Systematic Hot Spots Finding by Pattern Search with Similarity

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As device rule shrinks, the finding of systematic hot spots is no longer just relied on design rule checking (DRC) and lithography rule checking (LRC). There still have some unexpected systematic hot spots impact the yield of production. Using image contour extraction technique to extract the images of issued failure sites into unit clipped patterns and then do the patterns search with a similarity algorithm. Transfer these specific pattern search care areas into an in-line inspection recipe, and then prevent the failure issues happening again. Through regrouping the seed patterns after hot scan on focus exposure matrix (FEM) or process window qualification (PWQ) wafers, the exactly or similar pattern search of these seed patterns can help us to find out the unknown risky similar pattern of interests.

Introduction

Although the DFM (Dessign for Manufacturing) technique have been developed simultaneously as design rule shrinks down, engineers still struggle to obtain sufficient process window, and then provide insufficient feedback hot spots to OPC process for yield enhancement. The main root cause is due to the process complexity increases tremendously, which results in design-process are difficult to predict and control; LRC and DRC are not always reliable enough to highlight defective information for full chip (1-3). Therefore, the feedback of the printed wafer verification and wafer sort failure anlaysis information are quite important for yeild improvement in mass production. Furthermore, similar patterns in different periphery circuits may lead to the same failure items by these systematic hot spots. Before the issued patterns search, how to transfer the failure analysis pictures, FIB (focused ion beam) images, or SEM (scanning electron microscopy) image of failure sites into clipped pattern unit in design base is a key step for pattern search. Once image contours have been extracted, several shape features that are useful for identifying and classifying the issued pattern from database. Image contour extraction is an important technique applied for different applications, for example in analysis of medical image, computer vision, robot guidance, and pattern recognition (4), etc. Image contour extraction is a sequence of complex pattern recognition. It includes noise reduction, edge detection and connection to form the contours at GDS or OASIS formats. The accuracy of image contour is important for pattern search.

The aim of this paper is to provide a technique using image contour extraction technique to transfer the issued physical failure sites images into unit clipped patterns and then do the patterns search with a similarity algorithm automates the pattern detection process by extracting the similar patterns that the user is interested in.

Experimental:

e-Beam inspection and KLA 2830 inspection are used to monitor the specific care areas reduction from pattern search results. The landing energy of electron beam inspection is within 100-3000 eV, pixel size and scan rate can be selected between 10-200 nm and 100-200MHz, respectively. The defects review work is done by SEM review system. Failure analysis images are collected from FEI FIB tool.

Image pattern extraction process is done by a series of noise reduction, edge detection and connection to form the contours in GDSII or OASIS formats. If the image quality or contrast is not good, image calibration function will minimize the differences between ideal and real images. Calibration in SEM image includes noise reduction, rotation, shear and re-color. It primarily helps user making adjustments in either global or localized images for further analysis.

Pattern search with similarity feature allows the flexibility to define arbitrary template patterns with "fuzzy" edge or space dimensions to get a broader pattern search based on pixel based algorithm. The template patterns can belong to Pre/Post OPC layout or simulation contour. The template pattern is divided into user defined grids. The individual grids from the template and design layout patterns are compared for similarity. User can define the minimum threshold above which the pixel similarity, then all of similarity searched patterns large than threshold value will be searched out. The locations in the layout with patterns satisfying the user defined similarity threshold are saved in the search report.

Results and Discussion

Image contour extraction from Failure Analysis Hot Spot

Figures 1(a)(b) demonstrate the metal layer SEM pictures which are found in the PFA failure analysis highlight spots, and these defects induce electrial leakage failure. Figures 2(a)(b) illustrate the results of image contour extraction work. It can be seen that the prelayer topological patterns and via plug sites had been filtered out, and then output the contours format at GDSII. Furthermore, we use these image contour extraction results to do the pattern search in HPA^{TM} then dig out the killing pattern simliar sites with similarity 80% above. Figures 3(a)(b) show the search results with 80% similarity, it indicates that less matching sites from these patterns searches. Only one exactly matching unique pattern is shown in figure 3(a), the other two patterns are the similar ones. As shown in figure 3(b) that all the searched patterns are matching with the small polygon but the peiphery circuits enclosed the specific pattern are different. We can use these specific sites locations transfer into care area and then put them as in-line inspection and resolve the leakage failure issue.

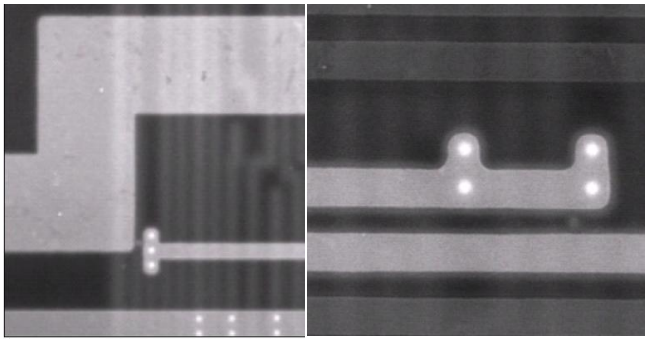
Pattern Search with known Pattern of Interests

Two known issued sites have smaller space which make it hard to fill-in and lead to electrical failure finally. Pattern search with exactly pattern matching (100%) is done for finding all issued sites in the full chip layout, as shown in figures 4(a)(b). There are over 30000 ea exactly matching pattern are found in a chip. Figures 5(a)(b) demonstrates the

random review results in three selected die, we indeed find some issues in these kinds of pattern.

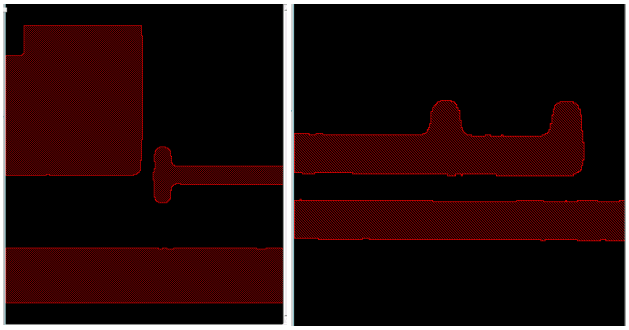
Systematic Hot Spots Finding in FEM or PWQ Wafer

Previous two examples demonstrate the performance of pattern search with similarity; inspect the specific care areas right after pattern search with known issued hot spots is the key methodology to resolve the failure items. However, in the most cases, we don't know the exactly hot spots sources at all. Figure 6 illustrates the methodology for the systematic finding at FEM wafers. Several kinds of inputs are put together to do the data mining process by HPA^{TM} tool, such as pattern grouping after hot scan, local critical area analysis, design rule analysis or loading the LRC points, etc. Through regrouping, sorting, filtering, and classification methodologies, the huge amount of defects or patterns can be diminished effectively with a group of seed patterns. These seed patterns can do exactly or similar pattern search to find out the risky similar pattern with similarity degree setting in the full chip. The search results can put in the data base as a library (design pattern library) for batch searching in next time if there has re-version masks or next generation mask want to tape-out.



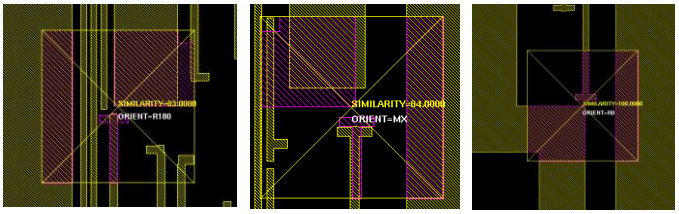
(a) (b)

Fig. 1 (a)(b) SEM pictures which are found in the PFA failure analysis highlight spots, and these defects induce electrial leakage failure.

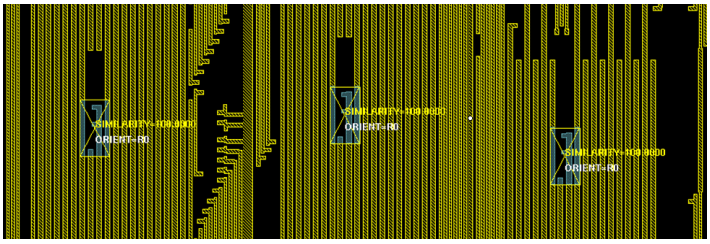


(a) (b)

Fig. 2 (a)(b) Image contour extraction from issued SEM pictures.

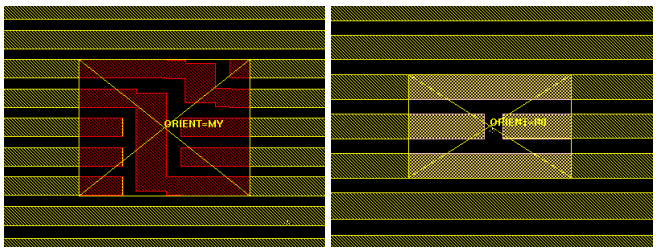


(a)



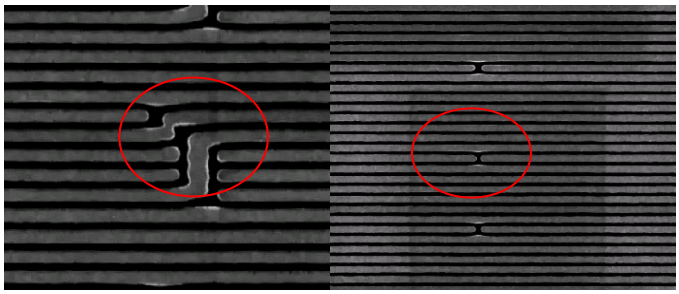
(b)

Figure 3(a)(b) Pattern search results with similarity 80% from figure 2(a)(b) image extraction results.



(a) (b)

Figure 4 (a)(b) Two known issued patterns that induce worse fill-in capability.



(a) (b)

Fig. 5 (a)(b) The space of issued repeating pattern SEM images show large variation and it will has fill-in problem as indicated in red circular.

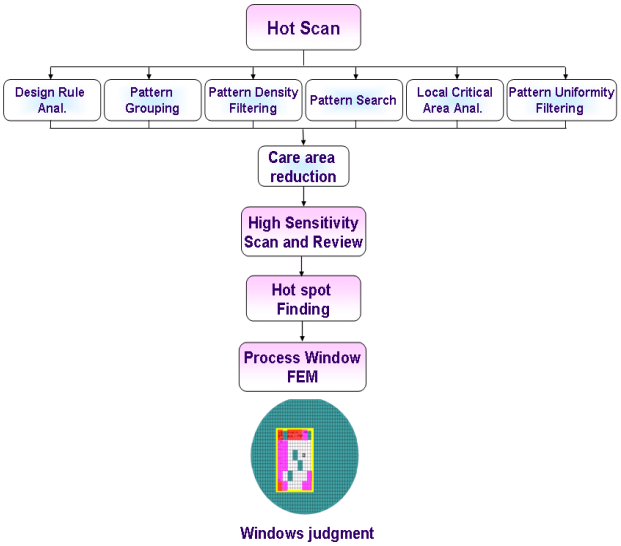


Figure 6 Methodology for finding systematic hot spots in FEM wafer.

Conclusion

In this paper, the methodology of image contour extraction for further pattern search with similarity is proposed. The wafer sort failure analysis images can be transferred into clipped pattern contours in GDSII format. Full chip pattern search with similarity degree is performed for the known clipped patterns and the specific care areas around those locations are generated for in-line inspection, and prevent it happening again. This methodology can also be implemented into the systematic hot spots finding on FEM or PWQ printed wafers.

References

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