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Surface characterization in fabrication environments using angle resolved light scattering: From roughness and defect analysis to in-situ coating inspection

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Abstract. The performance of an optical component or surface might quicky be limited by light scattering induced by the surface and coating roughness, as well as imperfections and contaminations. On the other hand, the scattered light contains valuable information about its source, which makes scattering based techniques powerful characterization tools for these important features. A major advantage is the fast, robust, and contact free measurement approach enabling even close-to process applications. Based on several examples we demonstrate the potential of light scattering characterization during the fabrication process up to even in-situ coating inspection.

1 Introduction

Light scattering due to interface and coating imperfections is a significant concern for optical components, even when advanced polishing and coating techniques are used. Unavoidable origins of scattering are for example surface and interface roughness, inhomogeneities in the bulk material, as well as surface defects and contaminations [1-6]. Therefore, surface characterization plays a crucial role in the manufacturing process of precision optics.

On the other hand, the scattered light contains valuable information about its source. This, again, turns scattering based techniques into excellent tools for the characterization of surfaces and thin film coatings [2-6].

2 Scattering based surface analysis

2.1 Roughness and defect characterization

While standard inspection systems like AFM, WLI, or LSM are commonly used in laboratories for surface roughness analysis, scattering based approaches offer several distinct advantages. They are non-contact, non-destructive, robust against vibrations, fast and at the same time exceptionally sensitive. The ability to fully inspect large sample areas with high resolution and sensitivity is particularly interesting for assessing properties such as roughness homogeneity and detecting isolated defects.

At Fraunhofer IOF, angle resolved light scattering techniques are developed and used for the comprehensive characterization of optical surfaces, coatings, and components for a broad range of applications and at various wavelengths from the ultraviolet to infrared spectral regions [3-6]. With these, extremely high sensitivities are achieved, corresponding to surface roughness levels of below 0.1 nm, and particles down to the sub-micrometer range can be detected.

2.2 Integration into fabrication environments

Beyond that, the non-contact, fast, and robust measurement approach makes the light scattering technique even suitable for integration into fabrication processes or test environments.

Compact scattering sensors were developed for a rapid full surface analysis on even extended surfaces and quick roughness and defect inspection [4]. This enables close-to process characterization, for example for rapid quality assessment during polishing processes [5, 6]. A scattering sensor can even be directly integrated into manufacturing environments [6].

2.3 In-situ coating inspection

Functional coating is an important step in the process chain for manufacturing precision optics, where the analysis and control of surface and interface roughness and imperfections can also play a significant role.

In a collaborative project, a light scattering sensor is integrated into a roll-to-roll process for fabrication of

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colorshift foil by evaporation. By combining in-situ spectrophotometric measurements with light scattering information, real-time data can be recorded and evaluated while the process is ongoing. Thus, even process adjustment might become possible.

Recently, a light scattering sensor was successfully integrated into a magnetron sputtering coating system. With this, roughness evolution and defect growth were monitored online during deposition, as can be seen in Fig. 1.

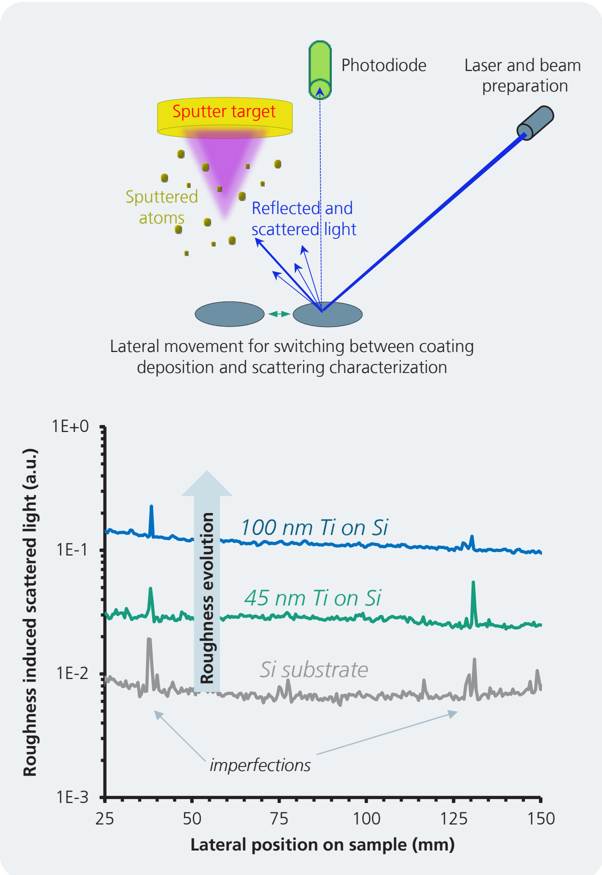

Fig. 1. In-situ monitoring of coating roughness based on light scattering measurement. Top: Schematic setup of the scattering sensor. Bottom: Roughness induced light scattering monitored during the coating process of Titanium on a Silicon substrate.

This technology allows for an enhanced process monitoring while maintaining a vacuum environment to improve reproducibility and optimize the coating process.

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