# PHYSICAL CHEMISTRY 2008

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***of the 9th International Conference on Fundamental and Applied Aspects of Physical Chemistry***

***Volume II***

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# SURFACE MODIFICATIONS OF TiN COATING BY PULSED IR LASERS: TEA $CO_2$ AND HF LASER

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## Abstract

Interactions of a pulsed Transversely Excited Atmospheric (TEA) $CO_2$ and chemical HF laser with polycrystalline titanium nitride (TiN) coating deposited on high quality steel AISI 316, were studied. It was shown that both lasers, at energy densities of 43 J/cm$^2$ and 38.6 J/cm$^2$, induce morphological changes on the target. The HF laser produces more pronounced damage than the TEA $CO_2$ laser. The energy absorbed from either of these lasers is mainly converted into thermal energy.

## Introduction

Surface modification studies of titanium-based ceramic coatings, especially titanium nitride deposited on steel substrates, by various types of energetic beams including the laser beam are of great fundamental and technological interest. There are not many papers in literature dealing with interactions of the TEA $CO_2$ [1] or HF [2] laser with TiN. The TiN coating has extraordinary properties, applied in industry, microelectronics, bio-medicine, etc.

The present paper deals with morphological effects of pulsed IR lasers emitting at ~10 μm (TEA $CO_2$ laser) and ~2.8 μm (HF laser) on polycrystalline TiN coatings deposited on high quality steel AISI 316.

## Experimental

TiN coatings (typical thickness 1 μm) were deposited on a steel substrate by: (i) reactive d.c. magnetron sputtering or (ii) vacuum arc deposition. The steel substrate was in the form of a plate.

Irradiations were performed with laser beams focused by KBr ($CO_2$ laser) and NaCl (HF laser) lenses of focal lengths 6.0 cm and 13.0 cm respectively. The angle of incidence of the laser beams with respect to the surface plane was 90°. The irradiation was carried out in air, at a pressure of 1013 mbar. Both TEA $CO_2$ and HF lasers were typically operated in the $TEM_{00}$ mode. Conventional $CO_2/N_2/He$ gas mixtures were used for the TEA $CO_2$ laser [3] yielding pulses with a gain switched peak followed by a slowly decaying tail. The HF laser operated with typical $H_2/SF_6$ mixtures [4].

Various analytical techniques were used for characterization of the samples, like X-ray diffraction (XRD); optical microscopy (OM); scanning electron microscopy (SEM) and atomic force microscopy (AFM). The SEM was coupled to an

Energy Dispersive Analyzer (EDX). A profilometer was used to characterize topographic changes of the irradiated area.

## Results and Discussion

X-ray analysis of the TiN coating prior to laser irradiation confirmed its polycrystalline structure. Laser induced TiN morphological changes showed dependence on beam characteristics: primarily on the energy density, peak power density, pulse duration, number of pulses, wavelength, etc.

Morphological changes of TiN resulting from 500 and 100 accumulated pulses for TEA $CO_2$ and HF laser are presented in Figure 1 and 2, respectively. The regime of high *l*aser *r*adiation *e*nergy *d*ensities (LRED) was applied. The induced modifications can be presented as follows:

***The TEA $CO_2$ laser***

After 500 pulses at 43 J/cm$^2$ (Figs. 1B1,B2) the morphology features at the surface were: (i) complete removal of the TiN coating, in the central zone, and appearance of relatively rough bottom; (ii) appearance of hydrodynamic effects at the periphery, in the form of resolidified droplets (Fig. 1B1); almost three outer damage zones can be observable at the periphery.

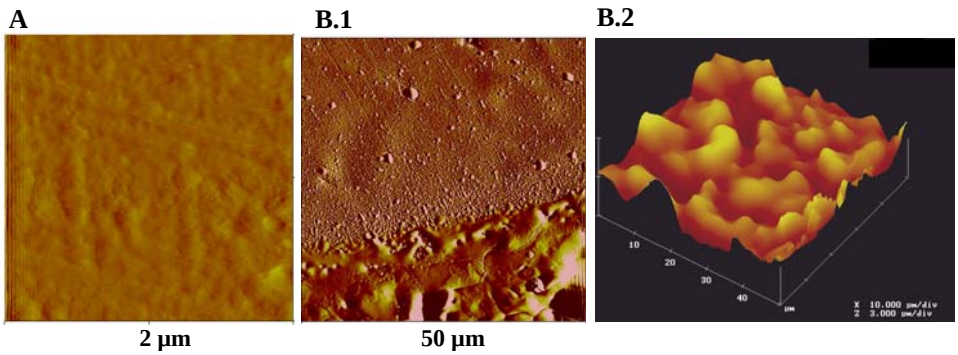


**Fig. 1.** TEA $CO_2$ laser-induced morphological changes of the TiN coating/steel, AFM analysis. Pulse width 120 ns (initial spike, FWHM). (A), (B)- Views of the TiN prior to and after 500 laser pulses, respectively.

***The HF laser***

The HF laser radiation at 38.6 J/cm$^2$ modified the TiN coating, Figure 2. Changes on the surface were: (i) ablation of the TiN coating in the central zone accompanied with partial material "lifting", Fig. 2B1; (ii) appearance of the accumulated material in the peripheral direction (crown-like form), Fig. 2B1; and (iii) appearance of roughly three concentric damaged zones on the periphery.

Generally, the energy absorbed from the TEA $CO_2$/HF laser beam is assumed to be converted to thermal energy which causes melting, vaporization of the molten material, shock waves, etc. Calculation showed that target surface tempera-

ture reached quite high values, i.e. about 3300 and 4000-6000 K for TEA $CO_2$ and HF lasers, respectively. These temperatures practically exceed the temperatures for TiN decomposition.

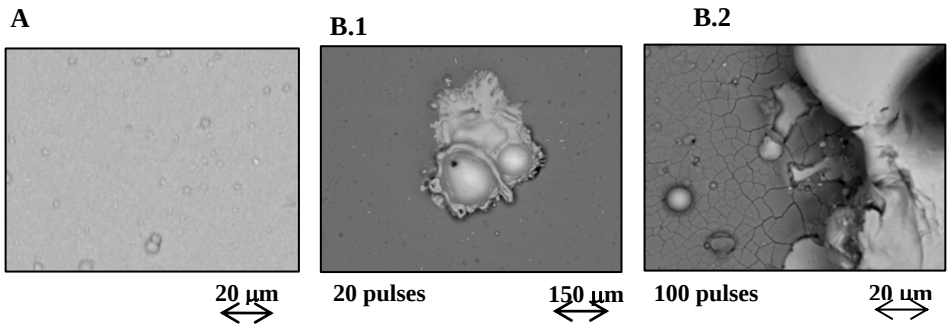


**Fig. 2.** HF laser-induced morphological changes of the TiN coating/steel, SEM analysis. Pulse width 230 ns (FWHM). (A), (B) - Views of the TiN coating prior to and after 100 laser pulses, respectively.

## Conclusion

A study of morphological changes of TiN coating deposited on steel AISI 316, induced either by a TEA $CO_2$ or a HF laser is presented. It was shown that both lasers induce morphological changes on the target. The HF laser action at a wavelength of 2.8 μm exhibits more pronounced damage than the TEA $CO_2$ laser at 10.6 μm. This is in correlation with a higher TiN absorptivity at the wavelength of 2.8 μm. Under the present experimental conditions, it is clear that the IR laser wavelength used has an important role in producing different morphological effects on the TiN coated steel.

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