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An application of AHP and sensitivity analysis for selecting the best slicing machine

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Abstract

Wafer slicing is a complex manufacturing process, complicating efforts to monitor process stability and quality control effectively. This study discusses and develops a manufacturing quality yield model for forecasting 12 in. silicon wafer slicing based on the Analytic Hierarchy Process (AHP) framework. Decision Makers can select evaluation outcomes to identify the most precise machine. Additionally, EWMA control chart is presented to demonstrate and verify the feasibility and effectiveness of the proposed AHP-based algorithm. Finally, sensitivity analysis is performed to test the stability of the priority ranking. Therefore, this work illustrates how the AHP model would be implemented to help engineers determine the manufacturing process yield quickly and effectively.

Keywords: Silicon wafer slicing; Analytical Hierarchy Process; EWMA; Sensitivity analysis

1. Introduction

The pervasiveness of electronic products and Internet-based technologies has contributed significantly to the accelerated development and global competitiveness of the Taiwanese semiconductor industry. Semiconductor manufacturers require wafers with larger diameter and more stringent technical specifications to produce increasingly complex semiconductor devices such as larger megabit memory chips and microprocessors (Lin, Chang, & Chen, 2006). The 12 in. wafer slicing is currently the most challenging process in semiconductor manufacturing in terms of controlling yield. Since silicon wafer slicing directly impacts production costs, increasing and maintaining wafer yield, as well as understanding the factors that contribute to declining yields are key concerns among semiconductor manufacturers.

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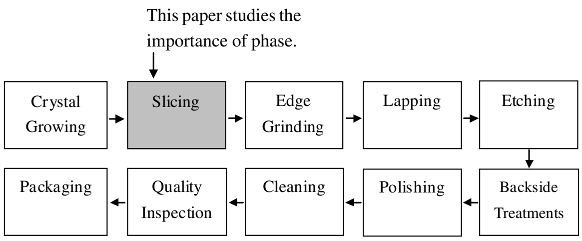

Fig. 1. Silicon wafer manufacturing process.

Previous studies on product quality in semiconductor manufacturing have largely adopted statistical methods to examine either wafer yield or how process engineers select the process parameters of wafer yield based on their subjective experiences. Statistical or experimental design methods have then been applied to analyze the results. However, semiconductor manufacturing includes thousands of process parameters that influence one another, making it extremely difficult to identify the key influences. Cunningham, Spanos, and Voros (1995) indicated that, although conventional statistical and experimental design methods have enhanced wafer yield, statistical methods suffer many limitations with respect to complex mutual influence and the non-linear problem. Additionally, Braha and Shmilovici (2002) found that given the large number of parameters used in semiconductor manufacturing, statistical methods could not efficiently analyze useful decision information.

The wafer manufacturing process needs to be performed in a clean room, as shown in Fig. 1. However, wafer slicing yield is the most difficult variable to control. Slicing describes the cut of silicon ingots into slices. This is usually done using a diamond saw. Each of the wafers is then polished until they are very smooth and just the right thickness. A wafer can be easily broken during inspection owing to its thinness and brittleness. Therefore, to make smaller crooked wafer to meet client demand advanced slicing machines are used (Kao, Prasad, & Li, 1997). Lin, Chen, and Chang (2002) studied silicon wafer slicing as a complex manufacturing process, and proposed that the slicing process involves several synchronously occurring multiple quality characteristics, such as thickness (THK) (ASTM F657, 1995), bow (ASTM F534, 1995), warp (Takeshi, 1998), total indicator reading (TIR) (Takeshi, 1998) and total thickness variation (TTV) (Takeshi, 1998), which must be closely monitored and controlled. Lin, Chang, and Chen (2004) investigated the slicing cutting procedure, which has difficulty in yielding the required precision. Lin used focus groups to identify the main influences on the quality of the manufacturing process, with the factors identified including machinery, personnel, management, measurement and so on. Identifying negative influences can avoid unstable operations during slicing and the production of incorrect quantities. Pai, Lee, and Su (2004) also deemed that the complexity and variability of wafer fabrication creates major difficulties in the relevant production management. Notably, Lin, Chang, and Chen (2005) applied the Chinese philosophy of yin and yang to illustrate issues involving wafer production management and controlling wafer slicing quality, and provided decision makers with philosophical concepts to help them balance the simultaneous consideration of various factors. Furthermore, to increase process yield and accurately forecast next wafer slice quality, grey forecasting is applied to constantly and closely monitor slicing machine drift and quality control.

This study presents a modified Delphi method to develop an evaluation framework. The AHP algorithm is used to evaluate three kinds of cutting machines and identify the machine with the optimum precision. Additionally, the EWMA control chart demonstrates the effectiveness of the proposed AHP method in selecting the evaluation outcomes and assessing the precision of the optimal performing machines. Finally, the sensitivity analysis is performed to test the stability of the rank order. The rank order can devise a standard operational procedure for ensuring quality yield in the semiconductor industry.

2. Method application and results

AHP is a method for decision formulation and analysis (Saaty, 1990). Yang, Su, and Hsu (2000) applied AHP to determine systematic layout planning on semiconductor wafer fabrication facilities. Moreover, Hwang (2004) proposed three steps to evaluate web-based multi-attribute model for engineering project. Ho (2004) applied the AHP model to strategically evaluate emerging technologies in the semiconductor