Abstract
Recent developments in nanotechnologies raised new issues in microscopy with nanometer and sub nanometer resolution. Together with the imaging techniques, new approaches in the metrology field are required both in the direct metrology issues and in the area of calibration of the imaging tools (microscopes). Scanning electron microscopy needs the calibration specimens for adjusting the size of the view field (correct magnification) and the shape of that field (correction of deflection field distortions). Calibration specimens have been prepared using different technologies; among them the e–beam patterning and the e–beam lithography have been proved to be appropriate and flexible tool for that task. In the past, we have reported several times our achievements in this field (e.g. [1]). Nevertheless, recent advances of the patterning tool (BS600), mainly the development of the technology zoomed exposure mode [2] and the installation of the magnetic field active cancellation system [3], pushed remarkably the technology necessary for further advances in this area. Within this contribution some theoretical, technology and practical aspects are discussed; achieved results are presented.

Keywords
E–beam technology; calibration specimen; scanning electron microscopy.

1. INTRODUCTION
The combination of e-beam direct write origination with the anisotropic Si etching techniques presents several potential advantages when preparing the calibration specimen for scanning e-beam microscopy (SEM). E-beam patterning enables a good level of flexibility for the design of various testing patterns. The precision of positioning is calibrated and it is deduced from the laser interferometers resulting in a high precision of artifacts nominal positioning. The facets etched in Silicon have good contrast when imaged by the SEM and the artifact edges are very sharp.

2. DIMENSION CALIBRATION SPECIMEN
We prepared several calibration specimens using the BS600 shaped beam pattern generator working with fixed energy of 15 keV. The high resolution exposure mode TZ-0 [2] was very useful as it allows better stamp size control and faster patterning process. Standard technology with 100 nm PMMA resist layer, exposure dose of 30 µC/cm² and n-AAC developer was used for resist mask preparation. Anisotropic etching of the Silicon substrate was processed through the resist mask.

The basic addressing step of the BS600 (LSB of the main beam deflection D/A converters) is 50 nm. However, fine D/A converters connected in parallel with the main D/A converters have the main step 20 times lower (2.5 nm). This step may be employed when the required notch spacing should be finer than the standard 50 nm spacing makes possible.
3. RESULTS AND DISCUSSION

3.1 Cross grating 4600 nm

The first example concerns the cross grating with the period of 4600 nm, its design is depicted in Fig. 1. One calibration sample consists of 11 × 10 vertical notches and 10 × 11 horizontal notches placed in the square matrix. The sample is prepared by the procedure described in the previous section. The given set of notch spacing was evaluated by the Czech Metrological Institute that issued the certificate of calibration [4] with the following results:

*Period of the grating in the x axis: \( d_x = (4606 \pm 13) \) nm.
Period of the grating in the y axis: \( d_y = (4602 \pm 14) \) nm.
Orthogonality of the grating: \( \phi = 89^\circ \pm 1^\circ \).
Sample standard deviation in the x axis: \( s_x = 13 \) nm.
Sample standard deviation in the y axis: \( s_y = 16 \) nm.

The standard uncertainty of measurement has been determined in accordance with EA-4/02 document. The reported expanded uncertainty of measurement is stated as the standard uncertainty of measurement multiplied by the coverage factor \( k \) corresponding to a coverage probability of approximately 95%, which for normal distribution corresponds to a coverage factor \( k = 2 \).

Fig. 1 Cross grating with a period of 4600 nm (design).

3.2 Cross grating 463 nm

Figure 2 shows a detail of a calibration specimen for SEM adjustment consisting of a cross grating with a period of 463 nm: the data were prepared using the proximity effect correction method for shaped electron beam, the pattern was exposed in the TZ exposure mode, standard technology resist development, anisotropic Silicon etching process and thin film Platinum sputtering. It might be noticed that even the shape of exposure stamps was rotated with respect to the deflection coordinates (−45°); the anisotropic etched artifacts reflect the crystallography of the Silicon substrate with \( \langle 100 \rangle \) orientation.

Fig. 2 Detail of a calibration specimen: cross grating with a period of 463 nm.
We performed the analysis of individual notch positions based on the SEM image of the specimen (Fig. 3 and Fig. 4). In this analysis the spread of position values rather than the exact spacing is analyzed.

A dedicated software was prepared for this analysis. First, the shape of the individual notches (see Fig. 5) is extracted from the original image. Next, the nominal coordinates of the notches are prepared by fitting a regular matrix on the original image. The next step consists of searching the real notch positions. Finally, a histogram plot of both individual notch positions (Fig. 6) and the 10-pitch spacing (Fig. 7) is evaluated.
When comparing these results with the results of the first sample, we conclude that the achieved variance is significantly worse. This is due to the insufficient power-line 50 Hz frequency magnetic field cancellation during the e-beam writing process.

4. CONCLUSIONS

Future work will be related to multi material samples that might be useful for material contrast microscopy techniques and other analysis. Eventual further improvement of standard uncertainty will be possible using the new e-beam patterning tool (Vistec EBPG 5000 ES) that is being installed in our facilities.

ACKNOWLEDGEMENTS

The authors would like to express their thanks to Miroslav Valtr and Petr Klapetek from the CMI (the certificate of calibration and technical discussions) and Filip Mika from ISI ASCR (the scanning on FEI Magellan Microscope).

This work was partially supported by European Commission and Ministry of Education, Youth and Sports of the Czech Republic (project No. CZ.1.05/2.1.00/01.0017 — ALISI), by the TACR project No. TE 0102 0233 (AMISPEC), by the Ministry of Industry and Trade project FR-TI1/576 and by the institutional support RVO:68081731.

REFERENCES


