RAPID LARGE-SCALE NANOSTRUCTURING TECHNIQUES WITH UP TO 40401 BEAMS AND PRODUCTIVITY UP TO 5.2 MIN/M^2

P. Hauschwitz[1*], J. Martan[2], R. Bičišťová[1], C. Beltrami[2], D. Moskal[2], A. Brodsky[3], N. Kaplan[3], J. Mužík[1], D. Štěpánková[1], J. Brajer[1], D. Rostohar[1], J. Kopeček[4], L. Prokešová[2], M. Honner[2], V. Lang[2], M. Smrž[1], T. Mocek[1]

[1] Hilase Centre, Institute of Physics, Academy of Sciences of the Czech Republic, Za Radnici 828, Dolni Brezany 25241, Czech Republic.
[2] New Technologies Research Centre (NTC), University of West Bohemia, Univerzitni 8, 30100 Plzen, Czech Republic.
[3] R&D Department, Holo/Or Ltd, Einstein 13b, Ness Tziona 7403617, Israel
[4] Institute of Physics of the Czech Academy of Sciences, Na Slovance 2, Prague, Czech Republic

INTRODUCTION

Suitable topography of structured surfaces may allow attaining innovative surface properties including friction reduction, superhydrophobicity, self-cleaning, anti-icing and many more. Despite a list of attractive applications of functional surfaces and demonstrated capability of lasers to produce them, the speed of laser micro and nanostructuring is still low with respect to many industry standards. In this work, we introduce a unique combination of high-energy pulsed ultrashort laser system HiLASE PERLA with up-to-date most promising multi-beam micro and nanostructuring technologies able to produce for example more than 40,000 beamlets with productivity over 1900 cm^2/min.

METHODS

Stainless steel plates (AISI 316L) were treated by selected Ytterbium based diode pumped solid-state laser system Perla (HiLASE, Czech Republic) emitting 1.7 ps pulses with M2 of 1.15 and wavelength of 1030 nm. The laser system can be operated at different repetition rates reaching either high average power of 200 W with the repetition rate of 50 kHz and 100 kHz or high pulse energy up to 20 mJ with 1 kHz repetition rate.

The input laser beam was guided through MS-805-I-Y-A or MS-835-J-Y-X (Holo/Or Ltd., Israel) generating a square shape matrix of 51x51 sub-beams with the spacing of 20 µm or matrix of 201x201 beams with the spacing of 5 µm, respectively. In both cases, the size of the square-shaped matrix on the sample was ~1 mm. In the following step, the beam was guided through the high dynamic galvo-scanner system (Scanlab GmbH, Germany) and focused on a sample using a telecentric F-theta lens with the focal length of 100 mm or used with a high NA lens to focus each sub-beam below 5 µm.

RESULTS

2601 nanostructured microcraters with diameter below 20 µm and 40 401 nanostructured microcraters with diameter below 5 µm ordered in square-shaped matrixes covering an area of 1X1 mm were fabricated simultaneously with 51x51 and 201x201 elements, respectively. To cover larger areas, the sample has to be moved to a different position for 201x201 element coupled with high NA objective or the whole matrix can be shifted by the galvanometric scanner in the case of 51x51 element. The advantageous square shape of the beam matrix allows 0% overlap and thus productive matrix stitching over the sample.

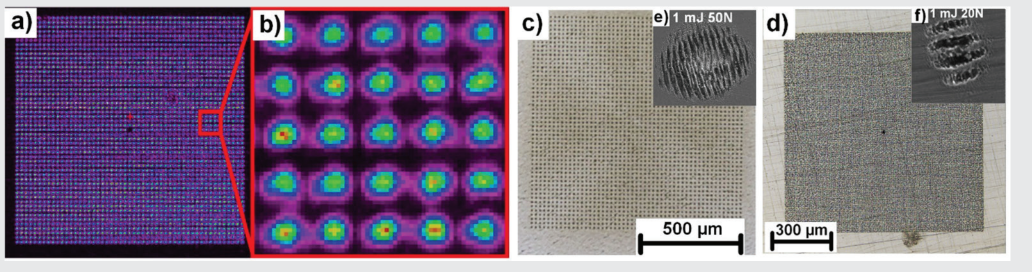

FIGURE 1. (A),(B) CAMERA IMAGE OF BEST-QUALITY MATRIX ACHIEVED FOR 51X51 ELEMENT; (C) SUB-BEAM MATRIX FABRICATED ON A STAINLESS STEEL SURFACE WITH THE USE OF 51X51 ELEMENT; (D) SUB-BEAM MATRIX FABRICATED ON A STAINLESS STEEL SURFACE WITH THE USE OF 201X201 ELEMENT; (E) SEM IMAGE OF MICROCRATER COVERED BY NANOGRATING FABRICATED BY SINGE SUB-BEAM IN 51X51 MATRIX; (F) SEM IMAGE OF MICROCRATER COVERED BY NANOGRATING FABRICATED BY SINGE SUB-BEAM IN 201X201 MATRIX.

To demonstrate the maximal throughput for nanograting fabrication, the sample area of 40x40 mm was irradiated by the maximum available average power of 200 W at 100 kHz producing nanograting with the periodicity of ~400 nm by 5 consecutive laser pulses and nanograting with the periodicity of ~900 nm by 50 consecutive laser pulses (see Figure 2). The matrix was shifted by galvanometric scanner with the scanning speed of 9 m/s resulting in a throughput of 1910 cm2/min and 797 cm2/min for microcraters covered by 400 nm and 900 nm nanogratings, respectively.

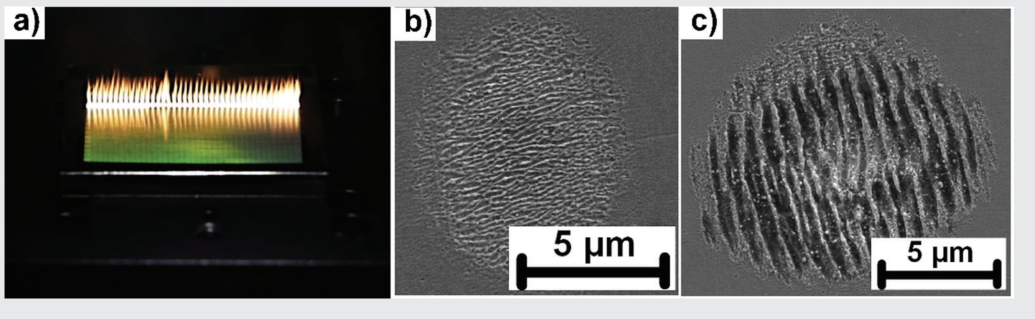

FIGURE 2. (A) PHOTOGRAPHY OF THE FABRICATION PROCESS WITH 200 W OF AVERAGE POWER, SCANNING SPEED OF 9 M/S UTILIZING THE 51X51 ELEMENT; (B) DETAIL OF NANOGRATING FABRICATED BY 5 CONSECUTIVE PULSES; (C) DETAIL OF NANOGRATING FABRICATED BY 20 CONSECUTIVE PULSES.

CONCLUSION

With the use of advanced multi-beam processing approaches the speed and efficiency of nanostructuring with high power ultrashort laser systems can be dramatically improved. Several approaches including DOE beam splitting, interference patterning and dynamic beam shaping have been introduced and compared with respect to the throughput during the production of nanogratings. The highest throughput reached 1910 cm^2/min with the use of high power and high quality ultrashort laser system

HiLASE Centre · Institute of Physics of the ASCR, v.v.i.
Za Radnici 828, CZ-25241 Dolni Brezany
solutions@hilase.cz · (+420) 314 007 718 / 314 007 710 · www.hilase.cz

hilase-centre · HiLASECentre · HiLASECentre · HiLASECentre

RELEVANT RESOURCES
www.hilase.cz/en/lmm-relevant-resources

Czech Academy of Sciences

EUROPEAN UNION
European Structural and Investment Funds
Operational Programme Research, Development and Education

MINISTRY OF EDUCATION, YOUTH AND SPORTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 739573 (HiLASE CoE)

FZU Fyzikální ústav Akademie věd České republiky