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Titanium target irradiation by picosecond laser in air and water – surface morphology and synthesis of nanoparticles

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Titanium target was irraditiated by picosecond lasers with pulse lengths **40 ps** and **150 ps** in **air and water** environment. The goal was studying of the induced surface features in both ambiences, as well as synthesis of **Ti-based nanoparticles (NPs) in liquid**. Morphologies of the target were studied by scanning electron microscope (SEM) and profilometry, while chemical analysis of the surface was done by energy-dispersive spectrometry (EDS). Interaction ps laser-Ti depends on a number of parameters – laser parameters, target surface condition, working ambience, etc. Irradiation conditions in this work were as follows: **τ=40/150 ps, wavelength 1064 nm, pulse frequency 10 Hz, pulse energy 2-20 mJ, pulse count 3000-9000, irradiation in focusing regime**. Generally, induced features differ in air and water surrounding – damage is more diffuse in water, with characteristic wavy surface. In both media **laser-induced periodic surface structures (LIPSS)** are observed on the damage periphery, however they appear at lower pulse count in water. Irradiation of Ti in water led to creation of nanoparticles (NPs) in most cases as established by UV-Vis spectrophotometry, and their size distribution was determined by DLS (dynamic light scattering) analysis. These were, as expected, Ti-oxide NPs as laser ablation in water always leads to formation of oxide particles except in case of noble metals. The size and shape of NPs obtained using laser ablation in liquid (LAL) method depends strongly on the liquid medium used, as well as laser parameters. In our case NPs were spherical, sized from few tens to few hundreds of nanometers, with occurrence of smaller particles in case of 150 ps laser. With further optimization of conditions obtaining of smaller NPs can be expected.

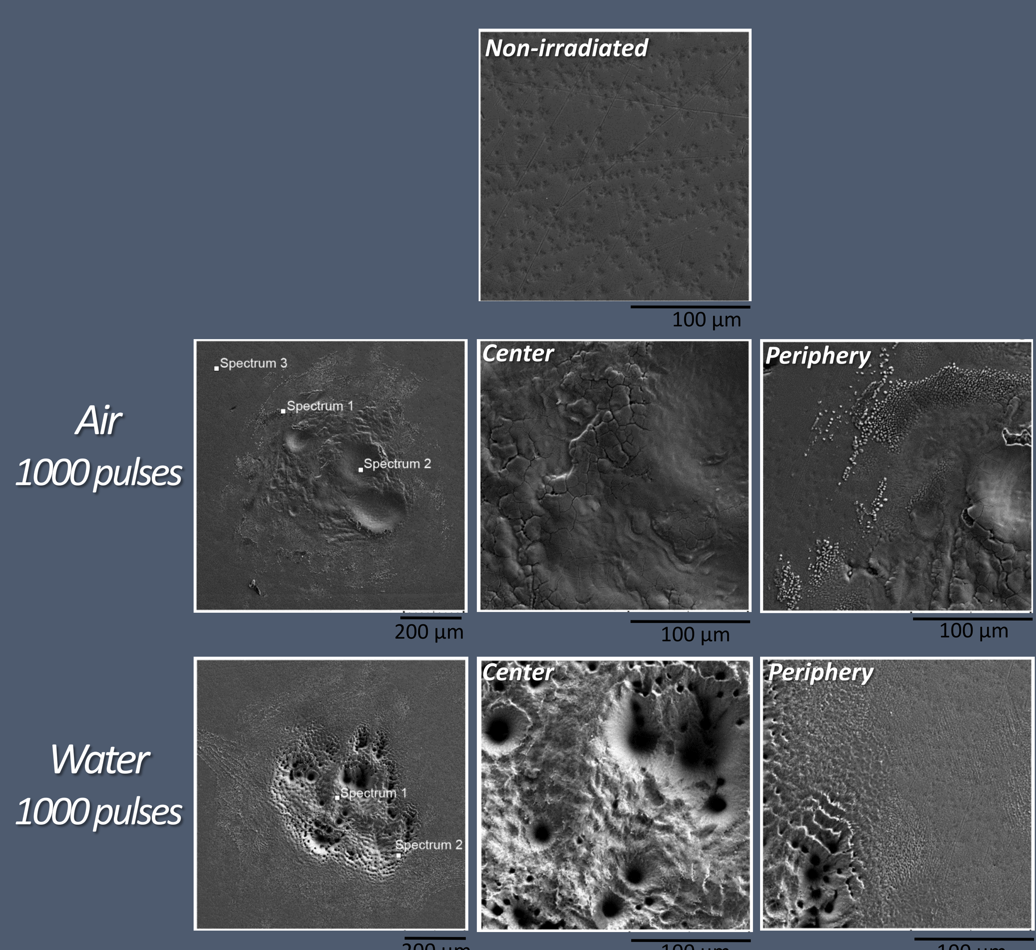

Fig. 1. SEM analysis of the Ti-target after 1000 pulses.
Air atmosphere: E = 17 mJ ($\Phi_1 \approx 10.0$ J/cm^2, $I_1 \approx 2.5 \times 10^{11}$ W/cm^2).
Water ambience: E = 17 mJ ($\Phi_2 \approx 7.6$ J/cm^2, $I_2 \approx 1.9 \times 10^{11}$ W/cm^2).

Surface modifications of titanium with **40 ps**-laser radiation have shown:
(i) Strong dependence on the ambience used;
(ii) ***Air*** – lower damage spot with diffuse character on the periphery. Presence of hydrodynamic and cracking effects. Appearance of LIPSS (*Laser Induced Periodic Surface Structures*) on the periphery at lower pulse count; ***Water*** – damage depth is higher. Rough surface, with prominent sponge-like character. LIPSS generation;
(iii) Irradiation in both ambiences followed by ***plasma formation*** which was more confined in water.

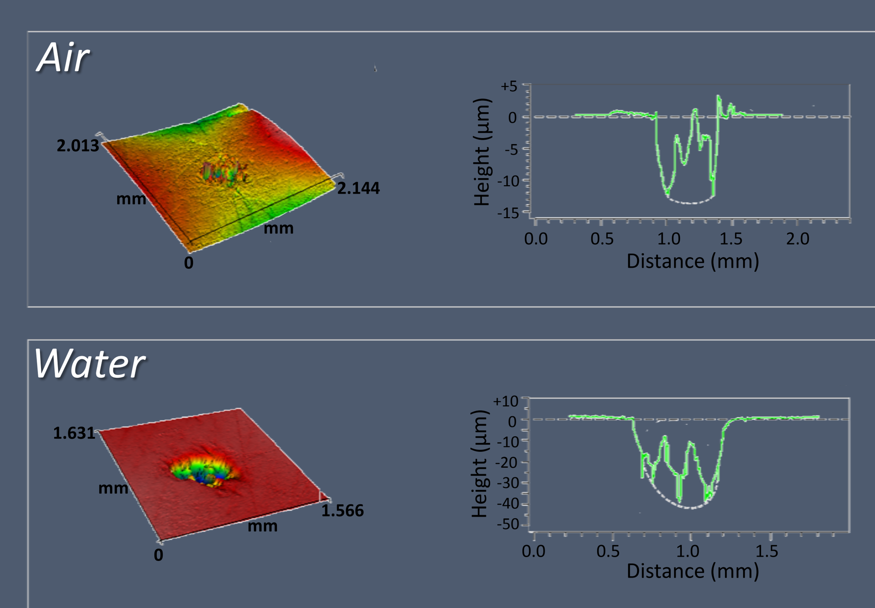

Fig. 2. 3D and 2D profilometric analysis.
Air atmosphere: E = 17 mJ ($\Phi_1 \approx 10.0$ J/cm^2, $I_1 \approx 2.5 \times 10^{11}$ W/cm^2).
Water ambience: E = 17 mJ ($\Phi_2 \approx 7.6$ J/cm^2, $I_2 \approx 1.9 \times 10^{11}$ W/cm^2).

Target topography highly impacted by the ambience : damage depth much higher in water (**40 µm**) than in air (**14 µm**).

Table 1. *Local EDS elemental analysis (after 1000 pulses) in dependence on the used ambience.*

	Air (sp. 2*, wt%)	**Water** (sp. 1*, wt%)	**Non-irrad. region** (wt%)
C	0.3	0.5	0.4
O	/	6.4	0.2
Ti	99.7	93.1	99.4
Total	100		

* Measuring locations (central damage zone) are given in Fig. 1.

It should be pointed out that irradiation in water environment enables direct collection of synthesized **titanium based nanoparticles** (Fig. 3).

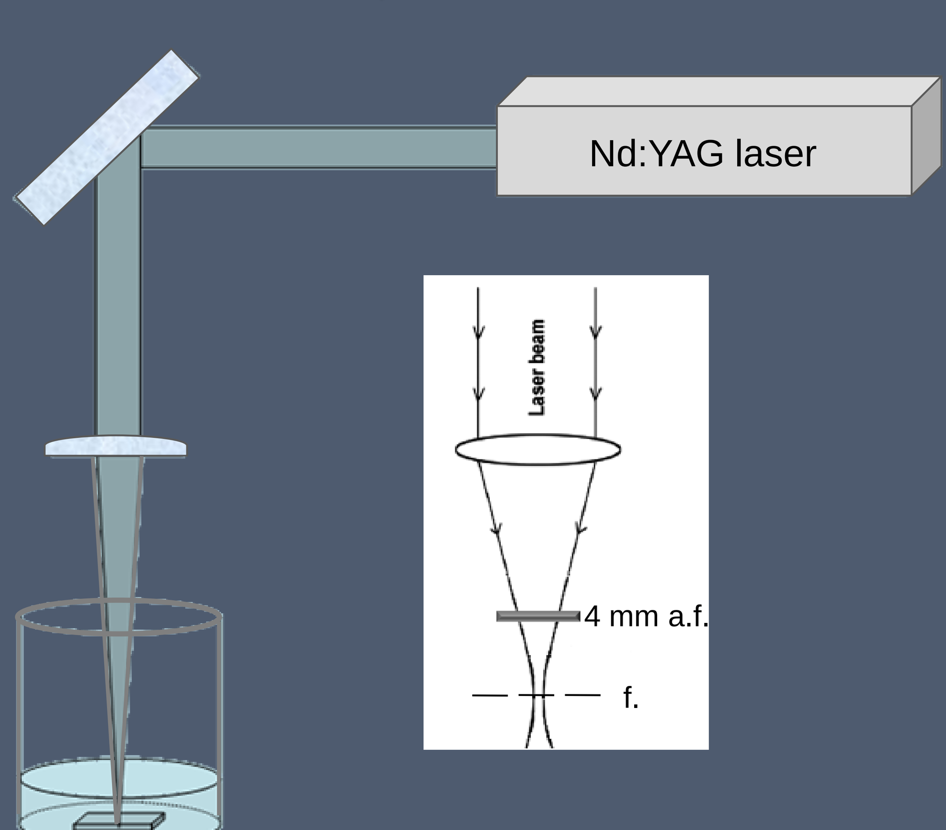

Fig. 3. *Exp. setup for synthesis of nanoparticles by laser ablation in liquid.*

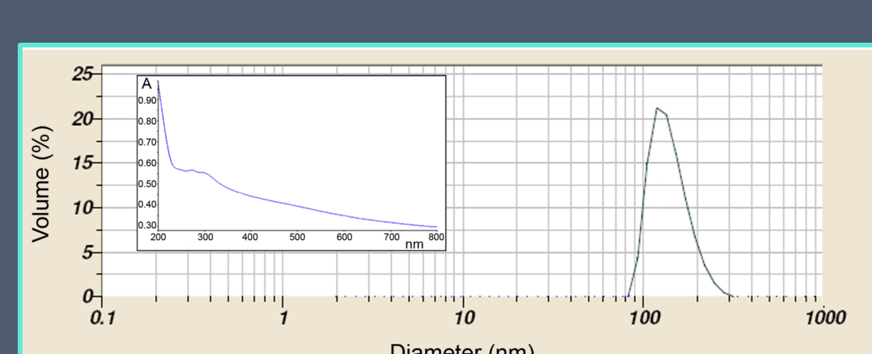

Fig. 4. *Size distribution of Ti-based NPs in water and corresponding UV-Vis spectrum - inset.*
(τ = 40 ps; E = 17 mJ; I≈ 1.9 × 10^{11} W/cm^2; pulse count 9000)

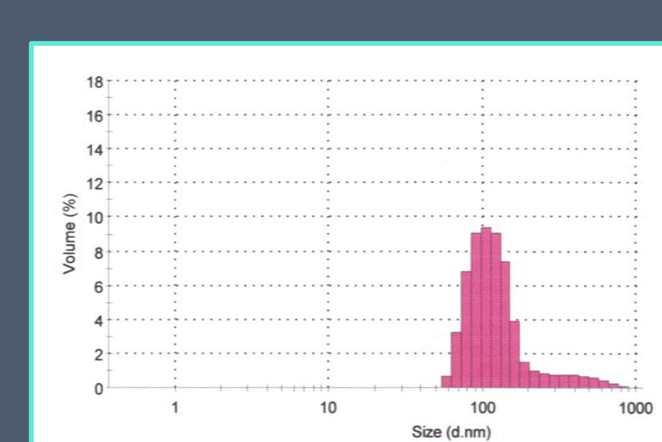

Fig. 5. *Size distribution of Ti-based NPs in water.*
(τ = 150 ps; E = 17 mJ; I≈ 1.9 × 10^{11} W/cm^2; pulse count 9000).

The action of ps-lasers (τ = 40 ps and τ = 150 ps) induced generation of titanium-based nanoparticles in water – more specifically, Ti-oxide NPs spherically shaped. Initial results have shown that longer laser pulses have some advantage (NPs size peak at 100 nm, τ = 150 ps) compared to shorter pulses (NPs size peak 150 nm, τ = 40 ps).

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