Optical Scatterometry for In-line Nano-Manufacturing[1]

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Nanoscale, noncontact optical in-line metrology is a challenge to implement during manufacturing. This research focuses on an in-line metrological tool that can be used during roll-to-roll (R2R) manufacturing of nano-size structures. Optical scatterometry is a fast, non-contact, non-destructive nanoscale metrology tool that is widely used off-line in IC manufacturing process for quality control.[2] In this presentation, we demonstrate an optical scatterometry set up that operates at speeds commensurate with R2R tooling.

Both ellipsometric and angular scan scatterometry systems have been widely exploited for off-line metrology.[2] We have previously reported on the wavelength dependence of angular scatterometry. Four different wavelength (244, 405, 633, 982 nm) were used to characterize wire-grid polarizer and photoresist gratings proving that angular scatterometry is capable for nano-metrology applications.[3] It was demonstrated by simulation that using a 405 nm laser source, off-line angular scatterometry is capable of measuring down to 20 nm period for wire-grid polarizer and 24 nm periodic photoresist structures[4]. Our in-line set up can scan the 0^{th} order reflection as a function of incident angle by using a 2-kHz scanning galvanometer mirror and parabolic optics to handle the large angular range. Fig. 1 shows an optical design for in-line scatterometry. The current set up accomplishes a total angular range ($\Delta\theta$) of ~30° with an initial angle (θ_i) at ~29° and final angle (θ_f) at ~59°. The angular range could be improved by using shorter focal length mirrors and variation of the off-axis-cut (45° vs. 90°) of the parabolas. Fig 2. .

Our current in-line scatterometry high-speed, non-contact, real-time, non-destructive tool can be integrated into both R2R manufacturing toolsand wafer scale nanomanufacturing systems. As nanomanufacturing becomes more prevalent in many optical and electronic systems, there will be many uses for a flexible, high-speed nanoscale dimensional metrology tool. Fig 3. Shows preliminary results of the current system vs. off-line optical scatterometry and RCWA modeling.

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[1] This work is based upon work supported primarily by the National Science Foundation under Cooperative Agreement No. EEC-1160494.

[2] Raymond Christopher. “Overview of Scatterometry Applications in High Volume Silicon Manufacturing.” *AIP Proc.* **788**, 394, (2005). DOI: 10.1063/1.2062993

[3] Ruichao Zhu, et al. “Scatterometry for nanoimprint lithography” *Journal of Vacuum Science & Technology B*, Volume 34, Issue 6, DOI: 10.1116/1.4967933

[4] Ruichao Zhu, Juan J. Faria B “CD Limits of Scatterometry.” EIPBN, 2017.

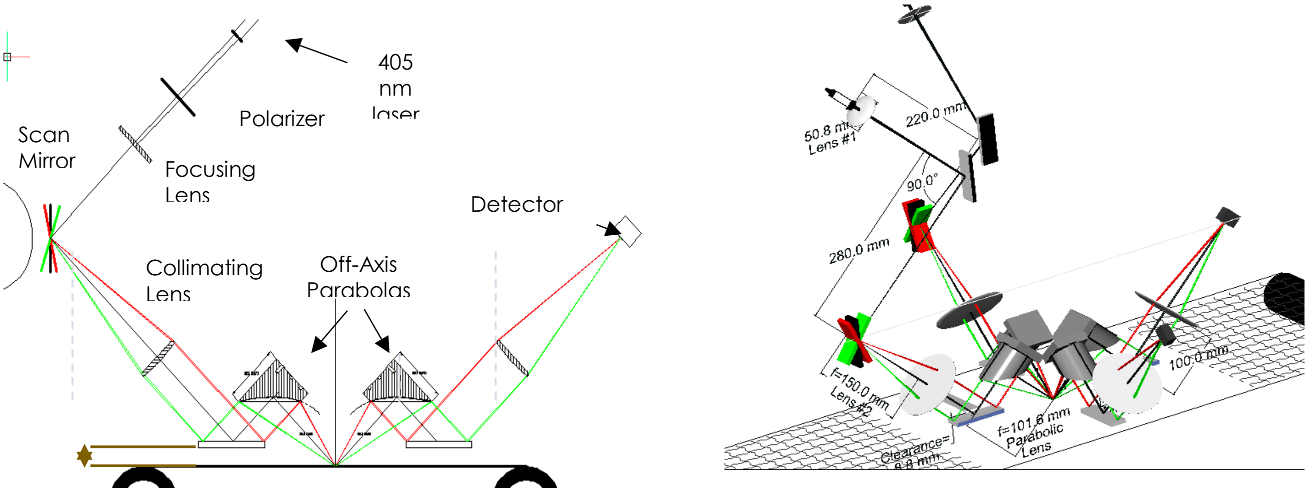

Fig 1. In-line Scatterometry 2D and 3D design with parabolic mirrors/ rotating beam and fixed sample. The colors refer to different galvanometer positions.

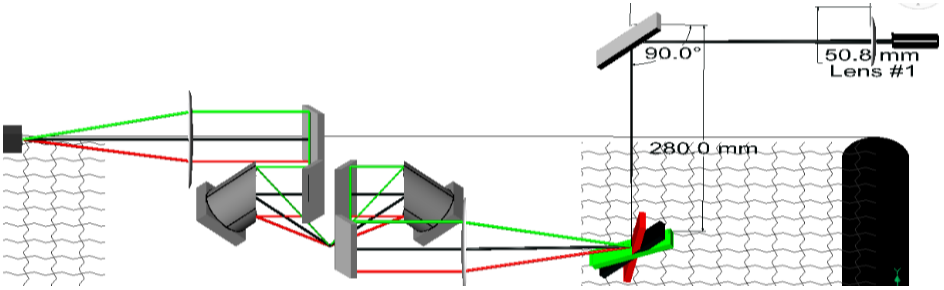

Fig 2. One leg 3D alternative design using 45° parabolas bringing incoming beam from the side of the parabolas.A significant advantage in improved clearance from the manufacturing web. Additional optics can be used to reduce the footprint, particularly along the web.

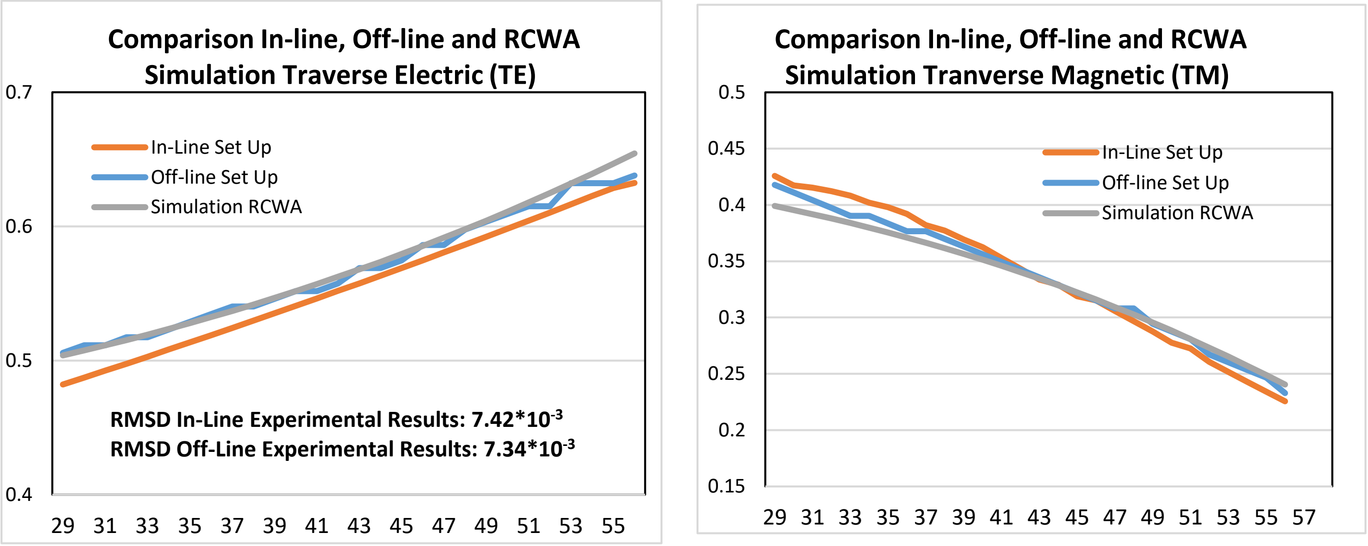

Fig 3. Experimental In-axis, off-line, and RCWA simulation comparison of Si with Alumina (4.9 nm) coated sample.