PMJ 2013 Panel Discussion
Challenges for future EB mask writers

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VSB vs. pixelated gray beam

**VSB**

Two shaping apertures used to form a triangular or rectangular beam.

**Pixelated gray beams**

A number of square shaped beams, of fixed size, created by array of shaping apertures.

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Yoshitake *et al.*, Proc. of SPIE Vol. 8166 81661D-8, 2011

**VSB**

Two shaping apertures used to form a triangular or rectangular beam.

**Pixelated gray beams**

A number of square shaped beams, of fixed size, created by array of shaping apertures.

32 ns, or shorter, settling time was demonstrated on test bench with EBM-8000 Sub DAC Amp

512x512 blanker array in 20 mm sq. chip

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*Yoshitake et al., Proc. of SPIE Vol. 8166 81661D-8, 2011*

*Platzgummer et al., Proc. of SPIE Vol. 8166 816622-1, 2011*

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Motivation for multibeam technology

- Throughput independent of pattern size
  - In VSB systems smaller shot size results in smaller exposure current and larger shot count, to increase total exposure time and total settling time.

- Curvilinear features can be written more easily
  - VSB systems use rectangular or triangular figures.
VSB vs. pixelated gray beam

**VSB**
Shaped beam (triangle, rectangle) exposed with uniform dose.

**Pixelated gray beam**
Square beam exposed with modulated dose

Dose profile can be reproduced with gray beam, if beam size is sufficiently small.

\[ D = D_0 \]

\[ D = 0.5D_0 \]
**VSB vs. pixelated gray beam**

**VSB**

Shaped beam (triangle, rectangle) exposed with uniform dose.

**Pixelated gray beam**

Square beam exposed with modulated dose

![Diagram showing dose, position, and comparison between VSB and pixelated beam](image)
VSB vs. pixelated gray beam

**VSB**
Shaped beam (triangle, rectangle) is exposed with uniform dose

**Pixelated gray beam**
Square beam is exposed with modulated dose

Dose profile can be reproduced with a gray beam if beam size is sufficiently

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Deposited dose with VSB, 20nm pixel, 50 nm pixel

Threshold dose for resist process

Design pattern size (300 nm)

\[ D = D_0 \]

\[ D = 0.5D_0 \]
Writing experiment (1)

VSB writing and pixelated gray beam writing were compared in writing experiments using the EBM-8000 (single VSB writer) and FUJIFILM PRL-009

- Shot sizes of 10, 20, 50 and 100 nm, with 50% dose for edge pixels.
- Edge pixels were written in different write pass.
- Several chips were written with different dose D.

(a = 100 nm)  (a = 50 nm)  (a = 20 nm)  (a = 10 nm)

Pixelated beam

VSB
Writing experiment (2)

Shot size: 100 nm

VSB

Pixelated beam

100 nm

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Writing experiment (3)

Shot size : 20 nm

VSB

pixelated beam
Writing accuracy of pixelated beam improves as beam size decreases.

- Beam size of 10nm and 20 nm brings the same CD accuracy, with a discernible slope difference to VSB writing.
Challenges for multi-beam writers

Beam size needs to shrink, as beam blur reduces.

- Introduction of multi-pass exposure with grid offset can improve gray beam write accuracy, but this is not addressed in this discussion.

How can pixel size shrink?

- Increased demagnification
  - Performance of high demag. optics is questionable.
- Reduction of aperture size, accompanied by either of:
  - Increased # of beams with reduced beam pitch
  - Increased beam current density
Challenges for MBMW

Which is the practical option?

Inevitable

Low sensitivity resist may multiply write passes and data volume

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Summary

- Pixelated gray beam can have writing accuracy equivalent to VSB, with sufficiently small beam size
  - Error budget is needed to estimate feasible accuracy, as actual, beamlets have error in position, size and exposure current.

Challenges for multi-beam mask writers

- Smaller beam size for smaller beam blur
  - Multi-pass writing with grid-offset is necessary.
  - Shrinkage of beam pitch required with increase of # of beams. Otherwise, J or optical demag. should be increased.

- Integrity of explosive data volume
- Roadmap for 10-year evolution

Challenges for VSB mask writers

- Smaller shot size for smaller patterns
  - Further increase of J and reduction of settling time is required.
- Shift to multi-column strategy
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