Uncovering Process Interdependency Using Data Mining

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I. Background

Semiconductor manufacturing processes are complex, and so are issues related to them. The root cause of some of these process issues cannot always be accurately identified by analyzing only parameters linked to an individual production run. In some cases, an engineer must look beyond the current production environment to determine whether secondary factors such as equipment operation from a previous run or equipment idle time between runs could possibly create interdependencies that adversely affect the quality of the active production run.

II. Process Interdependency Examples

For example, if two dissimilar recipes were executed contiguously with the same piece of equipment (recipe A first, then recipe B), it is possible that the first set or sets of production wafers from the latter recipe (recipe B) could experience quality issues if the proper re-conditioning of chamber parameters were not performed. In semiconductor manufacturing where process precision is extremely critical, parametric variation caused by carryover effects like this would more than likely result in product quality problems. Similarly, timing-related elements, like equipment idle time or wafer queue time, could also adversely influence the environmental parameters of process chambers and cause production issues. These are all elements of process interdependencies that should not be overlooked when performing root cause analysis.

III. Root Cause Analysis of Interdependency Issues

The traditional approach in root cause analysis examines only data from the specific process run that is directly related to a quality or yield event. While this might be an effective approach to solving a number of issues, it is not effective in identifying root causes for issues due to interdependency. Only with a broader examination of process and engineering data beyond the targeted process run could interdependency issues be discovered.

Advanced data analytic tools provide a platform for engineers to expand the scope of root cause analysis to include engineering data that signal potential interdependent effects. This enables a more thorough and insightful assessment of failure events. Whether it is process queue time, system downtime, or recipe interaction data, with an advance analytic solution, engineers can quickly and Intelligently identify its correlation to process impact.

IV. Case Study 1

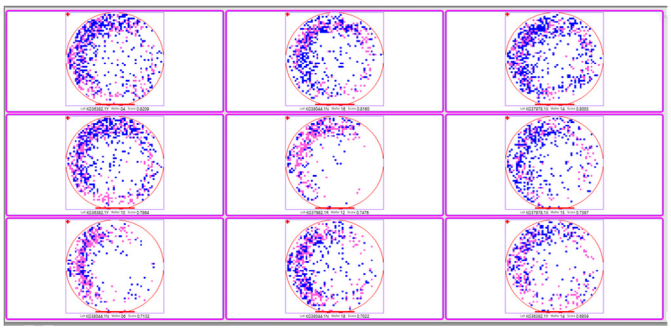

Figure #1 – Examples of wafers affected by the edge crescent-shaped low yield pattern

In the first case study, multiple lots were seen to be impacted by an edge crescent-shaped failure pattern - Soft Bin103 and Bin104 (Figure #1). Over 2% of the wafers in the 193 lots processed were affected by this pattern. A secondary analysis was performed comparing the affected wafers against the rest to determine the root cause. To increase the comprehensiveness of the analysis, along with the related FDC data, other interdependency variables such as process time, wait time, and recipe information were also included as cause variables to be examined (Figure #2).

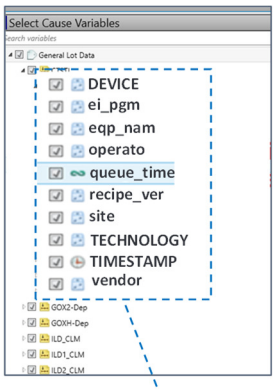

Figure #2 – Increasing analysis comprehensiveness by including potential interdependent variables

Modern root cause analysis solutions allow the inclusion of any operational and engineering variables including process stages tracking data, queue time, recipe versions, technology variables, and timestamp variables for analysis to assure that interdependency issues are not overlooked. In this example, with the addition of operational parameters as potential cause variables, the advanced data mining application easily pinpointed a high-potential root cause candidate – process queue time. All affected wafers had an abnormally high Process Queue Time of > 4.89sec during a specific oxide wet bench process step (Figure #3). Further offline investigation found that there was an equipment shutdown at this process step that caused high queue time. This information helps to identify an interdependency issue and narrow the scope of investigation for the engineer.

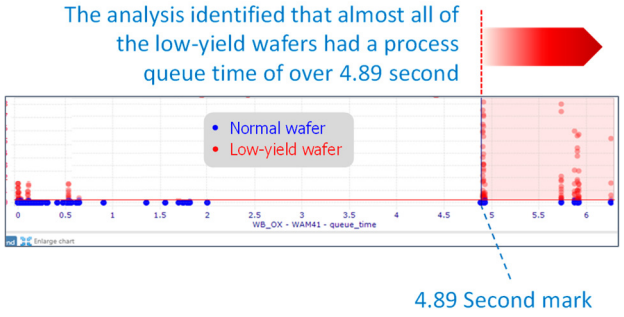

Figure #3 – Dependency analysis easily identified process queue time to be a low-yield factor

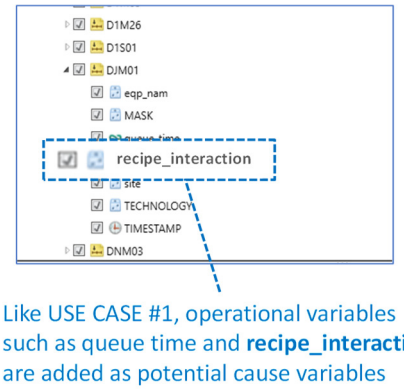

Figure #4 – Operational variables such as recipe_interaction is key to identifying the root cause in case study #2

V. Case Study 2

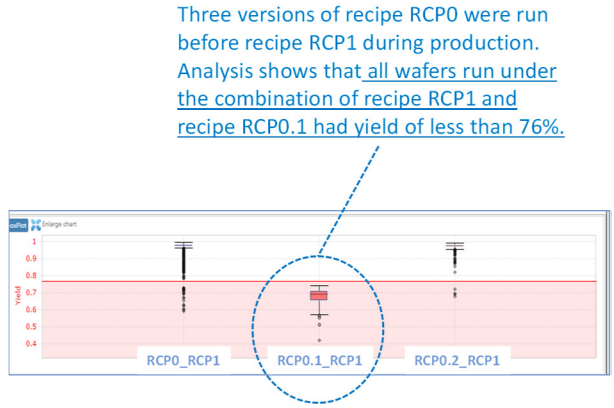

Figure #5 – An issue related to recipe interaction identified by dependency analysis

In the 2nd case study, a large number of wafers (277) were shown to have abnormally low yield of < 76%. A total of 6,681 wafers were queried for analysis, comparing the 277 low-yield wafers versus the remaining higher yield counterparts. Similar to CASE STUDY 1, in addition to the related FDC data, interdependency variables such as process tracking variables, queue time, and recipe_interaction, were included as potential cause variables (Figure #4).

Again, the advanced data mining solution quickly pinpointed an interdependency issue related to recipe sequencing during process stage: MET1 Dep and Sub-step: DJM01. During this process step, three slightly different versions of recipe RCP0 were executed prior to the processing of recipe RCP1. Analysis shows that every wafer processed under the combination of recipe RCP0.1

and recipe RCP1 had lower yield - under 76% (Figure #5). This provided engineering the necessary insight to further investigate. Subsequent offline investigation found that in the month of April 2019, a Metal1 adhesion layer thickness deposition evaluation was performed, and further Failure Analysis results validated the issue was caused by the recipe interaction of the metal deposition recipe RCP1 and prior adhesion layer deposition recipe RCP0.1.

VI. SUMMARY

- When performing root cause analyses, it is important to look beyond the parameters within the active product run. Factors such as carryover effect and other environmental interdependencies should be considered for a more thorough investigation.
- Advanced data analytic solutions can help engineers expand the scope of analysis allowing them to identify root causes of interdependency-related issues more quickly and efficiently.