Subwavelength diffraction for quality control in nano fabrication processing

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Optical means cannot image the critical dimensions that nanofabrication accesses. Nevertheless, optical techniques can control nanometer scale dimensions, like scatterometry controls thin films thickness, by monitoring the changes of a particular optical property. The link between the nanometer scale critical dimension and the optical property can be done by tracing back the optical property change or by comparing with a previously acquired/calculated library.
In the last years, we have developed a methodology for controlling the fidelity of nanoimprinting lithography: subwavelength diffraction (SWD)[1].It's well known that in a diffraction grating by changing the shape of the motive (the cell that repeats) one can select the light intensity distribution. In particular, to maximize the light filtered out by a monocromator, blazed grating are designed to distribute most of the light in the +1 diffraction order, reducing the losses (light diffracted in the other diffraction orders). The critical dimensions of that repeated cell lay already in the nanometer scale, and if repeated with fidelity in all of the periods determine the intensity distribution of the light diffracted by the grating. In the same way that scatterometry and ellipsometry relay on libraries to detect critical dimension changes, we can establish a univocal relation between the diffraction pattern of a grating (the intensity versus collected angle measurement) and the nanometer scale critical dimensions of the repeated cell.
Using this concept, in periodic structures (diffraction gratings) dimensional sub-wavelength features can be detected from the diffraction pattern (or diffractogram), given that enough orders of diffraction are measured and that the accuracy of the measurement allows distinguishing deviations from a reference. Most of the mass production nanofabrication processes, like nanoimprinting lithography, consist in reproducing a cell with nanometer scale features at least hundreds of times in a repetitive continuous way. The results of such approaches are periodic arrays of cells with well defined nanometer scale critical dimensions. The periodicities are normally in the micrometer range, and because of that, the periodic arrays constitute themselves good diffraction gratings for optical light.
Once we defined the magnitude to measure (diffractogram) we focused in making the metrology compatible with the fabrication process. Diffractograms are normally collected by repositioning the wave source and the detector (what determines the diffraction angle) in a sequential way. Standard X ray machines are a good example. Sequential acquisition is slow by nature and does not allow monitoring more than one order of diffraction at a time.
We have developed a **diffractometer** that allows implementing inline SWD as a metrology tool for inline nano fabrication. The optical design (patent pending) allows measuring at once (ms acquisition times) the diffraction pattern of an optical diffraction grating without movable parts and with high accuracy. The illuminated zone can be made as small as few 10ths of microns, improving the contrast for local defectivity, or arbitrarily big.

References:

1 a)Kehoe, T., Reboud, V., Kehagias, N., & Torres, C. S. (2011). Characterization of Nanoimprinted Line Profile using Subwavelength Optical Diffraction. *Proceedings of the 11th euspen International Conference*. b) Kehoe, T., Reboud, V., & Torres, C. S. (2009). Inline metrology configuration for sub-wavelength diffraction using microscope optics. *Microelectronic Engineering*, *86*(4-6), 1036–1039.