Four Level Category Commonality and a Loophole in Is/Is Not Analysis

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Abstract

A four level category commonality tool was developed and used successfully in the problem solving of a complicated resist residue case. A loophole of Is/Is Not analysis was also discussed in this paper.

INTRODUCTION

Is/Is Not is a standard analysis tool for problem solving, which is widely used in different problem solving methodologies, such as 8D [1], Six Sigma, and DMAIC [2]. By comparing the signatures of the defects or issues for which, what, where, when, who, and how, the Is/Is Not tool helps to define the models by focusing on the differences between good and bad groups or parts. Most of the time, this tool can help to shorten the time to the root cause. However, we found a loophole in the Is/Is Not analysis which misled us in the problem solving to wrong paths in a very complicated case.

Commonality is a very useful and widely used analysis tool. Usually, the input for the analysis can be two types: continuous data and categorical data. Yield and parametric data are good examples of the continuous input data. The categorical data usually only has two levels, such as good and bad. Because of the limitation of the two levels of the category data input, it cannot be used for very complicated cases which involve more than two levels of the category inputs.

In this paper, we developed a four level categorical commonality, which is a breakthrough in the problem solving of a very complicated in line defectivity problem. A loophole of the Is/Is Not analysis found during this problem solving is also discussed.

PROBLEM DESCRIPTIONS

The issue requiring a four level category commonality is an in line resist residue problem. Figure 1 shows images of the resist residues having different shapes. Figure 1(a) has the defect at the edge of the pad. Figure 1(b) has random spots on the pads. Figure 1(c) is scumming on the pad and Figure 1(d) has the bubble residue on the corner of the pads. These four different residue defect shapes can happen on the same wafers or separately.

This resist residue defect also has many different wafer patterns. Figure 2 shows seven of the ten different typical defect wafer patterns as examples. Figure 2(a) has a repetitive photo shot signature. Figure 2(b) has a mix of “X” and “+” pattern. Figure 2(c) has a blob shape. Figure 2(d) and (e) are stripes vertically and horizontally. Defect pattern in Figure 2(f) does not have a specific name and Figure 2(g) is a spin like pattern.

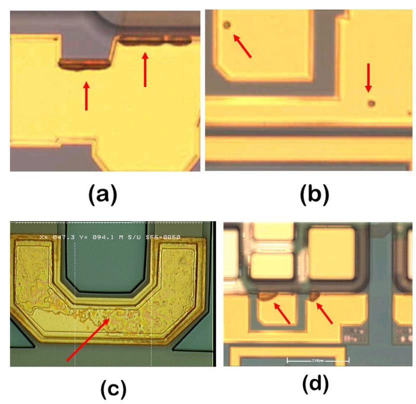


Fig. 1. Images of the resist residues show different shapes of the defects. (a) Defect at the pad edge; (b) Random Spots; (c) Scumming; (d) Corner bubble.

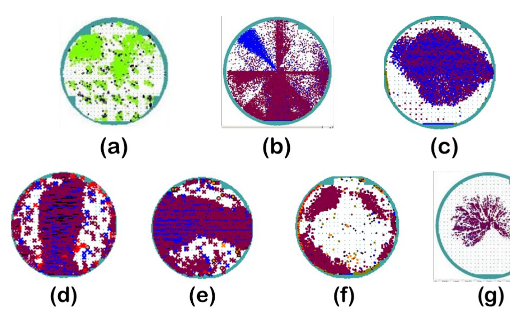


Fig. 2. Defect wafer patterns of the resist residues. (a) Photo shots; (b) X/+ pattern; (c) Blob; (d) Vertical stripe; (e) Horizontal stripe; (f) No name; (g) Spin like.

There are other defect signatures such as a wafer sequence dependence occasionally, some products and process dependences. However, there are no two level category tool commonality, no time commonality, no person commonality, and no material batch commonality.

Is/Is Not Analysis

A standard and thorough Is/Is Not analysis was used in the investigation, including which, where, when, who, what, and how. Process mapping was a part of the analysis. Figure 3 shows the simplified processes. For the resist residue defect issue, we could separate the processes in three blocks.

The Block 1 is the front end process which is prior to the pad metal deposition. As expected, the process mapping and comparison between impacted and non-impacted flows in the Block 1 do not show any differences.

The Block 2 is the process block where the pads are formed, which includes pad formation, film removal, and wafer clean processes. By comparing the impacted and non-impacted flows, the process differences are found at multiple process steps in the pad formation, film removal, and wafer clean. At the pad formation, the impacted lots and products use the process I, not process II. At the film removal, they are from film removal flow I and II, not flow III. At the clean, they use clean I, not clean II.

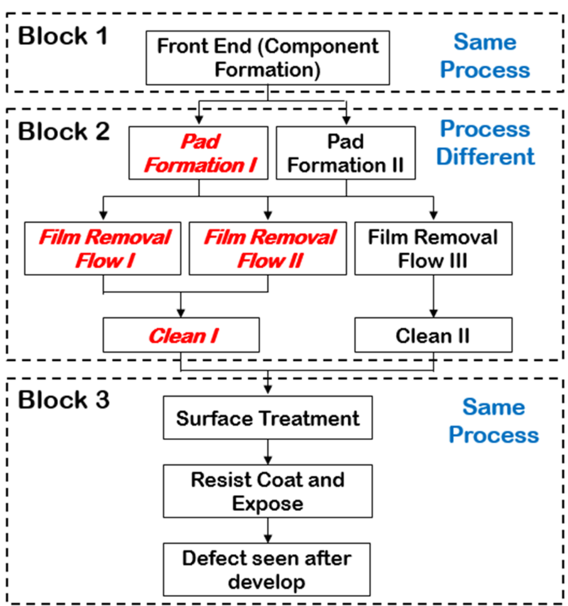


Fig. 3. Is/Is Not analysis for the process comparison for device and process dependences.

Block 3 is the photo process post pad formation and it is the process block where the resist residue is first seen. However, this photo process is common to all products and process flows. So, there was no difference found between impacted and non-impacted lots in this process block in Figure 3.

Based on the results from the process mapping and Is/Is Not analysis, extensive experimental splits were performed, such as partition splits, wafer sorting splits, process corner splits, and etc in the Block 2. There were also splits in the photo process of Block 3, such as photo focus and exposure matrix splits, develop corner splits, and resist bake corner splits. However, the results from these experiments were not conclusive. No matter what we changed, there was no conclusive response in the defect failure patterns and rates.

Four Level Category Commonality

By examining the wafer patterns of Figure 2(d) and 2(e), it can be found that they are the same, if one of them is rotated 90°. Therefore, we can assume that both patterns are from the same type of tools which may just have a difference in the configuration. In this manner, the wafer patterns can be regrouped as (1) horizontal stripe; (2) vertical stripe; (3) all other impacted patterns; and (4) non-impacted.

The breakthrough came from a new commonality we introduced: the four level category commonality. Different from the two level (good and bad) category commonality, the four groups of the wafer patterns were used as the four level categories. A tool commonality was run with these four categories for all process steps and tools. In the two level category commonality, we expected to have tools grouped also as “good” and “bad” corresponding to the defect, yield or other parameters. While in this case, we looked for a step where tools were grouped in three or four groups corresponding to the wafer patterns. This analysis was conducted for all steps which were not limited to Block 2

With careful review of all the charts, there is one interesting chart which show signatures of tool grouping per defect patterns at a specific step. At this step, there are seven tools with two configurations: 0° and 90°. Both Tool 1 and Tool 2 belong to 0° configuration and all lots with horizontal stripe pattern (Level 1) are from Tool 1. There is only one non-impacted lot from Tool 2, so the sample size is not significant. All other 5 tools are with 90° configuration and all lots with vertical stripe pattern (Level 2) are from both Tool 4 and Tool 5. Level 3 is a mix of all other different pattern and it is also from tools with 90° configuration. This commonality may not be true, because of the complicated mix of the defect patterns. With original plan, this is not our focus in this commonality analysis. It is not surprising to see that the non-impacted lots (Level 4) are from all tools with different configurations. The details are summarized in the Table I.

Table II gives the tool hit rate based on the commonality results shown in Table I. The hit rate of 0° tool configuration including Tool 1 and Tool 2, is 57% with the horizontal stripe pattern. The hit rate of Tool 4 and 5, which are part of 90° tool configuration, is 60% with the vertical stripe pattern. The remaining 90° configuration tools (Tool 3, Tool 6, and Tool 7) have 0% hit rate for both horizontal and vertical stripe patterns.

TABLE I.
COMMONALITY RESULTS FROM FOUR LEVEL CATEGORY COMMONALITY

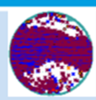
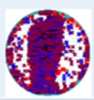
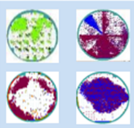
Category Level	Defect Patterns	Tool Type	Tool #
Level 1		100% from 0° configuration	Tool 1
Level 2		100% from 90° configuration	Tool 4 and Tool 5
Level 3		100% from 90° configuration	Multi tools
Level 4	Not impacted	Both 0° and 90° configuration	Multi tools

TABLE II.
TOOL HIT RATE FROM FOUR LEVEL CATEGORY COMMONALITY

Tool Type	Tool #	Category Level
0° Configuration	Tool 1 and Tool 2	57% Level 1 (Horizontal) 43% Not impacted
90° Configuration	Tool 4 and Tool 5	60% Level 2 (Vertical) 10% Level 3 (all other patters) 30% Level 4 (Not impacted)
	Tool 3, Tool 6, and Tool 7	50% Level 3 (all other patterns) 50% Level 4 (Not impacted)

Several experiments were designed and performed to verify the tool commonality from the four level category commonality analysis. Two of the key experiments are the split between tools and the split with wafer rotations.

Figure 4 shows the results from a split between Tool 1 and Tool 4. Figure 4(a) is from Tool 1 which has 0° tool configuration and gives the horizontal stripe defect pattern as expected. Figure 4(b) is from Tool 4 which has a 90° tool configuration and gives a different pattern. It is not the same as the vertical strip pattern, but it is also different from the Tool 1 pattern.

Figure 5 shows the results of a wafer rotation split with Tool 4, which has 90° tool configuration. Wafer 1 is at the top-left and wafer 12 is at the bottom-right. The odd wafers loaded as normal have the vertical stripe pattern as expected. While the even wafers loaded with manual 90° rotation show the horizontal stripe pattern.

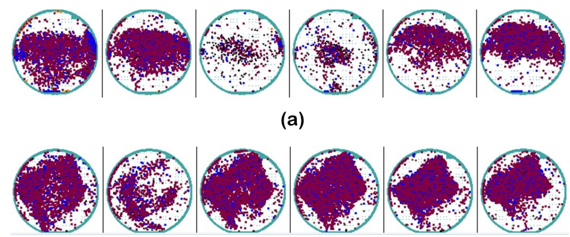


Fig. 4. Wafer splits with different tools. (a) Processed with 0° configuration tool: Tool 1; (b) Processed with 90° configuration tool: Tool 4.

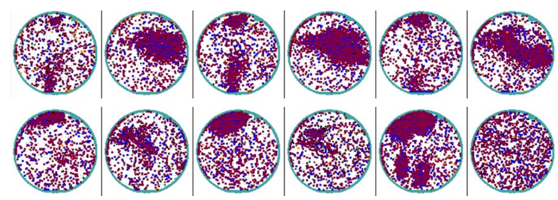


Fig. 5. Wafer rotation split with Tool 4 which has 90° tool configuration. Odd wafers were loaded as normal and even wafers were loaded with manual 90° rotation. Wafer 1 is at the top-left and wafer 12 is at the bottom-right.

DISCUSSIONS

Both splits between tools (Figure 4) and between wafer rotations (Figure 5) proved the tool commonality found by the four level category commonality. However, the process step which shows the commonality is a surprise. It is not in the Block 2, which has all the process differences between impacted and non-impacted products and process flows. It is also not in the photo coat, bake, and develop steps in Block 3. The tool commonality actually comes from the surface treatment step prior to the resist coat in the Block 3. This surface treatment step is common to all products and all process flows. Therefore, this result is opposite to what Is/Is Not analysis pointed to.

Although it is well known that Is/Is Not analysis cannot be used alone for the problem solving, the loophole of the Is/Is Not analysis is not what we expected and requires a special attention in complicated problem solving cases.

As we mentioned earlier, the results from the four level category commonality is just a breakthrough in this resist residue issue. It is still far away from the final root cause, because this commonality cannot explain all the defect shapes in the Figure 1 and all defect patterns except the horizontal and vertical stripes in Figure 2. However, understanding the mechanism of how the surface treatment impact the resist residue defect helped us to build a model which could explain all the patterns and lead us to the root cause and the solution. The discussion of the final root cause and the solution is not in the scope of this paper.

CONCLUSIONS

Is/Is Not analysis is a powerful tool used in the problem solving methodology, but it has a loophole and can point to a wrong direction, if it is not used carefully. Two level (good and bad) category tool commonality has its own limitation also. In this paper, we demonstrated a four level category tool commonality which was successfully used in a complicated case of a resist residue defect improvement. The concept of this four level category commonality is not limited to only four categories. Actually it can be extended to a multi-level category commonality

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ACRONYMS

DMAIC: Define, Measure, Analyze, Improve and Control)
8D: Eight Disciplines