ELECTRON OPTICS FOR HIGH THROUGHPUT LEEM

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[‡] In memory of Lee Veneklasen's contribution

In this paper, we will discuss several novel electron-optical components and concepts aiming at improving the throughput and extending the applications of a LEEM [1]: an immersion magnetic field in the objective lens and its implications for the illumination optics, a dual electron beam illumination approach, and imaging modes with tilted illumination.

Increased throughput requires a larger total beam current, which results in increased e-e interactions [2]. We have found that while the e-e interactions and the associated blur d_{ee} is comparable in electrostatic and non-immersion magnetic lenses [3], a further substantial reduction in blur can be seen in immersion magnetic lenses, since no sharp crossover is formed in the focal plane. The immersion nature of the objective impacts the design of the illumination, in particular for the mirror mode, where electrons reflect a few nanometers above the surface. In a magnetic immersion objective, this can be achieved only near the optical axis, and electrons further away from the axis turn around higher above the wafer, causing a serious degradation of resolution. This effect can be eliminated by immersing the cathode of the electron gun in an appropriately matching magnetic field that cancels the circumferential velocity at the substrate.

The dual beam approach is driven by the difficulties encountered when electron microscopes are used to image insulating surfaces and the imbalance between the arriving and leaving flux of electrons causes the surface to charge up. This charging effect can be mitigated when two electron beams with different landing energies are used for imaging. The first beam is partially mirrored and charges the surface negatively, while the second one strikes the wafer with an energy resulting in a secondary yield larger than 1, which charges the surface positively, resulting in a dynamic charge balance.   We have generated two independent electron beams in an electron gun equipped with two concentric cathodes, with a relative bias of a few hundred V.

In an attempt to further enhance fine surface features, we have explored LEEM imaging modes with tilted illumination. At or near glancing incidence, large shadows are formed on even the smallest topographic features, easing their detection. On magnetic substrates, the magnetic flux leaking above the surface can be detected with tilted illumination and used to image domain walls with high contrast similar to the Fresnel mode of Lorentz microscopy.

References

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