AN INTEGRATED SOLUTION FOR PRIME WAFER POLISHING

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Biography

Michael D. Kirkpatrick has a Bachelor of Science in Business Administration and Marketing from California Polytechnic State University, San Luis Obispo. Currently Michael is the Vice President of Worldwide Sales for Strasbaugh, a semiconductor equipment manufacturer. In the past he has served as US sales manager and general manager for Strasbaugh's data storage business. Mr. Kirkpatrick has been actively involved in Strasbaugh's CMP program for more than 15 years and helped pioneer the application of CMP for read/write head fabrication. Mike has presented several technical papers on the subjects of optics and semiconductor processing.

Abstract

Although the semiconductor industry as a whole has made major strides in automating the various processes used in fabricating integrated circuits on the surface of a silicon wafer, manufacturing of the silicon wafer itself is largely a manual process. The conventional methods currently used to manufacture silicon wafers produce inconsistent results and are inefficient. This paper describes a fully integrated silicon wafer-polishing system that combines several independent processing steps into a single machine.

Introduction

Wax mounting of silicon wafers to a polishing block has become the preferred approach for the polishing process of wafers up to 200mm in diameter. Usually there will be several wafers wax mounted to a single large polishing block. The polishing blocks can be made of metal or ceramic materials and provide a flat rigid reference for the wafer during the final polishing process. The wax also helps to seal the back side of the wafer protecting it from scratches, stains and other defects that might otherwise occur if the wafer were "free-mounted" in a carrier during polishing. For 300mm wafers it appears that double-side polishing may replace the single-side wax mount polishing methods currently in use. Double-side polishing has been chosen for 300mm wafers because of the superior flatness resulting from this approach. This however is not an option for processing wafers 200mm in diameter or smaller because of the negative effects associated with having a polished backside. Current IC manufacturing processes have been developed around the current standard silicon wafer where the backside is chemically etched and has a mat surface finish. A polished backside is incompatible with certain IC fabrication processes. For 300mm wafers new IC manufacturing processes and techniques that accommodate a polished backside will need to be developed. With the introduction of the new 300mm wafer format comes the opportunity to develop new IC manufacturing processes that are compatible with the new double side polishing approach.

When simultaneously polishing several wafers mounted on a single large polishing block the typical polishing anomalies associated with rotary polishing take effect. This includes higher polish removal rates near the perimeter of the block and slower removal rates near its center (center thick). Under certain conditions this trend may reverse (center thin). For either condition this can result in a “wedge” shape on the individual wafers and inconsistencies from wafer to wafer. Because the size of the polishing block is large there are few methods available to counteract these polishing effects.

As line widths for integrated circuits continue to shrink there are ever increasing demands on wafer manufacturers to produce flatter wafers. This is especially true for IC processes that will yield sub 1.5 micron line widths. Silicon wafers with good global flatness or TTV (total thickness variation) and good local site flatness or STIR (site total indicated reading) become critical to achieving acceptable IC yields.

The Model 6DZ Integrated Prime Wafer Polishing System

In order to achieve acceptable control over the polishing process and allow silicon manufacturers to produce consistent results wafer-to-wafer it was imperative that a new approach be considered. In order to obtain improved flatness and consistency it was necessary to improve the overall control of the polishing process. The following modifications to the typical polishing process are key:

- A single wafer per polishing block
- Control of the shape of the individual polishing block during polishing
- Improve consistency of the wax application
- Thermal stability of the overall polishing system during continuous operation
- Polishing pad conditioning and shaping
- Automation of the wax application, mounting, polishing, and demounting

It became obvious that mounting of a single wafer to a similarly sized polishing block would produce more consistent wafer to wafer results. Control of the temperature of the polishing block and the wafer during polishing also improves the flatness. Infrared sensors mounted above each polish table are aimed at the polishing pad. In the constant temperature mode the polish force is adjusted dynamically in response to the infrared sensor temperature readings such that a consistent polish temperature is maintained. The overall shape of the polishing block can also be controlled during polishing by use of vacuum in order to compensate for center fast polishing processes.

Automation of the wax application and wafer mounting procedures ensures a consistent wax thickness. A uniform quantity of wax is automatically applied to the spinning polishing block. Excess wax applied about the perimeter of the polishing block is removed prior to mounting the wafer to the block. After the wax is applied to the polishing block the block is transferred to a heating station where steam heat is used to heat the block and evaporate water from the water based wax formulation. The block is then transferred to the mounting station where the wafer is mounted to the block. At this station the wafer is pressed to the waxed block with a constant pressure while under vacuum so that no bubbles form in the wax layer. The entire wax mounting system was designed to provide consistent mounting of the wafer to the block.

It is very important to control the starting temperature of the polishing block and wafer in order to obtain consistent results from wafer to wafer. For this reason the block heater and mounting station were designed to deliver the block/wafer combination to the first polish table such that their starting temperature is equal to the steady state polishing temperature. This minimizes deformities of the components caused by thermal expansion and assures constant, predictable removal rates as well as a consistent shape of the polishing block. The provision of such an apparatus and method for minimizing operation variables in the wax mounting and polishing steps means that successive wafers are polished under substantially uniform operating conditions. Control of the polish pad temperature is further augmented by use of a polish-table temperature control system, which recirculates a temperature controlled fluid through a labyrinth within the table.

Polish pad conditioning and shaping is important to maintain a consistent removal rate and improve overall flatness. Using a diamond media or brush media, the pad conditioning process is automated. Each of the three polish tables has pad conditioning capability. The conditioning media can be varied to suit the particular pad and process being used. It has been demonstrated that a diamond conditioning media can be utilized to modify the shape of the pad by use of a highly controlled selective conditioning process. This provides improved flatness through control of the center to edge removal rates.

By completely automating the wafer mounting, polishing, and demounting process improved consistency can be achieved. Through improved process temperature control the process can be quickly stabilized and this stability can be maintained over long extended runs. The use of highly controlled pad-conditioning processes when combined with the ability to dynamically shape the wafer mounting block allows for precise control over center to edge removal rates. This fully automated silicon wafer process module produces wafers with superior TTV and STIR and assures consistent wafer to wafer results.

Data

The following process data demonstrates how pad conditioning can be used to improve TTV and STIR. All measurements are in microns. Pad conditioning was initiated between wafers #10 and #11.

Wafer Number	Average Pre	Average Post	Average Removal	Pre TTV	Post TTV	Change TTV	STIR Post
1	717.68	705.56	12.12	0.45	4.04	3.59	0.812
2	718.42	706.32	12.0	0.49	4.09	3.60	0.848
3	721.20	708.99	12.21	0.73	4.09	3.36	0.788
4	717.27	705.12	12.15	0.59	3.86	3.27	0.809
5	719.12	706.94	12.18	0.90	4.04	3.14	0.749
6	728.76	716.82	11.94	0.71	3.20	2.49	0.593
7	723.50	711.53	11.97	0.58	3.07	2.49	0.615
8	710.99	698.94	12.05	1.22	3.05	1.83	0.568
9	719.40	708.46	10.94	0.58	2.21	1.63	0.435
10	726.72	714.42	12.3	0.82	2.23	1.41	0.411
11	719.82	707.98	11.84	1.01	1.43	0.42	0.314
12	724.65	712.75	11.90	0.66	1.44	0.78	0.270
13	725.83	713.87	11.96	0.83	1.26	0.43	0.255
14	717.15	706.38	10.77	0.56	1.03	0.47	0.248
15	722.58	710.66	11.92	0.75	0.98	0.23	0.262
16	724.80	714.42	10.38	0.55	1.12	0.57	0.258
17	711.25	699.03	12.22	0.91	1.04	0.13	0.256

A Layout of the Model 6DZ

The following drawing illustrates the Model 6DZ. The automation module is located at the top of the page. This includes the robot in the center of the module surrounded by the various mounting and transfer stations. A complete description of each station is provided for better understanding:

Robot – The robot is located in the center of the automation module. The robot includes a gripper for handling and transport of the polishing blocks as well as an end effector for pick-up and transfer of individual wafers.

Send Elevator – A cassette of incoming wafers is placed onto the cassette platform at the send elevator position. Wafers are automatically transferred to a centering station located directly in front of the send elevator. From here the robot picks up the individual wafer and transfers it to the Vacuum Chamber where it will be mounted to the polishing block.

Spin Station – The spin station is located next to the send elevator. A polishing block is delivered to the spin station where the old wax is removed by a combination of chemical spray and a brush cleaning, which prepare the block for the new wax. Wax is then dispensed onto the center of the spinning wafer where it is evenly spread by centrifugal force.

Steam Chamber – From the spin station the polishing block is transferred to the steam chamber where the wax is heated by steam to a temperature suitable for evaporating excess water from the wax formulation in preparation for bonding of the wafer to the block. This station also serves to preheat the polishing block to the steady state polishing temperature.

Block Storage – The block storage rack is where the clean polishing blocks are stored at the start up of the machine. The storage rack is capable of holding five polishing blocks.

Vacuum Chamber – This chamber is where the wafer is mounted to the polishing block. A wafer is placed onto a rubber pad at the center of the vacuum chamber. A polishing block is removed from the steam chamber, inverted, and placed on top of the wafer at the vacuum chamber. The lid of the vacuum chamber comes down over the wafer/block combination and a vacuum is drawn. An air cylinder is used to press the block against the wafer. Mounting the wafer under vacuum assures that no bubbles are formed between wafer and the block. When the lid is lifted the wafer is firmly mounted to the block and is ready for polishing. This station also serves as the pick-up station for the linear robot, which transfers the block/wafer combination to the first polishing table.

Linear Robot – The linear robot traverses back and forth behind the polishing tables and transports blocks from the vacuum chamber to the first polishing table at the opposite end of the machine.

Polish Module #1 – The linear robot places a block/wafer combination at the load station in the #1 polish module. The overarm (spindle) picks up the block and moves to the polishing table where a fully programmable, multi-step polishing process is executed. Each polish table is capable of feeding up to five separate slurries or chemistries to the polishing table during the polish process. At the end of the first polish process the overarm places the block/wafer combination into the load station of the #2 polish module. A conditioning arm then conditions the pad in preparation for the next polish cycle.

Polish Module #2 – The process described above is repeated at polish module #2. At the end of the polishing process the wafer/block combination is placed into either the load station of polish module #3 or into the spray pot.

Polish Module #3 – The optional third polish module is not shown in this drawing but is identical to polish module’s #1 and #2. After completion of the third polish process the overarm places the block/wafer combination into the spray pot station.

Spray Pot – Here the wafer is cleaned of slurry and chemistry.

Demount Station & Receive Elevator – The robot gripper picks up the block/wafer combination at the spray pot, inverts the block and places it in the demount station. The demounter then uses two sharp flat blades to gently separate the wafer from the block while simultaneously pushing the wafer into the receive cassette.

References

United States Patent # 5,605,487

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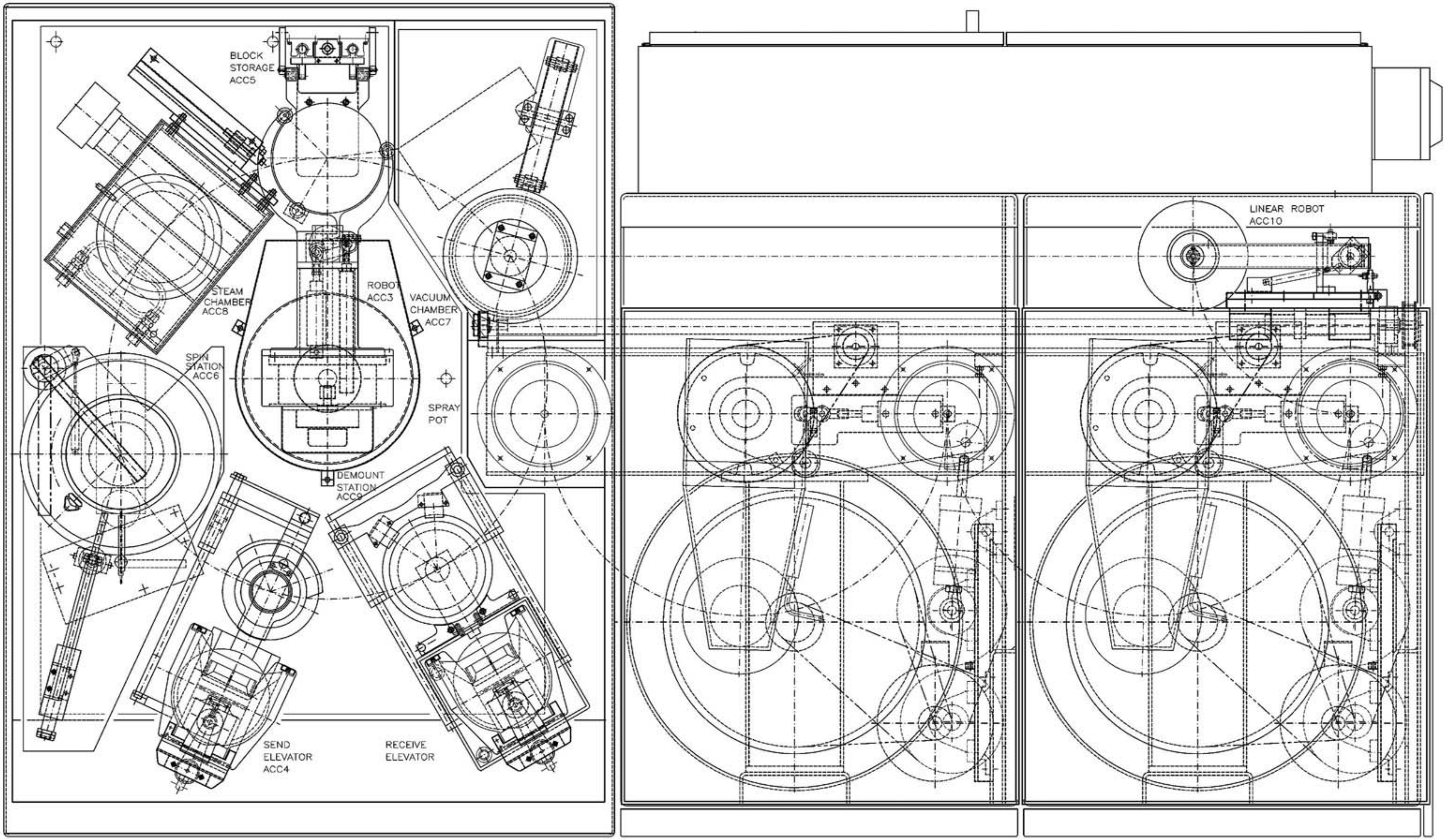
BLOCK STORAGE ACC5
STEAM CHAMBER ACC8
ROBOT ACC3
VACUUM CHAMBER ACC7
SPIN STATION ACC6
SPRAY POT
DEMOUNT STATION ACC9
SEND ELEVATOR ACC4
RECEIVE ELEVATOR
LINEAR ROBOT ACC10