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ABLATION OF TiN COATINGS BY TEA-CO_2 LASER BEAM

B.Gaković, M.Trtica, T.Nenadović, S.Petrović-Stepanović and N.Mijatović
The Institute of Nuclear Sciences "Vinča", P.O.B. 522, 11001 Belgrade, Yugoslavia

1. Introduction

Although the laser-beam interaction on thin films/coatings is used in many areas of technology, a better understanding of interaction kinetic is required. The surface features during the interaction processes depend on the beam characteristics but also on the physical and thermomechanical properties of target and the surrounding atmosphere of the bombarded target.

Laser sputtering causes rapid removal of surface material and many combine thermal and collisional effects. Process may be divided into laser induced ablation which presents high-yield sputtering process and laser induced desorption which include low-yield sputtering. The process of laser beam target interaction can be described in terms of heat model including few characteristic stages: absorption of the laser beam and transformation of its energy in radiative or non-radiative processes, heating of the target without damage, ejection of material from the interaction region, formation of the plume above the surface and finally rapid cooling when interaction occurs (Kelly et al. 1992).

In many application material processing relies on the heating effect due to the absorption of the beam energy which is characterized by photon energy, pulse duration and fluence F (J/cm^2). The amount of the absorbed energy depends on the optical and thermal characteristics of target. It increases with decreasing the wavelength ($E=hc/\lambda$). The reflectivity of the most metals in the optical range of wavelengths reaches 70-95% of incident radiation. At the wavelength 10.6 μm that corresponds to the TEA-CO_2 laser beam the reflectivity on polished metal can be higher (Rykalin et al. 1988)

The analyses of the laser beam induced changes allow us to determine the threshold damage on different coatings, the damage area induced by different shape of the laser pulses, and the mechanism of the interaction.

2. Experimental

In this work the laser induced surface modifications of thin film studies were carried out by pulsed, UV preionized, TEA carbon-dioxide laser. The laser operated with nontypical CO_2/X, X= N_2/H_2; H_2 gas mixtures. The presence of hydrogen in the laser makes that efficiency of the system greater in comparison when it has been absent. The laser gave multimode output of a pulse repetition of 1Hz. The beam cross-section was typically of quadratic form so that spatial-uniform distribution of intensity can be assumed. Output pulse was in the interval from 3 to 40 mJ for CO_2/H_2 gas mixture and FWHM = 80 ns.

The bombardment of coatings was performed with focused laser beam. The NaCl lens with focal length of 6.0 cm ensured the focusing on the target. Surface area of the laser spot of 0.0008 cm^2 was measured optically. The laser beam interacted with coating on zero incident angle.

The TiN layer (thickness = 0.85 μm) was deposited by reactive d.c. ion sputtering from a 99.98% titanium target, on polished austenitic stainless steel AISI 316 type (Gaković et al. 1998).

The coating characterization has been performed by X-ray diffraction analysis, wavelength dispersive - XRD and energy dispersive analysis – EDX. For morphology studies the SEM analyses has been employed. We used both, the secondary electron (SE) and backscattered electron (BSE) detectors.

3. Results and Discussion

XRD as well as EDAX analysis done before laser irradiation of TiN coatings have confirmed its polycrystalline structure and stoichiometric composition. The surface topography of TiN coatings was homogeneous relatively dense with spherical growth features on the surface. Analyses of the cross section have shown columnar crystal structure typical for low temperature zone, presented in a three zone model of structure. This have been expected since the deposition temperature (T = 473 K) was lower than 0.3 from the melting temperature of material (T_m = 3220 K). The grain sizes varied from few tens to one hundred nanometers.

Investigation of TiN coating morphological changes, induced by the laser radiation, has shown their dependence on laser fluence, number of pulses and laser pulse shape. In this work we present the results of 20 and 340 TEA CO_2 laser pulses interaction with TiN/AISI layer.

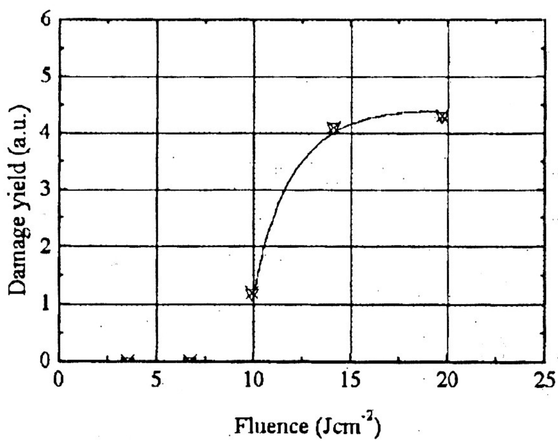

Fig. 1. Damages yield as a function of the fluence for twenty laser pulses.

Three types of interaction were obtained depending on the incident laser fluence. At the beginning target acted as a mirror for laser radiation (reflectivity 97%) and laser pulses were reflected without noticeable changes on the target surface. A damage threshold defined as the minimum fluence that creates a detectable damage on the surface. In this experiment the registered damage threshold was observed after twenty accumulated pulses The obtained value of 9.9 J/cm^2 is presented on Fig.1.

Finally the action of 340 laser pulses with fluences of 14 J/cm^2 and laser intensity I $\approx$170 MW/cm^2 leads to important changes in morphology of TiN coating, Figure 2. (a-c). During the laser action on the coating the three zones in damage area, can be distinguish.

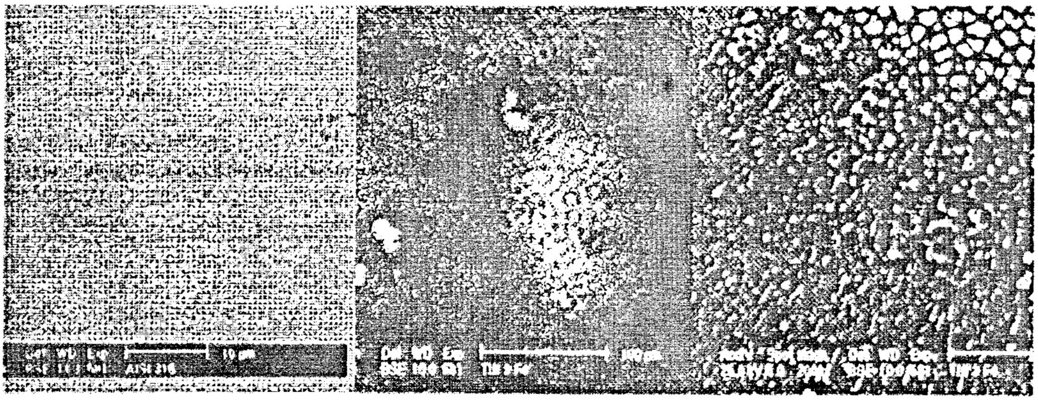

Fig. 2 (a-c). The morphology of TiN coating changes induced by 340 pulses of TEA CO_2 laser: a- as deposited coating surface, b- central part of the spot and c- rim of the spot periphery.

SEM analyses have shown that the target surface of this type of interaction shows signs of superficial melting. Heating in the zone of interaction must be the primary process of laser sputtering ablation (Nenadović et al. 1992).

Each shot after twenty pulses ignites a discharge in front of the target. The emitted particles above the target surface form a plume. The plume above the surfaces is always present after about twenty pulses. It increases up to 3-4 mm after about 100 pulses. The present of the plum suggests that there are also a thermal effects in sputtering (desorption and ablation) connected with induced surface morphology.

The X-ray analyses have shown that the composition of heated area differs from those of as deposited materials. The processes form an alloy layer of a specific composition. The analyses (EDAX) of the composition (^{w}/o) of the targets are presented on the Table 1. The obtained composition do not improve the cutting properties of laser bombarded coatings.

Table 1. The EDAX analyses of the targets.

	Ti	N	Fe	Cr	Ni	(Mo,Mn,Si)
substrate AISI 316	-	-	66.27	17.74	12.65	3.43
coating TiN on AISI 316	49.05	24.88	17.25	5.20	3.16	0.47
dark area in the bombarded zone	68.33	-	21.05	6.63	3.99	-
bright area in the bombarded zone	6.92	-	59.37	16.04	11.68	5.99

4. Conclusions

The interaction of the radiation of laser radiation of TiN coatings can be summarized as follows:

- Laser induced processes in central part of the spot cause the decomposition of the coatings and wave like structure in the interaction area. The distance between two following waves is about 10 μm, which corresponds to the wavelength of TEA CO_2 laser radiation.
- In the outer zones pulse shots produced thermally activated changes: material removal out of the interaction region and droplet formation. Solidified droplets melting of TiN are noticeable. Subsequently fast heating and cooling during multi-pulse laser bombardment cause the grain growth in the bombarded zone.

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