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Multi-beam Coherent Fourier Scatterometry

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Abstract. Recent technological advancements in the past decades have been driven by the miniaturisation of devices using surfaces with nano-scale features. These advancements require fast, large area measurement techniques that can be used in process control to detect surface contaminations or to monitor fabrication quality. Here we present a modified version of the scanning coherent Fourier scatterometer with multiple beams that can be used to scan larger areas without increasing the scan time or decreasing the spatial resolution.

1 Introduction

The race to miniaturise devices in different industries such as photonics, electronics, biomedicine and security is driven by manufacturing surfaces with nano-scale structures [1-3]. The advent of fast, large area manufacturing requires inspection techniques capable of fast and large scan area measurements. Accurate inspection of surfaces for contamination is also critical to guarantee the quality of fabricated devices. Traditional metrology tools such as scanning electron microscopy (SEM) and atomic force microscopy (AFM) are often quite slow, destructive and require stringent measurement conditions. Optical techniques such as scatterometry provides a fast, low cost, precise, and non-destructive alternative, making it one of the most prevalent inline metrology techniques currently used in industries. In scatterometry, the change in optical properties of the light scattered from the target such as intensity and phase are measured to estimate the attributes of the target. The inverse scattering problem is generally ill-posed with respect to the existence, uniqueness, and stability of the solution. The ill-posedness of the problem is overcome by the use of prior knowledge of the system [4].

Coherent Fourier scatterometry is an advanced scatterometric technique that uses focused coherent light to probe the surface [5]. Using a focused spot, one can measure the scattering response due to several incident angles simultaneously by capturing the Fourier plane image of the target. The spot is scanned over the surface and the scattered light signal from each position is measured using a two-pixel detector. The point-by-point scanning provides high resolution in the localisation and high sensitivity in the particle detection but it comes at the cost of long scan times. Parallelisation is a good strategy to increase the scan area without compromising either the scan time or the spatial resolution. We propose a multi-beam coherent Fourier scatterometry setup for fast and efficient scans over large areas. The method can also be adapted to use with structured illumination and 3D scanning.

2 Experimental Setup

In a standard coherent Fourier scatterometry scheme, the target surface is scanned using a high numerical objective and the response in the Fourier plane is measured using a split detector. The source and the detector are static while the sample is raster scanned. The detector consists of two photo diodes. The scattered field is made to be incident exactly at the middle of the two diodes. The light intensity on each diode is then integrated separately and their difference is amplified to give the output signal. The calculation of the difference signal has been seen to reduce background noise and improve the signal to noise ratio [6]. A signal becomes non-zero when the scattering from a structure or a particle causes an asymmetry between the two halves of the light beam.

In the multi-beam setup, the parallel beams are first generated using a diffraction grating with suitable periodicity. The scattering response due to each beam is recorded separately by an array of photo diodes, two per beam. The periodicity of the diffraction grating is chosen by the wavelength of the incident light, the size of each photodiode and the separation between them such that each beam gets incident exactly in the middle of two photodiodes. The diffraction grating has a periodicity of 30 μm which when used with the He-Ne laser of 633 nm yields an angular separation of 1.2° between the multiple orders. The sample is scanned in the x and y-directions using two piezo motors. The objective has a numerical aperture of 0.4 with a magnification of 20x. After scattering from the surface, the light beam is de-magnified using a micro lens array with periodicity equal to that of the detector array.

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3 Results and Discussions

The independent detection and measurement of structures by each beam was verified by scanning horizontally over a known structure and recording the output signal. The signal showed pulses at definite intervals corresponding to the measurement by each beam. The scattering response is dependent on the intensity of the diffraction order. Thus, for identical response signal, specialised gratings with equal intensity diffraction orders need to be used.

References

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