Short Papers

Process Parameters Optimization: A Design Study for TiO2 Thin Film of Vacuum Sputtering Process
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Abstract—This paper proposes a procedure for process parameters design by combining both modeling and optimization methods. The proposed procedure integrates the Taguchi method, the artificial neural network (ANN), and the genetic algorithm (GA). First, the Taguchi method is applied to minimize experimental numbers and to collect experimental data representing the quality performances of a system. Next, the ANN is used to build a system model based on the data from the Taguchi experimental method. Then, the GA is employed to search for the optimal process parameters. A process parameters design for a titanium dioxide (TiO2) thin film in the vacuum sputtering process is studied in this paper. The quality objective is to form a smaller water contact angle on the TiO2 thin-film surface. The water contact angle is 4° obtained from the system model of the proposed procedure. The process parameters obtained from the proposed procedure were used to conduct the experiment in the vacuum sputtering process for the TiO2 thin film. The water contact angle given from the practical experiment is 3.93°. The difference percent is 1.75% between 4° and 3.93°. The result obtained from the system model of the proposed procedure is promising. Hence, we can conclude that the proposed procedure is a very good approach in solving the problem of the process parameters design.

Note to Practitioners—This paper was motivated by the problem of finding optimal process parameters for the TiO2 thin-film but it also applies to other different processes that need to get better process parameters by experiments. Existing approaches have trial-and-error or experimental methods. The two methods are time- and cost-consuming, and could not guarantee to find the good process parameters. This paper suggests a procedure by combining both modeling and optimization methods to solve this problem. We employ the Taguchi method, the ANN, and the GA to search for the optimal process parameters for a TiO2 thin film in the vacuum sputtering process. The result is quite promising. In future research, we will improve the adopted methods and apply the approach to other problems for optimal process parameters design. Please feel free to contact us, if you have any questions about this approach. We will do our best to help you.

Index Terms—Genetic algorithm (GA), neural network, Taguchi method, thin film, vacuum sputtering process.

I. INTRODUCTION

Environmental pollution and destruction on the globe have drawn attention to develop totally new, safe, and clean chemical technologies and processes. These topics have been to be the most important challenges in the industries of the 21st century. Thus, photocatalysis technologies are becoming more and more attractive to the industries today. In the studies of Fujishima et al. [3], [4], TiO2 shows the advantages of strong oxidation power, stable chemical and heat resistance properties, low cost, corrosion resistance, and high decomposition efficiency as well as the super hydrophilicity. In the manufacturing process of the TiO2 thin film, the physical vapor deposition (PVD) of vacuum sputtering process has the advantages of high adhesion and compactness. Currently, the vacuum sputtering process producing the TiO2 thin film commonly adopts trial-and-error or experimental design methods. That is, one is to assume the initial experimental parameters, then modify and verify the experimental data to obtain feasible process parameters. The other is to collect and adjust the experimental parameters obtained from the past similar experiments to find better process parameters [11], [13], [16]. All of those methods are time- and cost-consuming, and could not guarantee to find the good process parameters. Therefore, it is very important to develop an effective procedure to search for optimal process parameters.

The Taguchi method [14], [17], [20] uses many ideas from the statistical experimental design for evaluating and implementing improvements in products, processes, and equipment. The Taguchi method is used to study a large number of design variables with a small number of experiments. The better level combinations of design variables are decided by the orthogonal arrays (OAs) and signal-to-noise ratios (SN). The artificial neural network (ANN) is a powerful data modeling tool that is able to capture and represent complex input/output relationships [5], [7], [8]. A multilayer ANN can approximate any nonlinear continuous function to an arbitrary accuracy [2], [9], [19]. Owing to its particular structure, a neural network is very good in learning using some learning algorithms such as the genetic algorithm (GA) [1], [6], [18], [19] and the backpropagation [12].

In this paper, we integrate both modeling and optimization methods to propose the parameters design procedure. The proposed procedure combines the Taguchi method, the ANN, and the GA. The detailed procedure for designing the process parameters is described as follows. First, define the experimental problems and parameters, and use the Taguchi method with a small experimental numbers to do experiments and collect data representing the quality performances of a system. Next, establish and verify the system model by using the ANN based on the data from the Taguchi experimental method. Finally, use the GA to search for the optimal process parameters. An example of the process parameters design for a TiO2 thin film in the vacuum sputtering process is tested in this paper.

II. VACUUM SPUTTERING PROCESS FOR TiO2 THIN FILM

A thin-film process contains three sequential steps as follows. A source of film material is first provided, the material is then transported to the substrate, and finally the deposition takes place [10], [15].

In this paper, a TiO2 thin film is formed in the vacuum sputtering process and the quality objective is to focus on its water contact angle. Because the TiO2 thin film has the hydrophilic property, it provides the functions of anti-pollution and self-cleaning. The smaller the water contact angle is, the better the anti-pollution and self-cleaning functions are. The measurement of water contact angle is shown in Fig. 1. The angle θ is the water contact angle between the line segment and the level surface. The line segment passes through the apex point a and the point b on the level surface. There are two main stages to form a TiO2 thin film in the vacuum sputtering process as following:

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model. Meanwhile, those parameters are employed to conduct the experiment for a TiO$_2$ thin film. The water contact angles obtained from the practical experiment at two different positions are 3.83° and 4.03°. The average angle is 3.93°. There is 1.75% difference between 4° and 3.93°. This result from the model of the proposed procedure is quite promising. In addition, the result is also better than the experimental results of $L_{18}$, shown in Table II. Therefore, the proposed procedure is a good approach to obtain better parameters for a TiO$_2$ thin film in the vacuum sputtering process.

VIII. CONCLUSION

This paper presents a design procedure of process parameters by integrating both the modeling and optimization methods. The procedure combines the Taguchi method, the ANN, and the GA to search for the optimal process parameters for a TiO$_2$ thin film in the vacuum sputtering process. The OA $L_{18}$ is used to collect experiment data representing the quality performance of a TiO$_2$ thin film. The Taguchi response table is used to find the best level combination of factors. Then, the 19 experimental data are collected as the inputs for training the ANN model by using backpropagation algorithms. Further, the better process parameters are searched by the GA. Those process parameters are employed to conduct the experiment for a TiO$_2$ thin film. The result is quite promising and better than the results obtained by the Taguchi experimental method usually used in the industry. Therefore, we conclude that the proposed procedure possessing the functions of modeling and optimization can be used to solve the process parameters design problems.

REFERENCES


Monitoring of Timed Discrete Events Systems With Interrupts

Adib Allahham and Hassane Alla

Abstract—A framework is introduced for monitoring the interrupting faults in the timed discrete events systems. We introduce the notion of acceptable behavior of the system subjected to these faults: permanent or intermittent. The acceptable behavior of a system is modeled by a stopwatch automaton. The timed sub-spaces in the locations of the automaton delimit exactly the range of the acceptable behavior. They are synthesized using the techniques of reachability analysis of stopwatch automata in a way to detect the system faults as early as possible.

Note to Practitioners—The final monitoring system is a stopwatch automaton. This automaton can be translated into a Sequential Function Chart (SFC), an industrially recognized and used tool of programming logic controllers (PLCs). Consequently, we can implement the proposed monitoring system by the PLC, used extensively in the industrial environment.

Index Terms—Interrupting faults, monitoring, reachability analysis, stopwatch automata, timed discrete events systems.

I. INTRODUCTION

Monitoring the complex systems plays an important role for economic, security and reliability reasons. It has been received a considerable attention in the literature of various domains. In this paper, the monitoring task consists in determining the occurrence of the faults in the systems that can be modeled as timed discrete-event systems (TDES). Our work considers only the intermittent and permanent faults [1] that interrupt the task of a resource. We call these faults interrupting faults. System availability relates to some tolerance against the intermittent faults—the capability of a system to execute its tasks even

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