Optical Characterization of EBL Overlay Alignment Using Arrays of Radially Symmetric Moiré Patterns

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Analysis of overlay alignment in electron beam lithography (EBL) is commonly done by careful imaging of Vernier patterns using electron microscopy[1]. This can provide high accuracy, but it is time consuming and labor intensive, making it impractical for high volume analysis. Moiré patterns, large scale interference patterns formed by the overlay of periodic structures, have been used both to aid in optical alignment and to measure alignment accuracy[2,3].

We present a technique to measure overlay alignment using moiré patterns formed by offsetting of overlaid radially symmetric patterns. A two-dimensional array of radially symmetric elements such as circular gratings is patterned in the first layer. In the second layer, the patterns are identical or complementary, but the pitch of the array is slightly altered, utilizing a key principle of Vernier patterns for highly accurate measurement. In perfect alignment, the center pattern in the array has no misalignment, and thus no moiré pattern. As the misalignment increases, the moiré patterns become increasingly apparent. Because the symmetry of the moiré pattern depends on both x and y misalignment, an overall radial pattern in the overlaid array becomes apparent. This takes advantage of a property of human vision called hyperacuity[4], which allows us to identify the center of a pattern with high accuracy. The misalignment can be determined by simply multiplying the pitch offset between layers by the number of elements the pattern center is shifted from the array center. Preliminary demonstrations show measurement of overlay accuracy down to 5 nm using brightfield optical microscopy with a horizontal field width (HFW) of more than 150 µm. Advances in computer vision and image analysis may also provide a path by which automated analysis of EBL alignment can be performed using low magnification optical imaging.

[1] Bartholomeus H. Koek et al. Sub 20 nm Stitching and Overlay for Nano Lithography Applications. Jpn. J. Appl. Phys. 33 6971 (1994)
[2] T.E. Murphy, Mark K. Mondol, and Henry I. Smith. Characterization of field stitching in electron-beam lithography using moiré metrology. J. Vac. Sci. Technol. B, 18(6) 3287 (2000)
[3] Wenbo Jiang et al. Lithography Alignment Techniques Based on Moiré Fringe. Photonics, 10, 351 (2023)
[4] Gerald Westheimer. Visual acuity and hyperacuity. Investigative Opthalmology, 14(8) 570 (1975)

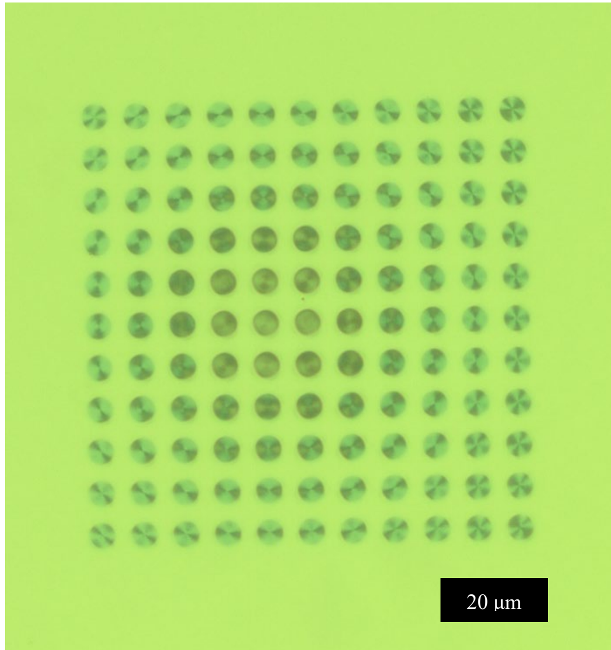

Figure 1: Optical image of circular grating array showing a misalignment of 5 nm in the x direction and < 5 nm in the y direction. Each pattern in the array is two overlaid circular grating patterns with a 5 µm diameter and 40 nm grating pitch. The first layer array has a pitch of 8 µm and the second has a pitch of 8.005 µm.

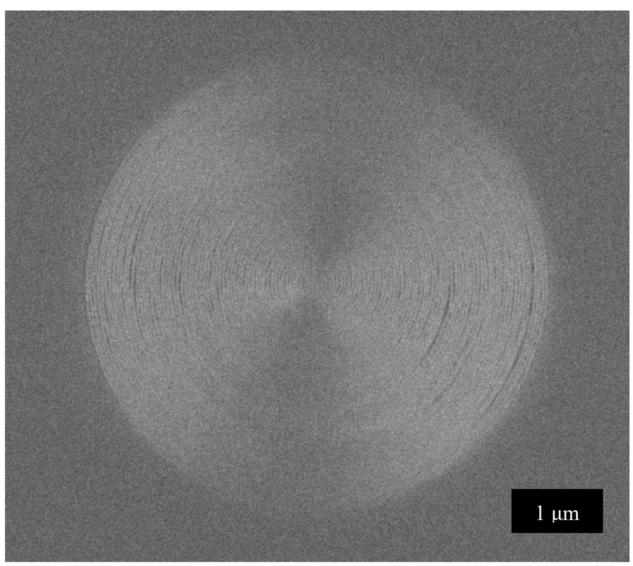

Figure 2: SEM image of one pattern in the array. Although the moiré pattern and the grating structure are visible, alignment accuracy cannot easily be measured on a single pattern.