3D Metrology of sub-60 nm Lines Using TSOM Optical Method

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ABSTRACT

This paper describes three-dimensional nanoscale measurement capability of the relatively new optical method called through-focus scanning optical microscopy (TSOM). The TSOM method converts a conventional optical microscope into a three-dimensional metrology tool. Nanoscale sensitivity to size and shape changes of lines are demonstrated here using optical simulations.

Keywords: TSOM, through-focus scanning, optical microscope, nanometrology, three-dimensional metrology

1 INTRODUCTION

In the current world of nanotechnology, fast and reliable 3D measurement of nanoscale features is extremely useful. Furthermore, it is beneficial if the analytical tools used are cost effective and have high throughput–such as optics-based tools. In this paper we utilize a novel optical technique called the TSOM (through-focus scanning optical microscope) method [1-4] that produces sub-nanometer scale dimensional measurement sensitivity using a conventional optical microscope by analyzing images obtained at different focus positions enabling 3D analysis of lines.

2 TSOM IMAGE CONSTRUCTION

In Fig. 1 we demonstrate the method to construct a TSOM image, using an isolated line as a target. Optical images are acquired as the target is scanned through the focus of the microscope (along the Z-axis) as shown in Fig. 1(a). Each scan position results in a slightly different 2D intensity image. From these images extracted optical intensity profiles passing through the location of interest on the target (through the center of the line, for example) can be assembled and conveniently plotted as a 2D image resulting in a TSOM image as shown in Fig. 1(b), where the X (horizontal), Y (vertical) and Z (color scale) axes represent the spatial position on the target, the focus position, and the optical intensity respectively.

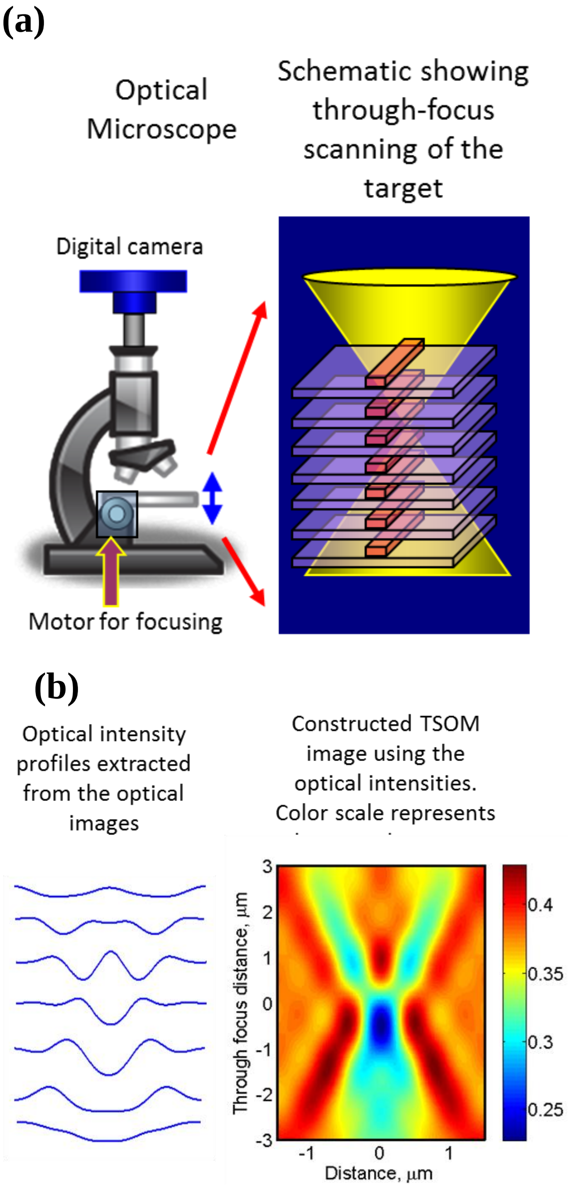


Figure 1. TSOM image construction method

3 DIFFERENTIAL TSOM IMAGE

A differential TSOM image (difference between two TSOM images obtained from two targets with small dimensional differences) highlights nanoscale 3D differences. A differential TSOM image provides a distinct signature for different dimensional differences. As shown in Figure 2, size and shape differences between nanoparticles produce distinctly different signatures. Greater differences produce a larger differential signal. In principle, this technique can be used to identify which dimension is changing between two nanosized targets, the magnitude of the difference, and to determine the dimension using a library-matching method [2,3].

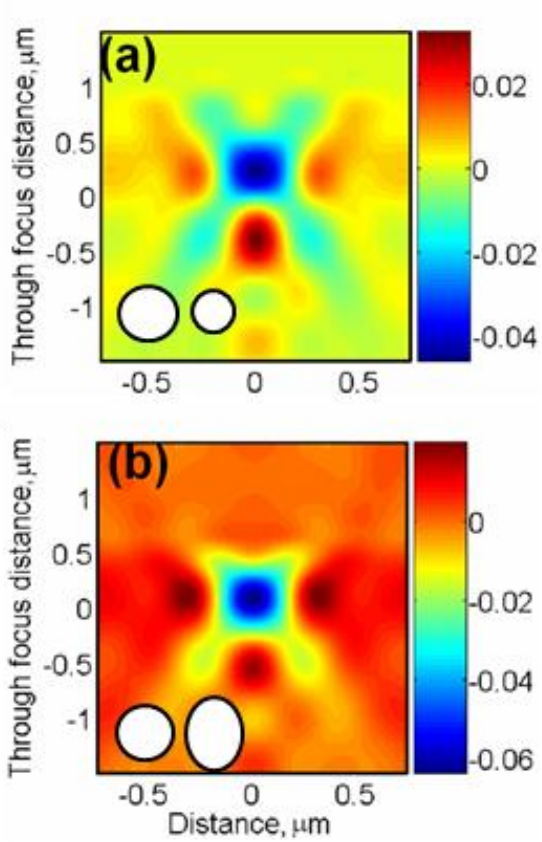


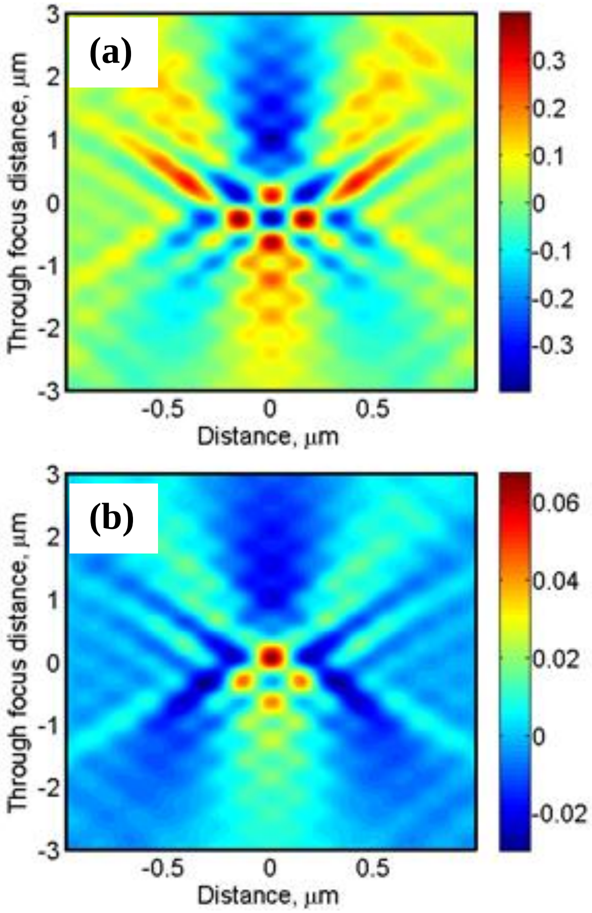
Figure 2. Differential TSOM images showing distinct color map for size and shape differences of nanoparticles [1].

4 THREE-DIMENSIONAL SENSITIVITY

Metrology demands for 3D structures and their more complex integration steps are considerably greater than for 2D devices. The ability to measure line dimensions accurately with good precision and to detect subtle process changes for feedback are essential to assure good semiconductor device performance and high yield in high volume manufacturing (HVM). For example, variations in FinFET height (for which 3D analysis is important) can likewise lead to drive current variability. Hence it is critical to measure the dimensions accurately with high throughput. Here we demonstrate three dimensional sensitivity of the TSOM method for shape analysis of dense lines.

For this we obtained optical simulations results for dense lines (pitch = 44 nm, linewidth (CD) = 19 nm, line height = 40 nm, wavelength = 248 nm, eight Si lines on Si substrate), the schematic of which is shown in Fig. 3.

Figure 3. A schematic of optical simulation structure.



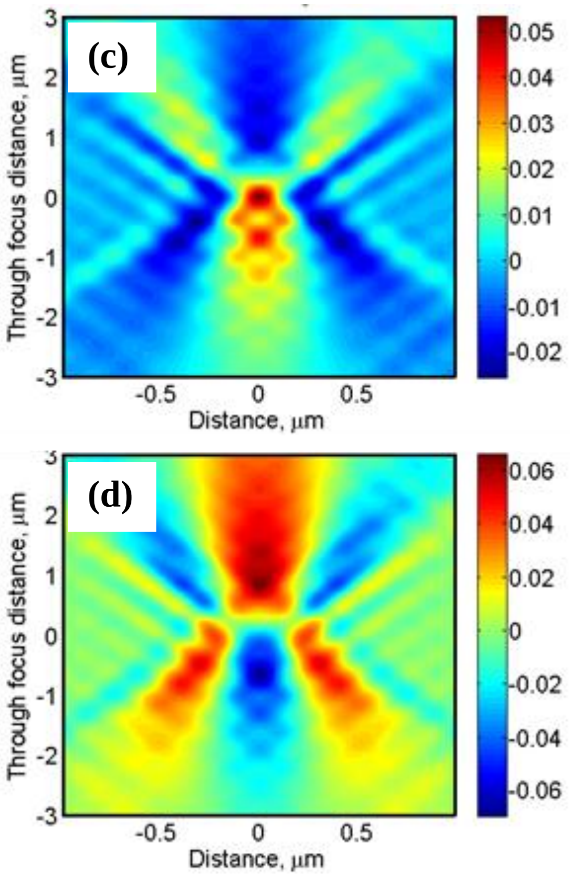


Figure 4. (a) A typical intensity normalized TSOM image of the selected structure. Differential TSOM images for (b) a line width difference of 2 nm, (c) a sidewall angle difference of 2^o and (d) a line heigh difference of 2 nm.

The results are shown in Fig. 4. The differential images show good sensitivity to small scale dimensional differences of dense gratings. Each type of dimensional difference also showed a unique color map reinforcing the characteristics of TSOM method [2]. The TSOM method results here demonstrate capabilities for measuring variations in very small features, far smaller than the optical wavelengths used. Sensitivity to CD, SWA, height, are needed for the metrology of basic fin structures, and the low cost and high throughput of TSOM make it a potential candidate for measuring such features in HVM.

Eventhough the method is robust to optical and illumination aberrations [5] it is a good practice to determine the ANILAS map [6] (three dimensional illumination condition at the sample plane) and select the best location in the field of view to minimize errors.

5 CONCLUSIONS

In the current paper using simulations we presented size and shape (3D) sensitivity of dense nanoscale lines using the TSOM method.The TSOM method shows good three-dimensional sensitivity at nanoscale. The TSOM methodology has potential utility for a wide range of target geometries and application areas, including nanotechnology, biotechnology, nanomanufacturing, and semiconductor process control.

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