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# A G&P EWMA algorithm for high-mix semiconductor manufacturing processes

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ABSTRACT

In mixed run processes, typical in semiconductor manufacturing and other automated assembly-line type process, products with different recipes will be produced on the same tool. Product based run-to-run control can be applied to improve the process capability. The effect of product-based controller on low frequency products is, however, minimal, due to inability to track tool variations. In this work, we propose a group and product based EWMA control scheme which combines adaptive *k*-means cluster method and run-to-run EWMA control to improve the performance of low frequency products in the mixed run process. Similar products could be classified into the same group adaptively and controlled by a group EWMA controller. The group controller is updated by both low frequency products and similar high frequency products; so that low frequency products can be improved by shared information from similar large frequency products. However, the high frequency products are controlled by individual product-based EWMA to avoid interference of the low frequency products. The advantages of proposed control scheme are demonstrated by benchmark simulation and reversed engineered industrial applications.


## 1. Introduction

Run-to-run (RtR) control [1,2] is a process control technique which adjusts the recipe of current runs using information of previous runs to maintain the process outputs on the desired target and reduce process drift, shift and variations. It has been applied on many semiconductor processes such as chemical mechanical polishing (CMP), photolithography, and etching [3–7]. As the wafer size increases and the critical-dimension shrinks in semiconductor manufacturing process, RtR control has become an important way to improve the process performance.

Exponentially weighted moving average (EWMA) controller is widely used in semiconductor industry because of simplicity and easy maintenance [8]. Ingolfsson and Sachs [9] analyzed the stability and sensitivity of the EWMA controller. Butler and Stefani [3] proposed a predictor corrector control (PCC) to reduce the impact of machine and process drift. Chen and Guo [5] developed an age-base double EWMA scheme which took the process age into account to adjust process random shifts and drifts. Wang et al. [4] developed a recursive least squares (RLS) estimation to overcome measurement delay and measurement noise of processes. Wang and He [10] analyzed the stability of gain updating EWMA controller. Smith and Boning [11] developed an artificial neural network (ANN) EWMA controller for higher order processes. The above methods were developed for the control of single product manufacturing.

However, semiconductor production is carried out in a multi-steps, multi-products, parallel tools manufacturing environment. In a typical plant, hundreds of steps, each of which is carried out on several to tens of similar tools for many different products using slightly different recipes. This kind of production, a mixed-run assembly line, is also employed in many other industries, such as liquid crystal display panel and automobile manufacturing. An important issue is how to control the mixed run process and has been concerned in the literature. Miller [12] proposed four RtR control strategies contain independent controllers, grouping controllers, one composite controller and cooperative controllers for the mixed run process. Firth et al. [13] proposed a method named just-in-time adaptive disturbance estimation (JADE) to estimate the biases state of each product and tool from previous production. Zheng et al. [14] analyzed the stability and performance of product-based and tool based EWMA controllers. They showed that product-based EWMA control was suitable for the mixed run process. Estimation of the bias state of the tool using information exchange between different products and incorporation into the product controller may lead to instability and performance issues. Ma et al. [15] used analysis of variance (ANOVA) as a constrained estimation of relative tool and product disturbances to analyze the mixed run process. An ARIMA model was added to improve the estimation of tool disturbance [16]. Similarly, Prabhu and Edgar [17] proposed a state estimation method based on a random walk model and Kalman filter to solve the high-mix manufacturing.

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