Sub-wavelength diffraction metrology for inline and critical dimension monitoring of the nanoimprint lithography process

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Nanoimprint lithography (NIL) is an alternative high resolution, low cost, lithography method for fabricating structures with features as small as ten nanometres. To characterise nanoimprinted structures, and structures made by other methods on the nanometre scale, there is a need for more convenient and non-destructive wafer-scale metrologies to complement scanning electron microscopy and atomic force microscopy. The reduction in feature size of manufacturing processes, to 32 nm by 2011, (as indicated by the International Technology Roadmap for Semiconductors) is also producing new challenges, such as the increasing importance of controlling systematic drift in lithography tools and process behaviour, a key part of which is in situ and inline, real-time monitoring of pattern shape and size, and the presence of defects.

Sub-wavelength diffraction is a new metrology technique which can be used to optically characterize structures as small as 50 nm formed by nanoimprint or other lithography methods. By analyzing the far-field diffraction pattern of line gratings composed of sub-wavelength sized features (Figure 1), information can be obtained about the critical dimension, height and presence of defects in the structures. The current work demonstrates the suitability of sub-wavelength diffraction for inline integration by using collinear delivery of incident light and collection of diffraction patterns through microscope optics, and recording of the diffraction pattern in a single image on a CCD camera (Figure 2). This reduces the space required to access and analyse the sample to the diameter of the objective lens and reduces the time required to position and focus the optics.

There is no fundamental limit to the resolution of optical metrology if the light is analysed according to properties such as scattering angle or phase. The present work demonstrates the practical resolution of a subwavelength diffraction apparatus to small changes in CD of nanoimprinted structures. Measured diffraction efficiencies were compared to values obtained from finite difference time domain and rigorous coupled wave analysis simulations (Figure 3), demonstrating that the method produces measurable changes in diffraction efficiency parameters, of 5%, for critical dimension changes as small as 5 nm.

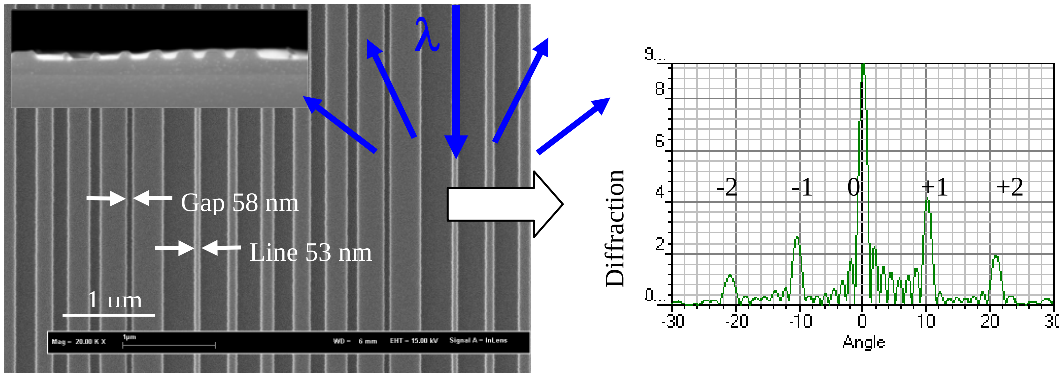

Figure 1. (a) SEM of grating test structure in Si stamp, with imprint (inset). (b) Far-field diffraction pattern, modelled, showing intensities of 1st and 2nd orders.

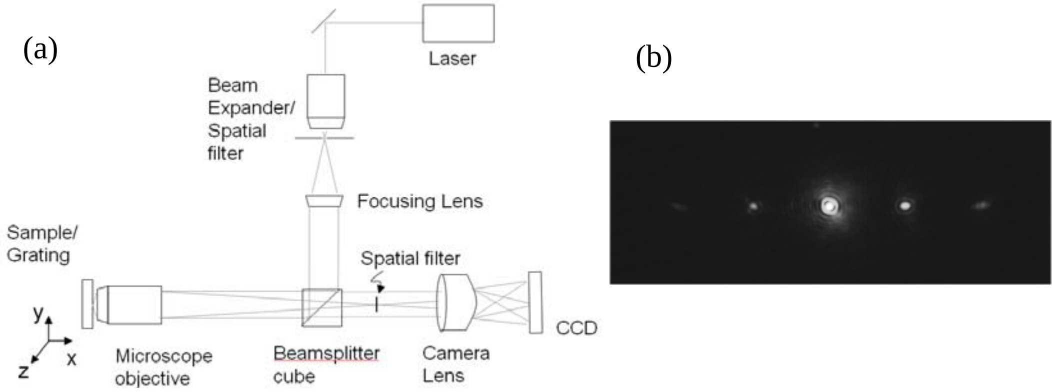

Figure 2. Diagram of the inline optical apparatus, and recorded diffraction pattern.

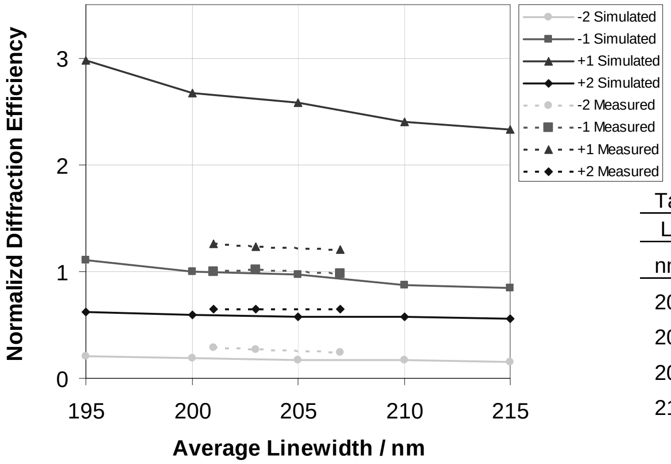

Table 1. Normalized diffraction efficiencies

Linewidth	Simulated		Measured	
nm	-2	+1	-2	+1
200	0.19	2.68		
201			0.29	1.26
207			0.24	1.20
210	0.17	2.40		

Figure 3. Measured and simulated diffraction efficiencies, as a function of average grating line-width.