Alpha Parameter, Resolution, Line Width Roughness and its Focus Dependencies in E-Beam Lithography

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The application of e-beam direct write for design verification and prototyping in the semiconductor device industry [1] pushes the resolution limit of available e-beam tools and raises the requirements for a stable and optimum process window [2]. We performed our experiments on a variable shaped e-beam writer, which is preferred in terms of throughput, and on Gaussian e-beam tools, which are more advanced regarding high resolution. The resist process and the substrates were kept the same in both cases. The comparison of the exposure results of both beam types ensures distinction between tool and process influences.
The previously published adaptation of the optical isofocal dose test to electron beam lithography is a suitable method to determine the process window [2]. Usually, the critical dimensions are measured against focus and dose. We were able to match the isofocal dose between the Gaussian and the shaped e-beam writer; with an increase of the acceleration voltage from 50 kV to 100 kV the isofocal dose also changes like expected, in accordance to the shift of the contrast curve. The process window of the shaped e-beam writer was found to be slightly larger than the window of the Gaussian tool (for same acceleration voltage).
Feature resolution is mainly determined by the influence of electron scattering and the corresponding proximity effect [3]. The α - parameter of the point-spread function plays a significant role. α is defined as the square root of the squared sums of a forward scattering part and a beam blur part [4]. Strictly speaking, the shaped e-beam profile results from the convolution of a Gaussian beam with specified width $\alpha_{beam \cdot blur}$ inside of a determined shot width. Determining α by measurement of resist features also includes process influences; the point spread function has to be convolved with the contrast curve. This means that α has to be divided into a portion which characterizes the utilized resist process and a portion which is determined by the e-beam exposure (scattering) and the tool (blur) itself. A new measurement method of α was applied. Its dependency on the focus, exposed on a 50 kV shaped e-beam writer, is shown in Fig. 1. α changes with a defocus, the optimum value of about 30nm is near a defocus of 0. Similar plots are achieved for the resolution and the line width roughness (LWR). Fig. 2 draws a Bossung plot for the LWR, exposed on a 100 kV Gaussian e-beam writer. The LWR achieves its lowest values for the isofocal dose in the best focus. With smaller acceleration voltages, the LWR and resolution curves are shifted to higher values.

In summary, this paper presents the interaction of α, resolution and line width roughness against the focus, compared for variable shaped and Gaussian e-beam writers at different acceleration voltages. The knowledge about this α characterisation method is beneficial for the development of maskless e-beam lithography tools [5].

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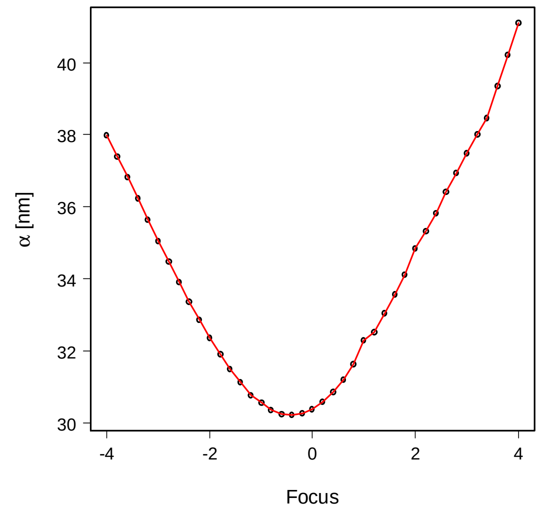

Fig. 1: α - parameter in dependency on the focus (exposed on 50 kV variable shaped beam).

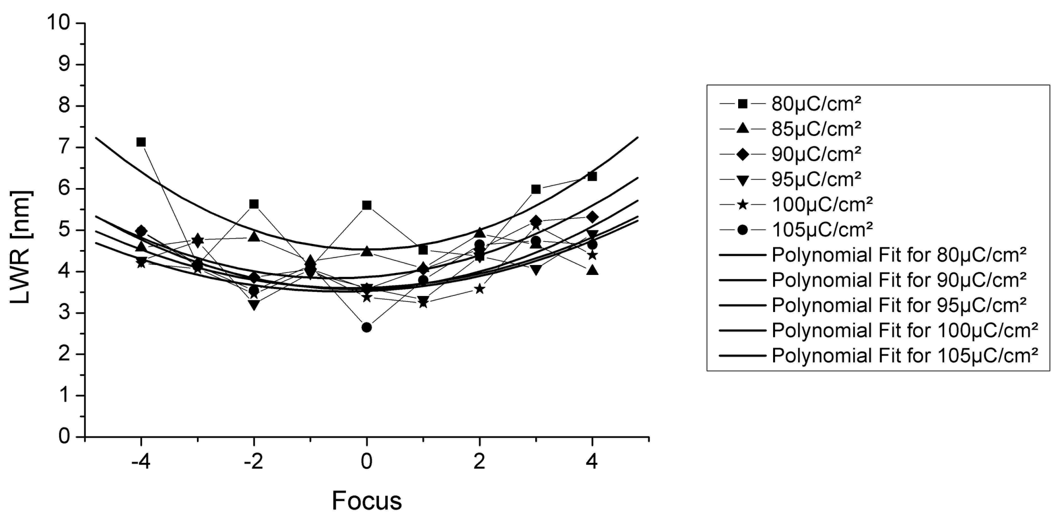

Fig. 2: Line Width Roughness in dependency on the focus (exposed on 100 kV Gaussian beam).