Online Experts Screening the Worst Slicing Machine to Control Wafer Yield via the Analytic Hierarchy Process

Chin-Tsai Lin[1†], Che-Wei Chang[2], Cheng-Ru Wu[3], and Huang-Chu Chen[4]

[1] Graduate Institute of Business Management
Yuanpei University of Science and Technology,
306 Yuanpei St., Hsin Chu 30015, Taiwan, Republic of China
E-mail: ctlin@mail.yust.edu.tw

[2] Department of Information Management
Yuanpei University of Science and Technology,
306 Yuanpei St., Hsin Chu 30015, Taiwan, Republic of China
Phone: 886-3-5381183 ext 2361, Fax: 886-3-6102362
E-mail: chewei@mail.yust.edu.tw

[3] Department of Finance,
Yuanpei University of Science and Technology,
306 Yuanpei St., Hsin Chu 30015, Taiwan, Republic of China
E-mail: alexru00@ms41.hinet.net

[4] Graduate Institute of Business Management
Yuanpei University of Science and Technology,
306 Yuanpei St., Hsin Chu 30015, Taiwan, Republic of China
E-mail: andy226626@yahoo.com.tw

Abstract

This study describes a novel algorithm for optimizing the quality yield of silicon wafer slicing. 12 inch wafer slicing is the most difficult in terms of semiconductor manufacturing yield. As silicon wafer slicing directly impacts production costs, semiconductor manufacturers are especially concerned with increasing and maintaining the yield, as well as identifying why yields decline. The criteria for establishing the proposed algorithm are derived from a literature review and interviews with a group of experts in semiconductor manufacturing. The modified Delphi method is then adopted to analyze those results. The proposed algorithm also incorporates the analytic hierarchy process (AHP) to determine the weights of evaluation. Additionally, the proposed algorithm can select the evaluation outcomes to identify the worst machine of precision. Finally, results of the exponential weighted moving average (EWMA) control chart demonstrate the feasibility of the proposed AHP-based algorithm in effectively selecting the evaluation outcomes and evaluating the precision of the worst performing machines. So, through collect data (the quality and quantity) to judge the result by AHP, it is the key to help the engineer can find out the manufacturing process yield quickly effectively.

Key Words: Silicon Wafer Slicing, Modified Delphi Method, Analytical Hierarchy Process, EWMA Control Chart

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†Corresponding Author

1. Introduction

The pervasiveness of electronic products and Internet-based technologies has significantly contributed to the accelerated development and global competitiveness of the semiconductor industry in Taiwan. Global semiconductor manufacturers confront another crucial moment over the past 30 years, each participator among them maintains at 12 inch wafer factories. The reason that 12 inch wafer factories having so great influence lies in the tow great factors that properties of product of quick promotion and reducing the production cost, thus elevating the global competitiveness of Taiwanese semiconductor manufacturers to unprecedented levels. Since 1980, the competition of semiconductor industry regards the manufacturing process technique, the yield and the cycle time as the targets of yardsticks. 12 inch wafer slicing is currently the most difficult in terms of controlling yield in semiconductor manufacturing. As silicon wafer slicing directly impacts production costs, increasing and maintaining wafer yield, as well as understanding factors contributing to declining yields are of priority concern among semiconductor manufacturers.

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. Those results are then analyzed using statistical or experimental design methods. However, semiconductor manufacturing includes up to thousands of process parameters that influence each other, making it extremely difficult to determine those factors that influence them. Cunningham *et al.* (1995) indicated that, although conventional statistical and experimental design methods have enhanced wafer yield, statistical methods have many limitations with respect to complex mutual influence and the non-linear problem. Additionally, Brada and Shmilovici (2002) found that under a large number of parameters used in semiconductor manufacturing, statistical methods can not analyze useful decision information efficiently.

Silicon wafers for the semiconductor industry are extremely complex materials with characteristics such as high purity levels, crystallographic perfection and precise mechanical tolerances. Material of silicon wafer can be doped with more than 12 kinds of dopants, such as B, C, N, Al, Si, Sb and others. Currently, the sizes of the firm's products are 8- and 12-inch wafers. The firm has 36 kinds of products, considering dopants and sizes, and each kind of product have different attributes according to which, 7~12 minutes are required to slice a piece of wafer. About 2 minutes are required to inspect the quality of a piece of wafer.

Slicing is a kind of sawing that cannot easily yield the required precision. Two kinds of situation will damage the work-piece: (1) How frequency to adjust the precision of the slicing machine? (2) Controlling the quality of the whole process by using sampling method is difficult, since the production model is small batch. The crystal growing of wafer raw material such an ingot can be sliced into 250~300 pieces. Using the standard sampling method, only one or two wafers need to be sampled to monitor and control the slicing process. Such a small number of samples do not provide sufficient information to identify the quality of the whole process.

Silicon wafer slicing manufacturing process exhibits several characteristics. They are: (1) the product type is small batch production, (2) saw cutting must be very precise, (3) the process run time is long, and (4) inspecting samples is difficult. Furthermore, the process involves several synchronously occurred multiple quality characteristics, such as thickness (THK), bow and warp, which must be closely monitored and controlled. Hence, quality control focuses largely on slicing. While adopting the EWMA control chart, Lin *et al.* (2002) verified that analysis bow is the worst quality characteristic in wafers. From the perspective of quality feature, the manufacturing wafer yield of silicon wafer slicing that bow is of priority concern.

The complex process and high variation in wafer fabrication make its production management very difficult (Pai *et al.*, 2004). Yield of the silicon wafer slicing is the most difficult to control. Silicon wafer slicing is a complex manufacturing process, complicating efforts to dominate process stability and quality control effectively. A wafer can be easily broken during inspection owing to its thinness and brittleness (Lin *et al.*, 2005). Moreover, slicing is a cutting procedure that has difficulty in yielding the required precision. Wafer slicing depends on variables of machine-related, human-related, management-related and measurement accuracy-related factors to ensure quality of manufacturing operations, errors in which would destabilize the slicing process (Lin *et al.*, 2004).

This study presents an evaluation decision model that assesses the yield quality of 12 inch wafer slicing in semiconductor manufacturing. A literature review is performed, along with the modified Delphi method and analytic hierarchy process (AHP) as well. Three kinds of diamond cutting machines used in wafer production are used as the test target of this study, with the results subsequently generated incorporated into the evaluation decision model proposed herein. Moreover, the evaluation weights are determined using AHP. Additionally, the proposed algorithm can select the evaluation outcomes to identify the worst machine of precision. Finally, the exponential weighted moving average (EWMA) control chart demonstrates the effectiveness of the proposed AHP method in selecting the evaluation outcomes and evaluating the precision of the worst performing machines. The proposed evaluation decision model significantly contributes to efforts in silicon wafer slicing to establish a standard operational procedure for ensuring quality yield in the semiconductor industry.

2. Methodology

The criteria for the evaluation decision model are derived following an exhaustive literature review through use of the modified Delphi method. After the evaluation criteria hierarchy is constructed, the criteria weights are calculated by applying AHP; the proposed algorithm can select the evaluation outcomes to identify the worst machine of precision. Finally, use of the EWMA control chart demonstrates the feasibility of the proposed AHP-based algorithm in effectively selecting the evaluation outcomes and evaluating the precision of the worst performing machines.

2.1 Modified Delphi Method

The Delphi method accumulates and analyzes the results of anonymous experts that communicate in written, discussion and feedback formats on a particular topic. Anonymous experts share knowledge skills, expertise and opinions until a mutual consensus is achieved (Sung, 2001). The Delphi method consists of five procedures: (1) Select the anonymous experts; (2) Conduct the first round of a survey; (3) Conduct the second round of a questionnaire survey; (4) Conduct the third round of a questionnaire survey; and (5) Integrate expert opinions and to reach a consensus. Steps (3) and (4) are normally repeated until a consensus is reached on a particular topic (Sung, 2001). Results of the literature review and expert interviews can be used to identify synthesize all common views expressed in the survey. Moreover, step (2) is simplified to replace the conventionally adopted open style survey; doing so is commonly referred to as the modified Delphi method (Sung, 2001). Therefore, this study develops quality evaluation criteria for silicon wafer slicing manufacturing by using the modified Delphi method, as well as by conducting interviews with anonymous experts, and survey of outcome direct to focusing in our research subject. Delbecq *et al.* (1975) suggested five to nine as the appropriate number of individuals in a Delphi method group. Murry and Hammons (1995) suggested that the modified Delphi method summarize expert opinions on a range from 10-30. Therefore, in this study, nine experts participated in the modified Delphi method-based decision group. To ensure non-interference, opinions of the expert group are accumulated, followed by synthesis of those opinions among the manufacturing engineering experts to identify the major factors for consideration in the quality evaluation criteria of silicon wafer slicing manufacturing.

2.2 Analytic Hierarchy Process

Analytic hierarchy process is a technique of multi-criteria decision making (MCDM), was developed by Saaty in 1980 year. AHP is used to solve complex decision-making problems in different areas, such as planning (Kwak and Lee, 2002; Radash and Kwak, 1998), resources evaluation (Jaber and Mohsen, 2001), measuring performance (Frei and Harker, 1999), allocating resources (Alphonce, 1997), choosing the best policy after finding a set of alternatives (Poh and Ang, 1999), setting priorities (Schniederjans and Wilson, 1991). AHP is also a measurement theory that prioritizes the hierarchy and consistency of judgmental data provided by a group of decision makers. AHP incorporates the evaluations of all decision makers into a final decision, without having to elicit their utility functions on subjective and objective criteria, by pair-wise comparisons of the alternatives (Saaty, 1990). Ho (2004) applied AHP model to strategically evaluate emerging technologies in the semiconductor foundry industry. Yang *et al.* (2000) applied AHP to determine systematic layout planning on semiconductor wafer fabrication facilities. Yurdakul (2004) adopted AHP to develop machine tool alternatives selection that contributes to the manufacturing strategy of a manufacturing organization. AHP has thus been successfully applied to a diverse array of problems, with the calculation procedure as follows:

2.2.1 Establish the Hierarchy Structure

The hierarchy structure can be decomposed when dealing with a complex issue. Given the inability of humans to compare more than seven categories simultaneously, each element of the hierarchy must be assumed to not surpass seven elements. Under this limitation, a reasonable comparison can be made and consistency ensured as well (Saaty, 1980). The first hierarchy of the structure is to achieve the goal. The final hierarchy involves selecting the projects or replacing the alternatives, while each middle hierarchy is either the appraisal factor or criteria.

2.2.2 Compute the Element Weights of Various Hierarchies

(1) Establishment of pair-wise comparison matrix *A*

Based on an element of the upper hierarchy is an evaluating standard, going on the pair-wise comparison to each elements.

If has assume that the n elements must make $n(n\text{-}1)/2$ elements of the pair-wise comparison. Let C_1, C_2, ⋯, C_n denote the set of elements, while a_{ij} represents a quantified judgment on a pair of elements C_i, C_j. The relative importance of two elements is rated using a scale with the values 1, 3, 5, 7, and 9, where 1 refers to “equally important”, 3 denotes “slightly more important”, 5 equals “strongly more important”, 7 represents “demonstrably more important” and 9 denotes “absolutely more important”. An n-by-n matrix *A* as follows:

$$A = [a_{ij}] = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_n \end{array} \begin{array}{c} \begin{array}{ccccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ 1/a_{12} & 1 & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ 1/a_{1n} & 1/a_{2n} & \cdots & 1 \end{bmatrix} \end{array}, \qquad (1)$$

where $a_{ij} = 1$ and $a_{ji} = 1/a_{ij}$, $i, j = 1, 2, \cdots, n$. In matrix A, the problem becomes one of assigning to the n elements C_1, C_2, $\cdots$, C_n a set of numerical weights W_1, W_2, $\cdots$, W_n that reflects the recorded judgments. If A is a consistency matrix, the relations between weights W_i and judgments a_{ij} are simply given by $W_i/W_j = a_{ij}$ (for $i, j = 1, 2, \cdots, n.$) and matrix A as follows:

$$A = \begin{array}{c|cccc|} & C_1 & C_2 & \cdots & C_n \\ \hline C_1 & w_1/w_1 & w_1/w_2 & \cdots & w_1/w_n \\ C_2 & w_2/w_1 & w_2/w_2 & \cdots & w_2/w_n \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ C_n & w_n/w_1 & w_n/w_2 & \cdots & w_n/w_n \end{array}, \tag{2}$$

(2) Calculation of eigenvalue and eigenvector

Matrix A multiply the elements weight vector (x) equal to nx, that is $(A\text{-}nI)\ x = 0$, the x is the Eigenvalue (n) of Eigenvector. Due to a_{ij} be makers' subjective judgment give comparison and appraisal, with the truly value (W_i/W_j) have the some level degree difference, so that $Ax = n.x$ can not to be set up. Saaty (1990) suggested that the largest eigenvalue $\lambda_{\max}$ be:

$$\lambda_{\max} = \sum_{j=1}^{n} a_{ij} \frac{W_j}{W_i}, \tag{3}$$

If A is a consistency matrix, eigenvector X can be calculated by

$$(A - \lambda_{\max} I)X = 0, \tag{4}$$

(3) Consistency test

The essential idea of the AHP is that a matrix A of rank n is only consistent if it has one positive eigenvalue $n = \lambda_{\max}$ while all other eigenvalues are zero. Further, Saaty developed the consistency index (CI) to measure the deviation from a consistent matrix:

$$CI = (\lambda_{\max} - n)/(n - 1), \tag{5}$$

The consistency ratio (CR) is introduced to aid the decision on revising the matrix or not. It is defined as the ratio of the CI to the so-called random index (RI), which is a CI of randomly generated matrices:

$$CR = CI/RI, \tag{6}$$

for $n = 3$ the required consistency ratio (CR^{Goal}) should be less than 0.05, for $n = 4$ it should be less than 0.08 and for $n \geq 5$ it should be less than 0.10 to get a sufficient consistent matrix. Otherwise the matrix should be revised (Saaty, 1994).

2.2.3 Compute the Overall Hierarchy Weight

After the weights for various hierarchies and elements are computed, computation results for the overall hierarchy weight are compiled. Finally, the most appropriate strategy is determined.

2.2.4 Implement the Analysis

This paper used implement is Expert Choice 2000 2nd Edition Software to process the data and analysis tools.

2.3 Exponential weighted moving average control chart

Regardless of whether the $\overline{X}/R$ or $\overline{X}/R$ control chart is used, the process is under control at time t. However, the EWMA control chart (Robert, 1959) notifies that the process is already abnormal. Although after time t, the observation point-trend is increasing, the $\overline{X}/R$ or $\overline{X}/R$ control chart shows that there is nothing for acting in the process. However, in the EWMA control chart, the statistic has set off the alarm. An EWMA control chart detects abnormal product quality efficiently and informs the product engineer (Lucas and Saccussi, 1992). Therefore, the proposed algorithm can closely monitor a slight variation in the manufacturing process. In the semiconductor industry, EWMA-based controllers have led to the development of EWMA feedback controllers for compensating against disturbances that affect the batch-to-batch variability in the quality characteristics of silicon wafers at a process setup (Butler and Stefani, 1994; Sachs and Montgomery, 1997). Also, a previous study adopted EWMA to verify the analysis results of bow (Lin *et al.*, 2002). By adjusting the drift of the wire knife to enhance the quality of discussions among experts on slicing, the EWMA control chart demonstrates the effectiveness of the proposed AHP-based algorithm. The precisely determined value of bow is plotted on an EWMA chart. A univariate EWMA chart is modeled as

$$Z_t = \lambda \overline{X}_t + (1-\lambda) Z_{t-1},\ t = 1, 2, \cdots, \mathrm{n} \tag{7}$$

where λ denotes the weighting factor (defined by the decision maker) and typical values for λ range between 0.05 and 0.3 in SPC applications; $\overline{X}_t$ is the subgroup average for the current subgroup at time t (or the current observation if the subgroup size is one $(n = 1)$); the value of Z at time zero, Z_0, is either a target value or the overall average of the selected subgroups (also defined by the decision maker).

The upper and lower control limits for the EWMA statistics are as follows:

$$UCL = Z_0 + \frac{3\sigma}{\sqrt{n}} \sqrt{\left(\frac{\lambda}{1-\lambda}\right)(1-(1-\lambda)^{2i})},\ \text{and} \tag{8}$$

$$LCL = Z_0 - \frac{3\sigma}{\sqrt{n}} \sqrt{\left(\frac{\lambda}{1-\lambda}\right)(1-(1-\lambda)^{2i})}, \tag{9}$$

where Z_0 represents the starting value (defined by the decision maker as either the target value or the process mean value), and n is the size of the subgroup.

3. Decision model application and results

This model for evaluating the worst machine of precision comprises the following steps, selection to worst machine of precision measurement process in Figure 1.

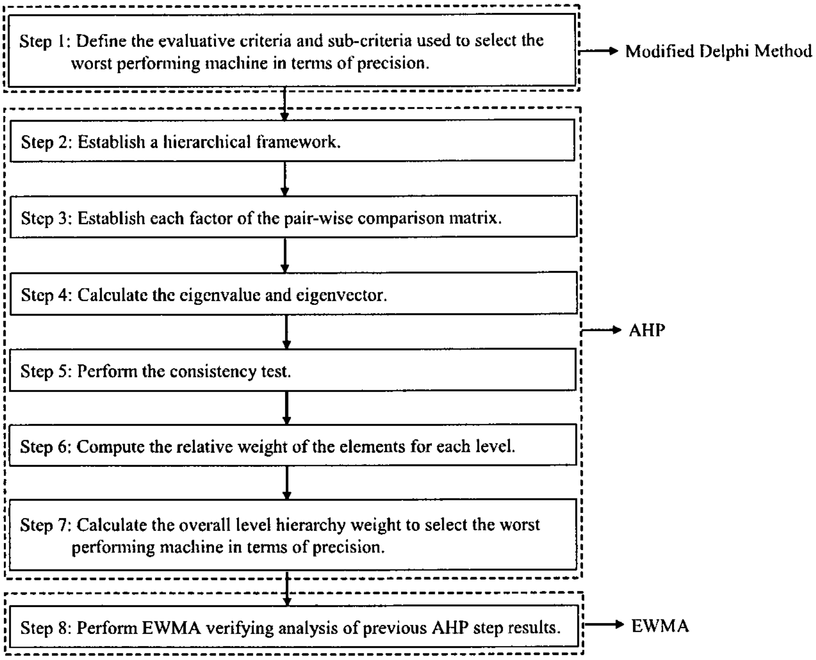

Figure 1. The manufacturing quality of silicon wafer slicing decision model to select worst machine of precision processes

Step 1: Define the evaluative criteria and sub-criteria used to select the worst performing machine in terms of precision.

Here, the evaluation criteria and sub-criteria are defined using the modified Delphi method. Administrators and engineers from thirteen wafer factories were then issued a preliminary questionnaire in which four evaluation criteria and eleven evaluation sub-criteria were incorporated. Each criterion was defined in terms of operation (Table 1).

Table 1. Operational type for defining criteria and sub-criteria factors

Criteria	Code name	The operating type defining
Machine-relate	(C_1)	The defective rate is owing to the machine.
Human-related	(C_2)	Human factors result in the reason of the slice defective rate.
Management	(C_3)	Implement the goal to ensure the process yield of the wafer slice.
Measurement	(C_4)	Balance the approaches of wafer slicing using a relevant measurement procedure.
Sub-criteria	**Code name**	**The operating type defining**
Wire knife life cycle	(CS_1)	The wire knife life has serious influence in its processing capability. As the wire knife is still used under the state of scrap item, it tends to produce injured knife and cause chip defective rate.
Machine precision	(CS_2)	Because of using machine for a long time, the accuracy of machine becomes worse that will influence the chip quality and the yield after processing.
Parameters setting	(CS_3)	A bad setting of the machine parameter would influence the process capability.
Establish adjusting standard procedures	(CS_4)	Establishing a suit of managements of the standard process would make the staff deal with the problem s of the process in order.
Engineer's experience	(CS_5)	An engineer has to accept the whole in-service training before working and has to possess the related technique knowledge so that operating the machine practically and raising the product yield.
Adjusting time	(CS_6)	Proofreading regularly could guarantee the process capability.
Color management	(CS_7)	Use color management to enable not only staff but the raw material and the control of the poor yield could be conducted.
Online education	(CS_8)	On-line training could enhance professional knowledge and engineering expertise, as well as reduce the errors of the artificial importation and increase productivity.
Multi-response	(CS_9)	Adequate control is available for the multiple quality characteristics, which could effectively determine the optimum factor-level combinations and raise the proficiency of the wafer slicing process.
Method to check	(CS_{10})	A verification method to achieve the most reliable measurement would effectively promote the ability and proficiency of the process.
Measure characteristic	(CS_{11})	Formulating the measurement quality characteristics could reduce engineering errors; otherwise, the characteristics of errors could be easily identified.

Step 2: Establish a hierarchical framework.

Based on the modified Delphi method, a general consensus among experts can be reached to establish a hierarchical structure. The worst performing machine in terms of precision can be selected and evaluated based on four evaluation criteria, eleven evaluation sub-criteria and, finally, the alternatives (Figure 2).

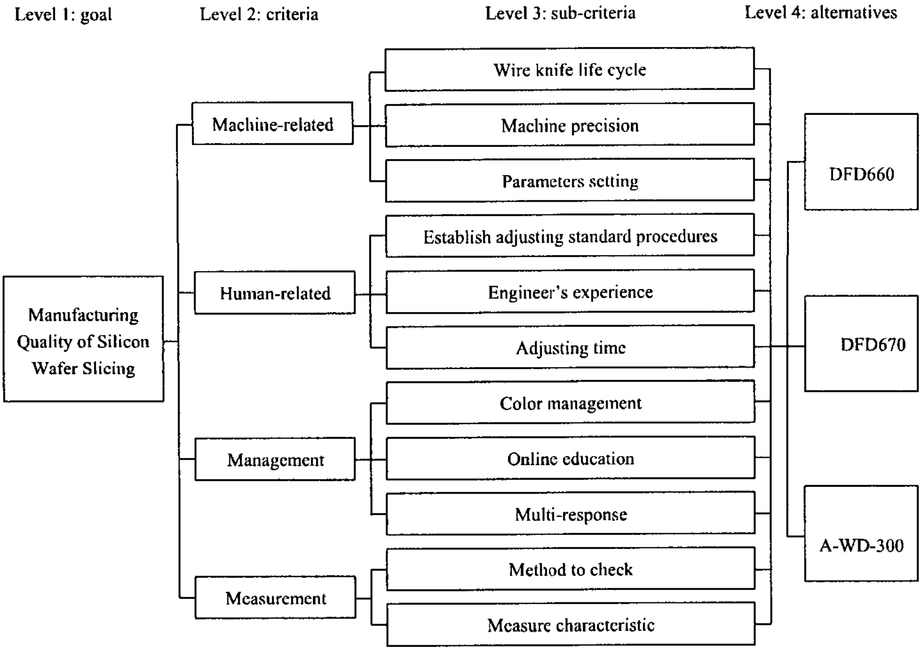

Figure 2. Hierarchical structure to select the manufacturing quality of silicon wafer slicing

Step 3: Establish each factor of the pair-wise comparison matrix.

In order to determine the importance values as to the alternatives, pair-wise comparisons are used. The pair-wise comparisons in question are made for;

- each sub-criteria taking each main criterion into consideration,
- each main criterion taking the goal to be achieved into consideration,
- each alternative taking each sub-criterion into consideration.

Pair-wise comparisons are based on the scale of relative importance that assumes values between 1 and 9. This scale can be applied with ease to criteria that can be defined numerically as well as to those cannot be defined numerically. Relative importance scale is presented. The decision maker is supposed to specify their judgments of the relative importance of each contribution of criteria towards achieving the overall goal. For this reason, a questionnaire was devised to find out an expert opinion in the form of a pair-wise comparison.

Purposive sampling is applied to sample sixteen respondents comprised of administrators and engineers from wafer factories. Base on the weighted value that experts finally assign, the geometry mean value is used to compute decision-making community scores of all experts in order to formulate the weighted values selected for silicon wafer slicing manufacturing quality. For instance, the main criteria are as the sample, such as in Table 2. Eq. (1) and (2) are used to calculate the aggregate pair-wise comparison matrix.

Table 2. Aggregate pair-wise comparison matrix for criteria of level 2

Goal	C_1	C_2	C_3	C_4
C_1	1	1.909	0.951	1.147
C_2	0.524	1	1.582	1.622
C_3	1.052	0.632	1	1.026
C_4	0.872	0.616	0.975	1
λ_{max} = 4.149056; C.I. = 0.049685; R.I. = 0.90 ; CR = 0.055206 $\leq$ 0.1				

Step 4: Calculate the eigenvalue and eigenvector.

Using the comparison matrix (such as in Table 2), the eigenvectors were calculated by Eq. (3) and (4). Table 3 summarizes the results of the eigenvectors for criteria, sub-criteria and three diamond cutting machines.

Table 3. Weights of the criteria, sub-criteria and three diamond cutting machines

Criteria	Weights of criteria	Sub-criteria	Weights of sub-criteria	Global priority	DFD660	DFD670	A-WD-300
C1	0.298	CS_1	0.285	0.085	0.198	0.510	0.292
		CS_2	0.323	0.096	0.360	0.342	0.298
		CS_3	0.392	0.117	0.262	0.409	0.329
		Global priority			0.278	0.415	0.307
C2	0.267	CS_5	0.298	0.079	0.358	0.310	0.332
		CS_6	0.382	0.103	0.314	0.360	0.326
		CS_7	0.320	0.085	0.341	0.362	0.297
		Global priority			0.338	0.341	0.321
C3	0.225	CS_8	0.250	0.056	0.327	0.430	0.243
		CS_9	0.348	0.078	0.177	0.464	0.359
		CS_{10}	0.402	0.091	0.361	0.347	0.293
		Global priority			0.287	0.408	0.303
C4	0.211	CS_{11}	0.453	0.095	0.345	0.418	0.236
		CS_{12}	0.547	0.116	0.352	0.355	0.293
		Global priority			0.349	0.390	0.261

Step 5: Perform the consistency test.

According to Eq. (5) and (6) the criteria comparison matrix of consistency for each criterion is calculated, as shown in Table 2. Results of the consistency test and the *CR* of the comparison matrix from each of the five experts and eleven users are all < 0.1, indicating "consistency". Furthermore, the *CR* of the aggregate matrix is also < 0.1, also indicating "consistency".

Step 6: Compute the relative weight of the elements for each level.

Aggregated scores provided by all decision makers are aggregated showed Table 3. Table 3 summarizes the relative weight of the elements for each level.

Step 7: Calculate the overall level hierarchy weight to select the worst performing machine in terms of precision.

The composite priorities of the alternatives are then determined by aggregating the weights throughout the hierarchy. The composite priorities of the alternatives are showed Table 4. According to Table 4, "A-WD-300" is used to select the evaluation outcomes and evaluate the worst performing machine in terms of precision.

Table 4. Selection of the worst performing machine in terms of precision in silicon wafer slicing

Criteria	Weights	DFD660	DFD670	A-WD-300
		Global priority	Global priority	Global priority
C_1	0.298	0.278	0.415	0.307
C_2	0.267	0.338	0.341	0.321
C_3	0.225	0.287	0.408	0.303
C_4	0.211	0.349	0.390	0.261
Result	aggregate score	0.311	0.389	0.300
	Rank	*2*	*1*	*3*

Step 8: Perform EWMA verifying analysis of previous AHP step results.

The process standard deviation, σ, is estimated using the X chart and, then, $\lambda = 0.3$ and $n = 0$ are set to monitor and inspect the bow of three diamond cutting machines (DFD660, DFD670 and A-WD-300). In this chart, 133 samples are generated while the process is controlled. Using Eq. (8) and (11), the upper and lower control limits for the EWMA statistics are used to calculate the bow of three diamond cutting machines. In Figure 3, the out-of-control conditions appear at the 12^{th}, 20^{th}, 33^{rd}, 47^{th} and 61^{st} signals. In Figure 4, the process is out-of-control at the 19^{th}, 40^{th} and 59^{th} signals. In Figure 5, the process is out-of-control at the 7^{th}, 14^{th}, 30^{th} 38^{th}, 49^{th}, and 64^{th} signals. Unusual operating conditions of the manufacturing process appear in A-WD-300 diamond cutting machines the most. Such identification significantly enhances the quality yield of silicon wafer slicing manufacturing.

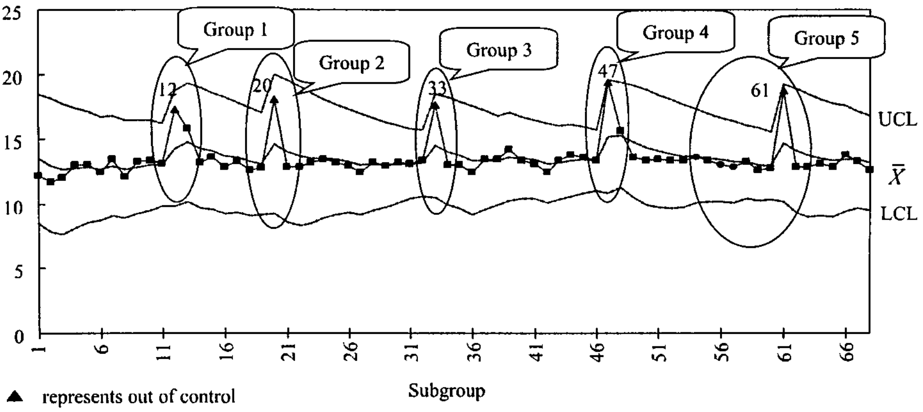

Figure 3. DFD660 of Bow's EWMA Chart by X Counts

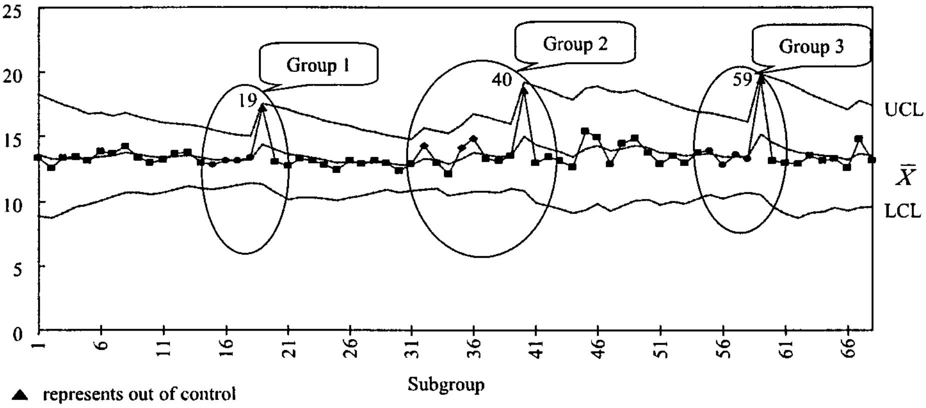

Figure 4. DFD670 of Bow's EWMA Chart by X Counts

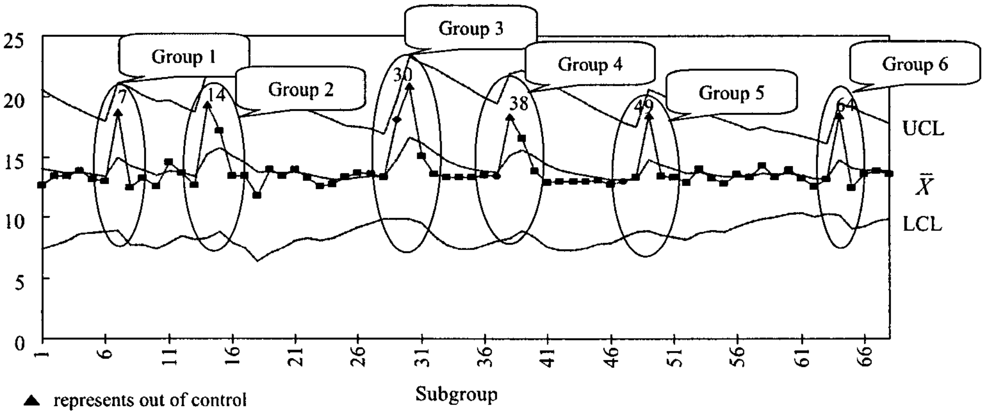

Figure 5. A-WD-300 of Bow's EWMA Chart by X Counts

Consequently, the quality of the EWMA chart for the bow verifies the analysis results, in which the AHP results are the same. Based on the evaluation outcomes, "A-WD-300" is determined to be the worst performing machine in terms of precision.

4. Conclusions

AHP is a popular method used in finding a solution to the problem of MCDM. One of the reasons for the popularity of AHP as an applicable method is the fact that it takes into consideration not just tangible but also intangible criteria. For instance, determining worst machine of precision processes is a problem that involves both many numerical and non-numerical criteria. Therefore, AHP method seems to be an easily applicable method in finding a solution to the problem of where exactly to build Selecting silicon wafer slicing manufacturing quality.

Selecting silicon wafer slicing manufacturing quality system is an extremely complex issue, often relying on the subjective assessment of decision makers. In particular, administrators and engineers in semiconductor manufacturing lack objective decision-making procedures and clearly defined evaluating criteria. Therefore, this study presents an AHP-based algorithm to determine manufacturing quality in silicon wafer in order to identify the worst performing machines in terms of precision. The EWMA control chart is also adopted to identify the worst performing diamond cutting machine in terms of precision as the A-WD-300 one. The proposed AHP-based algorithm significantly contributes to efforts to upgrade manufacturing quality in silicon wafer slicing. Specifically, the proposed algorithm can assist semiconductor manufacturers in similar muilt-criteria questions by offering an objective and systematic means of selecting the worst performing machine in terms of precision and increasing the quality yield of silicon wafer slicing. Final, the proposed procedure allows engineers to rapidly adjust a manufacturing system to eliminate problematic phenomena and increase slicing quality and process capability.

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