2단 진공 웨이퍼 정렬장치 및 다층 구조 설계
A Dual Vacuum Wafer Prealigner and a Multiple Level Structure

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Abstract: This study aims at aligning multiple wafers to reduce wafer handling time in wafer processes. We designed a multilevel structure for a prealigner which can handle multiple wafer simultaneously in a system. The system consists of gripping parts, kinematic parts, vacuum chucks, pneumatic units, hall sensors and a DSP controller. Aligning procedure has two steps: mechanical gripping and notch finding. In the first step, a wafer is aligned in XY directions using 4-point mechanical contact. The rotational error can be found by detecting a signal in a notch using hall sensors. A dual prealigner was designed for 300mm wafers and constructed for a performance test. The accuracy was monitored by checking the movement of a notch in a machine vision. The result shows that the dual prealigner has enough performance as commercial products.

1. Introduction

An essential step in the semiconductor manufacturing process is alignment which fixes the wafer center and direction during the wafer handling component within the aforementioned manufacturing process. The process of prealign- ment involves aligning a wafer in the XY directions using a separate device. A prealigner is a system that conducts the prealignment. Prealigners are widely used in Chemical Vapor process(CVP), etcher, sorter, implanter and sputter processes. When a wafer is loaded in a machine, a robot lifts the wafer, then places the wafer on a prealigner. The robot subsequently retrieves the wafer after prealignment and mounts it on a stage within the machine. The required accuracy is ±5 μm for translation and ±0.1° for rotation.

Prealignment technologies have been classified into four categories: mechanical alignment, optical sensing, machine vision and wafer profiling using a CCD. Mechanical alignment is based on geometric relations. If a circular plate is pushed from three points around its circumference on a radial direction by actuators, the plate will be aligned at a certain position. Mechanical alignment is applicable to circumstances involving wafers because wafers possess circular shapes1)-2). However, mechanical alignment exhibits lower accuracy than the other categories, thus necessitating additional devices in order to achieve rotational accuracy. An optical sensor generates an analog signal according to the power of light obtained from an optical source. The sensor and the source must be installed together in order to share an optical axis on which a wafer may be placed. Optical power reaches a maximum when a wafer's edge or a noth in the wafer passes the optical axis during rotation3). Sensors may be placed in the radial direction with respect to the wafer. During experimental investigations, Fu developed a four-axis prealigner using laser sensors. From the developments provided by Fu, the eccentricity is calculated from the data supplied by the laser displacement sensor, which was oriented in the radial direction4)-6).

The architecture of optical sensing can be compact and efficient. However, an additional mechanism for XY alignment is necessary and it is difficult to establish a fine algorithm to find an accurate center.

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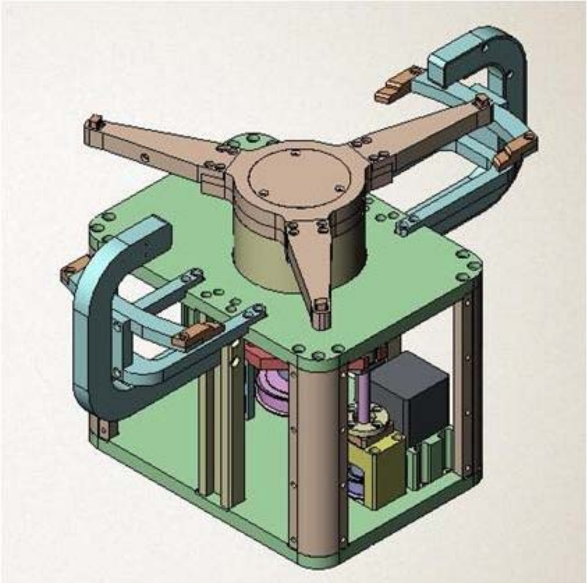

Fig. 1 A layout of a single prealigner

Prealignment can be achieved using intelligent machine vision. Na proposed a pattern recognition algorithm that lays the foundation for wafer die positioning of a prealigner. In his study, the corners of each die were found by a hierarchical gray level corner detector7). Lee proposed a method for calculating wafer eccentricity as well as correcting distortion using an area camera8). Some images of the wafer's circumference were captured during rotation and the wafer profile was also found in the images. Eccentricity is estimated based on the wafer profile. The rotation angle can be detected by recognizing the wafer ID in a flat zone. However, the rotation ceases before images are captured, thus requiring camera calibration.

Line CCDs have been widely used in prealigners. The basic structure of a prealinger using a line CCD is similar to that using optical sensors. A line CCD is installed in a prealinger instead of the optical sensor. In this type, the CCD pixels are placed along the radial direction of a wafer. Light from an optical source reaches a part of a CCD that subsequently forms bright pixels. The light-to-dark pixels are blocked by the wafer. The edge of a wafer is placed on the border of the bright and dark pixels. The wafer profile can easily be estimated by recording the border during rotation. Cong studied the process by which the wafer profile and the eccentricity are found using a CCD9). Most commercial prealigner companies utilized Cong's concept and leading to patents related to the arrangement of CCDs10)-12). This method using a line CCD is simple, accurate and reliable but sensor calibration is stillnecessary. Optical systems incorporating CCDs become relatively thick once situated in a stack configuation for multiple structures, thus presenting an issue in compactness.

Previous sentiments have suggested that all currently available prealigners process only one wafer at a time. Consequently, high-priced machines become idle until the process of prealignment commences followed by a robot conducting wafer transfer. A design has been suggested in which two prealigners are placed around a transfer robot, thus minimizing idling time13).

However, the demand for space required by prealigners increases and the motion performed by the robot which handles the wafers intensifies in complexity. Therefore, this research proposes a prealigner that handles multiple wafers. The proposed prealigner and method comprises a transfer robot that lifts multiple wafers and then simultaneously places the wafers on a multiple prealigner. The robot then loads the wafers onto the machines. This concept reduces idling time and increases efficiency in the wafer process. The proposed multi-structure is composed of a 4-point mechanical alignment, hall sensors and a DSP controller. A dual wafer was utilized for the test.

2. A Multiple Aligner Structure

The basic components that a prealigner encompasses are a vacuum chuck, a rotation unit, a controller and sensors.

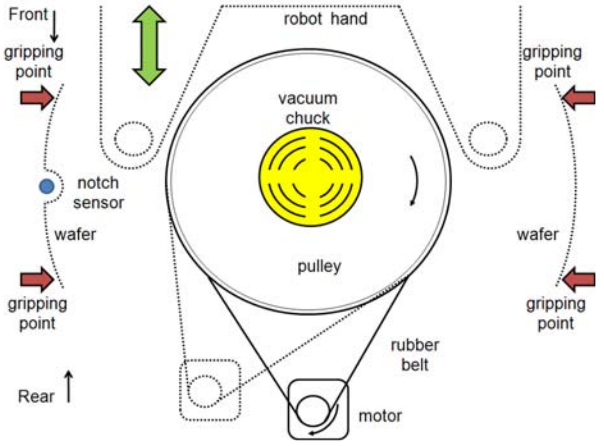

Fig. 2 Planar view of a layer in a multi-prealigner

A vacuum chuck fixes the wafer in a moving stage. The rotation unit produces a relative motion between the wafer and sensors. Sensors are used to locate the wafer profile as well as a flat zone or a notch. The controller drives kinematic units, samples signals from the sensors, calculates eccentricity and corrects errors. XY translation units are required to fix misalignment during wafer profiling, however, a notch sensor is necessary for mechanical aligning. Fig. 1 shows a single prealigner containing mechanical gripping and a notch sensor.

A single aligner structure may be easily constructed in which its components are easily selected. However, selection of these compo- nents is limited especially within multi-level structures. In addition, difficulty arises when applying bulky units, such as XY translation and vision camera to the multi-structure. Some prealigners possess a wafer up-down mechanism: however, such mechanisms are not easily utilized in a multi-structure. The layers of a prealigner should not interfere with each other. Lights from optical sources may inadvertently be mixed, thus fabricating an impossible situation in which each light cannot be separated from the sources using analog sensors. Laser headers and line CCD modules are relatively large for multi-structures, interfering the entry of a robot’ hand which grasps and transfers a wafer.

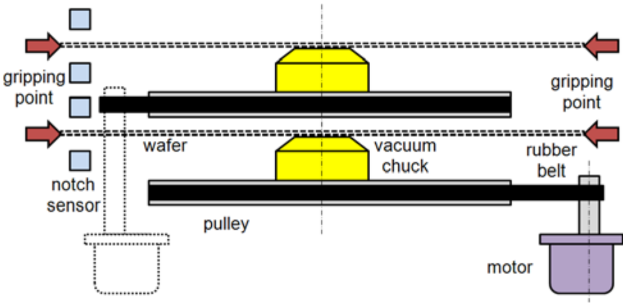

Fig. 3 Concept of a multiple layer structure

Therefore, we designed a multi-structure based on mechanical alignment as shown in Fig. 2. A robotic hand transfers a wafer from a load port and transmits the wafer through the front side of the prealigner. Grippings in the prealigner contain a four-point contact and moves horizontally. The contact forces the wafer to move in the XY direction and resolves into a uniform position as a result of the wafer’s geometric relationship with its environment. The grippings are actuated by pneumatic cylinders. The wafer will not be damaged under compressive forces due to the air chushions contained within the pneumatic cylinders. The wafer is fixed by a vacuum before the grippings release the wafer. The wafer is rotated by a motor and a belt-pulley. A vacuum chuck is attached on a pulley. The displacement generated by a motor is transferred to the pulley by a rubber belt. The motors are placed at the rear side of the prealigner. The locations at which a motor may be situated are limited in multi- structures due to the interference experienced among the motors and the rotation mechanism.

The rotation mechanism is arranged in a stacked configuration along the Z direction. Thus, the contact points between the belts and motors are fixed; however the location of the motors in the XY plane can be easily adjusted. Applied to the prealigner is a hall sensor which is used to detect notches. Hall sensors detect variation of voltages by movement of a conductor between the poles in the sensors. The movement of the conductor perturb flux between the poles but the flux is not diffused, reflected and scattered.

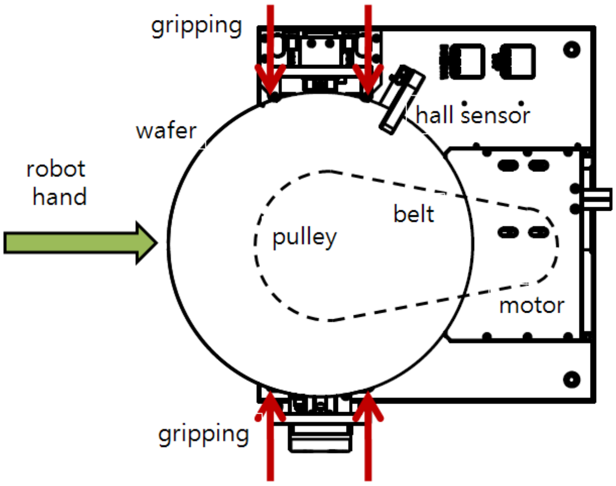

Fig. 4 A top view of a dual wafer prealigner

So, hall sensors do not affect to the performances of other hall sensors within a multi-structure. When a side containing a positive notch passes the hall sensor during a rotation, the position of the motor is stored by a trigger signal generated by the hall sensor. A side containing a negative notch can be found by the same sequence. The notch angle is the average angle value of the positive and the negative notches. The stack of a multi-structure is shown in Fig. 3. The figure shows a cross section in front of a multi-prealigner. The multi-structure can be composed of the proposed mechanism.

3. A Dual Wafer Prealigner

A dual structure for a 300mm wafer contains a two layer of aligning mechanism in which the proposed multi-structure concept is applied. We designed a dual wafer prealigner as shown in Fig. 4 and Fig. 5 displaying aerial and frontal views of the dual prealigner after mounting the wafers.

Wafers are transferred from the front side and placed on vacuum chucks. The mechanical grippings contain two fingers and are situated on both sides of the prealigner, thus allowing this mechanism to make 4-point contact. Pneumatic cylinders drive the grippings back and forth. Rubber rollings are inserted at the end of the fingers to minimize wafer damage.

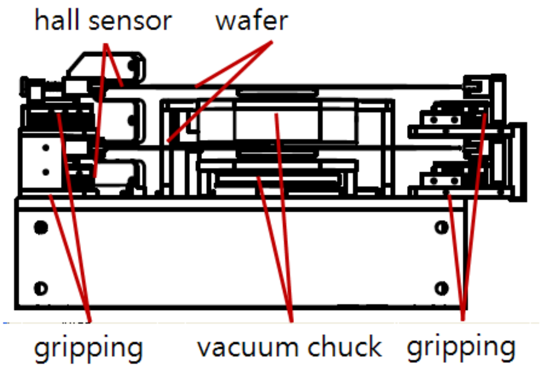

Fig. 5 A front view of a dual wafer prealigner

After mechanical alignment, the vacuum fixes the wafers. Then the wafers are rotated until notches are located. The rotation conducted by motors and belt-pulleys. The hall sensors are arranged in an array module and are placed on the side of the prealigner.

The location of the hall sensors is adjusted along the radial direction of the wafers. Misalignment exists after the mechanical alignment procedure, resulting in the occurrence of eccentricity during rotation. Thus, part of the wafer circumference can be mistakenly identified as a notch. When determining the location of the hall sensors, the possibility of this eccentricity must be taken into consideration in order to compensate for the possibility of error. The responses produced by the hall sensors and the rotation angle are carefully monitored. The wafer angle is calculated by the averaging the angular positions of the positive and negative triggers from the hall sensors. If the alignment is not satisfactory, the mechanical alignment and the process by which notches are located must be repeated. After prealignment, the wafers are rotated by moving offset value from the hall sensor to the front until the notches face the front. A robot then lifts the wafers in the prealigner and transfers them to another machine, as shown in Fig. 6.

4. Experiment

A dual wafer prealigner was established by the proposed design as shown in Fig. 7. Its base and body are composed of aluminium. A two layer aligning mechanism was mounted to the top side as designed. Vacuum chucks and pulleys were placed on the front and fixed by the rotational bearing. The grippings were situated on the left and right sides of the prealigner. The step motors were placed at the rear of the prealigner and the height is adjusted according to the corresponding pulleys. Both the upper and lower aligning mechanisms were activated independently.

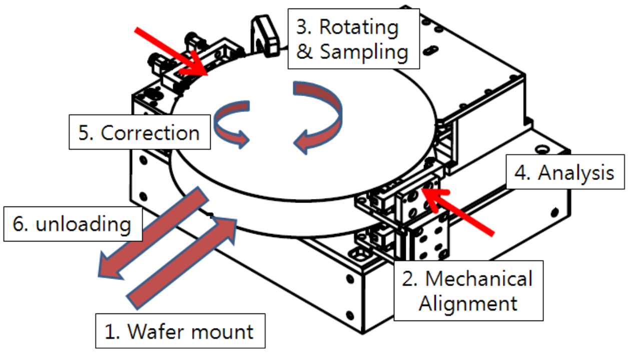

Fig. 6 Operating sequence

The controller, pneumatic values, drivers and a power supply are placed in the base. Two sheets of a 300mm wafer were manually placed on the vacuum chuck manually. The main CPU in the controller was

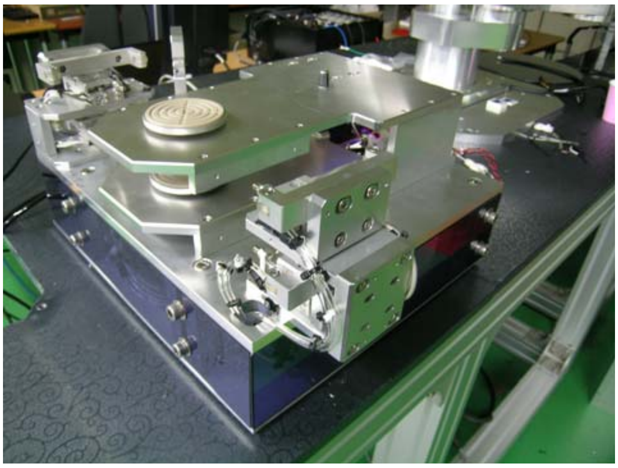

Fig. 7 A prealinger constructed for experiment

TMS320F28335 and the inter- connected I/O's were opto-isolated. The hall sensors(EE-SX670) were used for finding notches. The response time was 2000mm/s and was enough to detect the notch because of considering the wafer size and maximum rotational speed. Table 1 shows the specification.

Table 1 Specification

Wafer Size	300[mm]
Motor Resolution	2000[pulses/rev]
Gear Ratio	10:1
Max. speed	60[rpm]
Size(WHD)	418*330*218[mm^3]
Weight	6.5[kg]
Processing speed	100,000[cycles/sec]
Inputs	10
Outputs	6
Communication	RS−232C
DSP	150MHz
Hall sensor	1kHz(2000mm/s)
Camera	Monochrome, 29Hz
Framegrabber	1024x768
Power	220V, 3A

The DSP firmware was made using Code Composer Studio 3.3 and downloaded through the JTAG port. The final firmware was burned in a FLASH memory due to a characteristic through which the prealigner works like an embedded system. The dual prealigner was operated through the RS-232 port by protocol. The protocol was based on text and composed of 14 commands. The commands included moving, stopping, jogging, homing, setting motion parameters, activating I/O's and aligning. The operating program from the PC was built by VC++. The program was capable of multiple functions: interconnecting between the prealigner and PC, converting user parameters into machine parameters, formulating and transferring commands, and receiving responses.

Fig. 8 shows the flow chart of the DSP program. When the prealigner was on, the DSP set initial paremeters. The DSP repeated scaning various status of the prealigner from the sensors and decoded the commands from RS-232C. When a command for starting alignment was detected, alignment process was carried out. The upper aligner and lower aligner were activated individually.

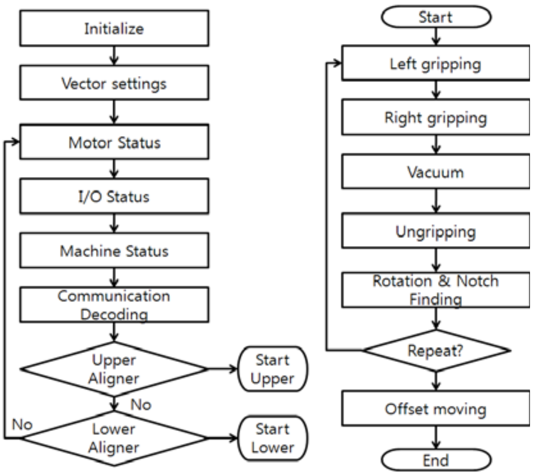

Fig. 8 Flow chart of the DSP program

Fig. 9 Performance test by notch recognition

The alignment procedure was mechanical gripping, vacuum fixing, ungripping, wafer rotation and notchi finding. The alignment was repeated until termination conditions were satisfied. After alignment, the wafer was rotated to place the notch in the front.

The alignment was repeated twice to increase accuracy. The first alignment rotated in the clockwise direction and the speed was set to maximum limit as a means to reduce tack time. The second alignment rotated in the counter- clockwise direction and the speed was varied as a means for determining an optimal condition for accuracy. Accuracy was measured by inspecting a notch using a machine vision. A camera was placed on the desired notch position after alignment. The notch was considered as a bright area by a back light, as shown in Fig. 9.

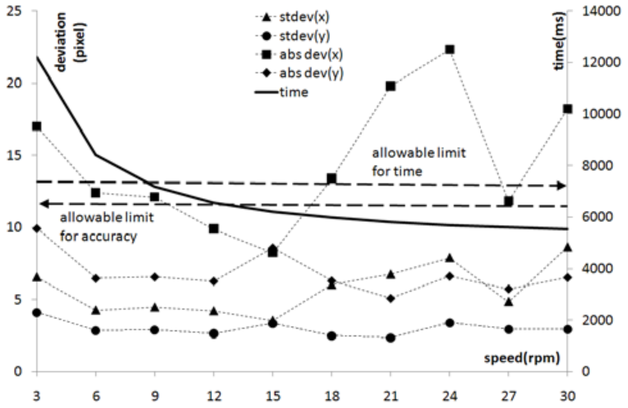

Fig. 10 Test results:speed and accuracy

The area was recognized using a blob search; therefore, the notch position was obtained from the center of the blob. The plot in the figure shows the variation of the center after repeating the alignment process 100 times. The frame grabber was Eurosys Domino Alpha2 and the camera was Sony HR-70 (Progressive Scan, 1024x768, 29Hz, Monochrome). The resolution of the image was 1024x768 pixels and 4.6㎛ per pixel.

5. Results

Fig. 10 shows the variation of performance after 100 repetitions with respect to speed and time. The horizontal axis represents the speed of rotation, the left vertical axis signifies the deviation in pixels and the right vertical axis is alignment time. The triangular and circular plots are the standard deviation of the XY notch position in the machine vision. The rectangular and lozengeshaped plots are the absolute deviations and the red line is alignment time. The alignment time decreased as speed increased. However, between speeds of 3 rpm and 18 rpm, a rapid change in alignment time is not observed. The deviations of Y was relatively small in comparison to the deviations of X. Both X deviations possessed a minimum when the speed was 15 rpm. The effect of friction may increase in the low speed, so notch finding error decreased in the high speed. Therefore, the maximum speed possible for the configuration was applied to the first alignment while an optimal speed of 15rpm was applied to the second alignment. The tack time was 6.2 sec for two sheets of the wafer. Accuracy was ±40㎛ for XY and ±0.015° for θ from the result. If the possible number of wafers increases, the tack time will not decrease. From this fact, we may conclude that a robot may carry multiple wafers simultaneously. This conclusion may also be extended to a prealigner: the prealigner is capable of handling multiple wafers at a time. Consequently, the idling time within costly machines can be minimized. The proposed prealigner may relieve bottle neck areas within some wafer processes.

6. Conclusion

A multi-structure for a prealigner was designed and a dual wafer prealigner was constructed to test its capabilities. Multi- structure mechanisms were considered an appropriate means by which the interference among the layers of aligning units may be avoided. The multi-structure consisted of a four-point mechanical gripping, notch sensors, vacuum chucks, motors and belt-pulleys.

The mechanical gripping was utilized to correct misalignment in the XY directions. The rotational error was detected by a hall sensor which generated trigger signal on a notch. A dual wafer prealigner was built and experimented for checking its performance. The result shows that the prealigner established by the proposed structure can handle multiple wafers at one time, thus reducing idling time caused by a conventional prealigner. In addition, bottle neck areas within the wafer process may be significantly minimized. Therefore, the efficiency of wafer processes can be improved by the multiple wafer prealigner.

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