Ph.D. thesis referee report

Title: Large surface functionalization by laser-induced micro and nanostructures

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The topic of the Ph.D. thesis is very actual. Laser micro and nanostructuring to enable new surface functionalities is intensively studied around the world. Increase of processing speed is a key element for its successful industrial application.

The thesis is well structured. At the beginning there is a nicely written description of present state of problematics in functional surfaces and their fabrication methods. In functional surfaces the main focus is given to superhydrofobicity, anti-icing and anti-bacteria properties of developed structures. In fabrication methods, after short introduction of different methods, the main focus is on laser processing methods. Physical processes of laser-material interaction are described for short and ultrashort pulsed lasers. Influence of different laser and process parameters is discussed. And finally three perspective ways of increasing processing speed are presented and compared in detail: ultra-fast beam scanning, interference patterning and multi-beam processing.

The following section is devoted to experimental work presented in the form of scientific articles in well-known international journals. Experiments are shortly introduced and summarized at the beginning. Then for each article a summary and author contribution is given. **The articles present careful experimental work with innovative ideas, efficient concepts and interesting results:**

Hierarchical micro- and nanostructures were produced by pico- and nanosecond lasers on different materials. Second production step for nanostructures formation using defocused laser beam and vacuum post treatment for faster achieving superhydrofobicity were introduced as new and innovative steps. Aluminium alloy, carbon fibre reinforced plastics (CFRP), steel, invar and tungsten samples were structured and micromachined. Nice structures were obtained with UV laser treatment of CFRP. Contact angles above 170° were obtained by both IR and UV wavelengths and both picosecond and femtosecond pulse durations. Optical systems for 2 and 4 beam direct laser interference pattering were designed, constructed and applied in combination of high average power high energy picosecond lasers. Multi-beam processing system producing more than 700 beams was set up and used for fast micro drilling and cutting of thin foils. Significant increase of processing speed for functional surfaces production was achieved in both interference and multi-beam processing with values of up to 200 cm^2/min and with outlook to possible upscaling to m^2/s range. Some of the developed systems are simple but very effective. Technical quality of experiments was very good (e.g. homogeneity of spots in multi-beam on page 98 or final processed surface by interference on page 81).

The text is well written and contains only low amount of mistakes, e.g.:

- Something is missing in sentence “And methods with good control over the structure formation such as lithography, etching and laser nano/microstructuring.” on page 22.
- Variable *n* goes to infinity in Eq (12), but there is no *n* in the equation.
- A references to Eqs. (12)-(16) and (18) should be given as they are probably taken from the literature.

- In the text “relation between beam diameter and radius” on page 31 was probably meant “beam divergence and radius”.
- “Nevertheless” at top of page 52 is strange. Probably “Although” would be more suitable.
- “squares with … decreasing diameter” on page 101

A bit surprising is referencing the work of the author in the description of the present state of the problematics. In the conclusion it is a bit too much spoken about the author. It should talk about the work. There is no outlook in the conclusion. In the list of publications of the author, in most publications no other authors are showed.

Publication of six articles in good level journals during a Ph.D. study is an outstanding achievement. Petr Hauschwitz is also the first author in most of them. In this work he has shown its capability of doing complete experimental scientific work from concept and methodology through performing experiments and analysing results to writing and discussing results. The Ph.D. thesis goals were fulfilled.

Based on this, I strongly recommend the Ph.D. thesis to the defence.

doc. Ing. Jiří Martan, Ph.D.

Referee

25th January 2021

Questions:

1. What does it mean “number of pulses/spot” in article A (page 55)? Is it number of repetition of the process (layers)? Scanning speed is the same for all experiments and repetition frequency is not mentioned (only maximal).
2. In article B, are in Fig. 2b really shown results for d=1 mm? Or it should be d=2 mm? In Fig. 1, there are better results for d=2 mm and also the values of HD are from 0.5 to 20 µm for d=2 mm. See also text concerning Fig. 1f.
3. In article C, there are micropillars in both directions (text on page 69 concerning Fig. 5). Was the sample movement done in both direction (and two orientations of interference lines)? On the bottom of page 70, there is written “independently on the orientation of the fibres with respect to the interference lines”. But from the description of the experiment and Fig. 1 it seems to have only one orientation of interference lines.
4. In article E, there are shown nice nanostructures produced on tungsten (Fig. 7a, page 90). Is it necessary to use the interference lines for production of these structures or can they be produced also by large flat-top beam?
5. What are the possible next steps for continuation of the research in this field (the outlook)?