Study of LIPSS replicas for surface enhanced spectroscopy

Ye.S. Hrabovskyi [1], N.I. Berezovska [1], I.M. Dmytruk [1], A.M. Dmytruk [2]

[1] Faculty of Physics, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine

[2] Institute of Physics of the NAS of Ukraine, Kyiv, Ukraine

We present results of initial studies of surface nanostructures created by mechanical imprinting of LIPSS onto soft metal substrate. Surface enhancement of Raman signal of test substance (Rhodamine 6G) on obtained nanostructured surface was observed.

- ***Motivation*** Laser induced periodic surface structures (LIPSS) are extensively studied since their discovery in 1965. This phenomena invokes interest both as a manifestation of complex processes of light-matter interaction and as a surface functionalization tool. [1]
- Potential applications of LIPSS include: structural color creation, liquid transport and surface wetting, modification of surface properties related to cell and bacteria growth, surface catalysis (heterogeneous catalysis), tribology, surface radiation emission, absorption and scattering efficiency modification, surface-enhanced photoluminescence and Raman spectroscopy. [2]
- Most of these applications require the homogeneous processing of LIPSS on large surface areas. Influence of laser surface structuring byproducts (re-deposited nanoparticles, surface oxidation) on resulting properties although should be taken into consideration.

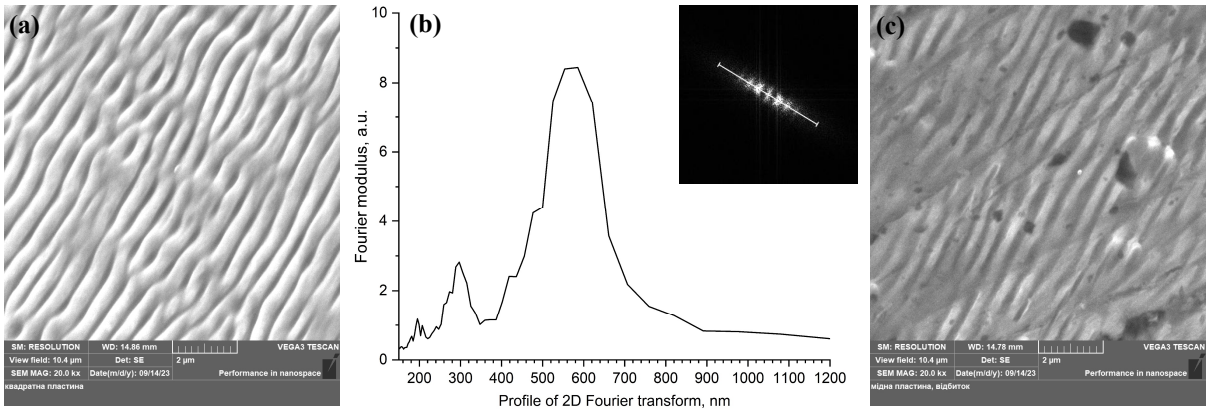

Fig. 1: (a) - SEM image of LIPSS created by irradiation of molybdenum foil with linearly polarized 800 nm radiation of femtosecond Ti/sapphire laser, LIPSS period 570 nm; inset (b) - 2D Fourier transform of this SEM image; (b) - 2D Fourier transform profile; (c) - SEM image of imprint of LIPSS on copper foil.

Some of the topical problems in the field are:

- Contributions of topography and chemical effects accompanying the formation of LIPSS to resulting surface properties
- Reproducibility – LIPSS characteristics depend on many parameters of laser beam, material and irradiation setup [1]
- Speed and price of large area surface modification [2]
- Problems of creation of particular types of LIPSS on specific materials, for example creation of highly regular LIPSS on plasmonically active metals [3]

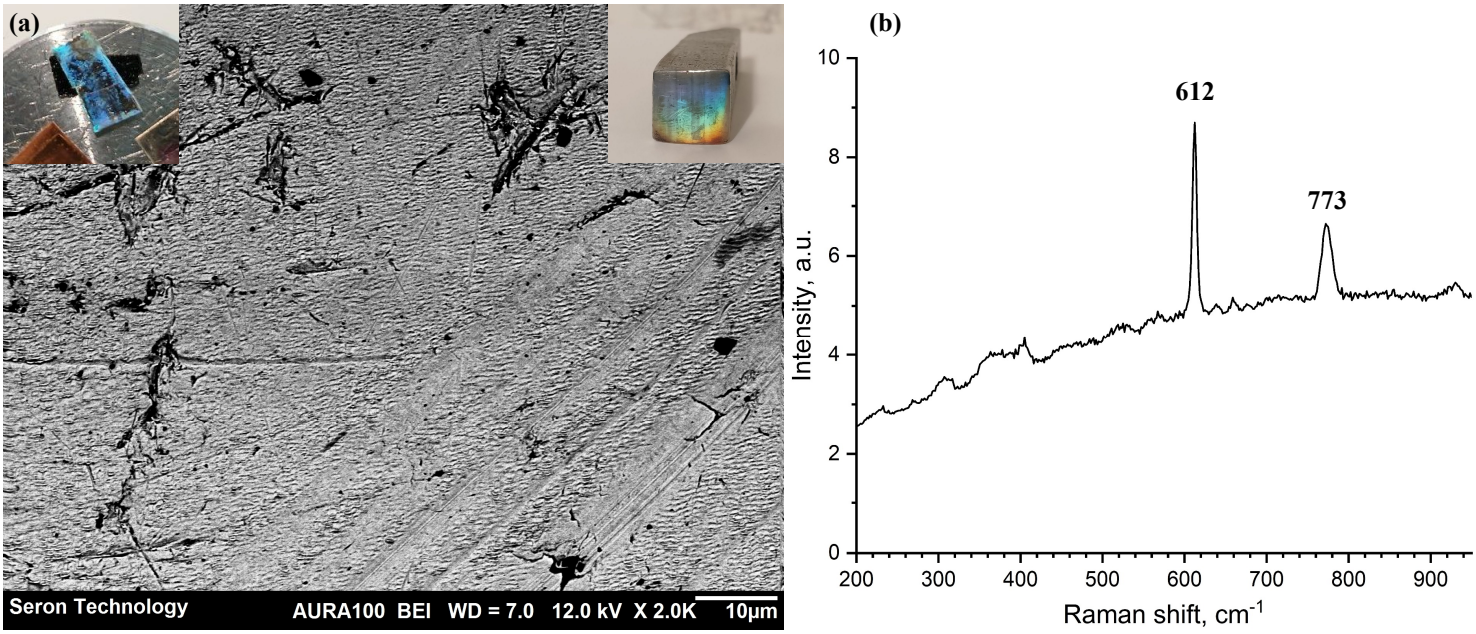

Fig. 2: (a) - SEM image of imprint of LIPSS on steel onto silver foil; left inset (a) - photo of silver foil sample, diffraction on surface structure can be seen; right inset (a) - photo of steel mould, diffraction on LIPSS can be seen; (b) - Raman spectrum (λ=532 nm) of Rhodamine 6G (concentration 10^{-6} M), drop coated on structure (a).

- ***Results and discussion:*** **Laser structured hard metals (steel, tungsten, molybdenum) were used as pressing dies (moulds) to create an imprinted nanostructure on soft metals (copper, silver) by a straightforward mechanical pressing. Mold and sample foils were placed between gauge blocks (Johansson gauges) and pressed in a small manual hydraulic press. Quasiperiodic surface structures were obtained, though their relief depth is smaller than on initial structures. Their applicability to SERS was verified. To our best knowledge, this has not been previously reported in literature. More sophisticated development of this approach (using high temperature, rolling) may prove to be interesting for surface functionalization tasks mentioned above.**

[1] Bonse J., Gräf S. Maxwell Meets Marangoni—A Review of Theories on Laser-Induced Periodic Surface Structures. *Laser & Photonics Reviews*. 2020. https://doi.org/10.1002/lpor.202000215

[2] Bonse J., Hohm S., Kirner S.V. et al. Laser-Induced Periodic Surface Structures— A Scientific Evergreen. *IEEE Journal of Selected Topics in Quantum Electronics*. 2017. https://doi.org/10.1109/JSTQE.2016.2614183

[3] Gnilitskyi I., Derrien T.J.-Y., Levy Y. et al. High-speed manufacturing of highly regular femtosecond laser-induced periodic surface structures: physical origin of regularity. *Scientific Reports*. 2017. https://doi.org/10.1038/s41598-017-08788-z

Acknowledgments: The authors appreciate funding from the Ministry of Education and Science of Ukraine (Project No. 0122U001956), the National Research Foundation of Ukraine (Project 2022.01/0011).

Contact information: *The additional information concerning report could be received via e-mails: hrabovskye@gmail.com (Hrabovskyi Ye.), nataliya.berezovska@knu.ua (Berezovska N.), igor_dmytruk@knu.ua (Dmytruk I.), admytruk@gmail.com (Dmytruk A.)*