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Hybrid EB-writing technique with 100 kV-SB and 50 kV-VSB writers: Use of the former for outlines and the latter for bodies after pattern data splitting

Hiroshi Fujita [a,*], Mikio Ishikawa [a], Naoko Kuwahara [a], Masaharu Fukuda [a], Masashi Sakaki [b], Tadahiko Takikawa [b], Hisatake Sano [a], Morihisa Hoga [a], Naoya Hayashi [b]

[a] Dai Nippon Printing Co., Ltd., Research and Development Center, Kashiwa-shi 277-0871, Japan
[b] Dai Nippon Printing Co., Ltd., Fujimino-shi 356-8507, Japan

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ABSTRACT

A new technique of hybrid use of a 100 kV-SB (spot beam) EB writer and a 50 kV-VSB (variable shaped beam) EB writer, based on an outline-and-body method, is proposed and examined for making nano-imprint molds. Here an original layer is split into an outline layer and a body layer, which the 100 kV writer and the 50 kV writer, respectively, take care of. This outline-and-body method is compared with a normal method (using only the 100 kV writer) in terms of CD linearity, pattern fidelity, and writing time. The CD linearity is similar. The pattern fidelity is satisfactory because no disconnected, shortened, or largely distorted features of the resist pattern are observed. A silicon mold with two layers of a 36 nm-rule logic/gate circuit was fabricated. The writing time for the 100 kV writer was reduced by 34%–64%. In conclusion, the outline-and-body method is effective to reduce the writing time without sacrificing fidelity.

1. Introduction

Nano-imprint lithography is a candidate for lithography for devices at the hp 32 nm and 22 nm nodes. Molds or templates for it are developed on the basis of the process of making phase-shift photomasks [1,2]. On the other hand, silicon molds with nano-scale features are important in thermal imprint. For 1X patterning, a combination of a 50 kV-VSB (variable shaped beam) electron beam (EB) writer and a chemically amplified (CA) resist does not have enough resolution. On the other hand, a combination of a 100 kV-SB (spot beam) EB writer and a non-CA resist satisfies the resolution requirement. Patterns of 20 nm lines and spaces on a quartz substrate have been obtained [1]. But this combination leads to an extremely low throughput due to low resist sensitivity.

In our previous study [3], we examined double patterning and double exposure with a hybrid use of two writers: a 100 kV-SB writer (JEOL JBX-9300FS) for delineating fine features and a 50 kV-VSB writer (JEOL JBX-9000MVII) for delineating rough features. In data splitting, each pattern in an original layer is classified according to size, namely line width, and split into two layers, fine and rough ones. Hereafter this technique is referred to as line-split method. We applied the method to a dense area ($100 \times 100\ \mu m$) cut out of a 36 nm-rule gate layer with a threshold line width of 70 nm. The writing time of the 100 kV writer was reduced by 45% of that for using it for all the patterns.

The line-split method, however, had an issue of lack of pattern fidelity; when a pattern is split into two layers and they are superposed in the writing process, they do not always reproduce the original pattern because of the overlay error. Fig. 1 shows an example. Several disconnected features, which are classified as fatal defects, and shortened features are observed in the SEM photo of the patterned resist. We need some measures such as edge correction to avoid yielding disconnected features.

In this paper, we will describe an improved hybrid EB-writing technique based on an outline-and-body method.

2. Hybrid EB-writing with layers split into outlines and bodies

In our new proposal, each pattern gives an outline (or edge pattern) and a body (or non-edge pattern), and the original layer is split into an outline layer and a body layer. Then, a 100 kV-SB writer and a 50 kV-VSB writer, respectively, take care of the outline

* Corresponding author. Tel.: +81 4 7134 1762; fax: +81 4 7133 9290.
E-mail address: fujita-h@mail.dnp.co.jp (H. Fujita).

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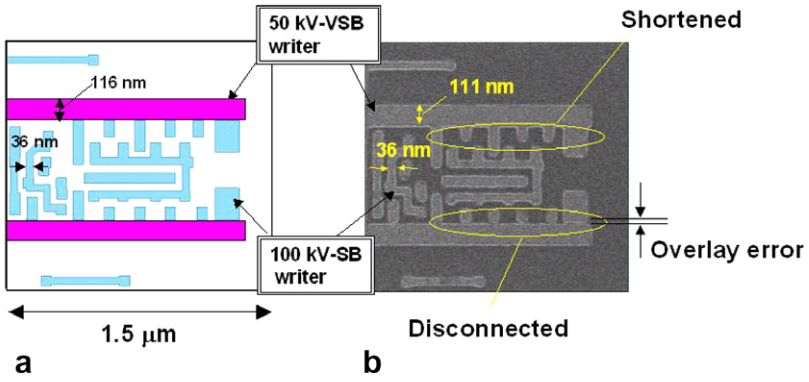

Fig. 1. Lack of pattern fidelity: (a) drawing of the superposed layer of the fine and rough ones and (b) SEM image of resist patterns with disconnected features and shortened features.

layer and the body layer. A similar splitting technique has been proposed in a hybrid electron beam and optical lithography method, where an EB writer and an optical exposure tool, respectively, take care of the outline layer and the body layer [4]. This method may be cost effective for wafer patterning. However, it is not always the case for making a mold (a kind of master mask) because a suitable photomask should be made prior to the exposure process.

We set the alignment margin (or the overlapping width) between the two layers to be 15 nm because the overlay accuracy for the hybrid writing was found to be 10–20 nm [3]. The outline is chosen to be 30 nm wide, twice the margin. Fig. 2 illustrates

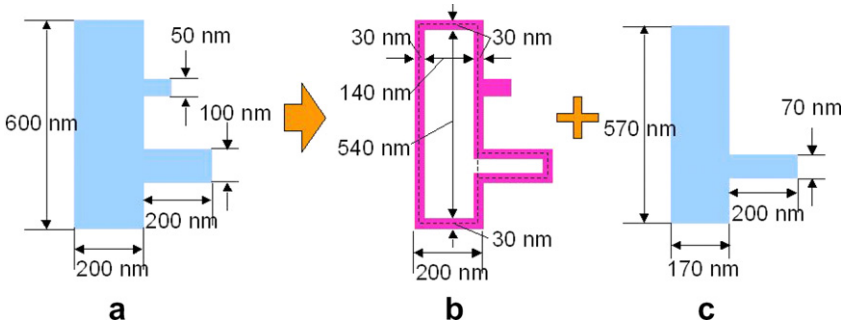

Fig. 2. Production of an outline layer and a body layer from an original one.

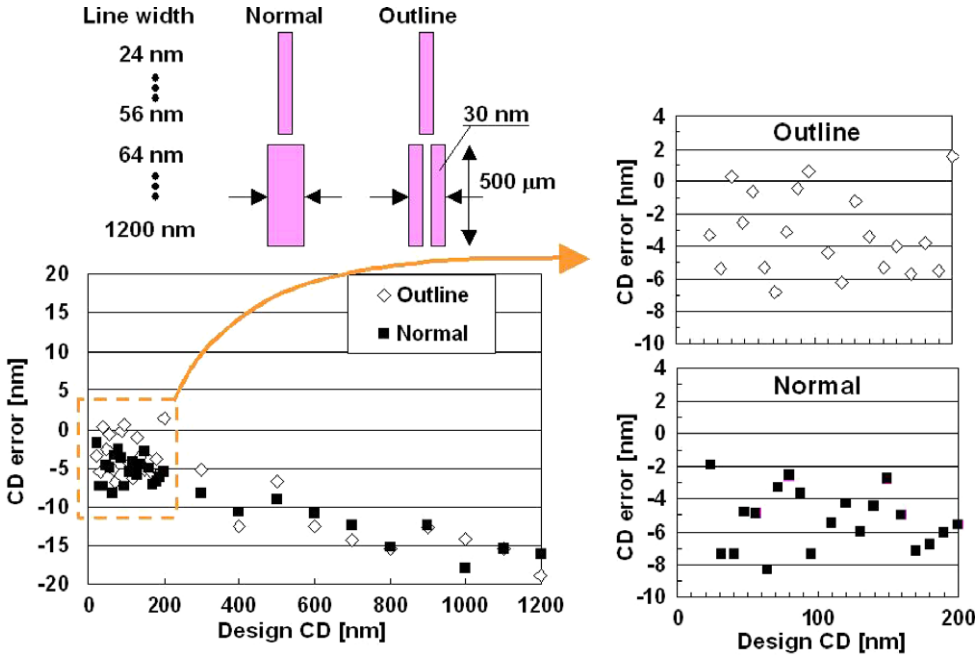

Fig. 3. CD linearity graphs for the outline layer and the normal layer, where the 100 kV writer delineated both.