Optik - International Journal for Light and Electron Optics 169 (2018) 228–235

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.com/locate/ijleo

Original research article

A novel overlay metrology method: Simultaneous utilizing spectral and angular spectrum

Bofang Peng*, Qixin Xu, Wenmei Hou

University of Shanghai for Science and Technology, Shanghai 200093, China

ARTICLE INFO

Keywords:
Metrology
Overlay
Scatterometry
Grating
Interference
Spectral
Angular spectrum
Lithography

ABSTRACT

In the lithography process, overlay describes the position errors of placing one mask layer pattern over an existing pattern on the wafer, and overlay metrology is one of the key challenges in semiconductor manufacturing. With the increase of process complexity especially for multiple patterning technologies in advanced nodes, the demand for accuracy, precision and process robustness in overlay metrology continues to tighten. In this paper, we have proposed and demonstrated a novel overlay metrology method with high process robustness. A straightforward theory called interference of diffraction light is developed for explanations why this method works for single layer overlay metrology. The overlay signals with continuous wavelengths and angles are simultaneously acquired in the pupil plane. Therefore, compared with the current monochrome measurement technology, this work can gather and utilize as much overlay information as possible for measurements. Experiments illustrate that this technique can achieve better measurement repeatability, faster measurement speed and better process robustness than current monochrome method, and thus this method has great potential to meet the higher node requirements for measurement accuracy. What' more, our work provides a novel idea for scatterometry technology in the field of micro-nano measurement.

1. Introduction

Historically, lithography engineering in semiconductor industry has focused on two keys, complimentary aspects of lithographic quality: overlay performance and critical dimension (CD) control. Overlay is the horizontal positional errors in placing one mask layer pattern over an existing pattern on the wafer. When optical lithography advances to 45 nm technology node and beyond, multiple patterning technologies has emerged as an attractive and feasible solution to circumvent the fundamental optical limitations before until extreme ultraviolet (EUV) lithography becomes commercialized [1].

Overlay control is essential to producing high yielding and high-performing semiconductor devices [2]. Meanwhile, multiple pattern technology poses unique demands on overlay control, thus making metrology even more challenging. With the shrink of device node and multi-patterning approach overlay metrology continues to be one of the key challenges for lithography in semiconductor manufacturing [3,4].

Scatterometry based overlay or in another name of Diffraction-Based overlay (DBO) metrology method is currently main stream to the nanolithography process control for producing advanced semiconductor fabrication nodes. Gratings printed on various layers are used as the overlay marks for the measurement of the horizontal positional error. The asymmetry of diffraction intensity between the +1st and −1st light from the overlay marks is used to derive the value of the overlay [5].

* Corresponding author.
E-mail address: pengbf_2011@163.com (B. Peng).

https://doi.org/10.1016/j.ijleo.2018.05.024
Received 13 May 2017; Received in revised form 7 May 2018; Accepted 8 May 2018

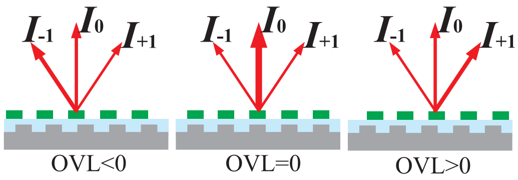


Fig. 1. Overlay will induce non-zero order intensity asymmetry.

In order to optimize overlay measurement technology, engineers have developed a variety of solutions at present such as different hardware principles (DBO or IBO (Image Based Overlay), different target sizes, and even different overlay mark types. All of these efforts aimed at solving the problem of measurement robustness caused by process variations [6]. Process robustness over production process variation is one of the most important components for the accuracy. Accuracy will never be guaranteed only when the process robustness meets the requirements [7].

Our work investigates a novel overlay metrology method by using pupil plane based continuous wavelengths and angles scatterometry for multi-patterning technology. In order to make a comparison, we implement experiments by both this work and traditional monochromatic method. The result shows that the precision of overlay measurement by this method is only about 0.17 nm, which is superior to 0.52 nm precision results from the traditional monochromatic light method. The simulation experiment proves that our method has better process robustness.

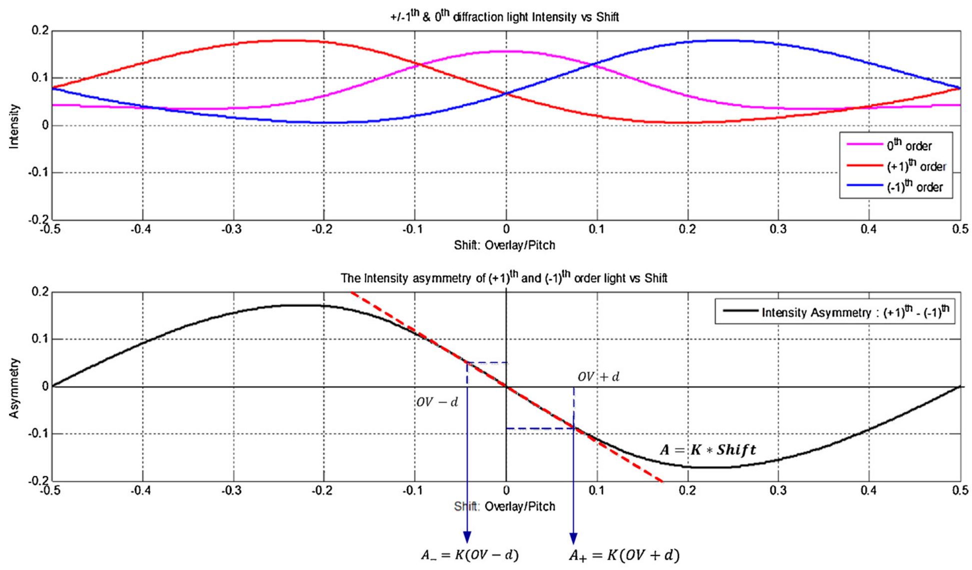
2. Principle and experimental considerations

2.1. Basic principles of DBO technology based on angular resolved scatterometry

DBO technology based on angular resolved scatterometry is the mainstream technology route in the industry, and DBO technology based on this principle has already been widely used in the semiconductor industry. From the perspective of optical measurements, the basic principle of diffraction based overlay metrology is a measurement implemented by using two overlapping optical gratings located in two different layers of the product stack with different materials; the two gratings are separated by other materials [8].

As shown in Fig. 1 below, we can find the overlay mark is actually two layer gratings. When the grating is illuminated by a light beam, the diffracted signal from the grating will be captured by the sensors. When there is no offset between the two gratings, in other words, the overlay is zero. Then the two gratings are symmetrical, we can easily understand the symmetrical two layer gratings as classical single grating. The intensity of the diffracted non-zero light will be equal. When an offset is added between the two gratings (overlay is not zero), then the two gratings are asymmetrical. We can simply understand that the asymmetrical is induced by overlay. The diffraction intensity of the non-zero orders light will not be equal (see Fig. 1).

As overlay will induce the intensity asymmetry of the non-zero order light, the relationship between the asymmetry and overlay can be used for overlay metrology. When the offset between the two layers is close to zero, the intensity asymmetry varies as a linear



$$Overlay = d \cdot \frac{A_+ + A_-}{A_+ - A_-}$$

Fig. 2. DBO principle: From asymmetry to overlay.