A multi-row writing method for massively-parallel electron-beam systems

S.-Y. Lee
Department of Electrical and Computer Engineering, Auburn University, Auburn, AL 36849
Fax: (334) 844-1809, leesooy@eng.auburn.edu

B.-S. Ahn, J. Choi, S.-B. Kim and C.-U. Jeon
Mask Development Team, Samsung Electronics, Hwaseong-Si, Gyeonggi-Do, Korea

Electron-beam systems with a large number of beams were recently developed in order to improve the writing throughput. For such a system, it is desired to have a writing method which can control beams to achieve not only a high throughput but also a high quality of writing. In a massively-parallel e-beam system (MPES), it is unavoidable that some beams are faulty and the current varies with the beam. An important issue is how to mitigate the effects of faulty beams and current variation to enhance the quality of a transferred pattern. In this study, the issue of designing a writing method to reduce the negative effects is addressed.

In the two existing MPES's, each beam exposes pixels in a row only in each writing path (which is parallel with rows), hence, *single-row writing*. This tends to localize the pixels affected by faulty beams and make large the dose reduction at an affected pixel. In the writing method designed in this study, the negative effects of faulty beams are reduced by allowing each beam to expose pixels over multiple rows in each writing path, hence, referred to as *multi-row writing*. This method spreads the affected pixels decreasing the localization and lowers the dose reduction at an affected pixel. For the realization of the multi-row writing method, the spatial distribution of pixels, referred to as *pattern*, to be exposed by each beam must satisfy certain conditions and then possible beam intervals in the row dimension can be accordingly determined. Also, the beam interval in the column dimension can be adjusted by stretching the pattern in order to decrease the localization of affected pixels in the column dimension.

In this paper, a realization of the multi-row writing method will be described and the conditions on the pattern and beam interval, required for the realization, will be derived. In Table 1, the multi-row writing method is compared with the single-row writing methods in terms of the dose reduction due to faulty beams and localization of affected pixels.

Table 1: Comparison of the single-row and multi-row writing methods

	Single-row I	Single-row II*	Multi-row
$\Delta D^{(1)}$	$n_s d$	$\dfrac{n_s}{n_g} d$	d
$\Delta D^{(n_f)}$	$n_f n_s d$	$\dfrac{n_f n_s}{n_g} d$	$n_f d$
n_c	$\dfrac{D}{n_s d}$	$\dfrac{D}{n_s d}$	$\dfrac{D}{d}$
n_f	$0 \leq n_f \leq n_c$	$0 \leq n_f \leq n_g n_c$	$0 \leq n_f \leq n_c$
ΔX	$0,\ n_s$	$0,\ n_s$	n_s
ΔY	-	-	N_e

*A group of n_g beams jointly exposes a pixel n_s times.

n_s:	the number of times a pixel is exposed by a beam in one cycle
$\Delta D^{(1)}$:	the dose reduction for a pixel due to a faulty beam in one cycle
$\Delta D^{(n_f)}$:	the dose reduction for a pixel due to n_f faulty beams out of n_c beams exposing the pixel through n_c cycles
n_c:	the number of cycles needed to achieve the dose *D* per pixel (the number of beams exposing each pixel)
n_f:	the number of faulty beams out of those exposing a pixel
ΔX:	the minimum horizontal distance between pixels affected by a faulty beam
ΔY:	the minimum vertical distance between pixels affected by a faulty beam
N_e:	the number of empty rows inserted between adjacent rows in a pattern