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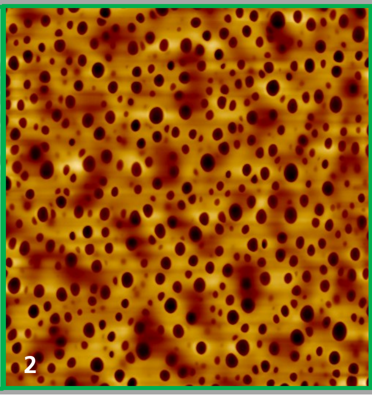

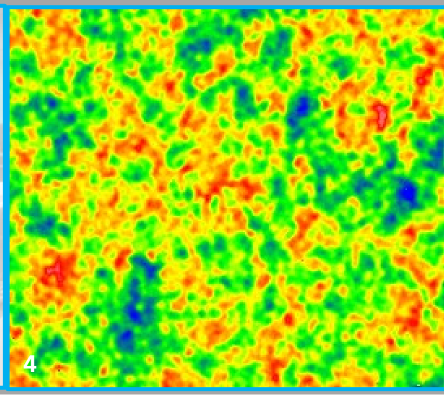

1 Atomic Force Microscope (AFM): Dimension FastScan / Icon

2 AFM topography image (10x10 µm²) of an porous silica coating on a glass substrate (rms-roughness = 13 nm).

3 White Light Interferometer (WLI): Zygo NewView 7300

4 WLI topography image (120x105 µm²) of a etched glass (rms-roughness = 140 nm).

Combinative Roughness Analysis

Motivation

Recent developments in multifunctional optical and engineering surfaces result in novel challenges for a concise characterization of structural properties. Roughness information is required over wide ranges of spatial frequencies. Furthermore, different types of surfaces ranging from extremely smooth to very rough require different measurement approaches. Very often roughness properties in the full range relevant for the application cannot be obtained by using only one method. Hence, our goals are to:

- identify the spatial frequency region relevant for the application at hand
- identify the method which is best suited for the particular task
- if necessary, combine different approaches
- retrieve robust measurement data and derive simple parameters
- link structural properties with functional and optical properties, in particular wetting and light scattering measurements
- if required, suggest methods the customer should implement on-site

In total, we offer tailored surface characterization methods in order to efficiently support your development of innovative surfaces, coatings, and materials.

Measurement techniques

For a comprehensive investigation of nano- or microstructures , we use and combine various measurement techniques :

- Atomic Force Microscopy (AFM)
- White Light Interferometry (WLI)
- Laser-Scanning Microscopy (LSM)
- Focus Variation Microscopy
- Light Microscopy
- Light Scattering

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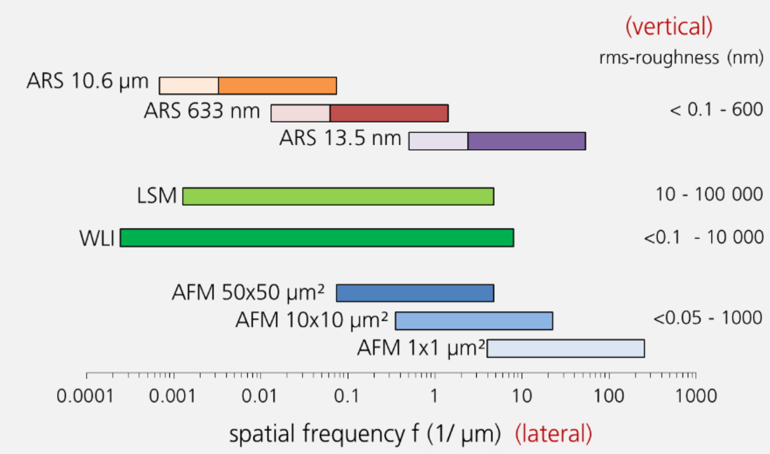

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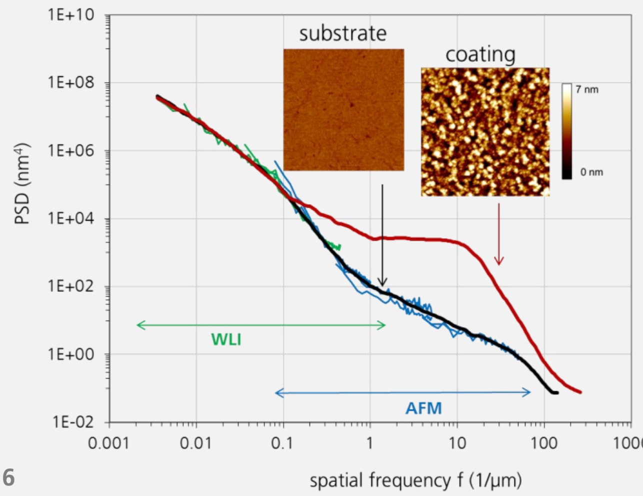

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5 Spatial frequency ranges of different light scattering and roughness measurement systems.

6 Single and combined PSD functions of AFM and WLI measurements of a polished fused silica substrate. Combined PSD of aluminium coated fused silica. AFM topography images (1x1 µm²).

Quantitative Roughness Analysis

The use of Power Spectral Density (PSD) functions /1/, defined by the absolute square of the surface profile's fourier spectrum, is our standard tool for extensive roughness analysis providing the following advances:

- Determination of quantitative information about the vertical and lateral distributions of roughness components
- Combination of different measurement techniques and measurement areas (e.g. spatial frequency ranges) (Fig. 5, 6)
- Description of structural properties over several spatial frequency decades
- Identification of measurement artifacts
- Establishing relationships between the surface roughness and the optical and functional surface properties

→ In-depth roughness characterization tailored to the specifics of the samples, the technical / scientific tasks and the application

Examples of Application

Optical superpolished surfaces

Surface roughness is a critical parameter for the specification of high-end optical components to ensure a certain performance. The main reason is that even the smallest levels of residual surface roughness give rise to light scattering which degrades the imaging properties and reduces the throughput. Linking the PSD function with light scattering offers a reliable prediction of scattering properties by roughness analysis as well as a derivation of roughness information from light scattering measurements.

Functional nanorough surfaces

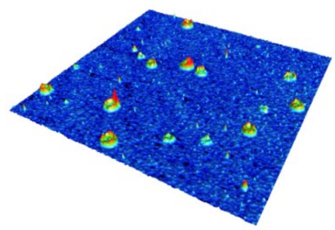
The final function and application of surfaces are determined to a large extent by their roughness properties. This is in particular true for extreme wetting properties such as superhydrophobicity, anti-icing, or anti-fog effects /2/. Designing tailored stochastic structures in the nano-range enables a successful technical realization of surfaces with specific functionality and high optical quality at the same time.

Microrough Engineering Surfaces

Energy efficiency and conservation of resources are increasingly important topics, in particular in mechanical engineering. In automotive and powertrain engineering, surfaces are required that transfer energy with low losses and tolerate high mechanical loads. One key element for this purpose are microstructured functional surfaces /3/. To optimize the desired surface functionality, roughness structures need to be controlled.

Other applications

The assessment of further surface properties such as homogeneity, and the distribution of defects is gaining more and more importance in particular close to, or even in, manufacturing processes. This area can also be covered by the presented surface characterization methods. Finally, a deciding advantage of our roughness analysis approach is the combination with light scattering metrology. This is especially useful if large, complex surfaces are to be characterized.



7 Defects in a multilayer thin film system

/1/ A. Duparré, et al, "Surface characterization techniques for determining the root-mean-square roughness and power spectral densities of optical components", Appl. Opt. 41, 154–171 (2002).

/2/ L. Coriand, M. Mitterhuber, A. Duparré, and A. Tünnermann: "Definition of roughness structures for superhydrophobic and hydrophilic optical coatings on glass", Appl. Opt. 50, C257-C263 (2011).

/3/ L. Coriand, M. Rettenmayr, and A. Duparré: "Relationship Between the Roughness and Oleophilicity of Functional Surfaces" in Advances in Contact Angle, Wettability and Adhesion (John Wiley & Sons, Inc., 2015), 165-177.

/4/ S. Schröder, et al, "Origins of light scattering from thin film coatings", Thin solid films 592, 248–255 (2015).