Development of Ultra-Precision Double-Disk Grinding Machine for Silicon-wafer

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1. Introduction

Recently, ultra-precision grinding systems are remarkably expected for manufacturing super flat wafer in sub-micron order flatness, instead of conventional lapping and etching processes.(1) To respond to the demands, a double-disk grinding machine based on motion copying concept(2) is under development for 8" and 12" silicon-wafer process. This paper introduces the newly developed grinding system including the configuration, mechanical structure and control system, and also presents some experimental evaluations of system's performance.

2. Configuration of Ultra-precision Double-Disk Grinding System

Fig.1 shows a schematic configuration of the newly developed double-disk grinding machine. This machine has a horizontal double spindle-type configuration in line, consisting of a stationary spindle, a movable spindle mounted on the saddle, wafer support/drive unit, and 1.0m×2.0m granite base plate. Two spindles are located facing each other, and both sides of wafer are simultaneously ground via cup-type diamond grinding wheels mounted on these spindles.

Each of spindles has a stationary inner stator and outer rotor (Fig.2), levitated by hydrostatic bearing to obtain high stiffness, damping and rotational accuracy.(3) In order to effectuate the control of the attitude of the rotor, three thrust pads on each side of the stationary inner stator, and four radial pads on the circumference of the inner stator are equiped. Three capacitive transducers are located at the back of the thrust hydrostatic bearing to measure the spindle attitude. The grinding wheels of ϕ320mm are mounted on the spindles, and the temperature of hydraulic oil is controlled within ±0.1℃ accuracy. Each rotor is driven by a low vibration-type induction motor and seamless belt. The saddle, on which the movable spindle is located, is guided via a double-V linear slide mechanism with hydrostatic preloading unit, being driven by a force-operational hydraulic linear actuator and a double nozzle-flapper type servo valve. A laser interferometer measurement system(HP 5518A USA) with the resolution of 2.5nm is used to obtain high-resolution position feedback signal for position servo control system. Its reflecting mirror is mounted on the side of the saddle near grinding point to minimize the wheel position measurement error based on the Abbe's principle. The wafer support/drive unit enables damage-free hold and rotation by employing opposed pad water hydrostatic bearing and friction drive mechanism using plastic rollers. Table 1 describes specifications of this machine.

3.Control System

A schematic block diagram of the control system is also shown in Fig.1. The machine control system consists of a host PC, saddle position control system, and the tilt control system for the two axis of the spindle. The saddle position control is achieved via the PID servo control system with the laser interferometer feedback, and that of the tilt motion of the two axis of the spindle by controlling the differential pressure of each thrust bearing pad using pressure control servo valves.

4. Experimental Evaluations

To realize the super-flat wafer grinding by the cup-type grinding wheels, the following machine performances are required.(4)

① High loop stiffness of machine.

② High positioning resolution in the order of 10nm.

Regarding this machine planned to use cup-type grinding wheel, we evaluated stiffness of spindle in the thrust direction, as a primary element to realize high loop stiffness. As a result the stiffness higher than 1,200 [N/μm] has been obtained as shown in Fig.3. The resultant value is significantly higher than that of the conventional rolling bearing.

Next we evaluated the saddle positioning capability. In the configuration of the machine the target mirror of the laser-interferometer is located near the grinding point, therefore the result of this evaluation is near equal as to the behavior of the movable spindle at the grinding point. Fig.4 shows the response to the 20nm stepwise motion command. The saddle feeding system realized 20nm positioning resolution without backlash and hysteresis. The evaluation of fundamental characteristics of the machine related with the grinding accuracy of wafers are in progress.

5.Conclusions

1) An ultra-precision double-disk grinding-machine for Si-wafer has been developed.

2) Some performance tests of its mechanical component have been carried out. The stiffness of

the spindle higher than 1,200 [N/μm] in the thrust direction has been achieved.
Moreover the 20nm positioning resolution exempt from backlash and hysteresis has been realized in response to the step motion commands.

References

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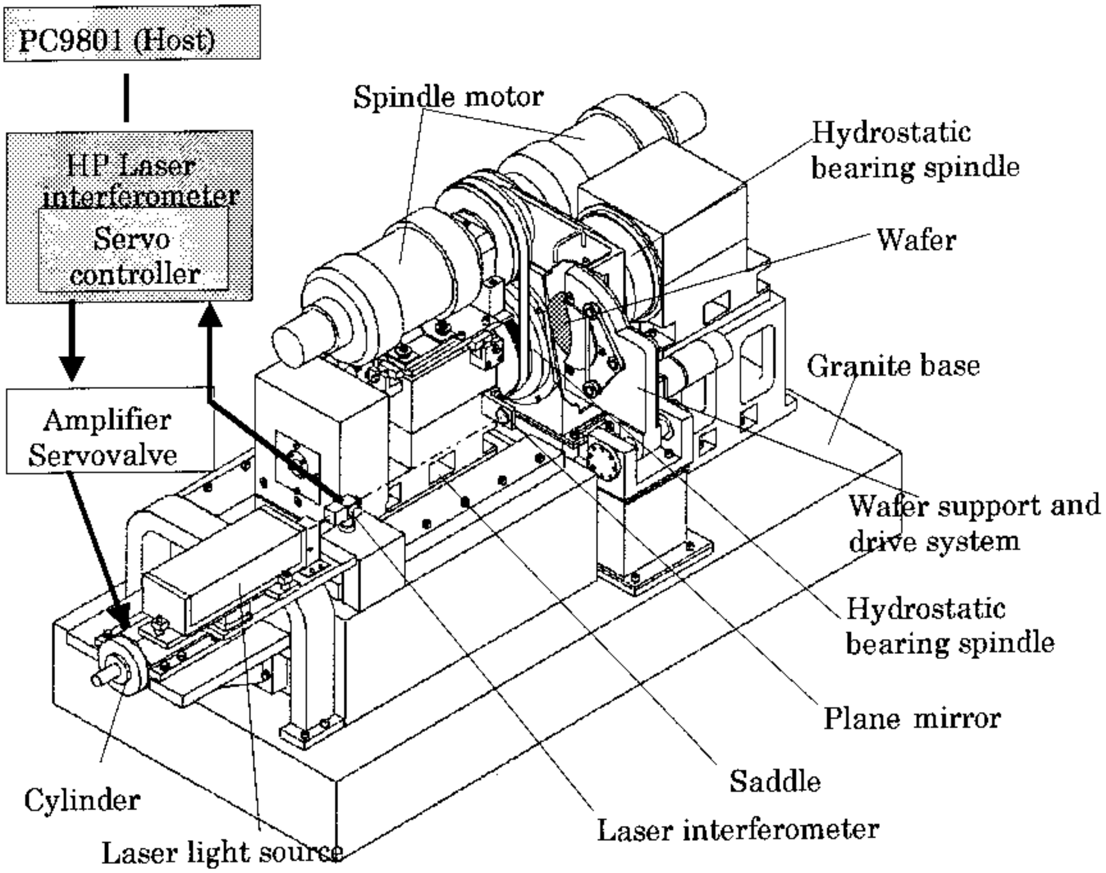

Fig. 1 Configuration of Ultra-precision Double-Disk Grinding Machine

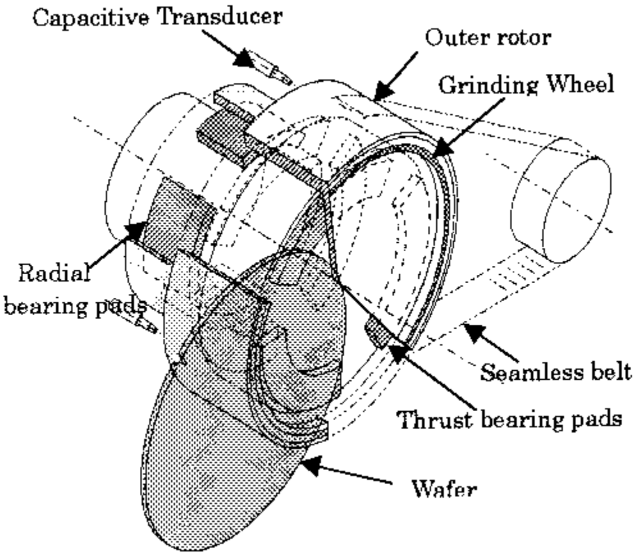

Fig.2 Spindle Structure

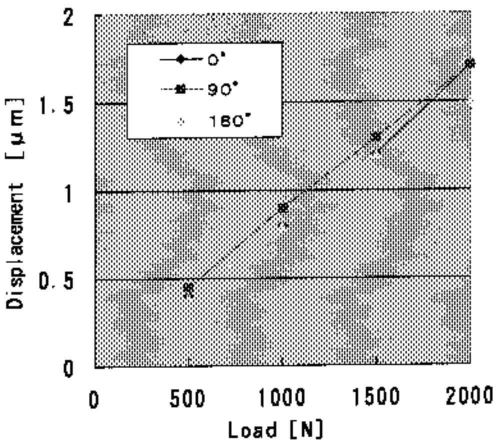

Fig.3 Result of Thrust Stiffness

Table1 Machine Specifications

	Machine specifications	Hydro-static spindle	
Configuration	orizontal type double disk grinding syste	Viscocity	10 cSt
Wafer size	200~300mm	Supplied pressure	2.94 MPa
Spindle	Hydrostatic bearing/Outer rotor	Rated speed	1910 rpm
Spindle motor	5.5kW/Belt drive	Thrust bearing	
Saddle	Stroke 100 mm／Velocity 20mm/min	Gap	30 mm
Drive of saddle	Operation by hydralic actuator	Pad configuration	3x2 pads
Position sensor	Laser interferometer(Resolution 2.5 nm)	Stiffness	1200 N／μm
Wafer support	Roller drive/Water-hydrostatic support	Radial bearing	
Dimension	1(W)×2(L)×1.3(H) m	Gap	30 μm
Weight	3.500 kg	Pad configuration	4pads

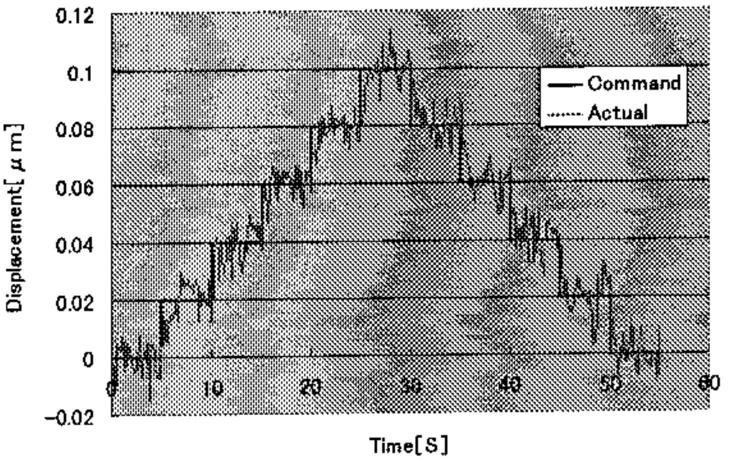

Fig.4 Response to Step Motion of 20nm