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In-line monitoring of submicron laser texturing: a test bench for scatterometry

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Abstract

Laser Induced Periodic Surface Structures (LIPSSs) with a submicronic periodicity induce a variety of surface properties (iridescence, hydrophobicity, antibacterial, etc.). In-line monitoring of LIPSS dimensions is challenging since the resolution of optical based microscopy techniques is insufficient or unable to withstand with harsh, industrial environment. These issues can be overcome using indirect measurement techniques such as scatterometry. It makes possible an indirect measurement of LIPSS morphology by analysing the reflection and/or diffraction pattern of an incoming light having a known spectrum and polarisation. We show that by using a proper configuration, scatterometry is barely sensitive to vibrations and fast enough for in-line monitoring fitting industrial requirements. In the frame of the NewSkin H2020 project, a scatterometer has been integrated and tested in a roll-to-roll machine including a fast polygon scanner (up to 200 m/s) and a 350 W femtosecond laser targeting mass production of LIPSS for antibacterial stainless steel.

Keywords: LIPSS; mass production; monitoring; scatterometry; femtosecond laser

1. Introduction

Laser texturing provides a fast way to functionalize surfaces. The interaction of the laser with the matter generates Laser Induced Periodic Surface Structures (LIPSSs) that can induce several properties such as hydrophobicity[1], iridescence[2] and limitation to bacterial development[3]. Nowadays, this texturing can be performed very rapidly (40 mm^2/s) using a polygonal scanner. In the frame of the NewSkin H2020 project,

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the goal now is to get closer to an industrial process by coupling this method with a roll-to-roll machine and a high-power industrial laser. However, it still lacks a method allowing an inline monitoring of the texturing able to check the LIPPs dimensions and their orientation in real time. In industrial conditions, the monitoring method must be robust to vibrations (i.e. it requires a large depth of field), accurate and fast enough to be able to probe a moving surface. Moreover, as the LIPSSs periodicity ranges from few hundred nm to ~1 µm, imaging methods cannot be applied due to the diffraction limited resolution. However, in the case of a periodic structures, such as LIPSSs, indirect measurement methods based on scatterometry [4] can be applied. This technique consists in the interpretation, based on a model describing the interaction between light and surface, of the features of a diffracted or reflected beam. Several methods exist. For example, in the case of angular scatterometry, the specular reflectivity is measured as a function of the incident angle [5]. Using this method, the inline monitoring has been reported to be consistent with the offline, but it requires a moving component and a complex set up, which are not suitable for industrial conditions. Another approach, Coherent Fourier scatterometry [6], can collect several diffraction orders simultaneously, reaching an accuracy measurement of 10 nm. However, this method, using a very large numerical aperture, suffers from stability issues. A last method, called spectroscopic scatterometry [7], is suited for industrial conditions and can measure the LIPSSs periodicity, their height and their width. In this case, the reflected light is collected at a fixed angle for a large range of wavelengths. As this method does not require a large numerical aperture, it is robust to vibrations. Moreover, as it does not require any motion during measurement, it is fast. Herein, the capabilities of this monitoring method will be demonstrated in a texturing set up composed of a polygonal scanner, a 350 W femtosecond laser and a roll-to-roll machine allowing the rapid texturing of large metallic foils.

2. Laser texturing and in line monitoring set up

The laser texturing set up is presented in Fig. 1. A roll-to-roll machine (designed by ISP Aquitaine) allows the translation of metallic foils (here stainless steel) under a polygonal scanner (UHSS-II-15, Raylase) able to scan the laser beam at a speed of 200 m/s. The texturing is performed using a 350 W femtosecond laser (Tangor, Amplitude) delivering pulses at 1030 nm with a pulse duration of 500 fs and at a maximum repetition rate of 13 MHz. The beam is focused on the surface with an F-Theta lens (S4LFT1655/328, Sill Optics, focal distance 649 mm) allowing to work in a field as large as 308 mm. The textured surface is monitored with a spectroscopic scatterometer designed by the Danish Fundamental Metrology. The device is composed of white light source and a spectrometer able to deliver measurements at a rate faster than 1 Hz. All the devices are synchronized and computer controlled such as the system is stopped when the texturing quality drops.

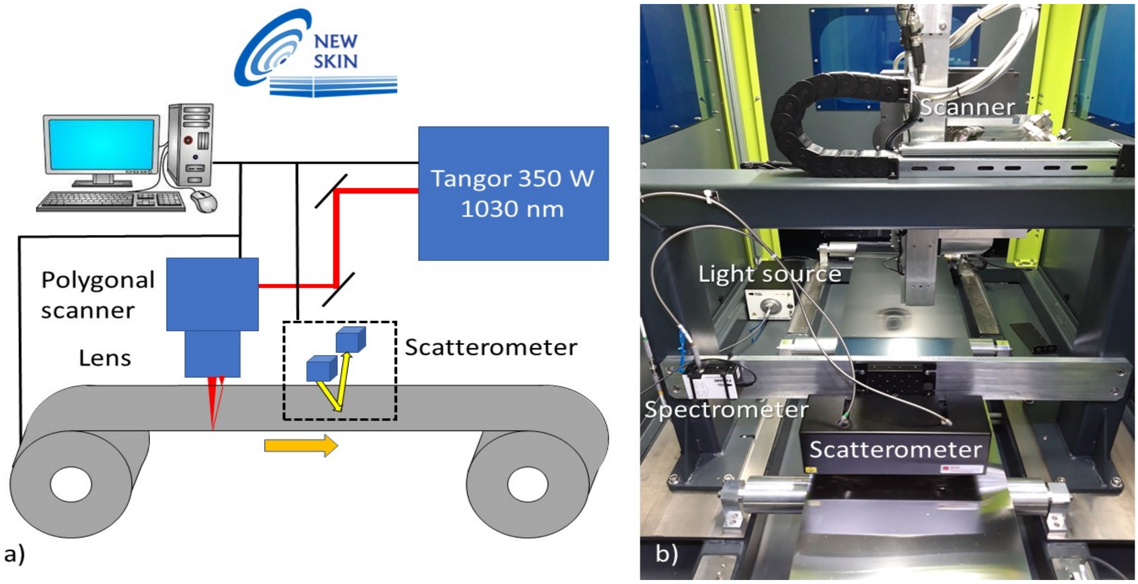

Fig. 1. a) Schematic of the texturing and inline monitoring setup. b) Photograph of the set up.

3. Experiment

In order to demonstrate the capabilities of the system, measurements have been performed on a textured stainless-steel surface. Upon acquisition of the spectrum, a software fits the data according to a Rigorous Coupled Waves Analysis model depending on several parameters: the structure periodicity, their height and their width. An example of acquired spectrum (black line) and its best fit (dashed red line) are presented in the fig. 2a. The goodness of the different fits is represented in the fig. 2b. The best fit gives a height of 202±5 nm and a period of 849±35 nm which are in agreement with our SEM and AFM measurements and reports [8, 9].

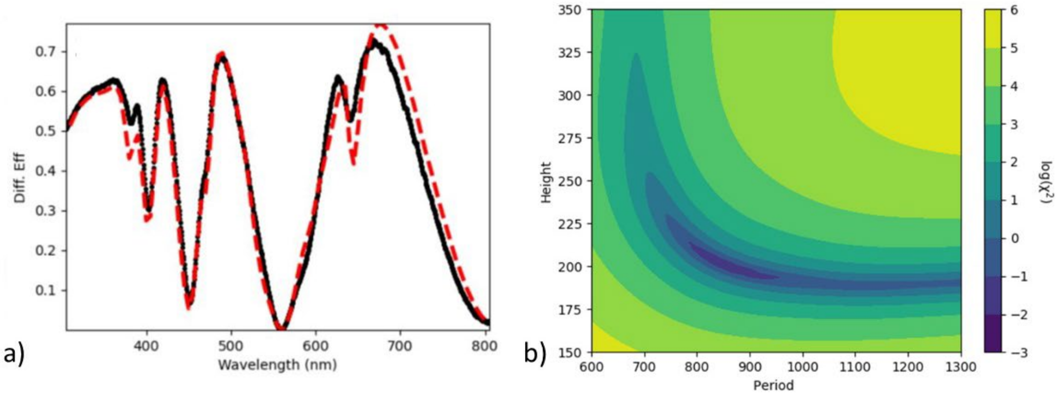

Fig. 2. a) Examples of acquired spectra. The measured data and the best fit are respectively represented by a black line and a dashed red line. b) Diagram representing the goodness of the fits.

4. Conclusion

Spectrocsopic scatterometry has been shown to be an adequate method for inline monitoring of a submicrometric periodically structured surface. As it is fast and robust to vibrations, it is suited for industrial conditions. Thanks to this technique, slow and complex imaging methods are not necessary anymore to control the quality of the surface. Moreover, scatterometry has the capability to characterize any 1D or 2D periodic structuring and is promising as well for monitoring other texturing techniques such as Direct Laser Interference Patterning.

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