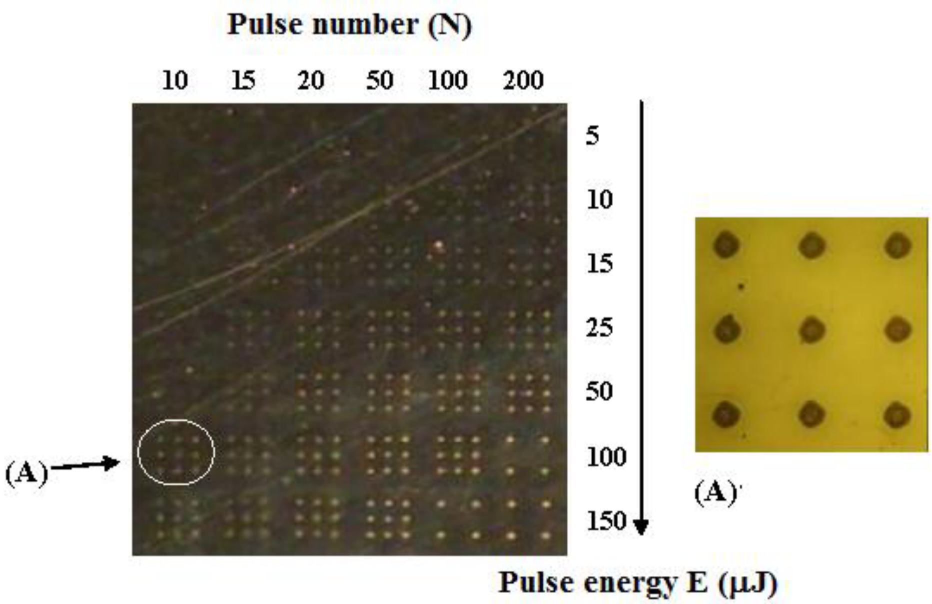

Figure 1. Part of the TiAlN/TiN coating surface after 200 fs laser pulse action. Each group of spots was made by constant pulse number and energy.

For the sample characterization various analytical techniques were used: optical microscopy, scanning electron microscopy (SEM), focused ion beam (FIB) system and profilometer.

Results and discussion

Some of results, concerning morphological changes of the target are presented in Figure 2. SEM micrographs showed effects on TiAlN/TiN hard coating deposited on the steel substrate after irradiation with different pulse energy/fluence and number combinations.

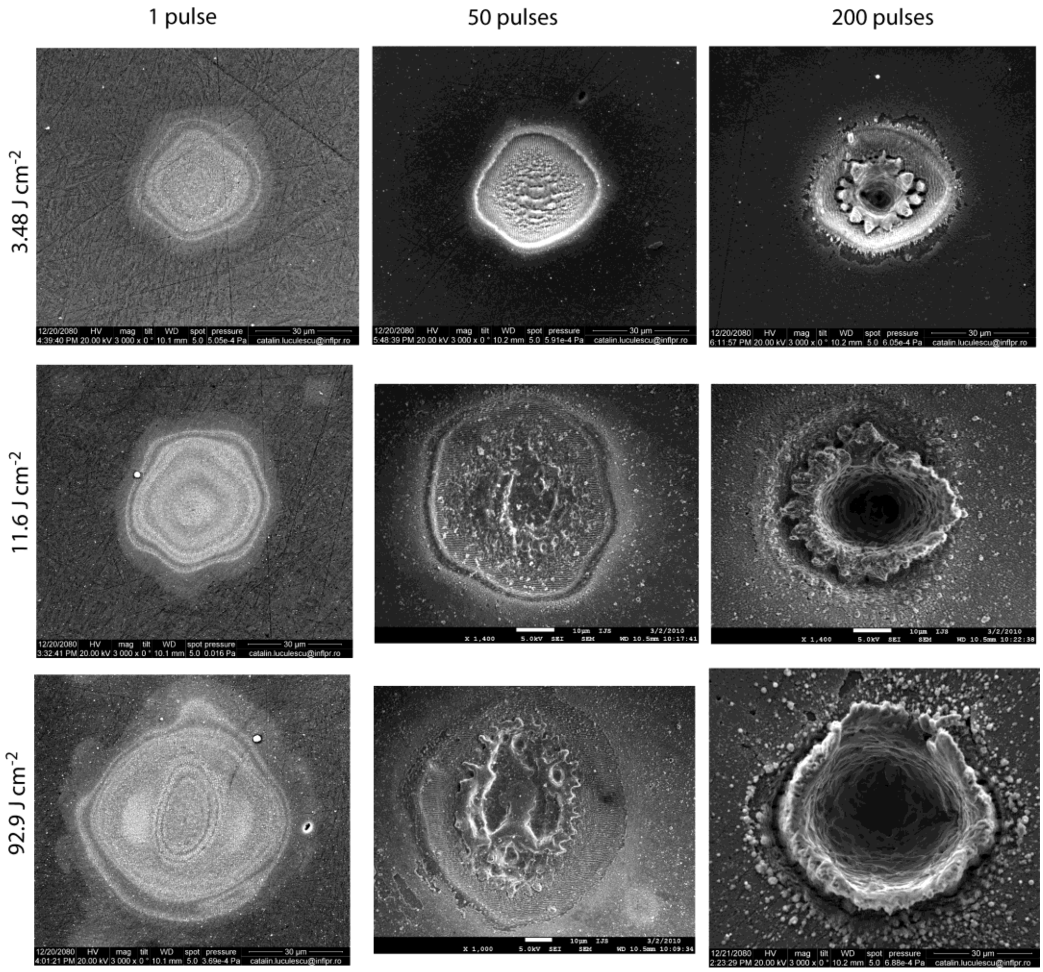

Figure 1. The SEM micrographs of TiAlN/TiN multilayer coating surface after irradiation with 1, 50 and 200 pulses and 15, 50 and 350 μJ pulse energy.

Fs laser pulses can generally produce conditions of no dissipation of laser beam energy out of the irradiated area, facilitate direct solid to vapour transition. In case of a large pulse number and high pulse energy combinations, modified area can be broadened and some thermal effects appear (Fig.2).

The damage threshold of coating, the lowest fluence that induces irreversible surface damage, is important parameter for application. For a Gaussian spatial beam profile with beam radius ω_0, and for pulse energy E_p, the maximum laser fluence at the surface is $F_0 = (2E_p)/(\pi(\omega_0)^2)$. According to the established procedure /4/, knowing diameter of the spots, the damage threshold F_{th} for the multilayered TiAlN/TiN hard coating was obtained, Tab.1.

Table 1. Damage threshold (F_{th}) as a function of the number of laser pulses (N) applied to the same spot.

N	F_{th} (J cm^{-2})
1	0.66
20	0.39
50	0.26
400	0.19

At low laser fluences, very clear formation of LIPSS was recorded. Evolution of their formation is illustrated in Figure 3. The spacing/periodicity between the ripples created is 580 nm on average and the LIPSS were orientated perpendicularly to the laser beam polarization.

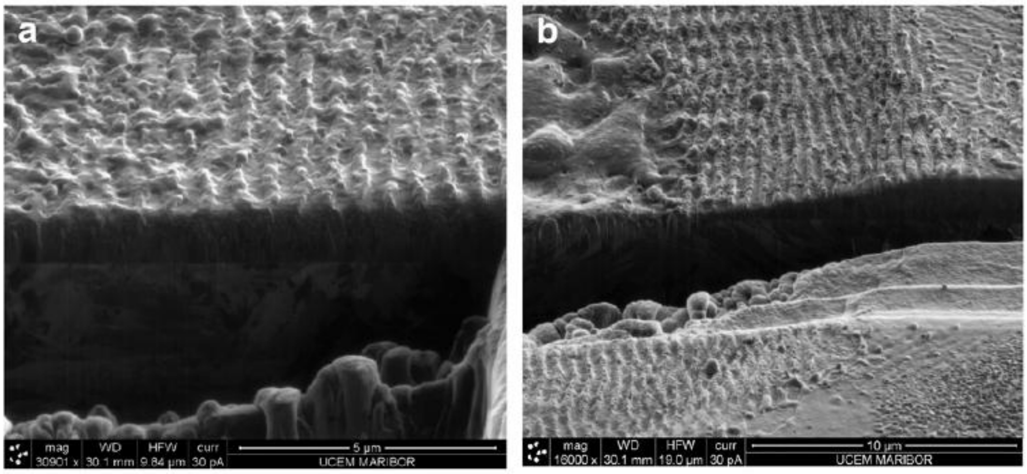

Figure 3. Images obtained by FIB cross sectional profiling after fs laser-coating interaction. Effects of (a) 10 pulses, at 50 µJ and (b) 20 pulses, et 350 µJ.

Summing up, a multilayered TiAlN/TiN coating was irradiated by 200 fs pulses at 775 nm. Laser fluences of 1.16 Jcm^{-2} to 116 Jcm^{-2} produced a range of modifications, from well defined parallel surface structures on the coating, to deep craters in the substrate, depending also on the number of accumulated pulses.

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