Etch Run-to-Run Controller Optimization with ProcessWORKS - Denis Pompier[1]

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The benefits of Run-to-Run (R2R) control, e.g., improved process and product performance, increased machine utilization and process throughput, reduced number of non-production wafers, etc., have been well-known in the semiconductor industry and well documented in literature and conferences. To ensure high quality and high yield level of their heterogeneous products, STMicroelectronics (ST) have been using ProcessWORKS® as the corporate R2R solution for over ten years, and have benefited from R2R controllers deployed in various process areas. However, with the introduction of more and more sharpened technologies, the process windows required by their industrialization become more and more stringent. Due to products' short lifetime, it is critical for ST and other manufacturers to get their new products out to the market as fast as possible with good process centering. Therefore, the existing R2R controllers need to be improved constantly to keep up with the advancing technologies. As an example, we present in this work the multiple improvements that have been done to optimize the performance of an existing etch control strategy.

This etch controller was initially designed to address the chamber mismatch on etch steps and it managed etch rate at the chamber level. Since the deployment of it, the process has been much more centered, resulting in improved Cp and Cpk. When we took a closer look, however, it was observed that the product-to-product variation in the post-etch depth—the process output—was significant, which indicates that partitioning etch rate by chamber only is not enough. Therefore, the first improvement to the controller was to add product to the partitioning scheme (control thread) and have the controller maintain a different etch rate for each chamber and product combination. This improvement, however, only benefits the existing products. As new products are continuously being introduced into the factory, the etch rate of a new product needs to be initialized properly in the controller to maintain the high Cp/Cpk of the process. A default etch rate can be used in this scenario, however, the result is typically not good and therefore requires the use of pilot wafers which will increase the cycle time and reduce the overall throughput. To address this issue, it was discovered that the reticles used at the upstream photolithography step are product specific and may explain the product-to-product variation in the etch rate. To verify this assumption, extensive analysis has been done in ST and finally a strong correlation was found between the etch rate and the open area on the reticle surface (Fig. 1). Based on this result, the reticle open area has been provided to the etch controller as feedforward information which can be used to predict the etch rate of a new product based on the current etch rates of existing products. This leads to the second improvement to the controller. The latest modification was for the EWMA filter. Originally, a static EWMA coefficient (lambda) was used, it has recently been replaced by a moving coefficient (Fig. 2). Basically, the moving coefficient has a high starting value to allow a new product to converge faster to its nominal etch rate. As more lots for the same product get processed, the coefficient decreases asymptotically in order to smooth out the estimated etch rate and absorb the residual disturbances. The exact shape of the moving coefficient was obtained with the help of the simulator module embedded in ProcessWORKS. The simulator allows users to easily replay months of production data to validate the effectiveness of a new control strategy or changes in an existing controller, and therefore gives users confidence and peace of mind before deploying the changes in production.

Since the deployment of these improvements in the etch controller, the post-etch depth has been further centered on the process target, and the product-to-product variation has also been significantly reduced (Fig. 3). The optimization work done to the etch controller and other controllers powered by the flexibility of ProcessWORKS has greatly helped ST reduce time to market for their new products while also improving the overall quality.

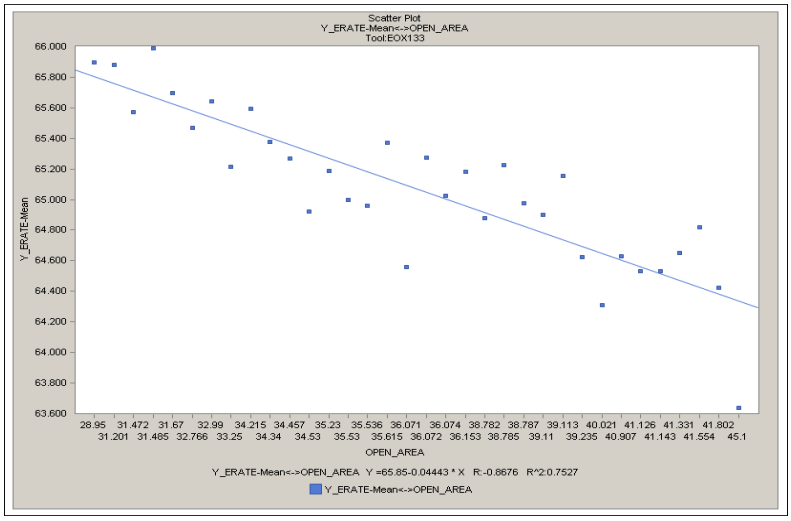

Figure 1: Correlation between etch rate and reticle open area for a specific etch chamber

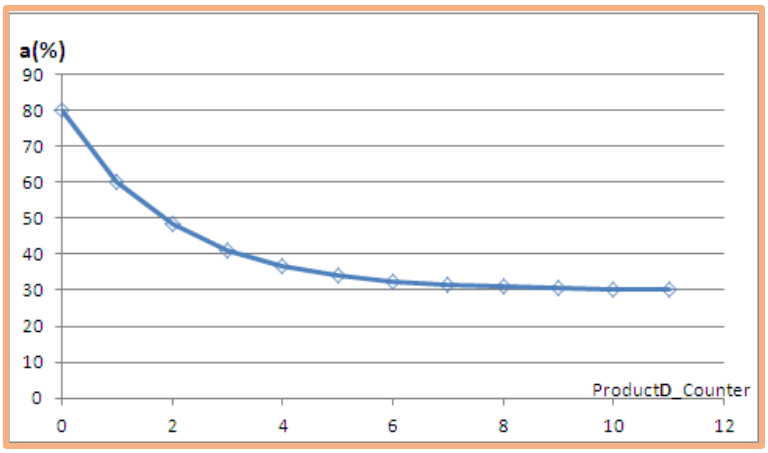

Figure 2: Moving coefficient (lambda) for EWMA filter

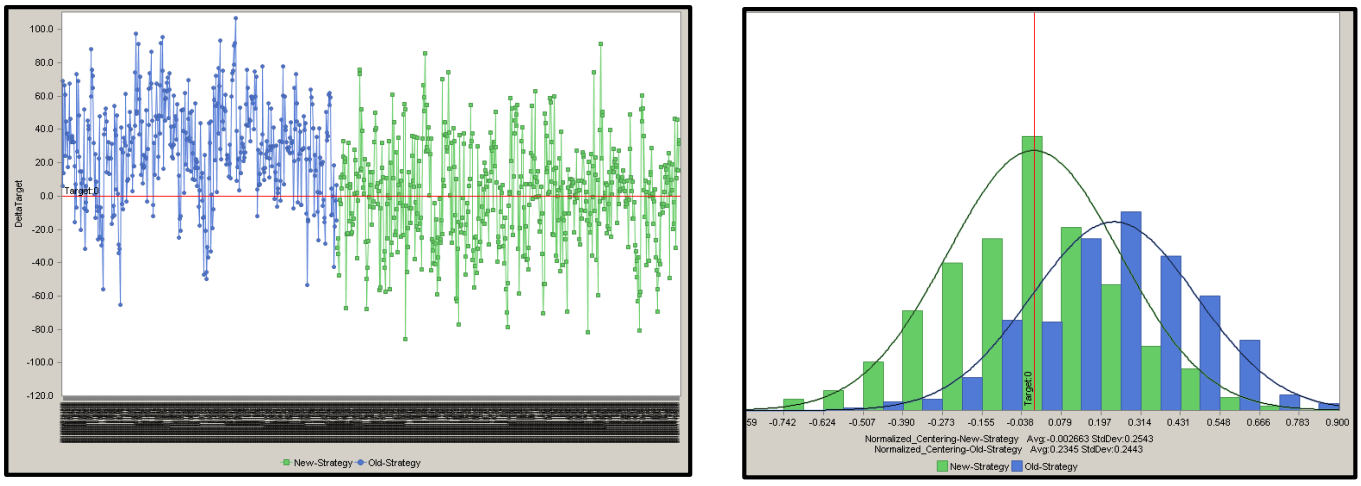

Figure 3: Comparison of SPC chart and histogram before and after etch controller was optimized