# Zone Plate Microscopy to sub-15 nm Spatial Resolution with XM-1 at the ALS

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With many advances in the last decade, soft x-ray zone plate microscopy has come to be a valuable imaging technique that complements conventional nano-analytic techniques such as electron and scanning probe microscopies. It offers large elemental, chemical and magnetic sensitivities and a myriad of permissible in-situ sample conditions at sub-50 nm spatial resolution. The highest measured resolution was 20 nm [1], achieved with a 25 nm outermost zone width zone plate at the full-field microscope XM-1, at the Advanced Light Source (ALS), Berkeley. The zone plate was fabricated using e-beam lithography. As spatial resolution is roughly equal to the outermost zone width of zone plate, zone width reduction has been the center focus of x-ray microscopy. While e-beam lithography has been providing a path to fabricate high resolution zone plates, shrinkage of outer zone width from 25 nm to 20 nm and below, however, was extremely difficult due to fabrication process limitations in dense line fabrication, such as electron scattering, low e-beam resist contrast and development issues. Isolated lines on the other hand, do not suffer from these problems, and lines of around 10 nm wide can be routinely fabricated. This fact led us to develop a new zone plate fabrication technique, in which a dense zone plate pattern is divided into two (or more) semi-isolated, complementary patterns, and each pattern is sequentially fabricated and overlaid to the other patterns. The key of success to this overlay technique is pattern alignment accuracy, which for zone plate is needed to be better than one third of the smallest zone width. Using the technique, we have successfully realized zone plates of 15 nm outer zone width, with alignment accuracy of 1.7 nm, at the LBNL's Nanofabrication Laboratory. Experiments showed that these zone plates have significantly improved the resolution of the XM-1 microscope, allowing the instrument to resolve 15 nm half-period test pattern [Fig. 1], which has yielded no contrast with our previous 25 nm zone plates. The results indicate that sub-15 nm resolution has been achieved. In the talk, the details of the overlay technique, and its extensibility towards fabrication of 10 nm zone plates will be presented.

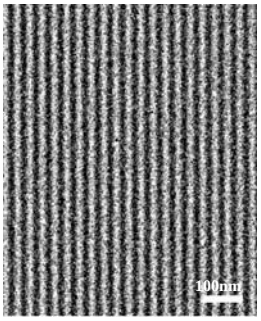


Figure 1. A soft x-ray image of 15 nm test pattern obtained with a 15 nm zone plate at 1.52 nm wavelength (815 eV).

[1]. W. Chao et. al., “20-nm-resolution soft x-ray microscopy demonstrated using multilayer test structures,” Opt. Lett. **28**, 2019-2021 (2003).