FEATURE ARTICLE

The PLCA-800 Series Inline Particle Sensor for Chemical Solutions

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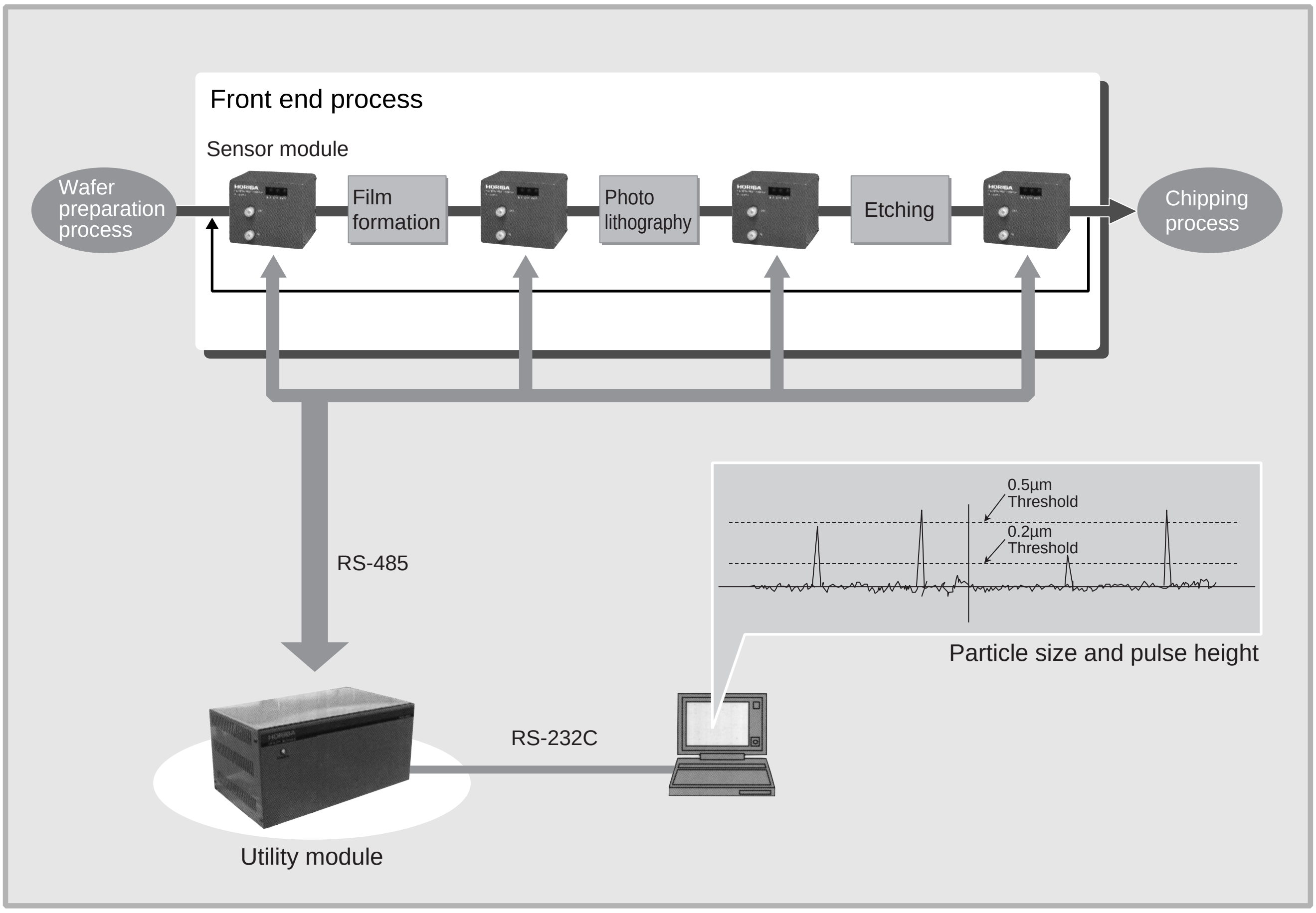

Abstract

The PLCA-800 series inline particle sensors for chemical solutions feature a compact design which permits inline meas urement at up to 10 locations. The sensor, signal processing unit, and control unit are each contained in a separate module. An optional sampling unit provides deaerating and cooling to assure stable measurement of chemical solutions to meet a variety of practical needs. This article discusses the development of the product, its features and uses, and recommends techniques to achieve superior performance.

1 Introduction

In the remarkable progress of high integration, hyperfine structuring, and systematization of semiconductor devices, yield improvement in the manufacturing process is vitally necessary. Particularly important are critical control of ultra pure water (D.I.W) used in the cleaning process, and control of the quantity of particles contained in the chemical solutions. As in semiconductor device manufacturing, particle control is indispensable in the manufacturing process for liquid crystal flat panels.

In the past, particles in liquid were evaluated using a dummy wafer for testing with a debris inspection device. However, this method was complicated, lacked real-time operation, and required a skilled operator and added tremendous cost. Under the circumstances, an inline liquid particle sensor with high accuracy and good repeatability is very desirable.

In 1986, Horiba first developed the PLCA-310 particle counter for ultra pure water. The system used a laser scattering method as the measuring principle. In 1989, the PLCA-700 particle counter for chemical solutions was introduced to the market. Thus, Horiba has developed a number of experiences and technologies. Applying these rich experiences and technologies, Horiba has developed a new inline particle sensor for chemical solutions, the PLCA-800 series, which is sensitive to the minimum measurable particle diameter of 0.1μm and capable of monitoring at least 10 lines simultaneously.

2 Background for Development

With advances in the semiconductor process, requirements for particle sensors are increasingly diversified and becoming more critical as time passes. One of the requirements is for an inline installation. The sensor must be incorporated in the production line to positively control the quantity of particles contained in pure water and chemical solutions. For this purpose, miniaturization and inexpensive cost are indispensable conditions. Further, it must comply with the requirements of each line and maintenance must be easy. Naturally, a highly- sensitive sensor capable of accurately detecting fine-particles is a major proposition. In the PLCA-800 series, the basic concept for development was the modularization of equipment to permit combining modules according to the individual needs of each customer.

3 System Configuration

The PLCA-800 is composed of three modules: a sensor module, a utility and power supply module, and a master module (personal computer contoroller). An RS-485 cable is connected between the sensor and the utility modules and an RS-232 cable connects the utility and the master modules. This allows the sensor module to be integrated into the production line and the utility and master modules to be installed at different places respectively.

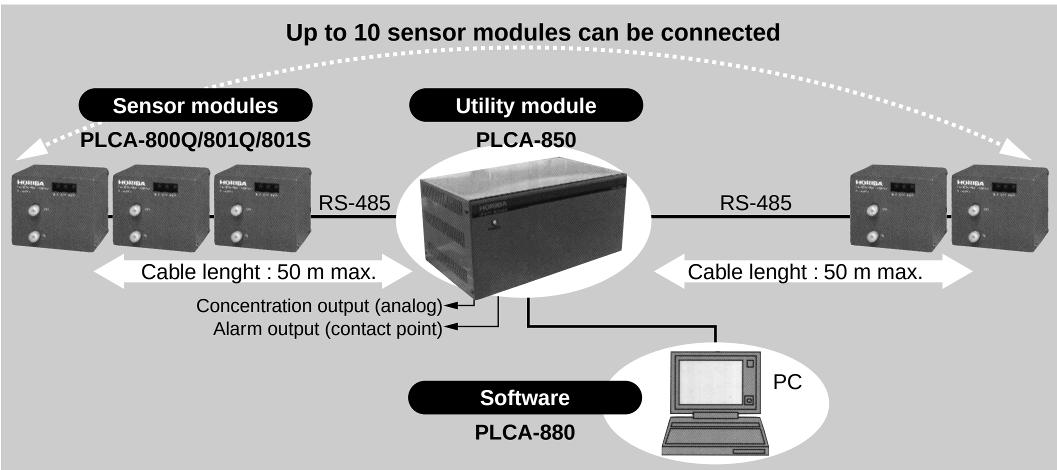

Fig.1 PLCA-800 Series Inline Particle Sensor for Chemical Solutions

It is therefore not necessary for an operator to go to the site to control the system. The utility module is a multi-drop system which is capable of connecting to a maximum of 10 sensor modules at a time. This allows multiple sensor modules to be controlled by one utility and master module group. What's more, it is effective for cost saving. Fig.1 shows an example of the PLCA-800 system configuration.

(1) Sensor Module

The sensor module directly samples from the piping in the semiconductor manufacturing line. It detects and counts fine-particles. The sensor module is classified into several types according to the specimen to be measured. For pure water and chemical solutions the PLCA-801Q is used for a minimum measurable particle diameter of 0.1µm, and the PLCA-800Q is used for 0.2 µm particles. For hydrofluoric acid, the PLCA-801S is used for 0.1µm particles. Table 1 lists specifications for the sensor modules.

(2) Utility Module

The utility module supplies power to the sensor module and relays the sensor signals to the master module. It can drive analog outputs corresponding to the particle counts, or close alarm contacts when an error occurs. Based on the signal output characteristics, two types of utility modules (PLCA-850UD or PLCA-850UA) are available. Table 2 lists specifications for the utility modules.

(3) Master Module

The master module is the software to control the sensor module from a personal computer. In addition to giving instructions for measurement starting and stopping and setting the alarm value, the software is used to display the trend of measurement results in a graph, allowing the user to see the process status at a glance.

The measurement data are automatically stored in a text file and can be verified at any time as necessary. Table 3 lists specifications for the PLCA-880 software.

cells	Standard type with quartz glass 0.1µm	Quartz glass cells with particle resolution of 0.1µm	Sapphire glass cell with particle resolution of
	PLCA-800Q	PLCA-810Q	PLCA-801S
Method of measurement	Laser scattering (90°scattering)		
Applicable samples	Particles in chemical solutions and pure water		Hydrofluoric acid (HF)
Cell material	Quartz glass		Sapphire glass
Sample temperature	15 to 35°		
Particle size	0.2µm min.	0.1µm min.	0.1µm min.
Threshold	2 channels [0.2][0.5]	2 channels [0.1][0.2]	2 channels [0.1][0.2]
Measurable volume	1.80 mL/min	0.22mL/min	
Sample flow rate	20mL/min±2mL		
Sample pressure	0.05MPa to 0.15MPa		

Table 1 Sensor Module PLCA-800Q, PLCA-801S Specifications

	PLCA-850UD	PLCA-850UA
No. of sensors	10 max.	
Sensor interface	RS-485×2 ports (50m max. per port)	
Computer interface	RS-232×1 port (10m max.)	
Alarm output 2 per channel (4 per sensor)	For 5 sensors (20 points)	For 10 sensors (40 points)
Analog output(4 to 20 mA) 1per channel(2 per sensor)	None	For 10 sensors (20 points)
Alarm output specification	FET open drain Maximum voltage 24V DC, maximum current 20mA DC	

Table 2 Utility Module PLCA-850UD, PLCA-850UA Specifications

	PLCA-880
OS	Windows NT Workstation 4.0 (English)
Computer requirements	133MHz CPU or better, 48MB RAM, 1GB hard disk, and equipped with an RS-232C port

Table 3 PLCA-880 Software Specifications

4 Principle of Measurement

The laser scattering method is employed as the measurement principle of the PLCA-800. The laser beam enters the flow cell in which the sample flows at a constant rate. When the laser beam strikes particles in the liquid, scattered light is emitted. The intensity of the scattered light depends on the particle diameter. Thus, the size of the particles can be obtained by measuring the intensity of the scattering light. Each time the laser beam strikes particles, a scattered light pulse is generated.

Fig.2 shows the pulses type obtained when particles flow through the flow cell. As seen in this figure, the pulse height depends on the particle diameter. If the particle diameter is large, a higher pulse is obtained. Using this characteristic, the threshold value can be set in advance according to the size (diameter) of particles of interest. Pulses in excess of this threshold value are counted.

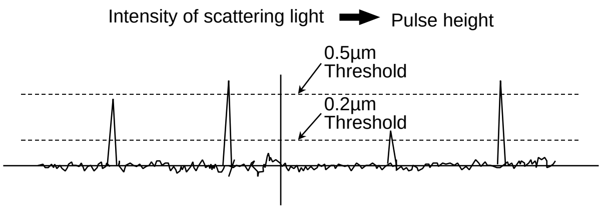

Fig.2 Relation of Pulse Height and Threshold

5 High Sensitivity

Fig.3 shows a simulation result of scattered light intensity from polystyrene latex particles in pure water. This figure shows that the pulse to be obtained becomes smaller in proportion to the particle diameter, making it difficult to separate pulse and noise. In order to measure with high sensitivity, a high-performance optical system and signal processing for clear separation between noise and pulse are required.

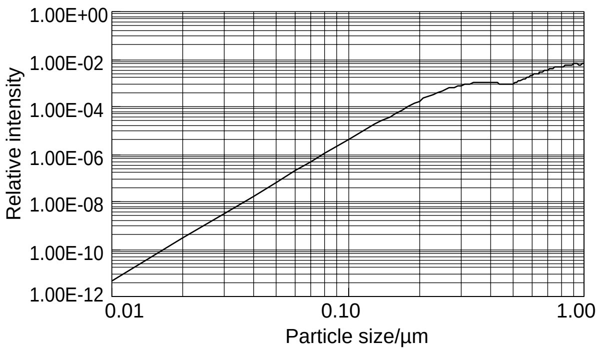

Fig.3 Calculated Relative Scattered Light Intensity from Polystyrene Latex Particles in Pure Water

5.1 Optical System

Fig.4 shows the optical system block diagram of the sensor module of the PLCA-800 Series. The laser beam from the Laser Diode (LD) is made parallel light by means of a collimator lens. It passes through a condenser lens and focuses in the flow cell. When particles pass through the cell, the laser beam is scattered by the particles. The scattered light is condensed by the light-receiving lens system positioned 90º from the incident direction. The scattered light is image-formed on the light receiving surface of the detector. To increase the detection sensitivity, the following are the key points:

(1) Give the light-receiving optics as much solid angle as possible
(2) Increase the light source power
(3) Use a detector with high photoelectric transfer efficiency and high responsivity

When designing the system, optimizing these factors and miniaturization of the optical system will be important.

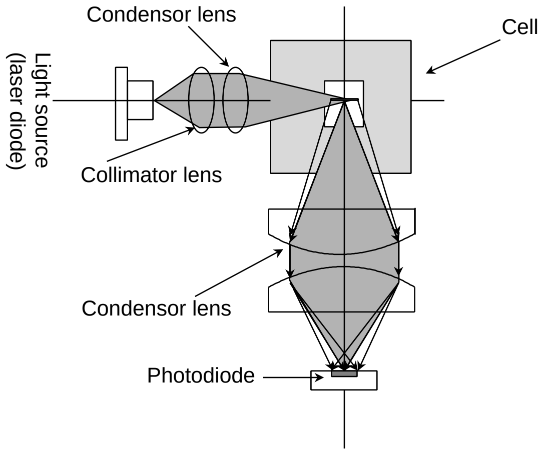

Fig.4 PLCA-801 Optical System Diagram

5.2 Signal Processing

The photoelectric current from the detector which receives scattered light pulse is I-V converted in the detection circuit and amplified as a voltage pulse. It is then sent to the comparator. The comparison-selected pulse is integrated within the preset time by the CPU. This data is serially sent to the master module over the RS-485 cable. The sensor module is provided with a self-monitoring function to monitor the LD and optical system status. It will immediately inform the utility and master modules if any error occurs.

5.3 Sampling System

The PLCA-800 samples parts of the pure water (D.I.W) or chemical solutions by branching from the circulation and supply piping (Fig.5). Where the sample has few particles, such as the case of pure water, variations in the measurement result are noticeable. When counting such particles coming at random, the measuring interval must be set longer. By increasing the counts, such variations can be minimized. It is also effective to install a flow damper at the measuring point to reduce flow variations resulting from pulsation of the circulating pump.

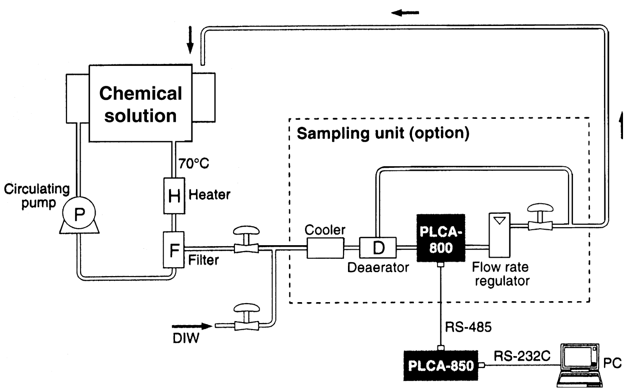

Fig.5 Flow Diagram of Wet-Station

6 Measurement of Foam Chemical Solutions

6.1 Bubble Formation

Foaming chemical solutions may generate bubbles in the piping or inside the measurement cell. During flow in long piping, small bubbles tend to grow to give rise to the liquid phase and gaseous phase as shown in Fig.6. If such bubbles are introduced into the sensor, they are judged to be particles, resulting in erroneous results. Special caution must be exercised when measuring high temperature chemical solutions which may generate bubbles.

Effective methods to prevent bubble generation include lowering the temperature of the specimen and applying pressure. The solubility of gases in liquids improves by lowering the temperature and increasing the pressure. As a result, bubble generation can be prevented.

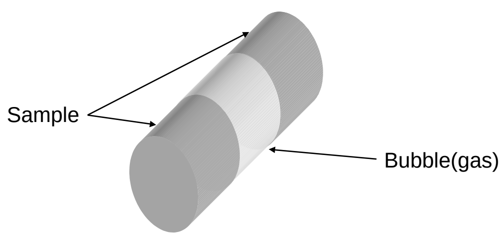

Fig.6 Generated Bubbles in a Tube

6.2 Sampling Unit

The PLCA-800 series provides an optional PLCA-SP-2 sampling unit to suppress bubble generation during inline measurement (Fig.5). The PLCA-SP-2 combines a cooling unit to cool the specimen flow piping by fan, and a defoaming unit to remove large bubbles. These special units are combined with the flow control module and sensor module. For measurement of solutions liable to generate bubbles at cold temperatures, the optional PLCA-SP-1 cold sampling unit may be used. This sampling unit uses a defoaming unit and a pressurization unit to suppress the formation of bubbles at low temperatures.

According to the characteristics of respective production lines, an optimum inline particle sensing system can be configured from a wide variety of options.

7 Features and Main Applications

The PLCA-800 series has the following features:

- Compact design.
  The sensor module is very small and lightweight (105mm (W) × 88mm (H) × 89mm (D), approximately 2kg) and best suited to inline measurement.
- High sensitivity with a minimum measurable particle diameter of 0.1µm.
  Optimized design of the optical system allows measurement to a minimum particle diameter of 0.1µm.
- Reduction of installation cost.
  Up to 10 sensor modules can be controlled by one master module and one utility module. This arrangement substantially reduces the installation cost and allows real-time control of the process.
- A wide selection of models.
  A wide selection of models are available to meet the characteristics of each process – such as the minimum measurable particle diameter (0.2µm, 0.1µm) and the material of the measuring cell (quartz, sapphire).
- Stable measurement of foaming chemical solutions.
  Various types of chemical solutions from room temperature to high temperature can be measured without being affected by bubbles using an optional sampling unit that is integrated with the sensor module. The optional unit performs such functions as cooling, defoaming, and flow control to eliminate the effect of bubbles on measurement.

The PLCA-800 series are used in the following processes as inline particle sensors for chemical solutions in the semiconductor process:

1. Cleaning solution control in the wafer wet-cleaning process
2. Pure water control in the pure water manufacturing and supply system
3. Chemical solution control in the chemical delivery system
4. Cleaning effect verification and control in the CMP post-cleaning process
5. Cleaning control (final cleaning chamber) in the FPD cleaning process

8 Conclusion

This paper has discussed the development background and technical points of the PLCA-800 series chemical solution particle sensor. Particle control in the manufacturing process for semiconductor devices and LCD panels is rising in importance and becoming more diversified. Today, high performance particle sensors are required. We expect that the small, lightweight, and modular PLCA-800 series will meet the present and future diversified needs of customers.

It is our earnest desire that we will be of help to our customers by applying our efforts and responding to challenges for further improvement in performance and completeness of our display and analysis software.

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