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Free Electron Laser Nitriding of Metals: From basic physics to industrial applications[1]

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Functional or smart surfaces and coatings play an increasingly decisive role for the applicability and performance of all modern materials, and numerous methods were developed for their fabrication, stretching from simple PVD and CVD processes to complicated plasma and hybrid methods. Recently, it was established that short laser pulses of high enough energy can induce a direct laser synthesis of functional coatings if the materials surface is irradiated in a reactive atmosphere. The process is based on complicated and combined laser plasma gas material interactions. The Free Electron Laser (FEL) can be just the right tool to drive the mentioned process into the direction of industrial applicability. The high power and the flexibility in its temporal shaping of the FEL at the Jefferson Lab was the drive to make first experiments on the direct laser synthesis of functional coatings. Titanium, aluminum, silicon and steel have been treated with the FEL in pure nitrogen atmosphere at 0.1 MPa pressure. The wavelength of the irradiation was 3.1 micron with a micropulse repetition rate of 37 MHz. The micropulses were shaped to macropulses with durations ranging from 50 to 1000 μs at 2 to 60 Hz. A meandering scanning technique was used to irradiate larger areas. The produced coatings were investigated by a number or methods (X-ray diffraction including stress and texture analysis, elemental depth profiling by resonant nuclear reaction analysis and Rutherford backscattering spectrometry, nanoindentation hardness, Scanning electron microscopy, EDX). The obtained results correlate to numerical simulations of the melt bath, diffusion and solidification dynamics. For titanium, it was found that TiN coatings of up to 100 micron thickness could be easily produced. Furthermore, (100) texturing of the TiN could be obtained for certain timings of the FEL, which could be explained by the numerical modeling and solidification behavior during the FEL irradiation.

(1) E. Carpene, M. Shinn, and P. Schaaf. Synthesis of highly oriented TiNx coatings by free electron laser processing of Ti in nitrogen gas. Applied Physics A 80 (2005) 1707-1710.

(2) P. Schaaf, M. Kahle, and E. Carpene. Reactive Laser Plasma Coating Formation. Surface and Coatings Technology 200 (2005) 608-611.

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