Accurate Electron-Beam Lithography and Microscopy

Positioning with ECS Nanopositioners in Extreme Environments

Thomas Ch. Hirschmann, Isabel Greisberger, Mark Braun, Gregor Schindler
attocube systems AG, Eglfinger Weg 2, 85540 Haar, Germany

Introduction

Electron-beam systems are used in a wide range of scientific and industrial applications. Specifically, in the semiconductor industry and for research & development purposes, e-beam applications are common within lithography systems and microscopy tools for physical defect inspection. To this day, e-beam systems offer the highest resolution for the smallest structures or physical defects, but are limited in regards of throughput, when compared to alternative technologies such as deep and extreme ultraviolet (DUV and EUV) systems [1]. However, with recent developments in multi stencil character projection, e-beam systems could be pushing for an even bigger role in the development and production of advanced nodes.

A standard scheme of an e-beam lithography system is shown in Figure 1. This type of system is usually in need of an ultra-high vacuum (UHV) and clean environment to increase the lifetime of the electron source, to avoid arcing events within the gun assembly and to prevent surface contaminations. Depending on the kind of electron emitter, the surrounding components might also be exposed to elevated temperatures. After the emission at the source, electrostatic and magnetic lenses and deflectors are used to shape and deflect the beam [2]. Multi stencil character projection makes use of a set of exchangeable shaping apertures and stencils to heavily reduce the writing time [3]. This adds complexity and challenges, some of which include micrometer (µm) or even nanometer (nm) precise positioning of individual components within this extreme environment.

This Application Note presents electron-beam aperture positioning, for which attocube's piezo-based nanopositioners are the perfect fit.

The moving wafer stage with mirrors as depicted in Figure 1 can be closed-loop controlled by attocube's IDS3010 interferometer. This additional application example is explained in another Application Note [4].

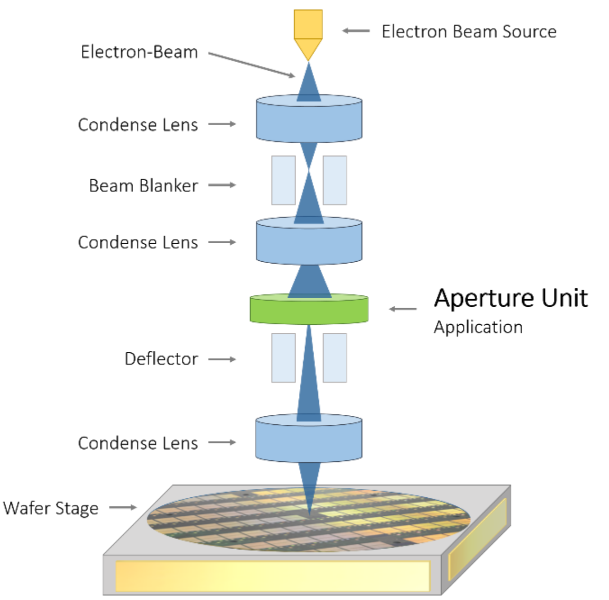

Figure 1: Sketch of an electron-beam system. One application example with attocube nanopositioners is explained in detail in this Application Note.

Electron-Beam Aperture Positioning

A basic electron-beam system is based on an electron source and a set of electrostatic and magnetic optical components, which shape and deflect the beam. All components combined are called column or axis. To decrease the writing time in lithography systems the e-beam can be shaped by special apertures within the column [3]. A holder with several different apertures/stencils moved with attocube nanopositioners can provide a high variety of different beam shapes during the writing process. Figure 2 depicts an aperture holder which is moved by two stainless steel ECSx5050 nanopositioners in x- and y-direction. Next to punctiform beams, also line, multiline or special pattern beams are created by placing the respective aperture into the beam path. attocube's nanopositioners can be used as an exchanging and position optimization unit for a multitude of different apertures placed onto one support structure.

In transmission electron microscopes (TEM) multiple apertures are also used to form the e-beam. One can distinguish between fixed and moveable apertures. Common versions of the latter are located at the condenser lens, objective and selector. In the case of the condenser lens, multiple apertures of varying diameters, ranging from tens of microns to hundreds of microns, determine the divergence angle and dose of the incident beam [5].

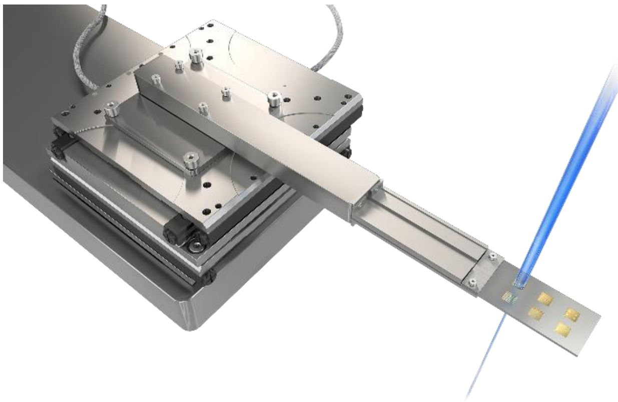

Figure 2: Two ECSx5050, which are mainly built from stainless steel. They can be used in UHV environments and precisely move an aperture holder in x- and y-direction.

The positioning needs to be performed within a vacuum environment and at either room temperature or at moderately elevated temperatures. A travel range of multiple millimetres is necessary to be able to move each aperture into the beam path. Position optimization of the µm-sized apertures is key and therefore a nanometer resolution optical encoder is required. The ECS line with travel ranges of up to 50 mm and 50 nm repeatability is perfectly suited for this application and can be operated within UHV conditions and up to 50 °C.

Next to precise movements, such positioners may need to fulfill additional requirements, such as elevated temperatures during operation and magnetic field compatibility, as well as a high amount of cleanliness and position stability. attocube’s AN series combines all those properties. With the standard RES encoder, positioning with µm accuracy and repeatability can be performed within UHV conditions and elevated temperatures of up to 150 °C. An additional ground modus ensures a stable state during e-beam operation.

Conclusion

attocube’s nanopositioners can be used for different applications within e-beam lithography and microscopy systems. Besides the accurate positioning properties, attocube’s nanopositioners fit well with the required harsh environments. In addition to the presented and explained application example, other e-beam applications are also suitable for attocube products, especially if customized adaptions are needed.

References

[1] E-beam *vs.* Optical Inspection, 2016

[2] Scanning Electron Microscopy, Central Microscopy Research Facility, 2021

[3] Hübner *et al.* Character projection e-beam lithography for wafer level nano-fabrication [Seminar, Leibniz ipht], 2017

[4] Application Note Motion & Sensing 18: Closed-Loop XY-Stage Control with Yaw Rotation Tracking

[5] Definition, condenser aperture (Hyperlink)