

Development of a precision positioning system for electron beam applications

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Abstract

The paper describes the mechanical design of a motorized x-y-positioning system for beam shaping elements in an electron beam lithography tool considering the special environmental requirements of the electron optical column. The results of characterization activities are discussed. A vacuum chamber developed for tests of differential pumping under conditions down to 10^{-5} Pa is described. The performance of the applied position measuring systems and the test setup in the vacuum chamber is characterized. Results of different performance tests of the positioning system are illustrated. Finally, challenges are discussed which are closely connected to the requirement of long term system stability.

1 Motivation and requirements

New lithography tools for Multi-Shaped Beam Lithography [1-3] require the accurate positioning of beam shaping elements with respect to the electron beam. By reason of calibration procedures, the beam shaping elements have to be placeable on different functional positions with reproducibility of less than 1 μm . During the writing procedure, the positions have to be stable on a scale better than 10 nm over a time period of 10 minutes. Thus, the requirements from the positioning system are a long-term stability in the low nm-range, a bidirectional reproducibility better than 1 μm , compatibility to high vacuum conditions (10^{-5} Pa), and no magnetic or electrostatic interference with the electron beam caused by positioning system components. The travel range for each axis is defined to be 12 mm.

2 Design of the positioning system

A two-axis positioning system consisting of a mounting frame to attach the assembly with beam shaping elements, actuators, an optical measuring systems and ceramic roller bearings (see Figure 1) was developed to meet the requirements given in section 1. Based on vacuum compatible components and processes, a demonstrator of the positioning system was built. The manufacturing quality of the ceramic bearings was measured to a surface flatness of less than 3 μm and a roughness of less than 0.1 μm (Ra). The chosen actuators based on a piezo-ceramic actuation principle and measuring system are also adapted to vacuum conditions. The step width of the positioning system shows values of 2.7 nm with a standard deviation (3 Sigma) of 0.3 nm. The measuring system has a resolution of 2 nm using a 16000 times interpolation rate. By reason of the necessary heating procedures of functional elements, the design of mounting structures of the positioning system is athermal to prevent thermally induced displacements of the beam shaping elements, which will be integrated onto the positioning system.

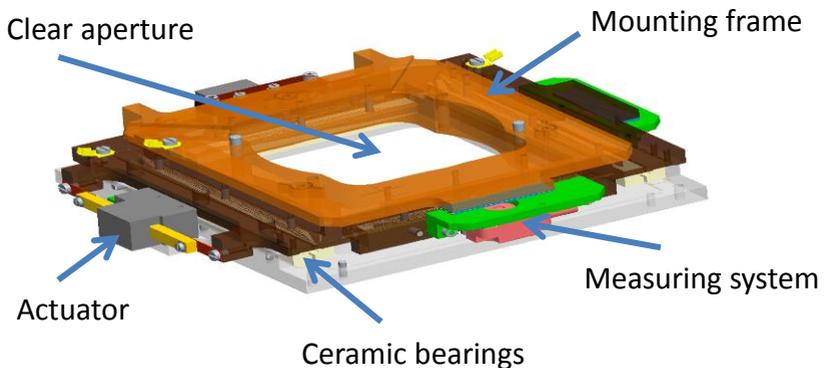


Figure 1: CAD model of the two-axis positioning system

The fixation technologies applied for the assembly and integration do not use any outgassing materials or gluing procedures. The mechanical clamping method was chosen, combined with the Solderjet Bumping fixation technology [4]. A controller connected to the actuators and measuring systems ensures that the positioning status meets the requirements of long-term stability.

3 Characterization of the positioning system

The characterization of the positioning system was performed under standard atmosphere and vacuum conditions. A vacuum test chamber (see Figure 2) was designed and installed for different test campaigns [5]. A vacuum of 10^{-5} Pa was reached at the inner clear aperture of the positioning system using a turbo molecular pump; at the outer side of the positioning system (main chamber) a vacuum of 10^{-3} Pa was reached during the positioning and position stability examinations.

The measurements of the positioning step width and the positioning stability were performed using the integrated optical measuring systems and additional capacitive sensors. The comparison of the test results on standard atmosphere and vacuum conditions shows a good correlation of the measured step width. Positioning steps down to 3 nm can be performed. The positioning stability shows an overall drift of less than 10 nm over a measuring period of 10 minutes. Depending on the thermal stability, the thermal induced deviations are higher at standard atmosphere, because of the influences of convective heat transfer.

The performance measuring shows a positioning accuracy of 1 μm and a bidirectional repeatability of 0.1 μm .

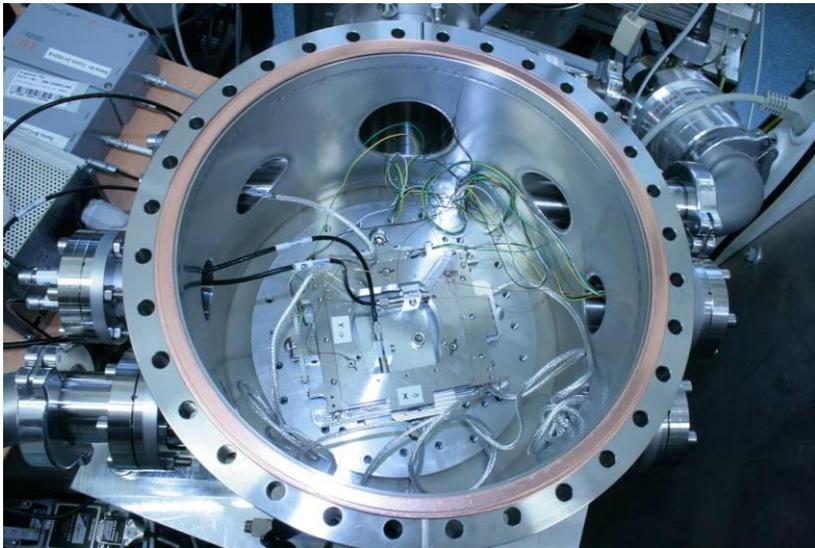


Figure 2: Vacuum chamber with integrated positioning system

4 Summary

By using state-of-the-art components like ceramic bearings, piezo driven actuators and optical measuring systems, a demonstrator of a positioning system for the use in electron-optical columns under vacuum conditions was developed and built. The characterization of the demonstrator shows reproducible step width with nm-resolution and a position stability of less than 10 nm over a measuring period of 10 minutes.

The control of the x-y-positioning system has to be adapted for industrial use in a lithography tool. In a next phase the performance of the component will be evaluated under electron beam working conditions.

5 Acknowledgements

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References:

- [1] Slodowski, M; Doering, Hans-Joachim; Elster, Thomas; Stolberg, Ines A.: Coulomb blur advantage of a multi-shaped beam lithography approach. SPIE Advaned Lithography, Proc. SPIE Vol. 72710Q (2009).
- [2] Slodowski, Matthias; Doering, Hans-Joachim; Dorl, Wolfgang; Stolberg, Ines A.: Multi Shaped Beam Proof of Lithography, Proc. SPIE Vol. 7637 (2010)
- [3] Slodowski, Matthias; Doering, Hans-Joachim; Dorl, Wolfgang; Stolberg, Ines A.: Multi Shaped Beam: Development Status and Update on Lithography Results, Proc. SPIE 7970 (2011)
- [4] Burkhardt, T., Kamm, A., Hornaff, M., Beckert, E., Eberhardt, R., Tünnermann, A.: Precision photonic packaging using laser-based Solderjet Bumping. Smart Systems Integration 2010, 4th European Conference & Exhibition on Integration Issues of Miniaturized Systems – MEMS, MOEMS, ICs and Electronic Components, edited by T. Gessner, VDE Verlag Berlin, ISBN 978-3-8007-3208-1 (2010).
- [5] Heidler, N; Mohaupt, M.; Risse, S.; Doering, H-J.: Investigations on clearance seal units for moving elements in an ultra-high vacuum region. 56th IWK Ilmenau, URN: urn:nbn:gbv:ilm1-2011iwk:5, September 2011