Pattern Wafer x/y Auto Align System using Machine Vision

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Abstract: The paper proposes an Automatic Semiconductor Measurement System using Wafer Auto Align using Pattern for semiconductor wafer measurement. The measurement of semiconductors is crucial for the semiconductor industry, and the proposed model aims to improve the semiconductor production automation process. The proposed system consists of three main components: the stage, the vision system, and the pattern alignment algorithm. The stage includes theWafer holder, Ellipsometer, and controller, and plays a critical role in aligning the X and Y axes of the Wafer to 100 mm/s after pattern analysis. The vision system captures high-quality images of the Wafer and analyzes the patterns on the Wafer to detect any defects or deviations from the standard. The pattern alignment algorithm uses the information obtained from the vision system to align the Wafer accurately. The Auto align process is fully automated and does not require any user intervention. The process operates in three major steps: selecting the Wafer Recipe, photographing the pattern of the designated recipe, and executing the Auto align. The proposed system offers a comprehensive and automated solution for Wafer alignment and measurement, providing high accuracy and efficiency, while also reducing the risk of errors and improving the semiconductor production process.

Keywords: vision, ellipsometer, semiconductor, pattern alignment algorism, align

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1. Introduction

Recently, the proportion of MI in the semiconductor industry is growing rapidly due to the semiconductor yield issue. It is important to develop, increase yield, and reduce time in semiconductor process, and the key for this is MI. Thin-Flim Metrology is a measurement equipment that is primarily used in semiconductor casting processes during the MI process. The Thi-Flim Metrology (thin film thickness measurement) of the photolithographic to deposition process is one of the most important element technologies because if the wafer Vision-Alignmen is defective, numerous defective wafers can be produced due to incorrect measurement. Accordingly, it is necessary to accurately find and align the variable wafer and die patterns using the shape pattern finding algorithm and Ellipsometer position alignment technology acquired from the wafer As the pattern becomes finer and high-degree stacking is repeated, even a small distortion of the alignment leads to defects.

It is essential to localize advanced stage and alignment algorithms for Ellipsometer analysis. Stage and Align algorithms linked to Vision/Elipsometer that can accurately specify Wafer's location are essential for the development of semiconductor production processes and inspection of fine patterns and limit stacks The Ellipsometer measures the change in polarization state after reflection or transmission of light, and the change in polarization state is measured It is a measuring instrument that is determined by the characteristics of the sample (thickness, complex refractive index, or dielectric function) and has a resolution of up to several angstroms (1 Å = 1.0 x 10–10 m = 0.1 nm). Therefore, each company is carrying out fine pattern identification and recognition of problems during the process by applying the Ellipsometer production process, and is promoting productivity maximization through process improvement activities. For this, the interlocking Align algorithm, which is HW Wafer Stage and SW, is essential, but the technology is dependent on foreign products. Existing fine pattern recognition methods were only able to align through designated marks, but in this topic, we developed fine pattern recognition-based align s/w through the form of repetitive patterns. Previously, a separate space was needed for Fiducial mark, but this study does not require a separate space for

Align If the pattern registration work to be a reference point is carried out, it will not affect Align even if the production processor or pattern is the same.

The paper proposes an Automatic Semiconductor Measurement System using Wafer Auto Align using Pattern for semiconductor wafer measurement. The system consists of a stage, a vision system, and a pattern alignment algorithm. The stage aligns the X and Y auto align to 100mm/s after pattern analysis, while the vision system captures and analyzes patterns. The pattern alignment algorithm processes the pattern image and commands the stage controller's auto alignment. The process does not require user intervention, and the results can be checked through UI/UX. The proposed model supports various wafer pattern recipes and can be used for different measurement processes without user intervention. The system aims to improve semiconductor production processes and increase productivity and profits for semiconductor companies.

The composition of this paper consists of five chapters as follows. Section 1 describes the background and necessity of the study as an introduction, and Section 2 introduces Ellipsometer, Semiconductor Align, and Pattern alignment algorithm necessary for this study. Section 3 describes the structure, process, and overall layout of the proposed model Section 4 describes the experimental environment, model implementation, and quantitative evaluation of the proposed model. The last section 5 summarizes the conclusion and proposal models and describes future research plans.

2. Related Work

2.1 Ellipsometer

Ellipsometry is technically complex as it is used in a huge number of applications compared to other equipment, so there are various types of lipometers suitable for various applications, mainly in research institutes and semiconductor industries. Among the various types of hi1ps00e161 are Rotating Polarizer Elipsometry (RPE), Rotating Ana-lyzer Elipsometry (RAE), and Rotating Compenser Elip-someryRCE (S). Eipsometry has a process that must be done before making a measurement. Because it is a light measurement technology, the light used in 806 must be well aligned with each optical component and the specimen to be measured, which is called a18n.0ema. After alignment, optical components such as po0lariz€09 and analyzer have an optical axis, so it is necessary to find an incident surface that changes slightly every time the specimen is placed, and the position angle of the optical components is called ali5ra660n.In most cases, the calibration time is much longer than the actual measurement time. In the calibration process, as the number of optical components increases depending on the type of ellipsometer, the position angle to be found increases accordingly. By using the compen-sator, a phase delay compensation plate, the experimental error that occurs when the reflected light approaches linear polarization can be reduced, and since the position is fixed while the polarizer ana-lyzer obtains data, there is no residual polarization or polarization sensitivity problem of the detector. In other words, it is elipsometry that eliminates the shortcomings of RPE and PAE. However, the calibra-tion process is much more complicated than RPE and RAE because it is necessary to find the position angle of the compressor as well as the polarizer and the analyzer. For this reason, ordinary users recognize the Ellipsometer as an equipment that is difficult to use.[1]

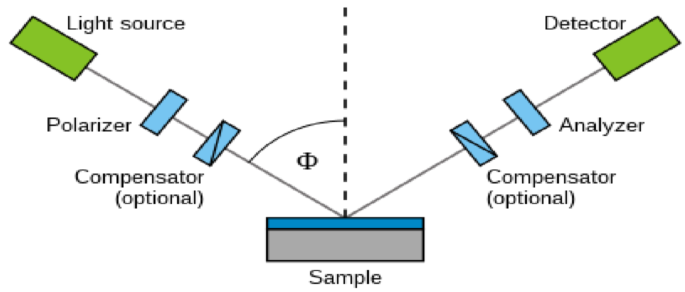

Fig. 1. Ellipsometry

2.2 Semiconductor Align

Wafer chips manufactured through semiconductor processing are used as key components of electronic devices in various industries. There are also various types of wafer defects or defects that occur when passing through these various process processes [3]. Stacking patterns formed on each layer vertically and continuously without missing the correct position is called an overlay. Accurate alignment techniques are required as one of the ways to increase overlay values [4]. The problem of misalignment can be minimized by increasing alignment technology that establishes the circuit of the mask to be newly formed in the circuit formed on the wafer and precisely adjusts the X and Y values. If the position value to be devised when stacking circuits vertically is an overlay, there is a critical dimension that horizontally represents the uniformity of circuits. This is the distance between the patterns and the minimum line width, and the CD value should not vary depending on the location of the wafer. In this way, the correction value should be calculated using the overlay result and the calculated value should be fed back to the exposure equipment to prevent misalignment from occurring on subsequent wafers. In addition, methods and devices for measuring errors in each unit process are being actively studied. As semiconductor devices become highly integrated in the photo process, accurate alignment can become difficult and problematic depending on issues such as alignment margin reduction, level stacking structure, and wafer Daegu hardening. In addition, equipment such as wafer stage, plate stage, lens, etc., and various defective issues in design can also affect the misseline problem. Alignment is one of the machine vision technologies that uses camera sensors to recognize and calibrate the position of alignment marks. Machine vision systems use special optical devices to collect images with digital sensors that are protected inside the camera, allowing the computer system to process and measure various characteristics for decision making[5, 6]. Image and image processing technologies capable of high resolution and high accuracy are increasing, and recent deep learning imaging using technologies such as image, lidar, ultrasound, and laser is gaining research value among computer vision and image processing. [7]

2.3 Pattern Alignment Algorism

Visual object tracking is a fundamental task in the field of computer vision. There are many applications such as video surveillance, human computer interaction, traffic pattern analysis, and robotics. Typical visual trackers can be classified in two types of ways [8]. One method is target representation and localization to cope with changes in the shape of the target. Other methods are filtering and data connection, which address the dynamics of tracked objects, scene pre-learning, and evaluation of other hypotheses. Formulation of filtering and data connection processes is achieved through a state space approach for modeling discrete-time dynamic systems [3]. If the dynamic and measurement functions are linear and the noise sequence is Gaussian, Kalman filters provide the optimal solution [4]. For various tracking scenarios, we applied the aforementioned filtering and association methods to computer vision. In this paper, we propose a novel tracking algorithm that can simultaneously overcome difficulties associated with rapid lighting changes, partial occlusion, similar color backgrounds, and low illumination. For the proposed tracking algorithm, we introduce a binary pattern-based SBP model consisting of several sets of SBPs. In addition, I proposed a kernel-based similarity measurement between the two SBP models for target localization. In addition, binary pattern-based SBP models provide better identification in situations of similar color regions or low illumination, where color-based models tend to fail to track targets.[9]

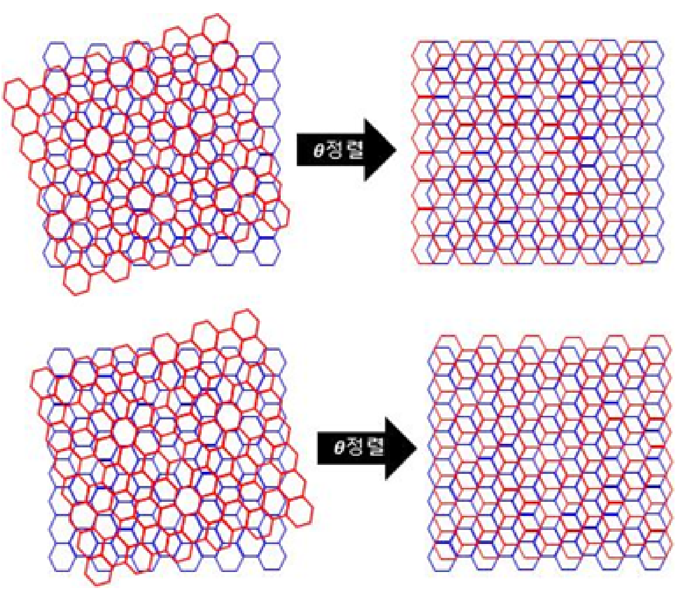

Fig. 2. Alignment using patterns

3. Proposed Idea

3.1 Automatic Semiconductor Measurement System Composition Chart

This paper proposes an Automatic Semiconductor Measurement System using Wafer Auto Align using Pattern for semiconductor Wafer measurement. The measurement of semiconductors is becoming a very important field in the semiconductor production automation process. The share of MI in the semiconductor industry was about 10%, but it is growing rapidly due to the recent semiconductor yield issue. Due to competition to refine semiconductor processes, development, increase in yield, and reduce process time are factors that maximize productivity and profits of semiconductor companies, and MI process is a key solution for this. Thin-Flim Metrology is a measurement equipment used in major semiconductor processes during the MI process. Thin-Flim Metrology in the exposure/deposition process is one of the most important element technologies because it can produce numerous defective Wafer due to incorrect measurement if the Wafer vision alignment is poor. Therefore, it is necessary to accurately find and align the highly variable Wafer and die patterns using the shape pattern finding algorithm and Ellipsometer Position Alignment technology acquired from Wafer. Stage and Align algorithms linked to Vision/Elipsometer, which can accurately specify Wafer's location, are essential to presuppose the development of semiconductor production processes with fine patterns, marginal stacks, and core equipment for inspection.

The following Fig.3 is the overall system configuration of the proposed model.

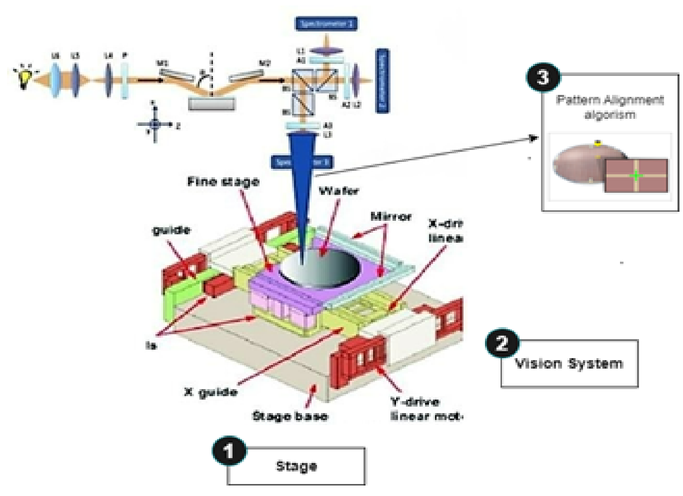

Fig. 3. System Configuration Diagram

The proposed Automatic Semiconductor Measurement System using Wafer Auto Align using Pattern is an advanced technology that aims to improve the semiconductor production automation process. The measurement of semiconductors is a critical aspect of the semiconductor industry, and the proposed model aims to maximize productivity and profits of semiconductor companies by optimizing the MI process.

The system configuration of the proposed model consists of three main components. The first component is the stage, which includes the Wafer holder, Ellipsometer, and controller. The stage plays a crucial role in aligning the X and Y axes of the Wafer to 100 mm/s after pattern analysis. The Ellipsometer is used to measure the thickness of the thin film on the Wafer, while the controller controls the movements of the stage during the measurement process.

The second component of the system is the Vision System, which includes cameras, lenses, and lighting. The Vision System captures high-quality images of the Wafer and analyzes the patterns on the Wafer to detect any defects or deviations from the standard. The lighting used in the Vision System is carefully designed to ensure that the images captured are of high quality and suitable for analysis.

The third component of the system is the pattern alignment algorithm, which is an essential part of the Auto align process. The pattern alignment algorithm uses the information obtained from the Vision System to align the Wafer accurately. The Auto align process is fully automated and does not require any user intervention. The results of the Auto align process can be viewed in real-time through the system's user interface.

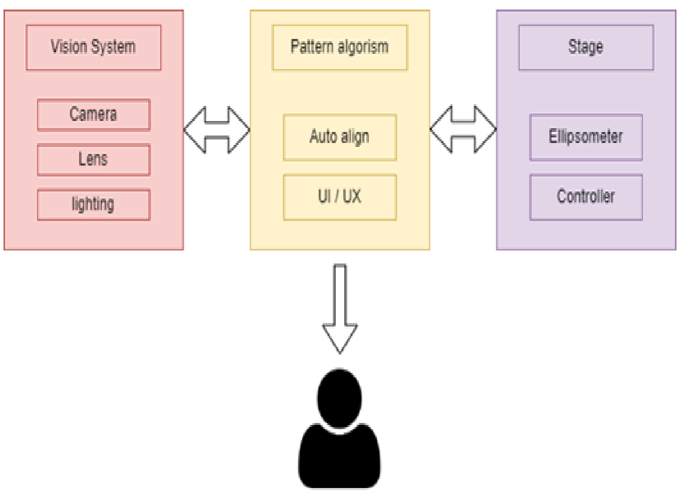

Fig. 4. Proposed Model Configuration Diagram

After analyzing the pattern image of the Vision System through the pattern alignment algorithm, the stage controller's control algorithm is commanded to perform auto alignment. As shown in Fig.4, the proposed model is performed without the user's special system operation in the process of auto aligning the X and Y axes, and the user can check the corresponding results through UI/UX.

3.2 X/Y Auto Align Process

The following Fig.5 is the flowchart of the proposed model process and operates in three major steps.

The process of selecting the Wafer Recipe is an important step in the proposed system, as it determines the type of pattern and the size of the Wafer, and the measurement point and pattern shooting location are changed accordingly. This

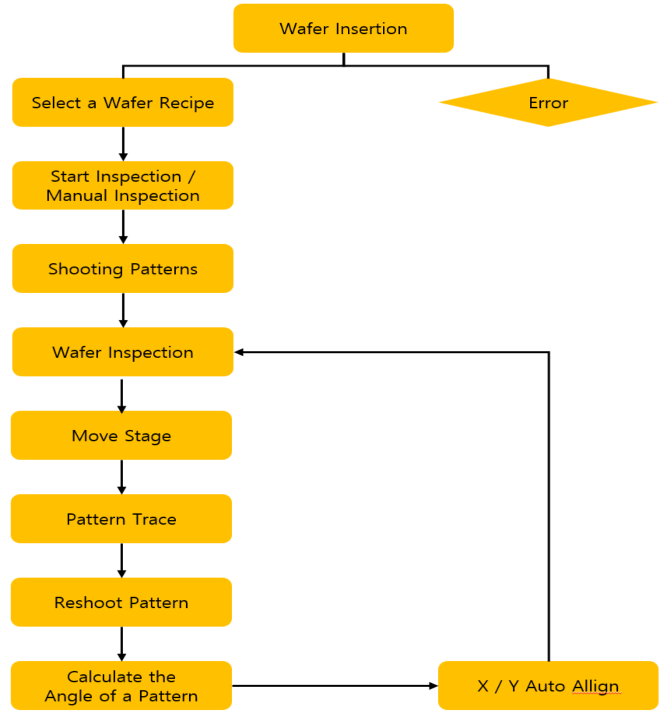

Fig. 5. Progress flow chart

ensures that the system can adapt to various Wafer patterns and sizes, and allows users to choose the Wafer Recipe they want based on their specific requirements. Once the Wafer Recipe has been selected, the system uses an Auto align algorithm to photograph the pattern of the designated recipe. The location of each of the four patterns designated according to the Wafer Recipe type can be found, photographed, stored, analyzed, and digitized to allow users to check in real-time on the user interface. After the main stage of the Auto alignment algorithm, the system tracks and re-shoots the pattern taken in accordance with the input of the new Wafer and the movement of the Wafer Stage. The Auto alignment algorithm then calculates the error of the changed X/Y axis alignment and attempts to align the Auto alignment of the Wafer's X/Y axis. This entire process is automated and does not require any user intervention, and the process can be checked in real-time through the user interface. The corresponding result value is then transferred to the Ellipsometer Controller, and the Auto align is executed. The process is repeated at the end of Wafer's measurement. The time required for each Wafer recipe may vary depending on the number of measurements and the complexity of the pattern, but the system is designed to handle this variability and provide accurate and efficient results. Overall, the proposed system offers a comprehensive and automated solution for Wafer alignment and measurement. By allowing users to select the Wafer Recipe and automating the alignment and measurement process, the system can provide high accuracy and efficiency, while also reducing the risk of errors and improving the overall productivity of the manufacturing process.

4. Experiment and Results

4.1 Data Description and Environment Description

The experimental environment for the dataset includes a C++ programming language and the tensorflow or pytorch machine learning frameworks. The hardware used includes an Intel i9-10900K CPU, a ROBO-8115VG2AR-Q470 SBC board, 8GB DDR4 RAM (2ea), Samsung 870 EVO 1TB SSD (2ea), K-RACK 5020TL 2,5” 2BAY, PBPR-12P4 BACKPLANE, RMC-4S 19” CHASSIS, DELTA GPS-1300CB POWER, and a 1.5U CPU cooler. The development environment and version are critical when using vision inspection and associated libraries (MILLs).

4.2 Configuring Layouts

In order to construct the layout of the proposed model, size information and pattern information of each Wafer Recip are required. The following Fig.6 summarizes the size information and measurement data of Wafer Recip, which are essential data to be included in the layout composition.

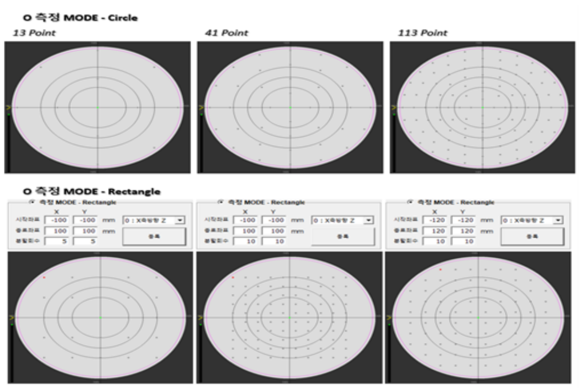

Fig. 6. Wafer recipe

The number of points measured for each Wafer size is different, and this paper will use the most commonly used 41 Point Wafer Recip.

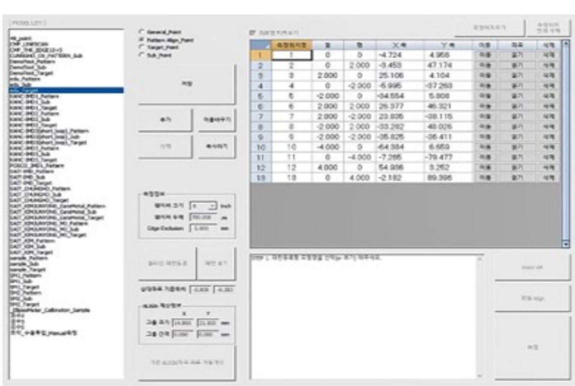

Fig. 7. Wafer recipe data

The following Fig.7 summarizes the details of Wafer Recip, which is essential data to be included in the layout configuration, and the Wafer Recip that you want to measure using the data can be registered and used.

4.3 Auto Align After Pattern Analysis and Recognition (Model Implementation)

The following Fig.8 is a UI/UX screen that allows users to analyze and measure the pattern after obtaining the Wafer Pattern Image using the Image acquisition function, and check the accuracy of the Auto Align.

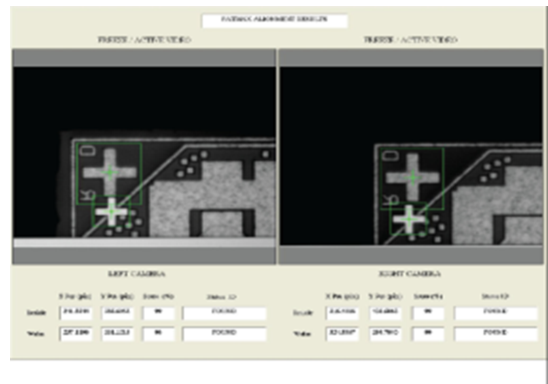

Fig. 8. Auto align UI/UX

The Wafer Pattern Image output on the left side of the screen is an image view for calculating the angle of the changed X/Y axis with the image taken and obtained before measurement, and the information of the corresponding X/Y axis is listed below. The Wafer Pattern Image printed on the right is an image obtained by re-taking the newly introduced Wafer Pattern after measurement, and is configured to compare it with the image taken before measurement, and information on the changed X/Y axis below the image is listed. By calculating the error of the changed X/Y axis through Auto alignment algorithm, the align of the changed X/Y axis is aligned and configured so that the user can check through the corresponding UI/UX.

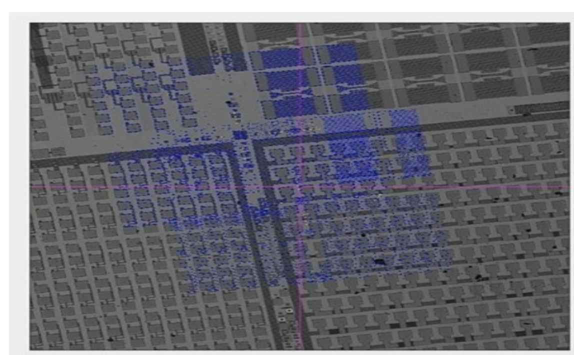

Fig. 9. Before proceeding with the pattern sorting algorithm

The following Fig.9 is a screen that sets the area of Wafer Pattern after obtaining an image and proceeds with Pattern Alignment Algorithm using data from the existing Wafer Recip.

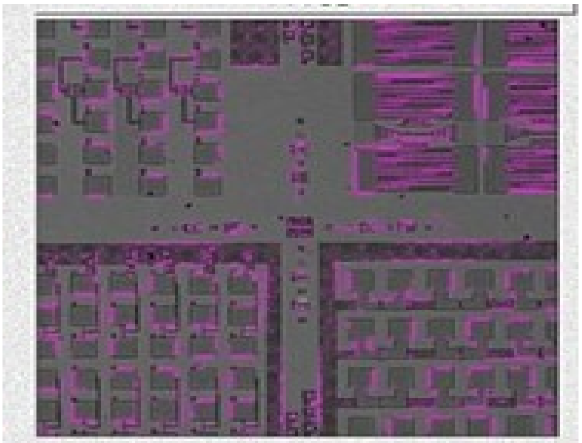

Fig. 10. After the progress of the pattern sorting algorithm

The following Fig.10 shows the result of auto alignment through pattern alignment algorithm, and the result of final alignment completion is indicated in pink area.

4.4 Result

The first task is to develop a GUI that can continuously validate the integration of the Align algorithm with the vision system. The second task is to develop iterative algorithms for machine vision results and fine capture, implement alignment algorithms to achieve 99percent accuracy, and are validated.

The following Table 1 is a table of Tact Time.

TABLE I
TACT TIME

	1st	2nd	3rd	4th	5th
TACT Time	14	15	15	14	16

The proposed technology presents a promising solution for achieving accurate alignment in a production setting while offering several benefits compared to existing methods. The technology's primary advantage is the ability to provide similar performance as traditional alignment methods but with reduced tact time and the elimination of the need for fiducial marks.

Traditional alignment methods require the use of fiducial marks, which are reference points used to align parts or components. The process of placing and identifying these marks can be time-consuming, leading to increased tact time, and the marks may not be reliable due to shifting or misalignment during production. In contrast, the proposed technology eliminates the need for fiducial marks, streamlining the alignment process and significantly reducing the tact time required.

Another benefit of the proposed technology is the user-friendly GUI, which allows for continuous validation of the integration of the Align algorithm with the vision system. The GUI provides a simple and efficient way to monitor and adjust the technology as needed, ensuring that it is always functioning correctly and providing accurate results.

In summary, the proposed technology offers a reliable and efficient solution for achieving accurate alignment in a production setting, with the added benefits of reduced tact time and the elimination of the need for fiducial marks. The technology achieves this through the use of iterative algorithms, integration of alignment algorithms, and a user-friendly GUI, making it a promising alternative to traditional alignment methods..

5. Conclusion

In this paper, the authors proposed a pattern matching alignment method using computer vision technology. The goal of the method was to align objects with high accuracy and efficiency in manufacturing processes, such as semiconductor wafer processing. To evaluate the performance of the proposed method, the authors conducted experiments and measured the error rate and tact time. The error rate is a measure of how accurately the method can align the objects, and the tact time is a measure of how quickly the method can perform the alignment. The results of the experiments showed that the proposed method achieved an error rate of within 5%, which indicates that it can align objects with high accuracy. Moreover, the tact time was faster than other methods, which suggests that the proposed method can improve the efficiency of manufacturing processes. Overall, the results of the experiments demonstrated that the pattern matching alignment method using vision proposed in the paper is a promising approach for achieving accurate and efficient object alignment in manufacturing processes. The authors believe that their method can have significant practical applications in various industries and can contribute to the development of advanced manufacturing technologies.

In this paper, a model of pattern alignment algorithm using Pattern Wafer's pattern was proposed. Based on the technology of the model, we will also develop an Auto align measurement model of plain Wafer using Vision to reproduce the complete Automatic Semiconductor Measurement System Composition chart.

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Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

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Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.