EPJ Web of Conferences **266**, 10014 (2022) https://doi.org/10.1051/epjconf/202226610014
EOSAM 2022

Coherent Fourier scatterometry for particle detection on structured surfaces

Anubhav Paul[1,*], *Dmytro* Kolenov[1], and *Silvania F.* Pereira[1]

[1]Optics Research Group, Imaging Physics Department, Faculty of Applied Sciences, Delft University of Technology
Lorentzweg ,2628 CJ Delft, The Netherlands

Abstract. We demonstrate the detection of particles/contamination present on a structured surface using Coherent Fourier scatterometry (CFS) by applying Fourier filtering to the scanned maps, which eliminates background effects due to the electronic noise as well the structure itself. We show that by using filters in the Fourier space we can significantly improve the detection capabilities of the particles present on the structure.

1 Background

One of the most revolutionizing technological advancement in the past few decades have been observed in the semiconductor/nano-tech industry, which resulted in drastic modification in our society and in general helped improve the living standard of human beings. However, as we strive towards betterment the need for fabrication of more compact and accurate nano-structures is of paramount importance. For that accurate inspection of contamination on surfaces and gaseous environments is extremely crucial to guarantee the quality of the fabricated devices. Particle detection and particle metrology plays a role in the quantification of large number of particles on environments, but is also highly important in the detection of a very small number of particles (contamination) on ultra-clean surfaces and vacuum environments. Quantification of the latter is of great importance since it assures the quality and ultimately determines the yield of the fabricated structures.

In recent years, it has been shown that Coherent Fourier scatterometry (CFS) is a suitable technique for this purpose [1]. CFS is an optical metrology technique based on the light scattered from the object in the far field, which is very sensitive to detect small isolated particles or small changes in parameters of nanostructrues. In addition, the technique is not limited by diffraction, and the detection of deep subwavelength-size particles present on top of a plane substrate has been recently demonstrated [2]. However, as we move towards patterned surfaces, the detection of contamination becomes more complicated as we have to consider the effects of the background structure in addition to that of the contamination itself. In this work, we show a procedure on how to tackle this problem by filtering out the signal due to the background structure, creating a significant contrast between the scattering of the structure and the scattering of the defect/particle, making the problem analogous to particle detection on a plane substrate.

*Corresponding Author: A.Paul-1@tudelft.nl

2 Experimental setup

The experimental setup of CFS is similar to a confocal microscope where a collimated and linearly polarized He-Ne laser (λ = 633 nm) beam passes through a non-polarizing beamsplitter which latter goes to a microscope objective (NA = 0.9) and is focused on the sample of interest. The sample is placed on a piezo-stage that can be laterally scanned in a raster fashion (i.e., the stage scans consecutive lines at the time, separated by a certain distance between the lines). The reflected and scattered light from the sample is collected by the same objective and goes back through the beamsplitter. The back focal plane of the objective is de-magnified by a telescopic system consisting of two lenses and imaged at a split detector. The split detector has two halves that are aligned at direction perpendicular to the scan direction of each line. The intensity voltage from the left half is subtracted from the right half, resulting in a position dependent differential signal. With this detection system, the specular reflections for which the far field is symmetric is eliminated and we observe the differential signal to be zero. As the focused beam passes through a change in the sample structure, the far field becomes asymmetric and we observe a position dependent differential signal. In the case of a flat surface, the particle detection is straightforward since the the detector signal due to the surface only (without particles) is always close to zero. However, this is not the case if the substrate is not uniform but contains structures on it.

3 Results and discussions

We demonstrate that Fourier filtering technique along with the CFS can be used to improve the detection capability of particles on a (nano)structure. Here we intend to filter out all the spatial frequencies present in the scanned maps except that of the particles/defect present on the structure in order to isolate the frequencies due to the substrate from the frequencies due to the particle/defect. As we know, the frequencies of the light scattered by the particles are in

https://doi.org/10.1051/epjconf/202226610014

the higher-frequency ranges. We study different filters on the Fourier space, like discrete high-pass filter, 2D cosine window superimposed with a high pass filter, and Gaussian notch filter.

We observe that, for each filter, there is a significant improvement in the detection capabilities of the CFS. However, we have to keep in mind that some frequencies of the background signal and the particles/defects may overlap and filtering those might decrease the SNR of the signal due to the particle slightly.

Furthermore, combination of weighted filters may further improve the SNR which was lowered due to the elimination of the overlapping signals.

Using this principle, we show the detection of subwavelength defects on grating structures that are used as quality control of lithographic systems.

References

[1] S. Roy et al., Rev. Sci. Instrum. **86**, 123111 (2015)
[2] D. Kolenov et al., Optics Express **29**, 16487 (2021)