Analysis of Electron Current Instability in E-Beam Writer

Jan Bok, Miroslav Horáček, Stanislav Král, Vladimír Kolařík, František Matějka

Institute of Scientific Instruments of the ASCR
Královopolská 147, 61264 Brno, Czech Republic
bok@isibrno.cz

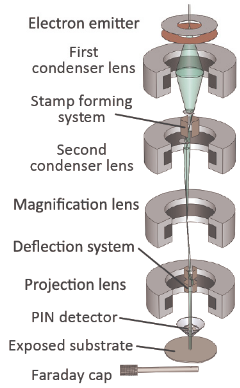
Introduction

In the **e-beam writer**, nanoscopic and microscopic scale regions of the electron sensitive resist are exposed by a rectangular-shaped and variable-sized e-beam pattern, called a **stamp**. One of the crucial parameters of the stamp is its current **homogeneity** [1], **intensity** and **time stability**.

The e-beam current instabilities can be caused by the emission instabilities of the electron emitter and by external influences on the electron optical system, such as temperature variations, electromagnetic fluctuations and surrounding vibrations. The current instabilities can be divided to **short-term** and **long-term** fluctuations. The long-term fluctuations with frequencies in order of 1 Hz and lower are called **drift**. The short-term fluctuations with frequencies over 1 Hz can be generalized as **noise**.

In the case of poor current stability during the exposure, the different regions of the resist are exposed by different dose. This feature decreases the exposure quality and for the improvement, it's necessary to study the e-beam current instabilities.

Experimental set-up

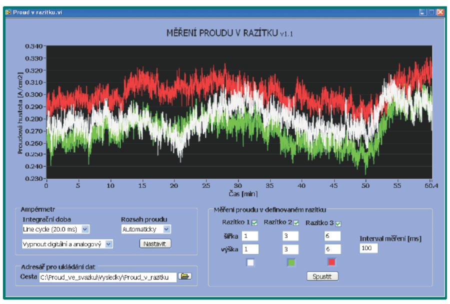


The e-beam writer **Tesla BS-600** creates an e-beam using the thermal-field electron emitter. The rectangular stamps are formed by the forming system. The size of the stamp can be adjusted independently in two perpendicular directions between 50 × 50 nm and 6.3 × 6.3 µm.

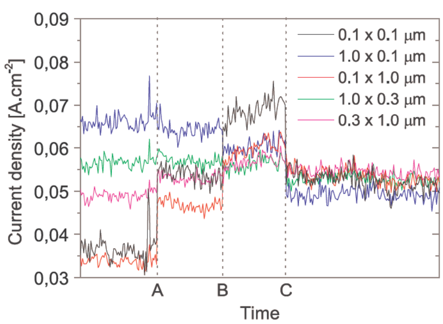
The electron current in the selected stamp can be measured directly by the **Faraday cap**, or indirectly by the **PIN diode**. The current from the Faraday cap is measured by the picoammeter Keithley 487, which uses 50 Hz signal integration frequency. The PIN diode, enables detection of the back-scattered electrons from the substrate with the 1 MHz integration frequency.

Current density measurement

A **software application** for the time dependent measurement of the current density was written in National Instruments LabVIEW. It acquires data from the picoammeter and enables automatic setting of the stamp sizes using serial communication with the e-beam writer exposition software.



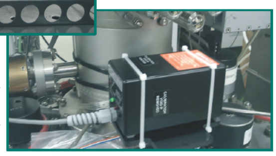
The stamp forming system possesses fine **adjustment instabilities** caused by external influences such as temperature fluctuations and the incoherence between the position of the electron emitter and the forming system. Therefore, the forming system setting has to be occasionally corrected. Using the measurement software, the forming system can be adjusted by the current density observing in various stamps during the optical system settings. Example of the optical system setting in time A, B and C is shown in the figure below.



E-beam current noise

The e-beam writer was equipped with the **magnetic field cancelling system** Spicer Consulting SC20 for suppression of external magnetic field [3].

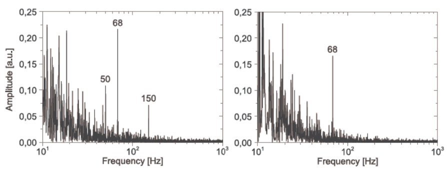
The control unit of the magnetic filed cancelling system



The magnetic field sensor with 3 orthogonal magneto-resistive elements

The signal from the PIN diode was digitalized by the A/D video channel converter and each signal sample was shown as one image pixel. The created image was read as a time sequence of the current intensity – the gray level of the pixel is proportional to the intensity. The Fourier analysis of the data shown, that the current fluctuations contains:

- **Current drift** with frequencies below 100 Hz
- Sinusoidal component at 68 Hz corresponding to the **end of the image line** (= image artifact)
- Sinusoidal components at 50 Hz and 150 Hz representing the **power-line frequency** and its third harmonic, respectively.



Without the cancelling system   With the cancelling system

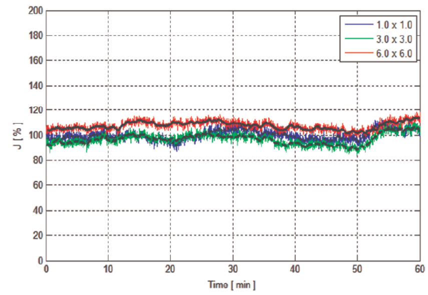
The same measurement was repeated with the magnetic field cancelling system activated. The analysis shown, that the power-line frequency isn't presented. It can be concluded, that the power-line frequency has the form of the time-varying magnetic field presented in the zone of the stamp forming system.

E-beam current drift

The current drift, were measured and analyzed in various stamp sizes. We performed several measurements, one of which is shown in the graph below. Herein, the current density of the stamps is plotted over one hour period with the sampling frequency of 1 Hz. Values in the largest stamp are visibly larger due to slight current density inhomogeneity (as discussed in [1] and [2]).

The measured (colored) values were low-pass filtered at a frequency of 1/30 Hz in order to separate the drift component (black lines). The 1σ deviation value of the **current density drift** ranges between 2.2 % and 6.0 %. This value depends mainly on the time span of the measurements. The **remaining component** (the difference between the measured line and the filtered one) is constant independently on the stamp size and time span. Its 1σ deviation value ranges between 1.9 % and 2.5 % of the nominal current density value.

The numerical evaluation of the drift helps in the selection of the exposure strategy and the scheduling of different lithographic tasks.



Conclusions

The presented measurement techniques and analysis of the e-beam current can be used in similar systems where the e-beam time stability is crucial. The developed software application for the time dependent measurement of the current density helps to adjust the forming system with high accuracy. The developed measuring system is also useful for analysis of cathode emission behavior at different periods of its lifetime.

References

[1] Bok, J., Kolařík, V., In Proc. of the 13th Int. Seminar on Recent Trends in Charged Particle Opt. and Surface Phys. Instrum., 2012, pp. 7-8. ISBN 978-80-87441-07-7.
[2] Matějka, F. et al., In Proc. of the 13th Int. Sem. on Recent Trends in CPO and SPI, 2012, pp. 27-28. ISBN 978-80-87441-07-7.
[3] Kolařík, V. et al., Jemná mechanika a optika, Vol. 56, No. 11-12 (2011), pp. 312–316, ISSN 0447–6441 (in Czech).