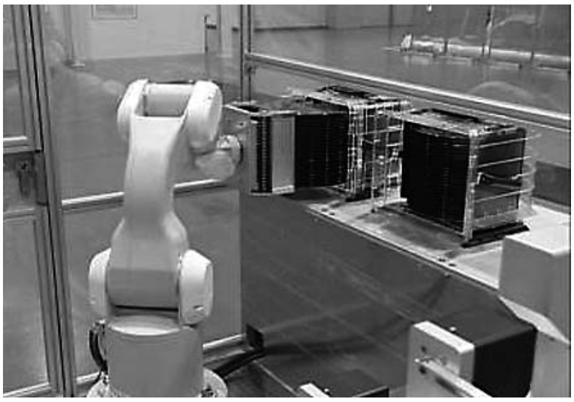

Mitsubishi Clean Room Robot
-Clean Material Handling Originated from Plant Equipment Inspection-

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The size of the silicon wafers and LCD panels produced in semiconductor device and Liquid Crystal Display (LCD) panel fabrication plants (hereunder referred to as fabs) are becoming consistently larger. As a result, obtaining material handling robots of greater size and higher performance is a crucial technical challenge currently facing fabs. Mitsubishi Heavy Industries, Ltd. (MHI) has developed and sold various kinds of robots, such as special purpose robots for use in plant equipment inspection, and portable general-purpose arms (PA-10) for robotic R&D and general industrial use. MHI has newly developed and released a brand new clean room robot to meet the growing needs of the semiconductor and LCD industries. This paper describes the technical background of MHI robots and introduces the features of the newly released clean room robot for handling semiconductor wafers and LCD panels.

1. Introduction

The size of the silicon wafers in leading semiconductor and LCD industry fabs is shifting from 200 mm to 300 mm in diameter, while the size of LCD panels is going to undergo a major shift from the current 1 m by 1 m (Generation 5) to 2 m by 2 m or greater size (Generation 7).

To meet this manufacturing trend, larger size robots for clean material handling are obviously indispensable, and in fact, the detailed needs for such robot has been placed on MHI, as the company has large-sized clean manufacturing facilities aimed for the production of power plant and space flight (aeronautical) equipment.

For more than twenty years, MHI has developed various kinds of special purpose robots in order to automate the on-site inspection and repair of equipment in power plants (**Table 1**). Through this experience, MHI has acquired abundant knowledge and skill regarding robotic products under special environments.

Since 1992, MHI has entered the general-purpose market with a robot named “Portable General-purpose Intelligent Arm PA10”. The PA10 robot is a light-weight manipulator arm with seven rotational axes. As of April 2003, 310 units of the PA10 robot have been sold. The robot has a reputation for being light-weight (approx. 40 kg body weight with a payload capacity as large as 10 kg), industry' first redundant 7-axis (first as a catalogued industrial robot), and open and easy operability with a regular personal computer.

Table 1 MHI robot products

Period	Main robot products
From 1980 to 1989	Maintenance robot for power plant Industrial spraying robot Maintenance robot for seabed cable Harsh environment robot with multi-finger hand
From 1990 to 1999	Tank wall inspection robot Large telescope lens exchanging robot Portable general-purpose arm PA10
On and after 2000	Disaster prevention robot with crawler and dual arms

The PA10 robot has also been applied as a special purpose robot with relatively small modification. It is very useful for providing special robots with shorter lead-times and smaller budgets than when the robot is completely tailor made.

Fig. 1 shows the PA10 applied in an underwater inspection vehicle, aimed to survey any structural flaws inside a power plant pressure vessel. **Fig. 2** shows another application of the PA10 as a spraying robot used inside the hull of a ship.

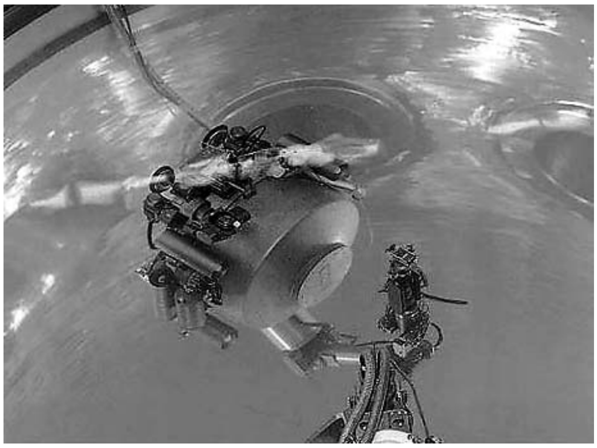

Fig. 1 Underwater plant inspection robot

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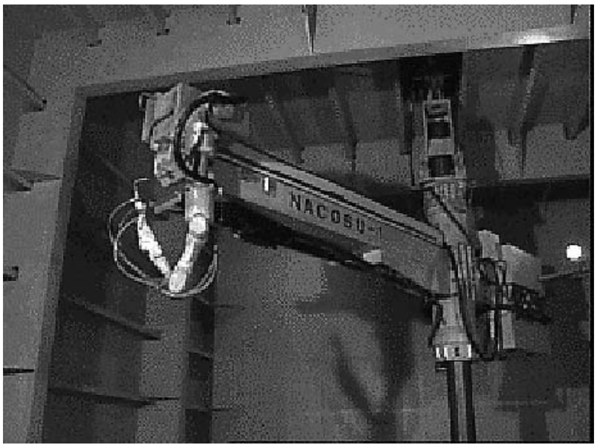


Fig. 2 Vessel structure spraying robot
(Courtesy of Nakata Mac Corporation)

Table 2 Comparison between Scalar robot and multi axis robot

	Scalar robot	Multi axis robot
Degree of freedom (DOF)	Handling without diverting wafer orientation	Capable of diverting wafer orientation with more than 5 DOF
Payload	Max. approx. 5 wafers (small tolerance for arm tip sag)	25 to 50 wafers (capable of adjusting arm tip sag)
Speed and accuracy	Generally high speed and high accuracy	Comparatively low speed and low accuracy
Easy installation	Requiring leveling	Not requiring leveling

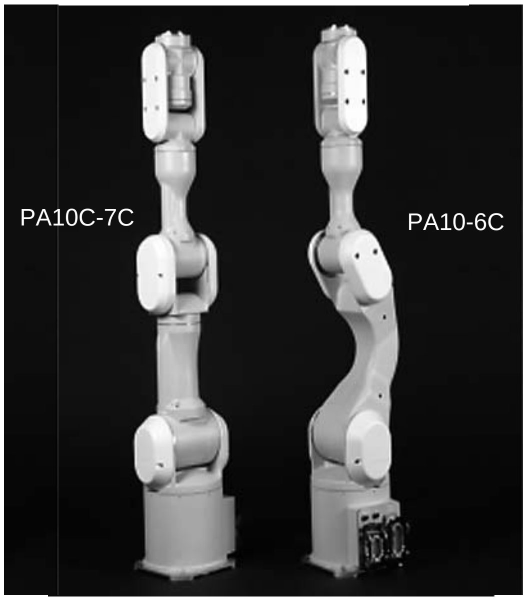


Fig. 3 Appearance of PA10 robot (clean compatible)

Table 3 Specifications for PA10 robot (clean compatible)

Model	PA10-6C	PA10-7C
Number of joint axes	6	7
Maximum distance between joints (mm)	930	
Self-weight (kg)	38	40
Payload (kg)	10	
Operating speed (^{o}/s)	Base (shoulder) axis : 28.5 Elbow axis: 57 Wrist axis: 180	
Positioning repeatability (mm)	±0.1	
Cleanliness	Class 1 (not requiring inside pneumatic suction)	
Protective structure	Dust and drip proof (IP54)	
Built in tubing and cabling	Complete (till arm tip) built in cables available	

2. Development of Semiconductor Wafer Handling Robots

Semiconductor fabs are in fact an assemblage of multiple (min. dozens to max. hundreds) wafer processing equipments which are running individually. Within each equipment unit, the wafer is exposed and handled one by one or on a batch basis. However, the wafers are housed in a unified cassette, which normally contains twenty-five wafers, while being transported between equipment units.

As the pattern width of the circuit formed on a semiconductor wafer is now less than 0.1 μm, wafer handling robots must be capable of achieving almost zero emission of particles larger than 0.1 μm.

Currently most of the wafer handling robots in conventional use have a scalar type structure. The technical advantages of the scalar type robot are its higher speed and accuracy, because it only allows planar motion. However, recently, the demand for multi axis robots has been emerged, due to their larger degree of freedom and ease of installation. In fact, the adoption of a multi axis robot instead a scalar robot enables wafer orientation diversion during handling and simplifies installation procedures without the need for leveling work (**Table 2**).

To meet this new demand, MHI has released a brand new *Clean Compatible PA10-6C/7C Robot* since summer 2002. The appearance of a PA10-6C/7C robot is shown in **Fig. 3** and its specifications are outlined in **Table 3**.

An O-ring seal structure has been adopted in thePA10 robot for all axes. The O-ring seal structure is the most compact and easiest to maintain compared with other structures. This structure also enables the underwater use of the robot and almost zero emission of internally generated particles.

The newly released PA10 robot has been confirmed to comply with Clean Class 1 standards (per Fed Std.209, 0.1 μm), as a result of the use of renewed grease material, rotational joint bearing structure, and other special features.

Some other clean robots adopt a negative-pressure suctioning installation instead of the joint sealing structure. One of the advantages of the PA10 robot is that it does not require such additional installation, and thus contributes to the reduction of operating costs.

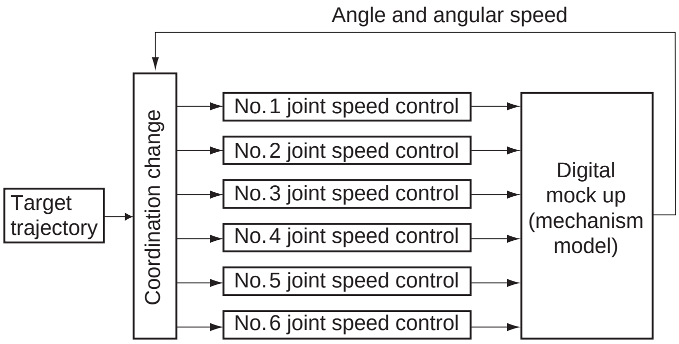


Fig. 4 Example of PA10 robot dynamics analyzing model

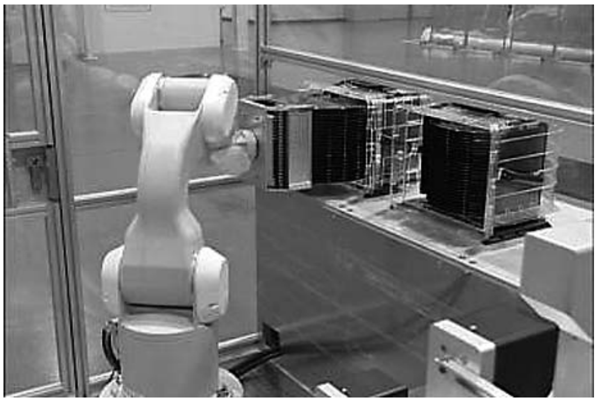


Fig. 5 Example of handling of 25 pieces of wafer using PA10 robot

In addition, any robot used for semiconductor wafer handling must be able to achieve low acceleration and high positioning accuracy in order not to damage the finest pattern etched on the wafer. To satisfy these requirements, the control parameters of the PA10 robot are optimized through dynamic analysis (**Fig. 4**).

A PA10 robot with a high clean class can be applied to the following applications in the semiconductor field:

- batch wafer handling (up to 25 wafers) (**Fig. 5**),
- wafer cassette handling, and
- handling of reticules for exposing machines (**Fig. 6**).

MHI is currently concentrating efforts on the development of a robot system with optimized handling speed and accuracy for the aforementioned applications.

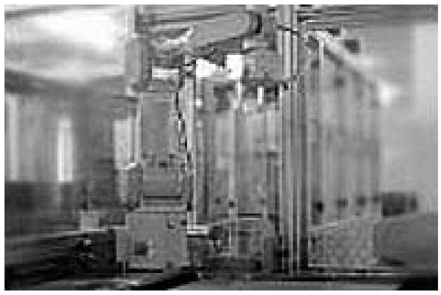


Fig. 6 Handling of reticule using PA10 robot
(Courtesy of Ulvac Coating Corporation)

3. Development of LCD panel handling robots

The size of LCD glass panels is expected to become larger from the current 1 m by 1 m class (Generation 5) to the 2 m by 2 m class (Generation 7) within a few years. In fact, this pace of enlarging LCD panels is remarkable compared to that of semiconductor wafers, which took almost ten years to change from 200 mm to 300 mm in size. This rapid enlarging of the LCD panel is due to explosive demand by consumers for larger LCD displays. However, to meet this demand, a drastic review and revision is required for every handling process of the LCD panels, because every handling robot or cassette is as large as 3 m in size.

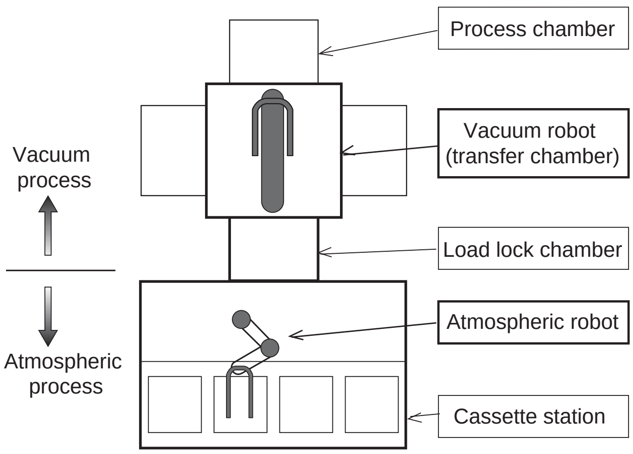


Fig. 7 Configuration of LCD panel handling system

MHI is currently focusing efforts on the development of a large LCD panel handling robot based on the company's special purpose robot technology. It is also engaged in the development of ultra thickness electro beam welding technology which will pave the way to the cheaper production of large LCD processing chambers.

As with semiconductor wafer handling, LCD panel handling is a combination of cassette handling between different equipment units and single panel handling within a single unit. The typical structure of a LCD panel handling robot used in the vacuum process is shown in **Fig. 7**.

The LCD panel handling robot consists of an atmospheric robot, which operates between the cassette and the load lock (vacuum preparation) chamber, and a vacuum robot, which operates between the load lock chamber and the vacuum process chamber. Generally, the atmospheric robot is very tall due to the height of the LCD panel cassette. The vacuum robot, on the other hand, must be capable of planar motion with very low acceleration shock to the panel, because the suctioning chuck of the panel is not applicable.

The appearance and specifications of the LCD panel handling robot now being developed by MHI are given

Fig. 8 LCD panel handling robot

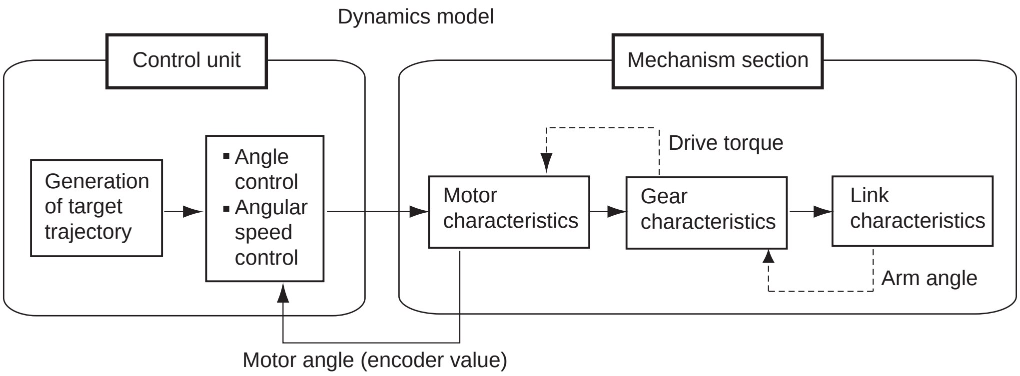
Table 4 Specifications for LCD panel handling robot

Specifications for atmospheric handling robot

Size of LCD panel	2.0 × 2.0 m or over
Structure	Vertical axis + Traversing hand (2 pieces)
Operation range	Vertical: 1 800 mm Horizontal: 2 500 mm or over
Cleanliness class	Equivalent to class 100

Specifications for vacuum handling robot

Size of LCD panel	2.0 × 2.0 m or over
Structure	Vertical axis + Traversing hand (2 pieces)
Operation range	Vertical: 200 mm Horizontal: 2 500 mm or over
Cleanliness class	Equivalent to class 100



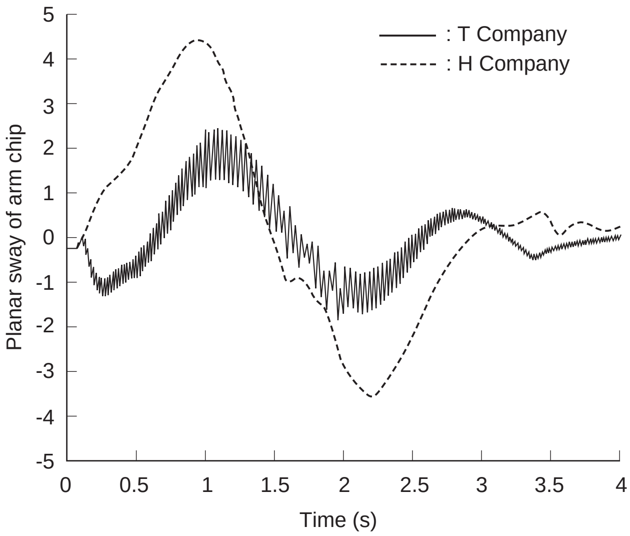


Fig. 9 Simulation of dynamics for planar handling of the robot in atmosphere

in **Fig. 8** and **Table 4**, respectively. The technical targets of the large-size LCD panel handling robot are as given below:

- development of vertical drive structure that allows large payload, higher speed and long life;
- development of planar drive structure that allows 0.1 mm positioning accuracy of a 2 m by 2 m LCD panel;
- development of light-weight fork hand that is sufficiently “thin” allowed by the cassette pitch; and

#cleanliness technology which minimize the particle emission from the robot driving joints.

Of these technical targets, the development of a planar drive structure with high positioning accuracy is especially important. MHI has performed dynamic analysis of the driving structure, which had been applied to the wafer-handling robot, in order to achieve the optimal selection of robotic components.

Fig. 9 shows an example of the dynamic simulation of the trajectory accuracy of LCD panel handling by a three-axis planar atmospheric robot, with two different types of reducing gear adopted inside the robot. The result of the simulation shows that a robot with a planocentric type reducing gear provides better trajectory accuracy than a robot with the other type of gear.However, the two types of gears have their own advantages regarding the amount of backlash or rigidity and could not be prioritized by the gear alone.

Further, the three-dimensional model shown in **Fig. 10** was used to check the mutual interference between each robotic component before starting production of the robot so as to minimize the cost of trial and error.

As for the substrate handling robot in a vacuum, MHI has concluded technical collaboration with American Brooks-PRI Automation Inc., and is engaged in the development of a Generation 7 LCD panel handling robot with original mechanism and control.

4. Conclusion

This article has presented a brief review of the history of MHI's special purpose robot technology, and has unveiled the semiconductor wafer handling robot system using the clean compatible PA10-6C/7C robotic arm, and the LCD panel handling robot which are both being newly developed.

The field of semiconductor wafer and LCD panel handling is undergoing severe competition and drastic change in terms of both technology and cost. However, MHI is determined to make an all- out effort and use our diversified technologies and equipment in the hope that they will be of some service to our customers.

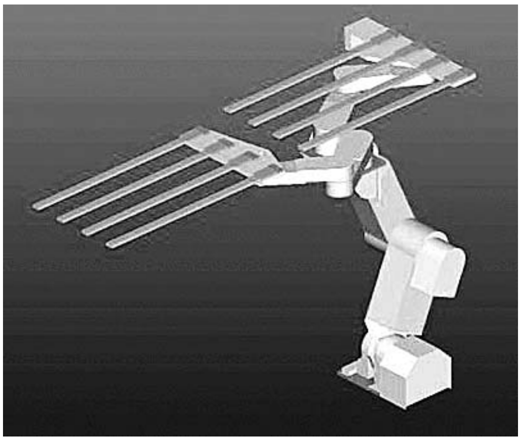


Fig. 10 Three-dimensional evaluation (assessment) model of atmospheric handling robot

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