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Enhanced double patterning decomposition using lines encoding

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Abstract

Double patterning photolithography (DPL) is considered one of the best solutions used for enabling 32 nm/22 nm technology. In this paper, we propose a new technique for double patterning post decomposition conflict resolution. The algorithm is based on lines positions encoding followed by code pattern matching. Experimental results show that the usage of encoded patterns decreases the time needed for pattern matching and increases the matching accuracy. The overall manual problem solution time is reduced to about 1%.

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Keywords: Double patterning; Pattern matching; Photolithography; Line position encoding

1. Introduction

Nowadays, the number of transistors per chip increases rapidly. The 193 nm wavelength used for fabrication is not enough. Photolithography is a process used in the semiconductor fabrication to remove parts of a substrate selectively. It uses light to transfer a geometric pattern from a photo mask to a light-sensitive chemical called “photo-resist” on the substrate.

In DPL, the layout patterns are decomposed into two masks (colors), and manufactured through two exposures and etch steps. If the spacing between two features (polygons) is less than a certain minimum coloring distance, they have to be assigned opposite colors. However, a proper coloring is not always feasible. The distance between two neighboring patterns in the same mask may be less than the minimum allowed distance due to complex pattern configurations. Due to technical issues, the minimum allowed wavelength is 193 nm. In this case, a feature may need to be split into two parts or the layout should be modified to resolve the conflict. Stitch insertion or layout modification decision is taken based on several techniques. As the designs get more complicated, the need for process automation increases. Many

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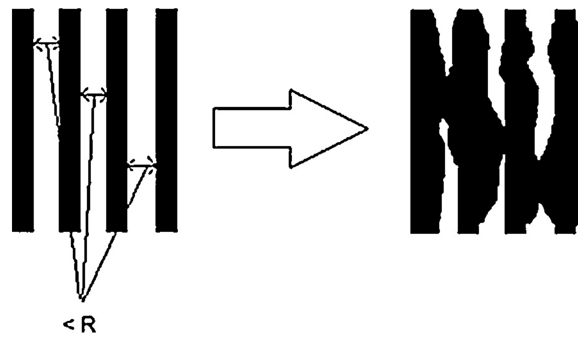

Fig. 1. Feature size less than R.

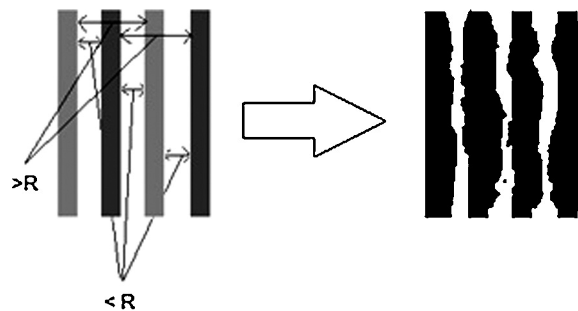

Fig. 2. Double-patterning idea. Line spacing greater than R for each layer.

researchers tried several techniques to automate layout decomposition process. One of the most techniques used for photolithography is double patterning.

Correct-by-Construction and Construct-by-Correction are two types of solutions to double patterning problem. Both solutions have many algorithms to determine the change of the design or the part that should be split with the minimum cost (minimum number of splits). For example, converting the design into a graph then calculating the minimum weighted perfect matching Xu and Chu (2010) or detecting a conflict cycle Ghaida et al. (2013). On the other hand, some algorithms depend on the usage of pattern matching to detect the most likely parts that may cause conflicts Rubinstein and Neureuther (2008). Moreover, a library of patterns may be used for finding the best split method by pattern matching to convert the design into a decomposition-friendly one Wang et al. (2013). Our proposed technique is used for the second approach as an extra step before manual fix.

The rest of this paper is arranged as follows. Section 2, gives an overview of double patterning basics, a brief description of the line encoding technique for purpose of self-containment is given in Section 3. Our proposed algorithm for solving it is proposed in Section 4. Section 5 is dedicated to the implementation and testing results. Finally, conclusions and recommendations are given in Section 6.

2. Double patterning basics

Double patterning is a lot like trying to create an intricate oil painting using a broom Nassif and Nowka (2010). Now, the minimum available is 193 nm Abou Ghaida (2010). If we try to print a design less than R the result after printing will be as shown in Fig. 1

Therefore, the design should be split into two layers (blue and red layers for example). In this case, the distance between any two disconnected patterns in the same layer should be more than R as shown in Fig. 2.

This method of double patterning is called LELE Mack (2008) (Litho-Etch–Litho-Etch). In this method, the first layer is printed (Litho) and etched then the second layer printed and etched. The alternative double patterning method is called SADP Auth et al. (2008) (Self-Aligned Double-Patterning) also known as spacer double patterning and it is out of the scope of this paper.

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