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Recent developments in coherent Fourier scatterometry

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Abstract. Coherent Fourier Scatterometry (CFS) enables low-power, high-resolution, non-destructive metrology for nanoscale structures. Recent advancements have extended its applications to improving the measurement of critical dimensions, such as steep-sidewall angles of fabricated nanostructures and the detection and shape determination of defects for semiconductor and power electronics applications. Innovations like beam scanning, multi-beam setups, and synthetic optical holography enhance its speed and sensitivity, making CFS increasingly viable for industrial in-line inspection.

1 Introduction

Coherent Fourier Scatterometry (CFS) has emerged as a powerful optical metrology technique capable of measuring nanoscale structures with low power, high sensitivity, and sub-nanometer resolution. It operates by analyzing the angular-resolved scattered light from a nanostructured surface illuminated with a focused coherent beam. The far-field diffraction pattern contains rich information about the structural parameters of the surface, such as height, critical dimension (CD), and sidewall angle. Unlike incoherent scatterometry, CFS benefits from coherence to achieve enhanced contrast and phase sensitivity, which is particularly beneficial for detecting small defects and retrieving complex surface geometries.

Originally developed for metrology of periodic gratings, CFS has expanded into detecting isolated sub-wavelength particles on flat wafers [1] and patterned structures [2, 3], and determining geometrical shapes of nanostructures [4]. The use of tightly focused beams and high numerical apertures allows access to higher spatial frequencies, making CFS highly sensitive to fine structural details. Recent works have demonstrated the ability of CFS to reconstruct grating features with nanometer accuracy, comparable to that of AFM and SEM techniques, but in a faster and non-destructive manner [5]. The versatility of CFS has led to its adoption in critical areas like semiconductor manufacturing and power electronics. In semiconductor metrology, CFS is used for characterizing critical dimensions and sidewall angles of photoresist patterns and etched features. Recently, a calibration-based CFS method was used, where a visibility parameter determines steep sidewall angles and feature heights with high accuracy, validated against AFM measurements [6]. In power electronics, where killer defects are often very small, low contrast and lie deep in the substrate, the ability of CFS to measure these killer defects has been demonstrated [7]. To meet the stringent requirements of high-throughput manufacturing environments, recent efforts have focused on increasing the

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scanning speed of CFS. One significant development is the implementation of beam scanning using galvo mirrors instead of translating the sample, which improved scanning speeds by nearly two orders of magnitude [8]. Another breakthrough is the parallelization of CFS using a multi-beam setup, where multiple probe beams and split detectors enable simultaneous measurements across different sample regions. This approach significantly reduces the total scan time and brings CFS closer to industrial in-line inspection applications [9]. Furthermore, the integration of synthetic optical holography (SOH) into CFS has enhanced sensitivity at low illumination power, enabling detection of low contrast polystyrene nanoparticles as small as 60 nm on Si substrates with an SNR improvement of up to 4 dB [10].

These advancements demonstrate the growing maturity of CFS as a metrology tool, not only in research but also in industrial applications. As the need for fast, accurate, and non-destructive characterization tools grows in advanced manufacturing, CFS offers a combination of speed, sensitivity, and versatility. Future developments are expected to focus on improving robustness against system instabilities, optimizing signal processing for noisy environments, and further integrating CFS into hybrid metrology systems for structural analysis.

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