Robust FDC based on gray box model– Yuko Jisaki

Noritoshi Takada, *Tomoya Tanaka
jisaki.yuko@jp.panasonic.com, takada.noritoshi@jp.panasonic.com, tanaka.tomoya@tpsemico.com
Panasonic Industrial Devices Engineering Co., Ltd., *TowerJazz Panasonic Semiconductor Co., Ltd.
800 Higashiyama, Uozu City, Toyama 937-8585, Japan
Phone: +81 -765-22-3138

1. Introduction

At high-mix, low-volume production foundries, the creation of new products to meet customer needs requires a succession of new process recipes. For each new recipe, optimized fault detection and classification (FDC) are necessary to prevent quality loss. However, setting optimal control limits for new recipes before new production start is problematic to the lack of historical data that would enable the control limits to be calculated statistically. To overcome this drawback, we have developed a new and robust FDC method based on a gray box model that combined a physical model and a statistical model to achieve a common control limit for all recipes. Our robust FDC method based on a physical model enables the setting of optimum control limits before new production start for any recipe (Fig. 1).

2. Approach

Figure 2 is a diagram of the relationship between equipment parameters based on our strategy. Active parameters are set values imposed within the recipe, and passive parameters change with the variations in physical phenomena in the process chamber. The set point of active parameters is usually described in the recipe (Case A) but is sometimes not (Case B). In both cases, if the ideal values of active parameters and passive parameters can be estimated from the recipe information, the difference between actual value and ideal value will be independent of the recipe. One effective strategy would thus be, to monitor the difference in common control limit values for any recipe. Figure 3 is flowchart illustrating the practical use of robust FDC. First, we statistically analyzed the relationship between recipe information and active parameters and constructed a gray box model that can calculate ideal values of active parameters from the recipe information (step 1). Second, we constructed another gray box model that can calculate the ideal value of passive parameters based on active parameters (step 2). Finally, we monitored the difference between actual values and ideal values for both active and passive parameters. The variables of the gray box model were combined based on the physical model, and the coefficients of the gray box model were calculated using historical data on existing recipes.

3. Results: case study

To verify the method's feasibility, we tested our method using an angular energy filter (AEF) unit used in ion implantation equipment. AEF units separate out specific ions by using different circular orbits traced by different ion species in constant magnetic field (Fig. 4). The set point of the magnetic field is determined by the recipe information, and the magnetic field is controlled by varying the coil voltage (Fig.5). We interpreted the magnetic field as an active parameter and the coil voltage as a passive parameter.

3.1. Gray box model design

In step 1, the statistical analysis results indicated that the magnetic field is related to the mass, energy, and electric charge of an ion. We therefore adopted, as our physical model, the uniform circular motion of a charged particle in a uniform magnetic field. Based on this, we constructed the gray box model shown in Figure 6. In step 2, it was found by statistical analysis that the coil voltage is proportional to the square of the magnetic field. We therefore adopted the magnetic domain theory and the Ampere's law, and constructed the gray box model of the coil voltage shown in Figure 7.

3.2. Practical use of robust FDC

Figure 8 shows trend charts and frequency distributions of actual coil voltages and of calculated values using the gray box model for multiple recipes. The actual values are distributed on multiple levels but the calculated values are distributed on the same level and can be monitored using common control limits as shown in Figure 8. Moreover, we have achieved practical use of robust FDC and could prevent abnormalities in the control of magnetic field at AEF unit.

4. Summary

We developed a robust FDC method using a gray box model and applied our method to ion implantation equipment. We have achieved quick setting of control limits for new recipes before new production start, and a 92% reduction of workload in setting control limits.

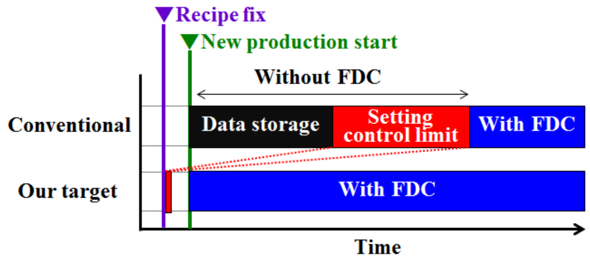

Figure 1. Purpose of this study. Quick setting of control limits before new production start.

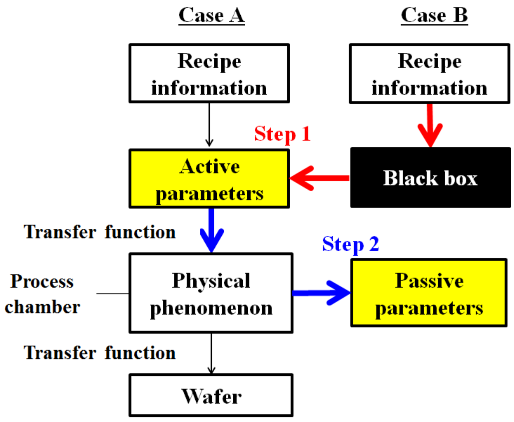

Figure 2. Diagram of the relationship between recipe information, active parameters and passive parameters.

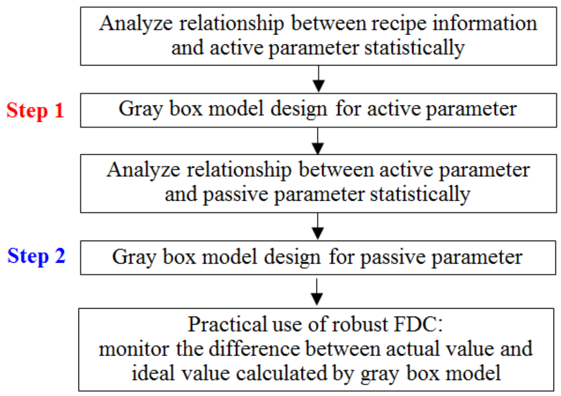

Figure 3. Our approach to the practical use of robust FDC based on our gray box model.

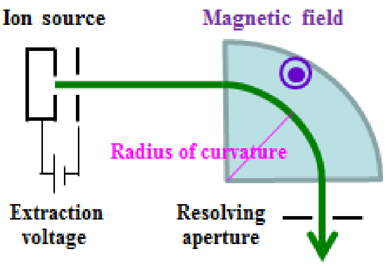

Figure 4. Schematic drawing of AEF unit

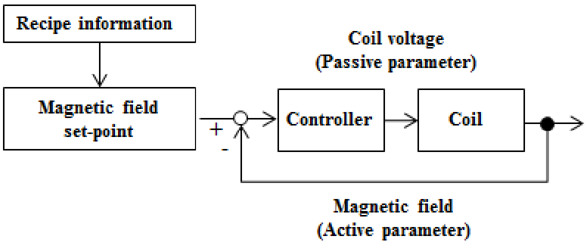

Figure 5. Determination of magnetic field set-point by recipe information and closed-loop control of magnetic field by coil voltage.

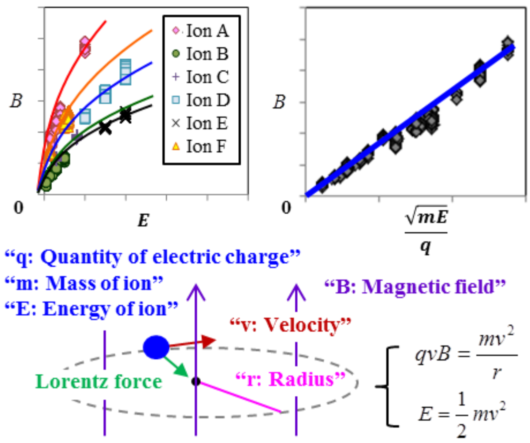

Figure 6. Gray box model of magnetic field (step 1).

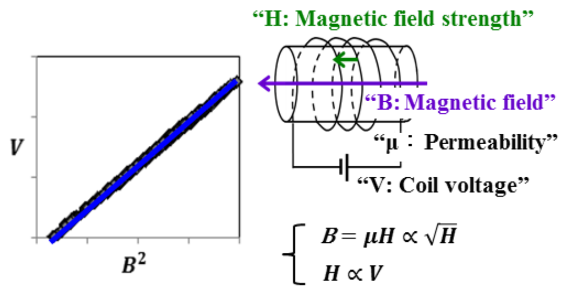

Figure 7. Gray box model of coil voltage (step 2) .

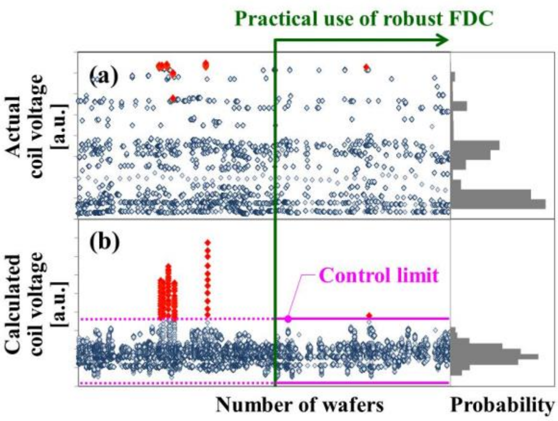

Figure 8. Chart showing coil voltage. (a) Actual data; (b) Calculated data using gray box model. Plots in red mean abnormities.