SELECTIVE ABLATION AND LASER INDUCED PERIODICAL SURFACE STRUCTURES (LIPSS) PRODUCED ON (Ni/Ti) NANO LAYER THIN FILM WITH ULTRAFAST LASER

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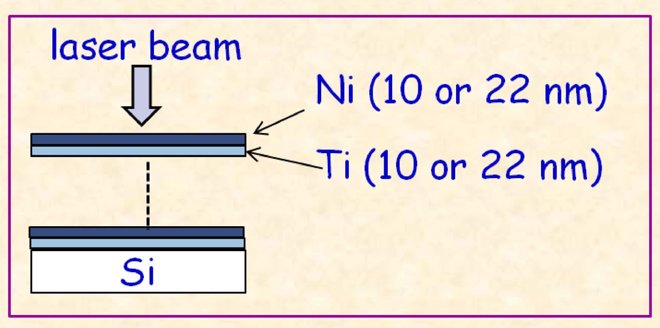
INTRODUCTION

- Thin metalic films have broad applications in the modern life. Among them, nano layered thin films (NLTF) with alternated layers of different materials are important for usage as catalytic components, optical devices, photovoltaic gas sensors, mirrors for ultraviolet and soft x-rays lasers, etc.
- Ultra fast laser (UFL) processing (pulse duration from a few tents of fs to 10 ps) uses in precise modifications of materials on micro-/nano-meter scale.
- UFLs can be used to selectively remove a specific layer or the entire NLTF from the substrate, and formation of laser induced periodical surface structures (LIPSS) on them.
- In this study we identify the "window" -interval of laser parameters needed to achieve partial/selective ablation of nanolayer Ni/Ti thin films, and produced LIPSS.

EXPERIMENTAL

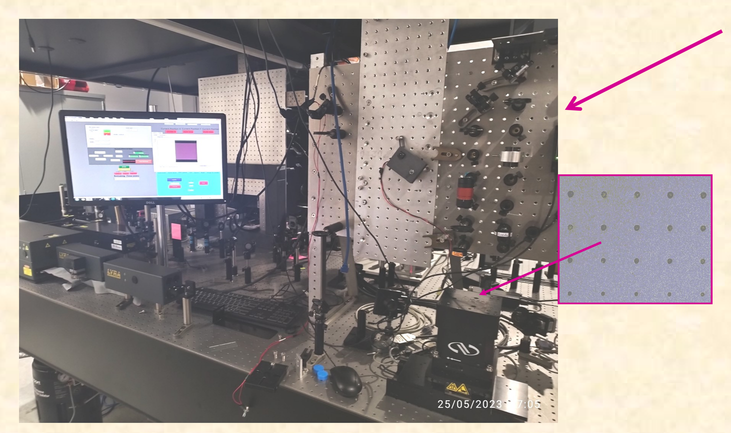
Samples used in the experiment- preparation



The samples- NLTF were deposited by ion sputtering (PVD) in a single vacuum run, at constant rate for all components without heating of the Si substrate.

I. 5x(Ni/Ti)/Si, thickness ~ 100 nm, Ni is the top layer (a single layer ~ 10 nm)
II. 10x(Ni/Ti)/Si, thickness ~ 440 nm, Ni is the top layer (a single layer ~ 22 nm)

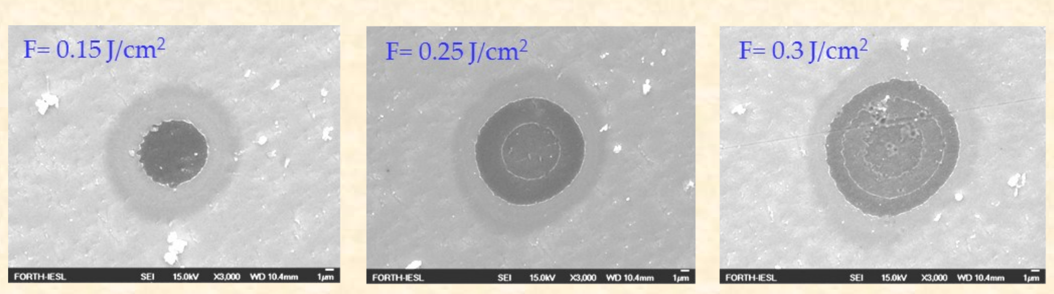
Laser and irradiations



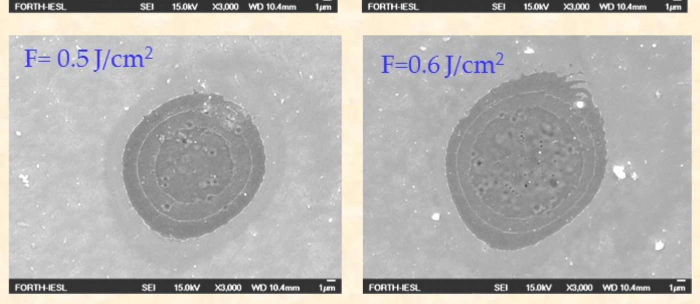
Experimental set up.
Irradiation was done in air by UFL (λ=1026 nm, t=170fs, R=1 kHz) with single and multy pulses. Gaussian beam was focused onto a sample surface through a microscope and $1/e^2$ radii was 27 μm.
For achieving selective ablation, the single pulse energy was gradually increased from near the ablation threshold to a level that completely removed the NLTF.
Multi pulse irradiation was done in the static mode by 1,2,3,5,10, 20, and 50 pulses delivered on the same place.

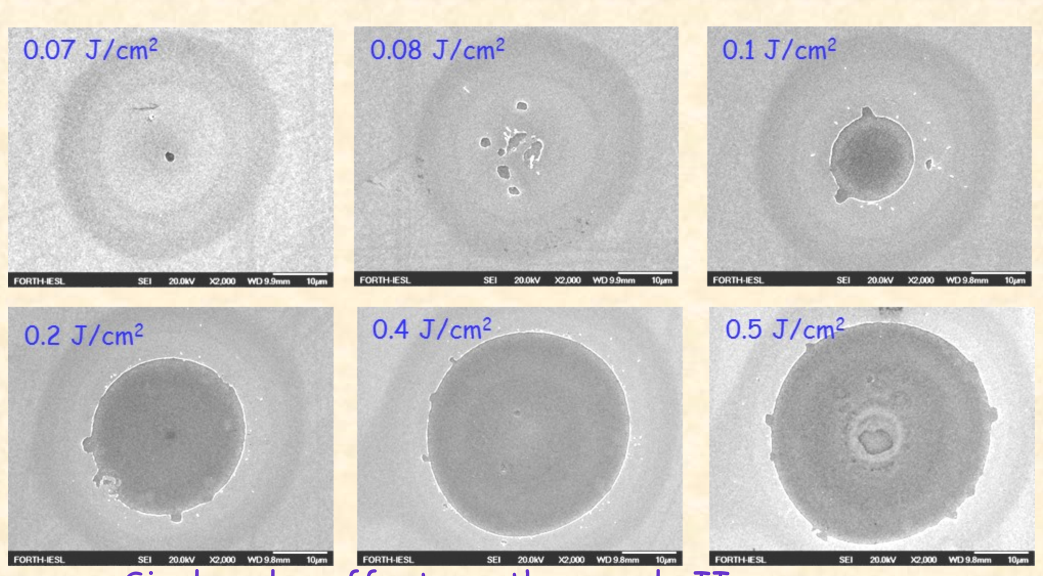
RESULTS

SEM-Selective ablation/spallation



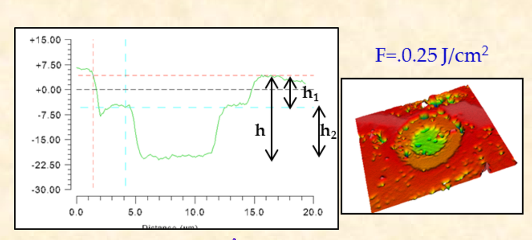
Single pulse effects on the sample I





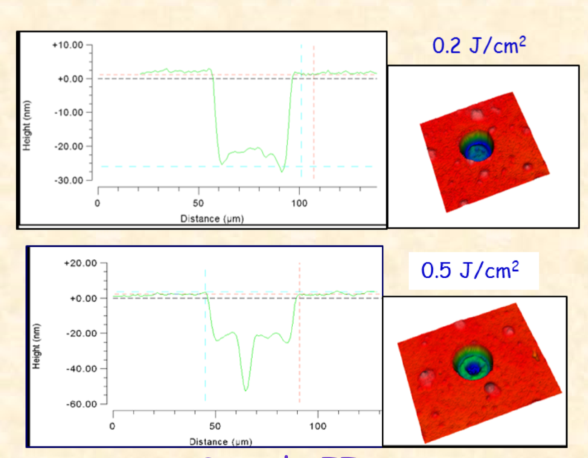
Single pulse effects on the sample II

PROFILOMETRY



Sample I

Pulse fluence [J/cm²]	h-total depth (nm)	h_1 [nm]	h_2 [nm]
0.15	10.9		
0.20	11.1		
0.25	24.2	9.6	14.6
0.30	~43.5	10.5	12.6
0.50	-	9.9	12.1
0.60	-	10.9	18.7

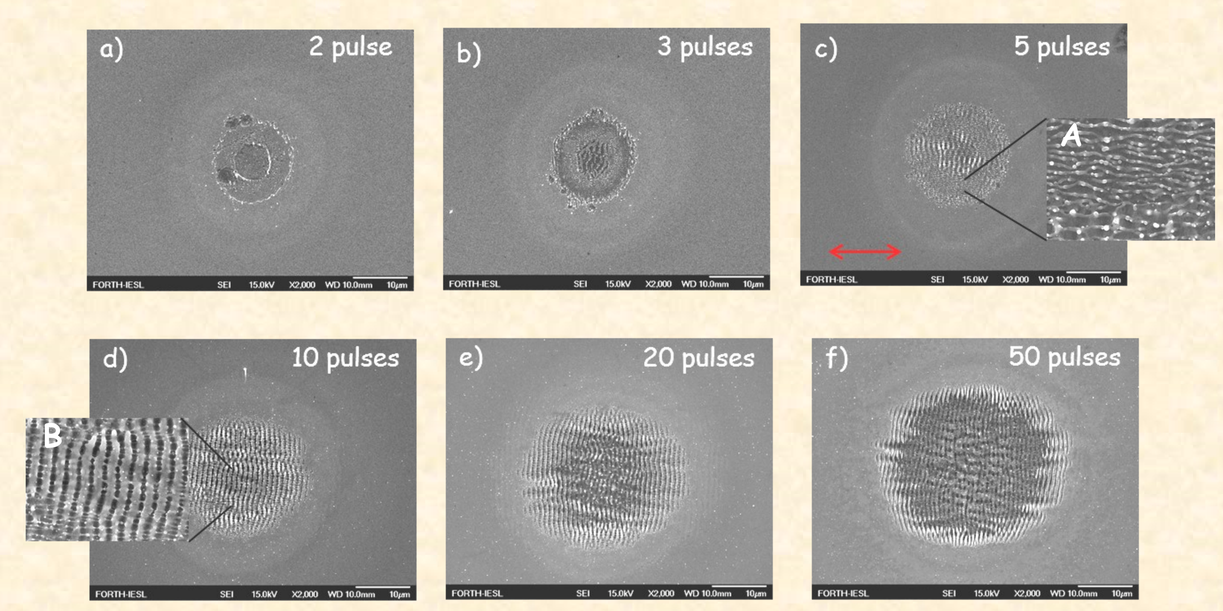


Sample II

Pulse energy fluence [J/cm²]	h-total depth (nm)	h1-first step (nm)
0.1	24.0	-
0.2	24.6	-
0.3	26.0	-
0.4	26.0	-
0.5	59.0	23.0
1.15	>440	25.0

SEM-LIPSS formation

Multi pulse effects on the sample II



B: Low-spatial frequency LIPSS (LSFL), L> λ/2, ~ 800 nm

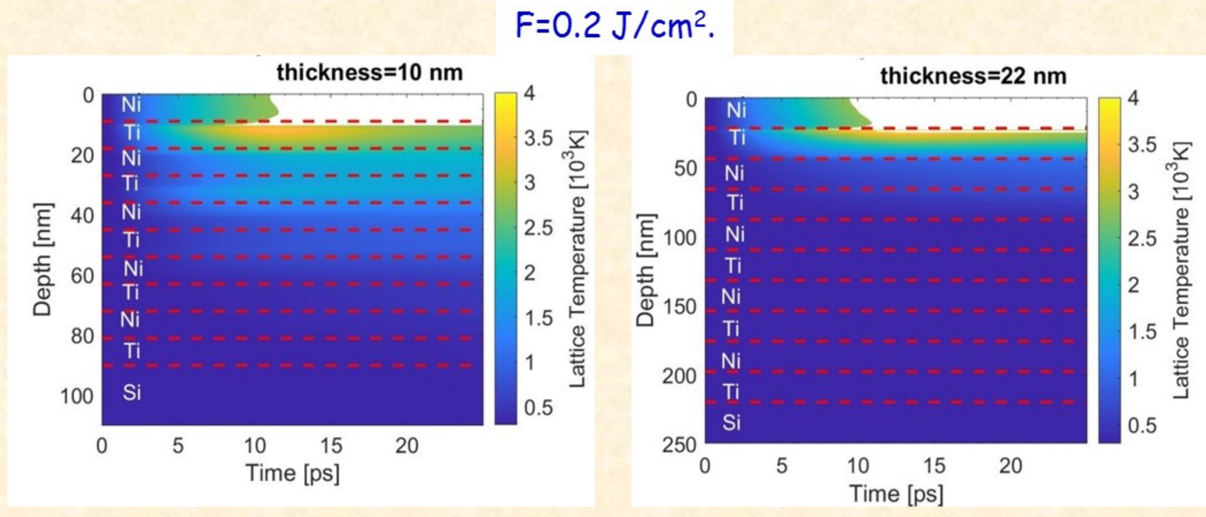
F= 0.08 J/cm²

A: High-spatial frequency LIPSS (HSFL), L < λ/2, ~ 200 nm

Temperature evolution after single pulse irradiation

Due to the fact that the laser spot radius is substantially larger than the film thickness, an 1D Two Temperature Model (TTM) can sufficiently describe the relaxation process following electron excitation and thermal respons of NLTFs after fs laser heating.

F=0.2 J/cm².



Lattice temperature field evolution in depth, perpendicular to the surface of the sample. White region indicates temperatures leading to the material removal, horizontal dashed lines indicate the borders of each layer.

CONCLUSIONS

Single-shot femto second laser ablation of NLTF demonstrated selective, pulse energy/ fluence-dependent process.
Removal with UFL irradiation of a single layer from the surface of the NLTFs was recorded at particular fluence intervals (I: 0.15 -0.20J /cm², II: 0.10-0.40 J/cm²).
Better results, conncernindg selective ablation are achieved with thiner bilayer, the sample I.

LIPSSs were formed on both NLTFs. The best produced LIPSS were acheived on the sample II after 10 pulses, and at the fluence near to the ablation treshold.

Presence of an interface between metal layers in the NLTF helps selective ablation of the first layer from the rest of the films.
Selective ablation was registered in the irradiated areas/craters inside the layers too! The inside rapture can be attributed to the interference of rarefaction waves, caused by UFL irradiation, propagating toward each other from the free surface and the interface.

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ACKNOWLEDGEMENTS

B.Gaković and S.Petrović thanks to NFFA-Europe platform (grant ID 259) for supporting them to use facilities at Institute of Electronic Structure and Lasers, FORTH, Greece. This work was supported by the Ministry of Science, Technological Development and Innovation of the Republic of Serbia (projects No. 451-03-47/2023-01/ 200017).