Introduction of Product

Introduction of Wafer Surface Grinding Machine Model GCG300

Junichi Yamazaki

Meeting the market requirements for silicon wafers with high flatness and minimal damage, which have become increasingly stringent in the face of highly integrated semiconductor devices, a fully automated surface grinding machine has been developed and introduced into the market, where it is making a contribution in high volume production lines in semiconductor plants. The background to the development and technologies used in the grinding machine are described and the product profile is presented.

Key Words: *silicon wafer, high flatness, low-damage grinding, high productivity, ultraprecision grinding, high loop rigidity, air spindle, nanolevel micro feed*

1. Introduction

The integration of MPUs, memories and other semiconductor devices is further accelerated. This requires silicon wafers to be higher in flatness with minimal damage. The manufacturing process to meet these requirements has been researched. From the standpoint of securing a flatness of high accuracy before final polishing, prior research has shown that the introduction of a grinding process is an effective means to accomplish these tasks.

Photo 1 GCG300

Against this backdrop, a 300mm-diameter wafer surface grinding machine model GCG300 has been developed based on the development technology for a 200mm-diameter wafer grinding machine manufactured to implement the grinding technology propelled under a cooperative project undertaken jointly by four companies, Komatsu Electronic Metals Co., (currently SUMCO TECHXIV Co.), Komatsu Corporate Research Division, Waida Mfg. Co. and Komatsu Machinery Corporation. The new model features high flatness and minimal damage. The grinding machine has been contributing to the production of 300mm wafers in high volume production processes since its market entry. The overview of the machine is described below.

Table 1 Principal specification

Item	Specification value
Processed wafers	φ300mm
Grinding wheel spindle revolution speed	600 to 3000min^{-1}
Chuck spindle revolution speed	0 to 450min^{-1}
Grinding wheel feed axis stroke	120mm
Number of chuck tables	2
Number of cassettes installed	4

2. Aim of Development

The grinding machine was developed on the premise that it would meet wafer quality after next generation as far as the basic design concept and main mechanical elements are concerned, pursuing high flatness and low damage as a fully automatic surface grinding machine for wafer making.

Table 2 lists the development aims and means to accomplish them and an emphasis was placed on linking them to the selling points described later.

Table 2 Development aims and means to accomplish them

Development aim	Means for accomplishment	
1) High flatness grinding	"Low thermal displacement"	• Low overall height by lateral processing unit • High rigidity and high precision air spindle and low heat generation by main shaft cooling
	"Flatness adjustment"	• Independent adjustment of declinations of grinding wheel spindle and chuck spindle
	"Retention of high flatness"	• Original chuck
2) Low-damage grinding	"Low vibration"	• Static air pressure used in grinding wheel and chuck spindles
	"High rigidity"	• High loop rigidity of grinding wheel and wafer holding systems
	"Micro feeding"	• High precision micro feeding of nanolevel
	"Grinding wheel"	• R&D in cooperation with a grinding wheel manufacturer
3) High productivity	"System"	• Both side processing by two heads in left and right direction + Transfer robot
	"IT"	• Status display, collection of control data and communication

"Selling Points"

Features by high flatness grinding:

- Small fluctuations of flatness on entire wafer surfaces (GBIR)
- High shape controllability
- High flatness of chip size at sites (SFQR)

Feature by low-damage grinding:

- Small polishing removal in post-process

High productivity achieved through these features

3. Principal Features

3.1 High Flatness Grinding

Komatsu's unique lateral processing unit structure is adopted as a means to enable high flatness grinding, achieving a high rigidity and low thermal displacement. A high and stable flatness is achieved in continuous processing also. Both the grinding wheel spindle and chuck spindle adopt high accuracy air spindles and incorporate a main spindle cooling mechanism, enabling operation with low heat generation.

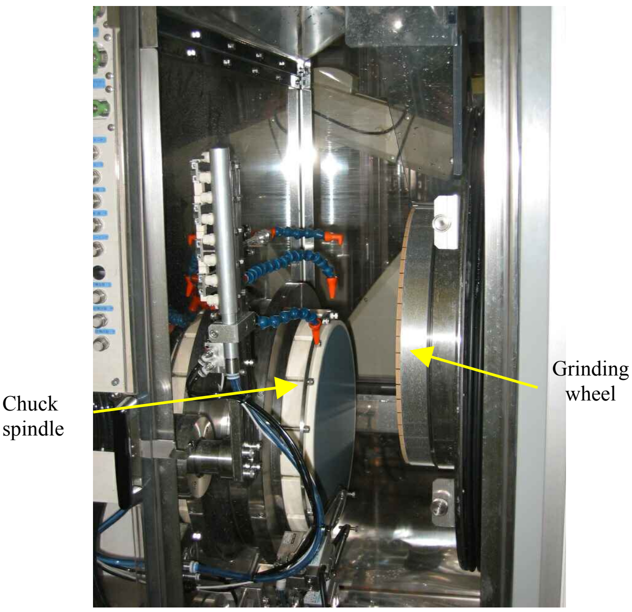

Photo 2 GCG300 grinding wheel and chuck

The grinding wheel and chuck of the grinding machine are shown below. (**Photo 2**)

1) Processing accuracy (Source: Test data of Komatsu machinery Corporation)

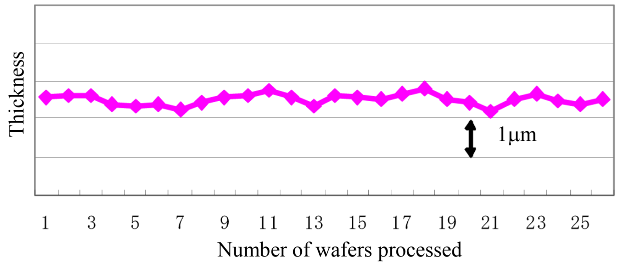

Fig. 1 Thickness dispersion

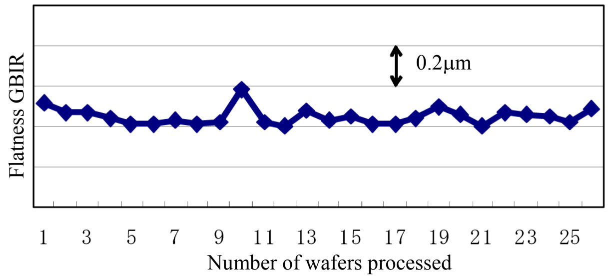

Fig. 2 Flatness GBIR (300mm diameter) dispersion

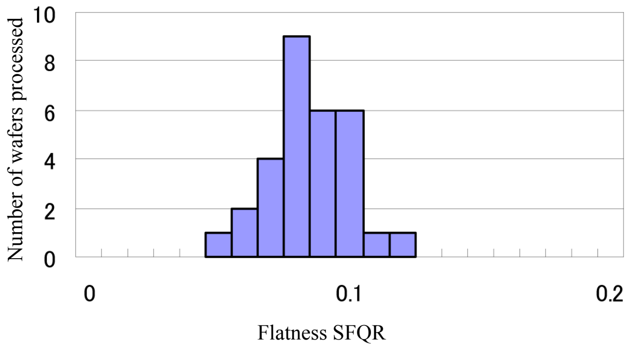

Fig. 3 Flatness SFQR (25mm square)

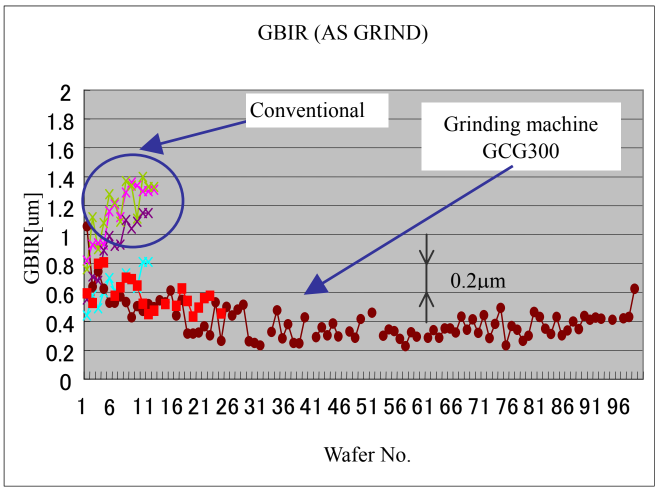

Fig. 4 Variations of flatness GBIR (300mm diameter)

Dispersions of processing accuracy for both thickness **(Fig. 1)** and flatness GBIR/300mm diameter **(Fig. 2)** are small and flatness SFQR **(Fig. 3)** of the chip size at sites is good. Recently, flatness is enhanced further through R&D of grinding wheel. **Figure 4** shows that flatness immediately after starting machine operation is very stable, indicating that low thermal displacement, which is a feature of the lateral processing unit, is demonstrated.

Next, the technologies that make this high flatness grinding feasible are described in detail.

2) Means to accomplish high flatness grinding

(1) Low overall height by lateral processing unit

A unique lateral processing unit structure is adopted with this machine by reducing the height of the processing unit to ensure dynamic and thermal stability. This has achieved a high rigidity and low thermal displacement, making a stable, high flatness in continuous processing also.

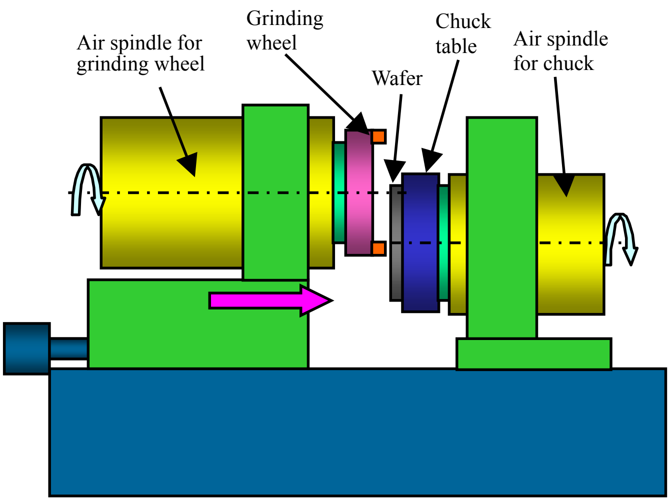

Fig. 5 Lateral processing unit

(2) High rigidity, high precision air spindle and main spindle cooling

Large porous air bearings are adopted in the grinding wheel and chuck spindles, assuring a high rigidity. The rotating main spindles are levitated by air and are supported contactless, providing high speed and high precision revolutions.

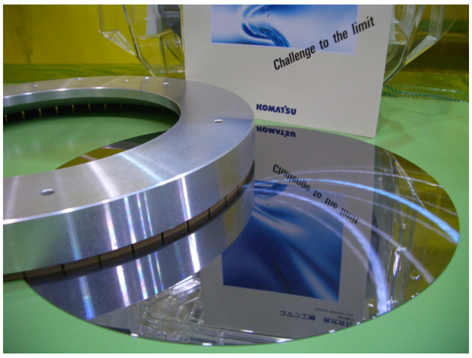

Fig. 6 Grinding wheel and a wafer after processing

The spindle on the grinding wheel is driven by a built-in motor. Low heat conduction material between the bearing and cooling of the motor outer casing keep thermal displacement low.

(3) Independent adjustment of declinations of grinding wheel spindle and chuck spindle

The wafer is processed by the infeed grinding method whereby the wafer is chucked onto the chuck and the grinding wheel spindle installed opposite the chuck is slowly moved to the wafer side, to grind the wafer to the desired thickness.

The position relations between the grinding wheel and wafer are illustrated in **Fig. 7**. The grinding wheel spindle is slightly tilted against the chuck. As adjustment before processing the wafer, the chuck table surfaces are self-cut by the grinding wheel for chucking so that the surfaces are slightly bumped. Thus, the portion of a wafer that is processed at a random point during processing is the "grinding length" part from the periphery of the wafer to the center of it as illustrated. Contact of the grinding wheel with the wafer in this area determines the processing accuracy.

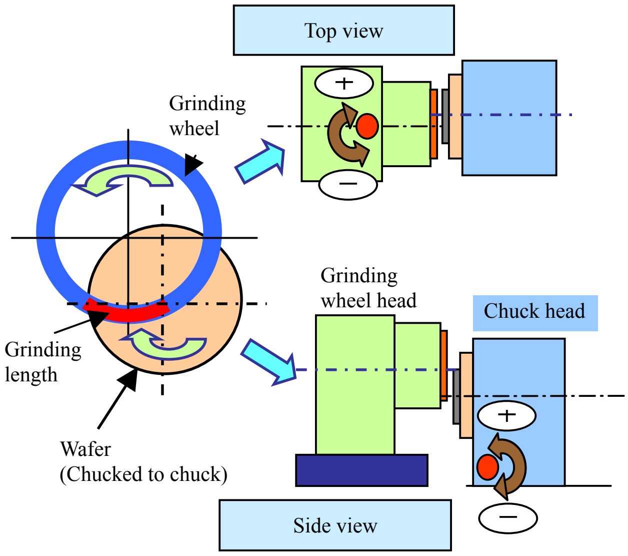

Fig. 7 Flatness adjusting mechanism

The position relationship between the grinding wheel and the wafer is very important for ultrahigh precision grinding of a wafer. Due to a difference in the processing loads caused when self-cutting the surface of the chuck table before processing a wafer and then grinding a wafer, the difference is produced in the wafer shape in relation to the chuck if the position relationship is maintained as is, failing to produce an adequate flatness and necessitating spindle adjustment. The grinding wheel head and chuck head of the GCG300 have independent spindle adjusting mechanisms. As shown in **Fig. 8**, the wafer surface bump quantity is adjusted by adjusting the grinding wheel spindle declination and the linearity from the periphery to the center of a wafer is adjusted by chuck spindle declination adjustment, both independently. This mechanism allows easy control of the shape and high mechanical rigidity, resulting in a good repeatability and short adjusting time.

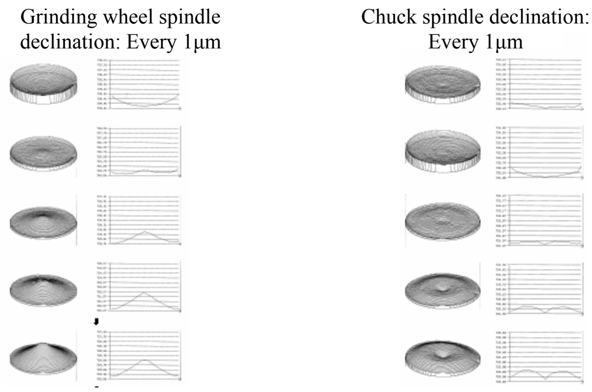

Fig. 8 Control of wafer shape by spindle adjustment

(4) Original chuck

Recently, flatness is demanded maximally to the very limit of the wafer periphery to increase the wafer yield. For this reason, roll-off of wafer edges needs to be reduced. A chuck has been developed hardly causing leak during chucking so that the wafer can be chucked correctly up to its periphery and allowing flat processing to the periphery of the chucked wafer even if the chuck is self-cut.

By using this original chuck, wafer edge roll-off could be reduced and flatness SFQR could be improved.

Figures 9 and **10** show edge roll-off and shapes of chucked wafers. Chucking by a conventional chuck produced large roll-off of wafer edges and the wafer is wavy. On the other hand, the original chuck produced slight roll-off of wafer edges and the wafer was chucked correctly along the chuck profile, producing no waviness.

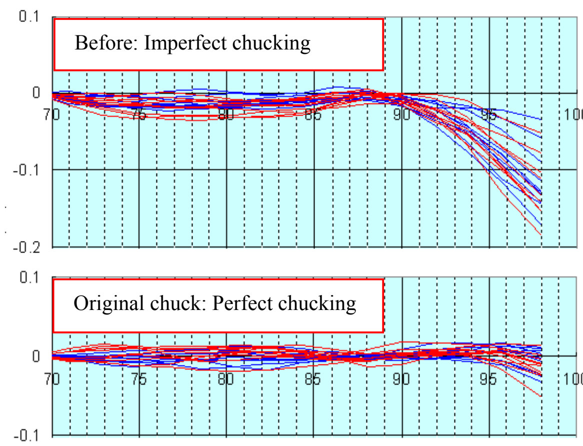

Fig. 9 Wafer edge roll-off

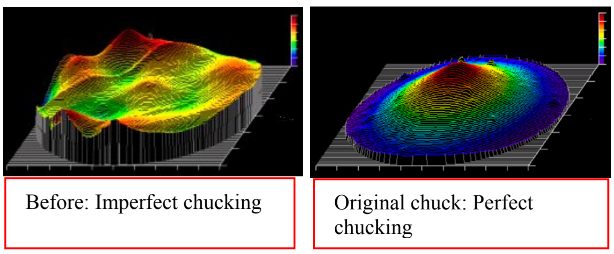

Fig. 10 Shapes of chucked wafers

3.2 Low-Damage Grinding

Flatness and "damageless" are the quality requirements that are ultimately required on semiconductor wafers. Damage to wafers can be removed perfectly only by the final process of the wafer making process, namely, polishing. The polishing process has a low processing rate, but has no shape creating ability. Therefore, the polishing removal must be reduced to mitigate the load to the polishing system and to maintain the shape created during grinding. The wafer grinding process before polishing should avoid inflicting damage on the wafer as best as possible.

1) Means to accomplish low-damage grinding

The most ideal low-damage grinding method is ductility mode grinding illustrated on the right of **Fig. 11**. Shown on the left is an example of grinding in the brittleness mode, which is the usual grinding method, and damage remains deep. Ductility mode grinding can be accomplished by controlling to stabilize the grinding wheel cross feed to less than Dc (critical penetration depth for fracture initiation), which corresponds to about 0.1μm with silicon wafers.

In other words, ds must be ds < Dc ≒ 0.1μm

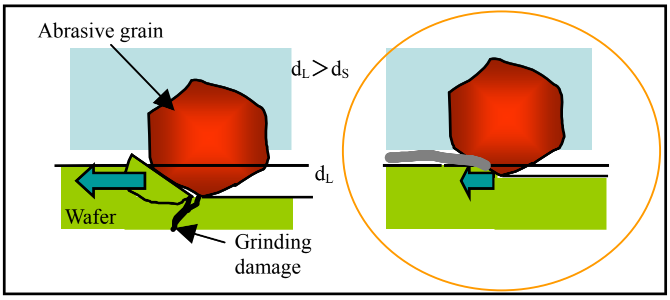

Fig. 11 Image of grinding mechanism

Low-damage grinding by ductility mode processing can be accomplished by:

"Low vibration" • Static air pressure adopted in grinding wheel and chuck spindle

"High rigidity" • High loop rigidity of grinding wheel and wafer holding systems

"Micro feeding" • High precision micro feeding of nanolevel

The motion accuracy of a nanometer order based on the motion transfer principle produces a modified work damage layer with extremely scant damage.

The structure of the grinding machine has been developed with the configuration illustrated in **Fig. 12** to realize this ductility mode.

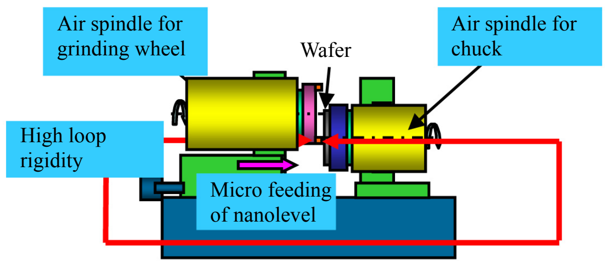

Fig. 12 Machine configuration for low-damage grinding

2) R&D in cooperation with grinding wheel manufacturer

To further eliminate damage to achieve low-damage grinding, R&D of a super fine grinding wheel that uses abrasive grains less than 1μm in size is undertaken jointly with an abrasive manufacturer.

TEM observations of damage after grinding using a conventional grinding wheel and super fine grinding wheel are shown in **Fig. 13**. The damage depth has been reduced to about 1/5. Optimization will be pursued further such as optimizing processing conditions.

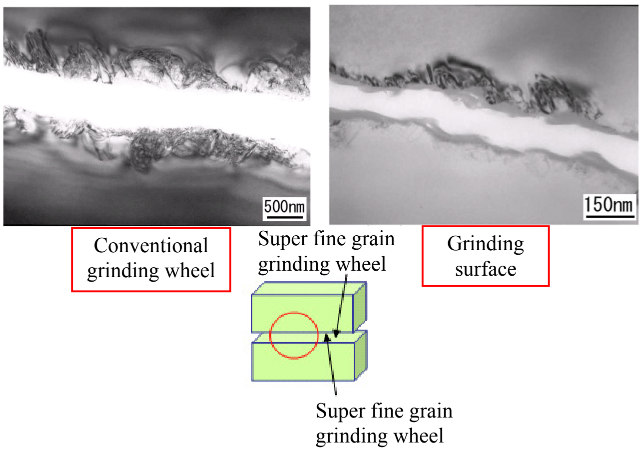

Fig. 13 Results of TEM observations

3.3 High productivity

1) High throughput system

The system illustrated in **Fig. 14** operates as follows.

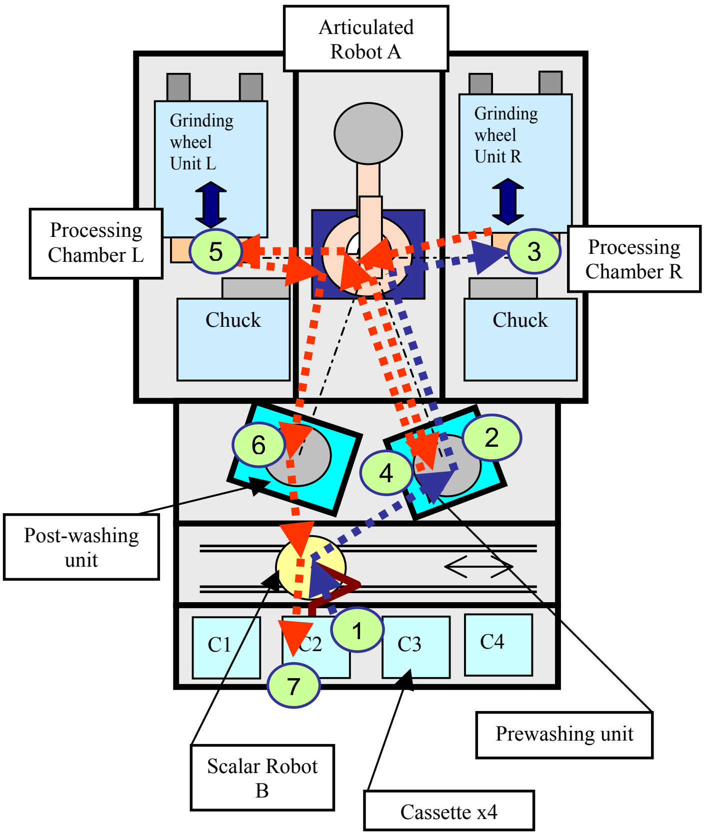

Fig. 14 System

(1) Robot B picks up a wafer from a cassette and mounts it on the prewashing unit.

(2) A brush washes the surface of a wafer, which will be chucked by the chuck. The surface of the wafer is then dried by air blowing.

(3) Robot A transfers the wafer from the prewashing unit to Processing Chamber R. Side 1 is processed.

(4) The processed side (the side to be chucked in the next process in Processing Chamber L) is washed.

(5) Robot A transfers the wafer to Processing Chamber L for processing on Side 2.

(6) After processing, Robot A transfers the wafer to the post-washing unit. The wafer after processing is washed with water and is dried by spinning.

(7) Robot B stores a wafer, whose both sides are processed, in a cassette.

2) Enhanced production efficiency by IT

(1) Stable wafer quality and preventive maintenance of system

- By locally connecting the GCG300 to a PC for data collection, analysis of trends such as the amount of grinding wheel wear, chuck suction pressure, quantity of grinding water and motor current can be performed, thereby contributing to the stable production of wafers.

(2) Production control

- By connecting the GCG300 to a host PC by a network, lot Nos., contents in a cassette, processing recipes, system IDs and other indication data, as well as processing start time, grinding wheel current, amount of grinding wheel wear, thicknesses before and after processing and other processing data are sent. The communication protocol is SEMI standard (GEM) compatible.

(3) Enhanced system operability (Shorter downtime)

- The data collection PC is remotely accessed through the Internet or through an internal circuit (VPN - virtual private network) to allow operation just like by the operation panel supplied with the system as an accessory, thereby facilitating failure cause analysis and resetting. The control circuit can be edited and updated allowing direct interaction with the production site, thereby reducing downtime to a minimum.

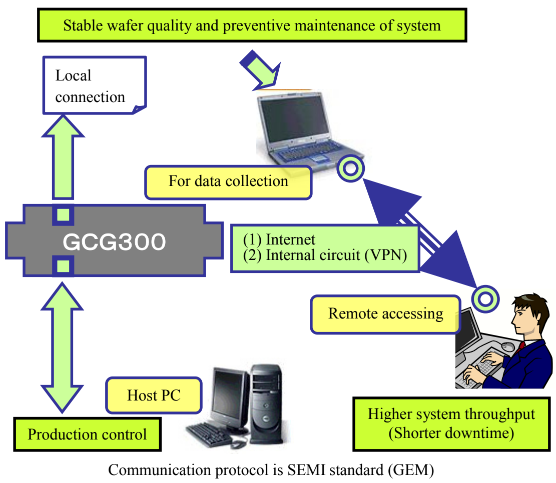

Fig. 15 Enhanced production efficiency by IT

4. Conclusion

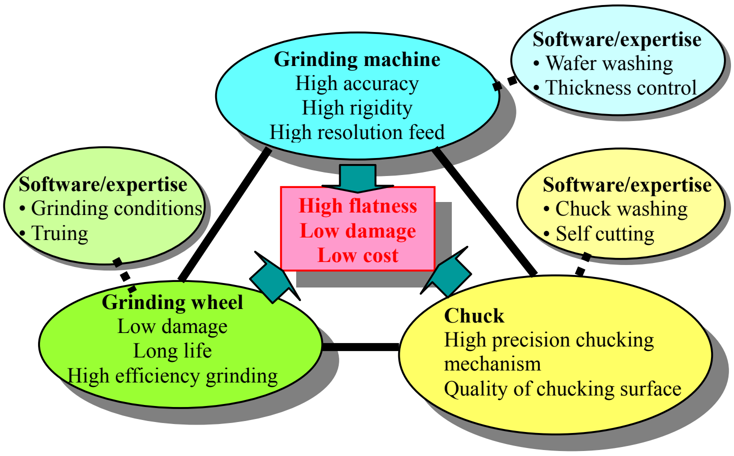

Fig. 16 Total solutions

The GCG300 is a grinding machine featuring high accuracy and high rigidity pursued hand in hand with the technological capability of a machine tool manufacturer. The joint development of a grinding wheel with a leading tool manufacturer has enabled the use of an optimum grinding wheel that has a wide application scope and that matches the user needs.

A chuck that is unique to the GCG300 suiting high flatness grinding is installed.

The GCG300 responds to the needs of the customer with total solutions for the wafer grinding technology with a focus on the grinding machines.

Introduction of the writer

Junichi Yamazaki

Entered Komatsu in 1982.
Currently assigned to the Electronics Development Office, Electronics Division, Komatsu Machinery Corporation.

[A few words from the writers]

Komatsu Machinery Corporation specializes in machine tools, mainly machines for engine crank shafts, and is engaged in the machine tool business. Parallel with the machine tool business, Komatsu Machinery Corporation produces and sells semiconductor production equipment and liquid crystal manufacturing systems as electronic business. In the area of semiconductor production equipment, the Company has been manufacturing silicon single crystal pulling systems for many years. The Company has been facing the task of introducing a product into the market in the semiconductor wafer production process as a next mainstay product. The wafer surface grinding machine model GCG300 described above has been developed and introduced to the market, contributing to production by high volume production processes. The business environment of semiconductors is facing great changes at present. However, this situation will be seized as a business opportunity and these changes will be fed back to product development to ensure further growth of our business.