Analysis of and Solution to Ion Trim Drift Utilizing FDC Software and a Residual Gas Analyzer

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Abstract

Ion-beam sputter etch must be a repeatable process to be effective in manufacturing. With the use of advanced FDC (Fault Detection and Classification) data collection of PVD (Physical Vapor Deposition) tool data and an additional remote RGA (Residual Gas Analyzer) sensor it was possible to resolve the cause of Ion Trim Drift Error and devise a solution.

INTRODUCTION

In general, we strive for the manufacturing ideal to achieve a repeatable unit process without deviation wafer-to-wafer and lot-to-lot. Anomalies in the processes do occur and finding their causes and solutions to them are time-consuming and costly. Use of process monitors and advanced FDC provides the engineering tools to rapidly detect anomalies and help find solutions to improve repeatability.

Our approach to achieve high yield of narrow bandpass BAW filters is to use spatially-resolved ion-beam sputter etch, or “ion trim” to reduce the inherently broad wafer-to-wafer distributions of as-deposited filter structures. Inline corrections to the ion trim process are made using test wafers, and generally allow improved across-wafer uniformity and stable across-lot processing. (Figure 1)

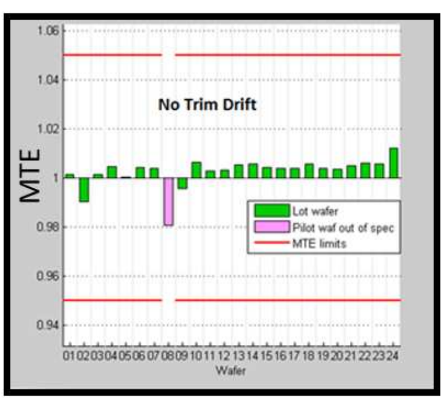

Figure 1: The graph shows Mean Trim Error (MTE) with only a small variation across the lot.

A stubborn exception has been one of the trim processes which frequently shows an across-lot drift in frequency and MTE (Mean Trim Error). The lot in Figure 2 was trimmed based on the pilot wafer, with additional corrections which would have given the pilot wafer an MTE of 1 and frequency error near 0. While the lot trend shows this null-point is correctly positioned at the pilot wafer, we observed an increasingly negative frequency error with increasing wafer number, called Trim Drift. Trim Drift is not specific to device or processing tool.

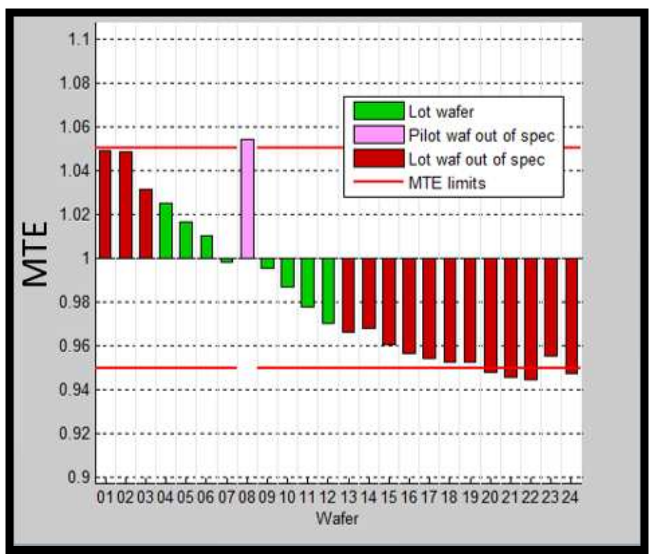

Figure 2: This lot displays strong Trim Drift, with MTE varying strongly across the lot.

In this paper we explain how to identify the source of this trim drift and find methods to prevent it or to decrease its impact. By solving this issue, significant time can be saved in both the deposition and trim processes and yield can be improved by the improved filter frequency control across the lot.

7b

BACKGROUND

Investigations had identified the process responsible for the Trim Drift trend to be the PVD film deposition done prior to the trim step. The relationship between Trim Drift and the recipe run previously on the PVD tool was noted in the past; however, the relationship was attributed to the power used in the metal deposition. It was hypothesized that processes with low power operations being run before the affected operations caused Trim Drift while high power operations did not. This hypothesis was eventually proven false by running pilot wafers at different powers in the deposition chamber prior to running the affected operation. These pilots were found to have no difference on the prevalence of trim drift.

The time-gap between wafer processing was also investigated. It did appear tentatively that increasing the time-gap caused the trim drift to be less severe but it did not stop trim drift from occurring. This approach was a costly solution because it impacted machine utilization.

The surface of the deposited film was inspected by SEM for lots which had trim drift and lots which did not. There were no consistent or repeatable differences in grain structure across lots that showed trim drift.

Although this work did not yield results for the exact cause of Trim Drift, it did provide knowledge which led to the discovery of the signature outlined in this report by narrowing the scope of causes and sources extensively.

FDC ANALYSIS

In order to further investigate the Trim Drift issue, the primary data gathering and analysis methods were FDC software analysis and the use of RGAs installed in the sputter etch chamber and the transport chamber of a PVD Tool. Extensive effort was made to look at the deposition chamber parameters to try to find a predictor for the observed drift pattern but to no avail. The focus shifted to the unlikely candidates: load locks, transport, cooldown and degas/sputter etch chambers.

The summary residual gas data in the sputter etch and transfer chambers immediately following this etch step was analyzed. The RGA data was only able to be collected immediately after the process was complete because of the high chamber pressure. The sample summary was typically the average value over 5 seconds. A trend for a particular RGA species was noted which correlated directly with the Trim Drift occurrence. As can be seen in figure 3, when the species trends upwards over the course of a lot, Trim Drift occurs. No other collected species had a consistent correlation trend with Trim Drift.

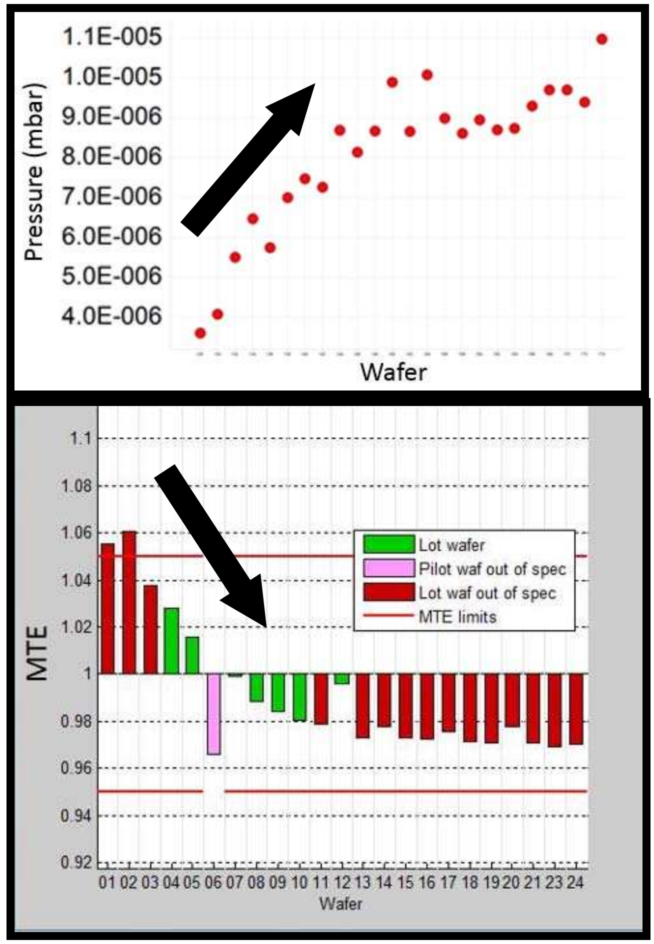

Figure 3: RGA-data plots for a given species with the associated Trim Report. Each point in the RGA-data plot is collected immediately after a wafer has finished the Sputter Etch step.

One of the many questions to answer was the reason for the occurrence of Trim Drift. There are multiple recipes running in the sputter etch chamber. One type was a high pressure wafer degas and the other was a sputter etch or a combination of both. The ability to have the context data with each data point like recipe was key to the analysis. Plotting all recipes in a sequence and marking the chart (Figure 4) by recipe shows that the high pressure degas recipes dominate the RGA trend.

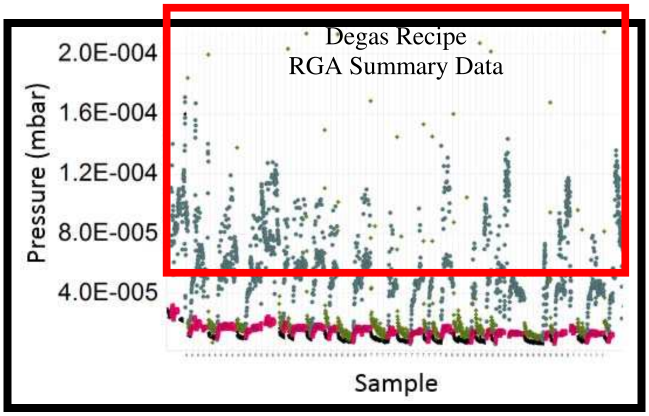

Figure 4: RGA-data plots for a given species. Each shade is a different process recipe in the sputter etch chamber.

The degas recipe summary data was filtered out of the chart and the increasing trend over time was found to occur only on lots which were processed immediately after a 40 second sputter etch recipe in another operation. The 40 second recipe and the 10 second recipes are identical with the exception of the etch time. The observed increasing trend is due to this phenomenon: **Both the 10 second etch and the 40 second etch have baseline RGA species pressure. As wafers are run, the pressure gradually corrects itself to the baseline.** This can be seen in the Figure 5 below. This phenomenon was observed and verified on all tools that ran this mix of recipes.

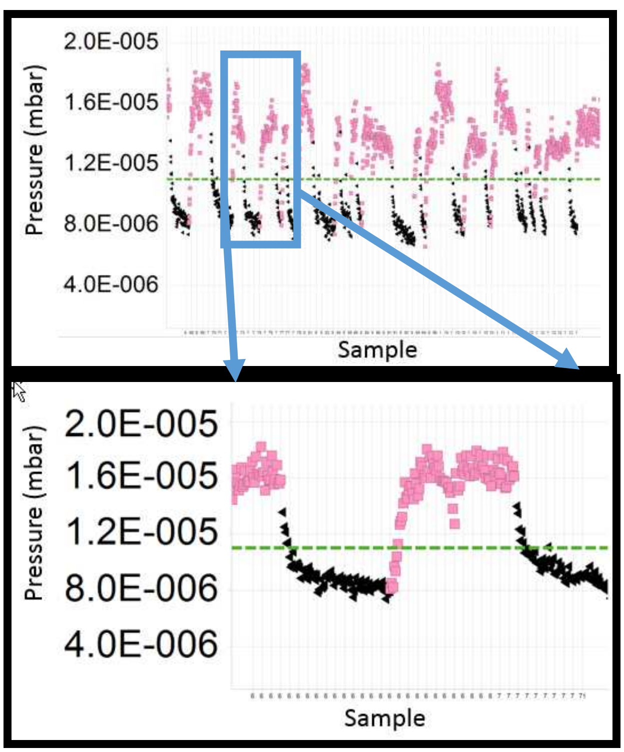

Figure 5: Squares are the 10 Second recipe. Triangles are the 40 second recipe.

To verify that stability in the RGA signal could be maintained the recipes were isolated. The results are shown in Figure 6 below.

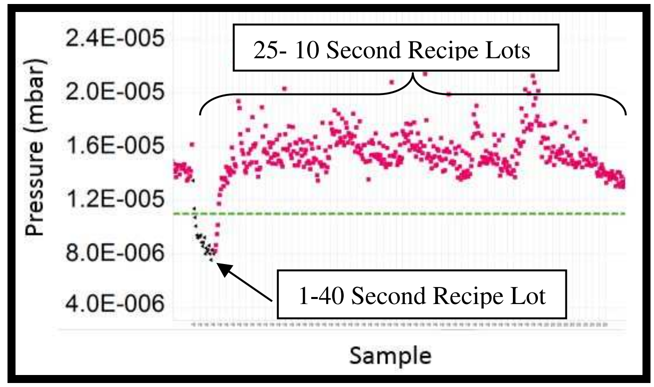

Figure 6: Initial 40 second recipe followed by 25 10 second recipe lots.

CONCLUSION

In this work we showed that by using FDC analyses with RGA sensors we could investigate assumptions regarding the cause of a problem and then identify the actual cause.

The effect was independent of the degas recipe that was run just prior or in between the etch recipes. The effect was also independent of the wafer type being processed (product or blanket dummy). The sputter etch recipes were identical in structure with exception to the time but the solution was now apparent. Either the recipes had to be isolated from each other or conditioning wafers must be run prior to running the recipe that is prone to Trim Drift.

7b

ACRONYMS

FDC: Fault Detection and Classification
RGA: Residual Gas Analyzer
PVD: Physical Vapor Deposition
MTE: Mean Trim Error
BAW: Bulk Acoustic Wave
SEM: Scanning Electron Microscope