AF Fixer: New incremental OPC method for optimizing Assist Feature

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Due to shrinking design nodes and to some limitations of scanners, extreme off-axis illumination (OAI) required and its use and implementation of assist features (AF) to solve depth of focus (DOF) problems for isolated features and specific pitch regions is essential. But unfortunately, the strong periodic character of OAI illumination makes AF's print more easily. Present OPC flows generate AFs before OPC, which is also causes some AF printing problems. At present, mask manufacturers must downsize AF's below 30nm to solve this problem. This is challenging and increases mask cost.

We report on an AF-fixer tool which is able to check AF printability and correct weak points with minimal cost in terms of DOF after OPC. We have devised an effective algorithm that removes printing AF's. It can not only search for the best non-printing AF condition to meet the DOF spec, but also reports uncorrectable spots, which could be marked as design errors. To limit correction times and to maximize DOF in full-chip correction, a process window (PW) model and incremental OPC method are applied. This AF fixer, which suggests optimum AF in only weak point region, solves AF printing problems economically and accurately.

Keywords: *Assist Feature(AF), incremental OPC, DOF, PW model*

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1. INTRODUCTION

Pursuit of patterning reduction and expand scanner life leads to increased use of OAI. However, at specific pitch range, process margin reduction is inevitable and implementations of assist features are common nowadays. However, use of AFs may introduce unwanted side effects. Firstly, OPC step and database size increase leads to increases in OPC runtime. Secondly, an effective method to generate efficient AFs are needed and insertion of these features in manual or automatic method. Lastly, AFs printability check and ever decreasing AFs manufacturability [1)] and inspection are key issues for successful implementation of AFs to improve process margin.

Among many issues, the most critical is the printing of AFs from fabrication standpoint. The easiest method to alleviate printing issue is to fabricate smaller AFs but this creates mask process difficulties. In other words, mask process capability limits the AFs size and lower patterning design node without reduction in AFs size will increase AF printability. In development and production, AFs printability is one of cause for mask revision of critical layers. This leads to cost increase and lengthy TAT is directly relates to loss in productivity. In Fig 1, AF printing is cause for defects and trend for AF need and current manufacturability with decrease in design node. It shows that AFs size can't follow the trend of design.

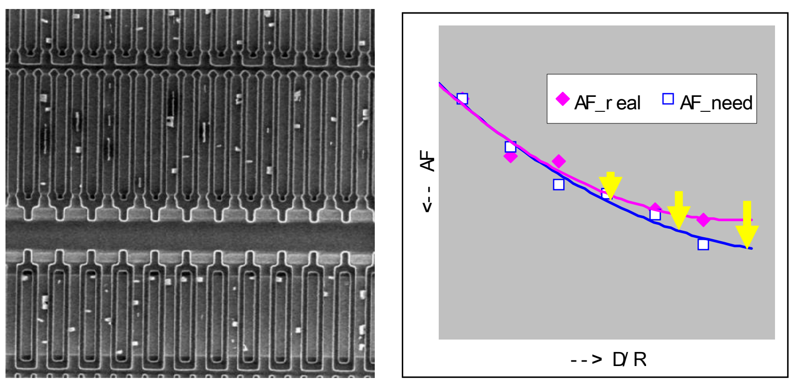

Fig 1. left] defects from AF printing, right] design rule vs. AF size graph

Aside from AFs printability defects, OPC flow structure may lead to AF printing insertion. A standard OPC flow sequence is shown in Fig. 2. As shown in the figure, AFs are generated prior to OPC and main feature changes are not considered which may lead to loss of AF efficiency and printability. For a remedy, AF generation during OPC is required but AF optimization increase number of iteration such that post-OPC CD change is considered in the AF rule generation. In addition, post-MTO changes such as illumination or process may lead to printing of AFs.

Fig 2. OPC flow including assist feature generation

The causes for AFs printability are OAI illumination, improper rule, OPC flow scheme, and process changes which leads to mask revision. And such AFs fix require extensive OPC runtime and data size increase. Compared to conventional OPC, AFs insertion and broken hierarchical structure also creates data size and runtime increases. The trend indicates runtime and data size increase with increase in AFs polygons, and model based AFs [2) 3)] insertion implementation require exponential increase in time as shown in Table 1.

Layer	No AF	# of AF < 2	# of AF >= 2	MBAF
Contact	650M	-	1.9G	20G
Line and Space	-	620M	800M	-

Table 1. comparison of data volume after OPC

This paper focuses on minor shift of detected AFs error correction rather than entire AFs regeneration. The method is geared toward automated fix to detected AFs error.

2. AF FIXER

2-1 Concepts

We implemented incremental OPC 2) in order to overcome very long OPC run time. In the incremental OPC, the whole OPC regions are divided many sub-regions depending on the degree of OPC difficulty and each different OPC technique is applied to each OPC region for short Turn Around Time (TAT) of OPC. For example, the incremental OPC fixes only small regions where AF error is found, which enables the short TAT. Fig. 3 shows the fixing flow of the incremental OPC.

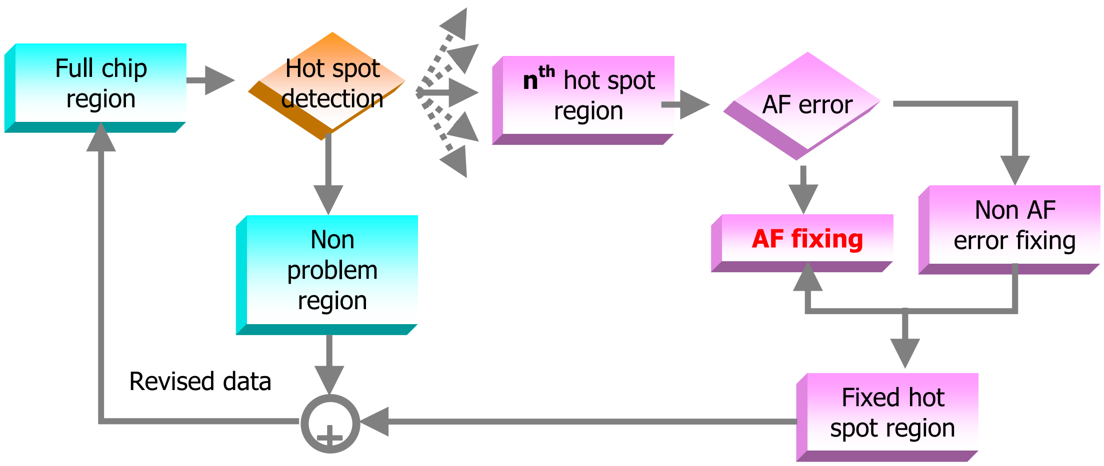

Fig. 3. Concept of incremental OPC flow for AF fixer

At first, AF fixer detects and categorizes the hot spots in the current-existing OPC data base. Next, in the incremental OPC, the whole procedure of hot-treatment from detection to fixing is integrated as a module and added into an OPC recipe.

In the hot-spot detection, any commercial tool can be used as long as it can yield the position information. The unit region of the incremental OPC is basically a correction template from OPC. All the adjacent templates are fixed in case hot spots are founded near the edge of a template. There can be many types of hot spots other than AF error. However, only the AF error will be discussed in this work since they are out of the scope of this study.

The possible fixing options are changing;

- the width of AF
- the space between AFs
- the space between the main feature and AF
- the number of AFs.

Among them, we discuss changing the number of AFs where printable AF is removed in this work.

2-2. algorithm and function coding

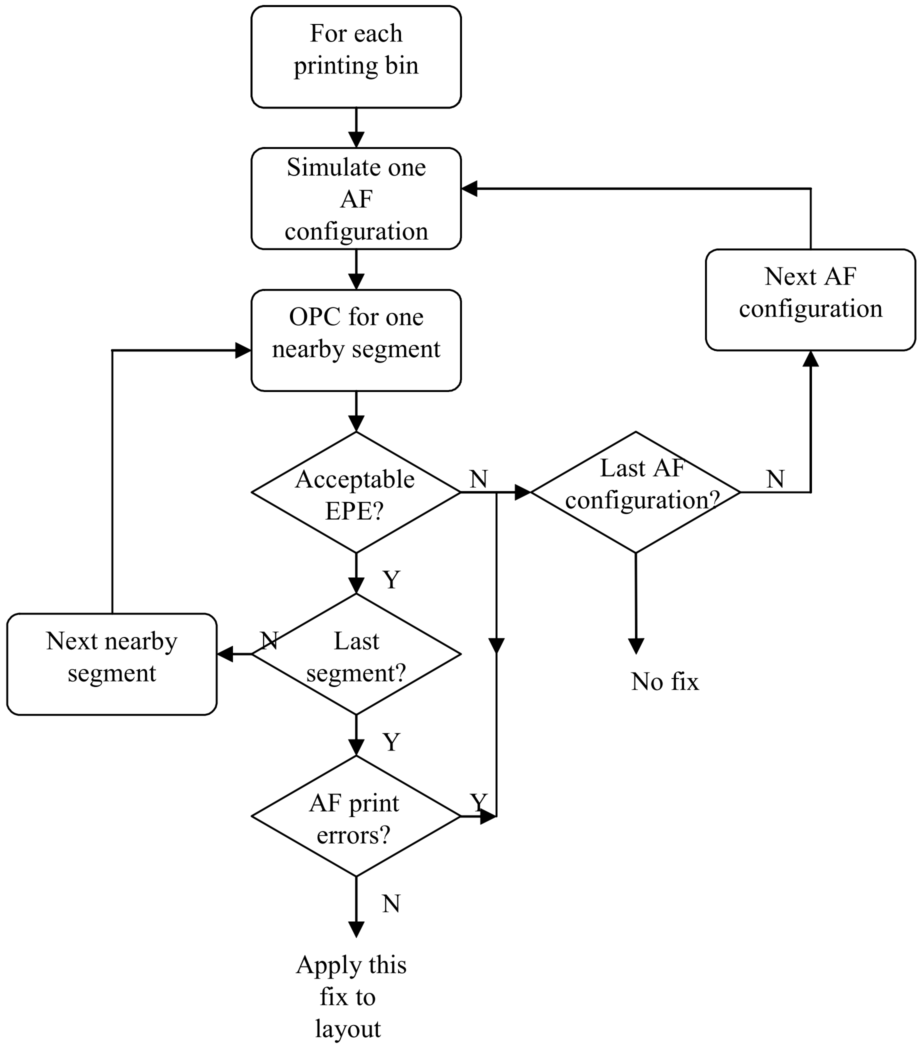

Fig. 4. Algorithm flow for AF fixer

Fig. 4 is the algorithm of the AF fixer. AF printability is checked so that the bins of the OPC regions which include the printable AFs can be sorted. Different OPC are applied depending on the bins based on the AF printing. Edge-Placement Error(EPE) is checked whether it is within spec. for the number of cases of 2^n-1 (n is the number of AFs) and the secondary AF is set to be removed prior to the first AF. For through-focus performance, the summation of EPE through focus is used. If EPE spec. and non-AF printing are not satisfied at the same time, the case will be reported

The most challenging problem is to do OPC at the whole points for all the possible AF options, and through-focus EPE should be calculated for every results, which requires enormous run time. In order to solve this problem, for an AF option, we consider corrected value only at a single edge instead of the whole edges during OPC. This enables to find the best AF option as reducing the run time. Also the graphics update is skipped for the short run time.

As a matter of course, increase in the run time from the AF-printability checking which is located at many points during reOPC is inevitable. Images at the two-dimensional periodic grid over a large area must be calculated for the check of AF printability. This large amount of calculation is very critical in flash OPC where the OPC run time increase as the area. The printing-check grid should be optimized.

2-3. evaluation results

AF printing example in sub 50nm node device is Fig. 5. Illumination condition was 1.2NA cross pole, 0.6~0.9σ and 30nm AF width was applied. This figure shows that AF printability calculation can predict in-line SEM results well and AF size should be under 25nm for non-printing. The solution will be removing printed AFs if not possible to make sub 25nm AFs for increasing DOF.

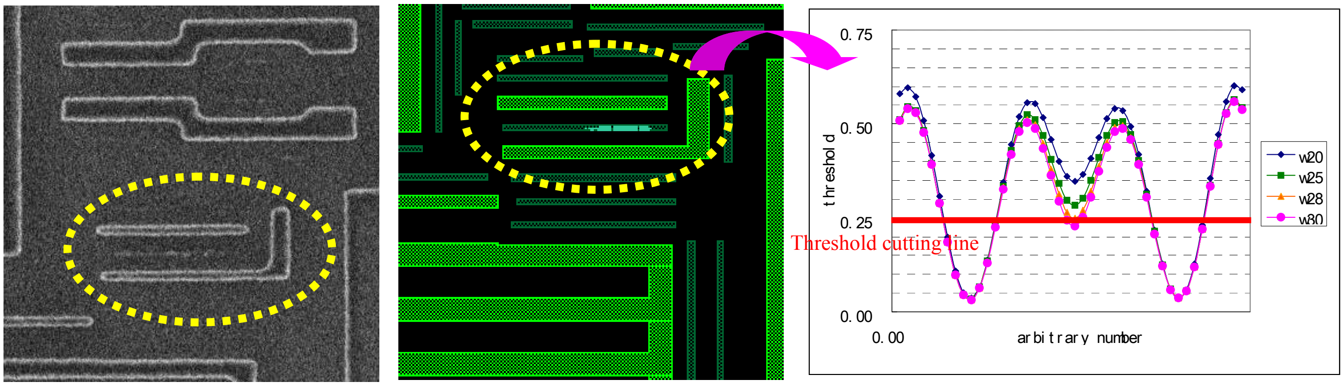

Fig. 5 AF printability checking for sub 50nm design. Right graph shows cross-section intensity at AF printing point.

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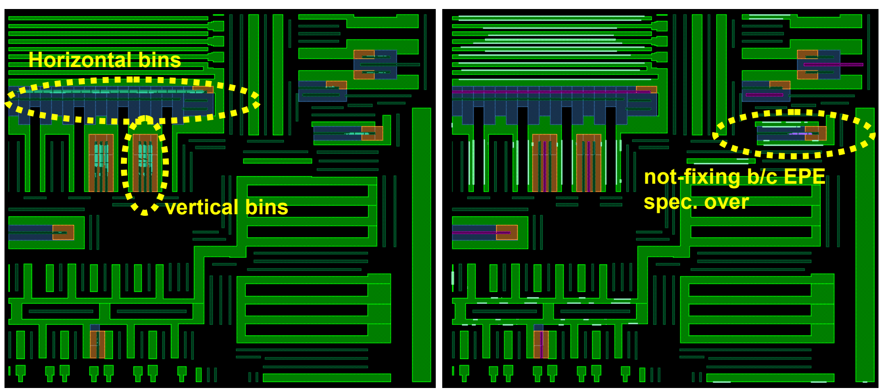
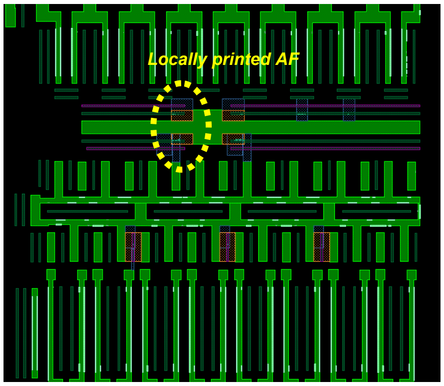


Fig.6 left] making bins after printability checking. right] selecting AFs which should be removed.

Fig.6 shows next fixing procedure after checking printability. Left picture is the results of making bins which are applied for decreasing calculation time with delimiting simulation region. we divide into horizontal and vertical bins so that we can treat AFs as a direction of illumination angle. Right figure shows the best AFs option that is considered the whole number of AFs each bins. It is notable that there is non-fixed bins including printed AFs. It means that we can't satisfy through focus EPE of target patterns if deleting AFs in that region because EPE spec. is not proper or design target should be changed. It reports the coordinates of those points such that engineer treats them manually.

3. CONCLUSION AND FUTURE WORKS

Awareness of AFs printing issue is being increased and some efforts are attempted to mitigate the issue using OPC flow and AF fixer tool to minimize AFs printing is developed. In order to minimize runtime, Incremental OPC methodology was implemented with AFs printability check and fix module which analyzes through focus EPE as a standard sequence. AF fixer was applied to a layout, and AF fixer provided weak points and reported those regions which did not meet EPE specification. However, as shown in Fig. 7, some AFs printability issues require removal of AFs and model based AFs shifts partially. In addition to AFs removal, optimal placements and size of AFs are needed for future study.



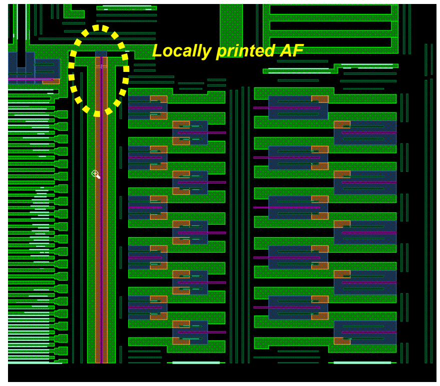


Fig.7 future works. Some AFs are treated locally and removed partially.

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