50th Anniversary Product

PR-PD3 Reticle/Mask Particle Detection System Details of a Method to Discriminate between Particle and Pattern Signals

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Discriminating between scattered light from particles (particle light) and scattered/diffracted light from patterns (pattern light) is the most important element of techniques for the reticle/mask particle detection system, which utilizes light scattering. The PD Series discrimination methods mainly used the polarization properties of scattered light. The early stages of development of this system utilized quenching of the pattern light by alignment of the optical system and the polarizing plate. The next generation utilized the signal intensity ratio between the pattern light-quenching detector and the particle light-quenching detector. While the most recent machines perform the signal processing, concentrating on the signal forms of pattern light and particle light. The latest PR-PD3 adopts a discrimination method of signal processing so as to cover all the advantages of the conventional methods and so become capable of dealing with more patterns.

Introduction

As technology has advanced in the semi-conductor device manufacturing field and its inspection field, the requirements of the performance of foreign particle detection systems has also changed drastically.

In recent years especially, the gap has increased between state of the art technology and conventional technology. Accordingly, the sample characteristics with which the light scattering particle detection systems have to deal are becoming significantly diverse and the technology, focused on limited cases only, is facing difficulties in responding. Considering this background, we collected the advantages of the patterns and particle discrimination methods acquired in past PD series systems and developed a signal processing method to deal with the various reticle/mask patterns for incorporation into the new PR-PD3 system. Figure 1 is a photo of the PR-PD3 system.

The descriptions below are the mechanisms and features of these discrimination methods, along with conventional discrimination methods.

Figure 1 Appearance of PR-PD3

The Challenge of the Reticle/Mask Particle Detection System

The function of the scattered light type particle detection system is explained in Figure 2; it scans the measuring surface with an appropriately focused laser beam, then detects the scattered light generated by the beam irradiating the particle on the sample surface.

It is possible to increase the sensitivity to particles by increasing the light intensity of the light source or the signal gain of the detection system. However, the pattern on the sample also generates scattered/diffracted light, which will be an interfering factor. Therefore, simply increasing the sensitivity not only increases the false detection, which results in unsuccessful detection of the target particle, but also fails to provide accurate measurement by consuming the storage capacity of system due to too many false detections. In other words, when increasing the sensitivity, it is required to improve S/N ratio of the particle light against the pattern light in excess of the increase of sensitivity.

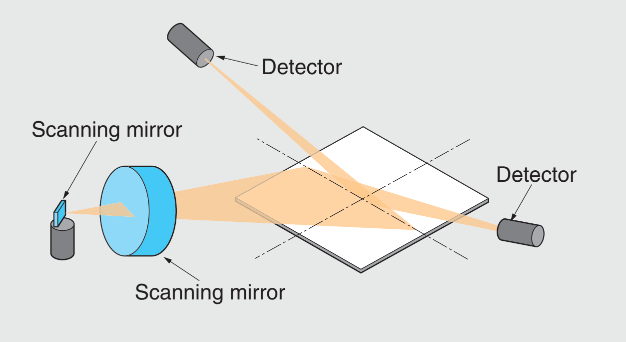


Figure 2 Basic Optical System

Features of Conventional Method for Signal Processing

Conventional Method for Signal Processing I: Polarized Light Differential Method

Basic Configuration

The polarized light differential method is one of the methods for improving the S/N ratio of lights from particles against pattern light. Figure 3 shows the detection system configuration of the polarized light differential method.

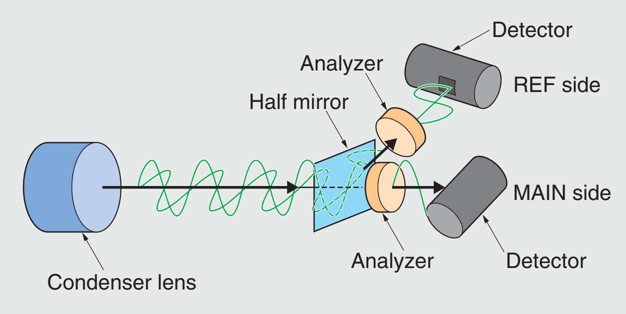


Figure 3 Polarized Light Differential Detection System

The polarized light differential method works by using a property of pattern light. Pattern light comes close to linear polarization at a certain polarization angle because of, the radiated light's polarization or the incident angle or the alignment of the detector, while the polarization properties of particle light vary according to the particles.

Taking the signal output and changing the angle of analyzer (polarization plate) in the optical system shown in Figure 3 ideally identifies the signal status as in Figure 4. In this case, a signal above a certain intensity can be regarded as a particle light signal. Actually there are pattern light signals with high total intensity as well as with the characteristics shown in the figure. If a signal above a certain intensity is regarded as a particle light signal, a false detection is caused. The purpose of the polarized light differential method is to discriminate the particle light from the pattern light by capturing the characteristics shown in Figure 4 even when the pattern light signal is intense.

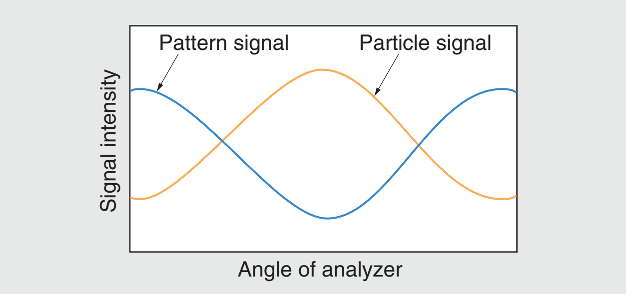


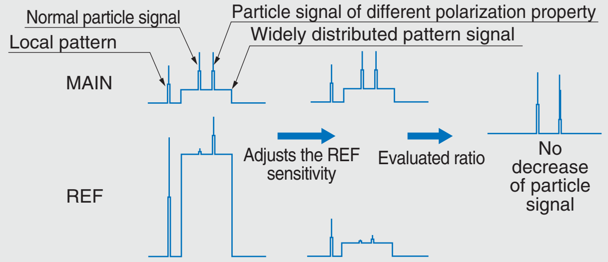
Figure 4 Particle/Polarization Properties of Pattern Scattered Light

Firstly the light beam is split to two directions by the half mirror as shown in Figure 3. One goes to a detector equipped with an analyzer at an angle quenching the pattern light (MAIN), and the other goes to the detector with an analyzer at an angle optimized to detect the pattern light (REF).
Then both signals are compared. When the MAIN signal is more intense, it is taken as a particle signal. When the REF signal is more intense, it is rejected because it is pattern light. With this method, the particle light can be discriminated from the pattern light.
The REF sensitivity needs to be set so that the REF signal of pattern light exceeds the MAIN signal.

Features of the Polarized Light Differential Method

Figure 5(a) shows the case of a high ratio of REF to MAIN signal. The polarization characteristics are of a pattern signal. Adjusting the REF sensitivity so that the REF/MAIN ratio of the pattern signal slightly exceeds 1 makes the particle signal, appearing on the REF side sufficiently low, due to the REF detector sensitivity being set sufficiently low. Then it is possible to take the particle signal only (obviously it is a particle signal if the ratio is less than 1) by evaluating whether the REF/MAIN signal ratio exceeds 1.
Meanwhile, to diminish the pattern signal so as to be not so high on the REF side, the REF sensitivity must be set higher as shown in Figure 5(b) compared with Figure 5(a). As a result of this, the REF signal of particle does not lower appropriately thereby missing the particle signal.
Thus, the efficiency of the polarized light differential method varies according to the REF/MAIN signal ratio of the pattern light.

(a) Case when the REF/MAIN signal ratio of the pattern light is sufficiently high



(b) Case when the REF/MAIN signal ratio of pattern light is not sufficiently high

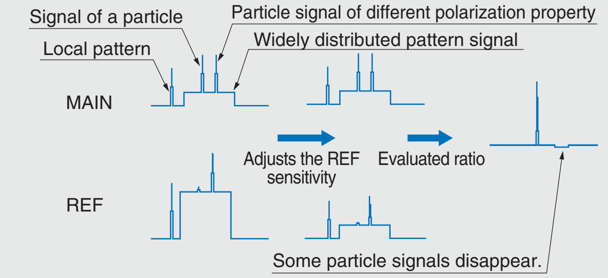
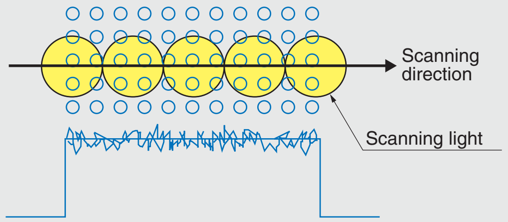


Figure 5 Signal Processing Stage using the Polarized Light Differential Method

Conventional Method of Signal Processing II: Low-Pass Difference

With the PR-PD2 system, a detector with 0.35 µm sensitivity, whose main target is a sample on which fine and dense patterns are widely distributed, applies the following signal processing method to reduce the pattern signals.
Figure 6(a) shows the signal from dense patterns. When plotting the time along the horizontal axis and the signal intensity along the vertical axis, the signal from the fine patterns is shaped like a rectangle.
On the other hand, the signal from non-dense aligned patterns or particles exists independently, showing the sharp signal plot as shown in Figure 6(b).

(a) Case when the patterns align with a narrower interval than the beam spot



(b) Case when the patterns align with a wider interval than the beam spot

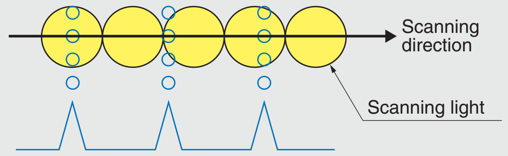


Figure 6 Difference of Signal Forms according to Pattern Alignment

The signal processing method below tries to reduce the rectangular signals only, based on the above-mentioned characteristics.
The output signals from the detector are split into two. One signal passes through the low-pass filter and is then subtracted from the other signal.
At this time, the signal height of rectangular part is reduced but the particle signals are not, as shown in Figure 7.
Although the effectiveness of signal processing is greatly affected by the pattern distribution state, two features can be summarized: An easy to understand an effective signal processing mechanism, and even a single particle existing in a pattern with a specific, measurable intensity is rarely missed.

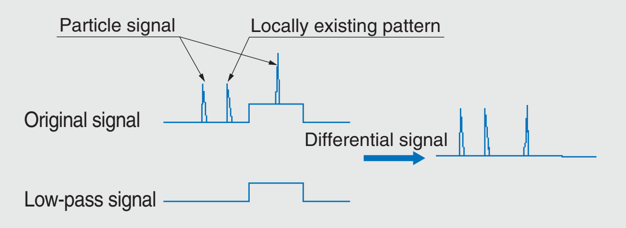


Figure 7 Signal Processing Method Based on the Signal Form

Signal Processing Method of PR-PD3 System

The characteristics of signal processing methods described so far can be classified as shown in Table 1 with regard to the pattern form:

Table 1 Pattern Characteristics and Effects of Signal Processing

Pattern form or distribution			REF/MAIN signal ratio			
Coarse or Fine	Dense or non-dense	Distribution	Near 1 or less than 1		Sufficient	
			Low-pass difference	Polarized differential	Low-pass difference	Polarized differential
Fine	Dense	Wide	Yes	No	Yes	Yes
		Local	No		No	
Coarse	Non-dense	Wide				
		Local				

Yes : Possible to properly detect particles
No : Not suitable for particle detection

The above table suggests that the two methods of signal processing are related, partially complementing each other. Enlarging the range of applicable patterns is possible as shown in Table 1, if the two signal processing methods can be used together maximizing the features of each method.

The signal processing method described below is a combination of the two signal processing methods, adding the slight change to the usage of the polarized light differential method to obtain the effect in reducing the pattern signal, even in the part marked as “No” in Table 1.

PR-PD3 system has changed from the polarized light differential method to the one that takes the difference between the MAIN signal and the REF signal, applying the signal processing shown in Figure 7 to the difference signal obtained from the polarized light differential method.

Figure 8 shows the case when the REF signal is not high as with Figure 5(b). The initial stage shown in Figure 8 is the polarized light differential method. Here the REF sensitivity is held at low level so as not to miss particles, which lowers the REF pattern signal compared with the MAIN signal. This means that the effect of reducing the pattern signal is not enough, however, a certain level of effect can be seen in both local patterns and the widely distributed patterns. (Conventionally REF/MAIN ratio would have been evaluated. This situation is not effective at all for the pattern signal.)

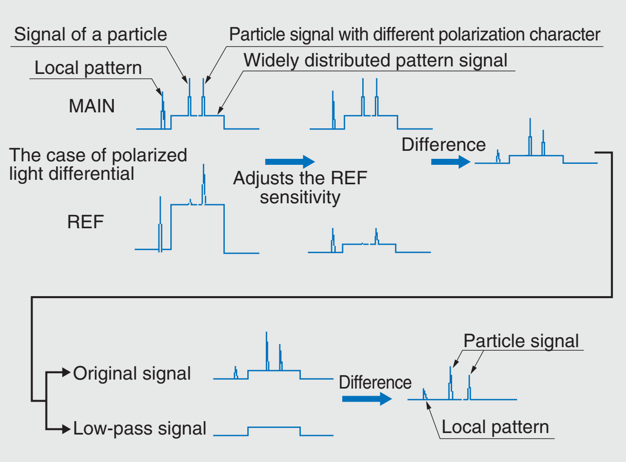


Figure 8 Signal Processing Method of the PR-PD3 System

In addition, using the signal processing at a later stage reduces widely distributed pattern signals.

Thus, the following new effects can be observed by continuing with the polarized light differential method and the low-pass filter method together.

- Even at the REF sensitivity setting level, sufficient so as not to miss particles, it is possible to obtain the effect of reducing the pattern signals.
  The signal can be reduced even when sufficient reduction of the pattern signal is difficult because the original REF signal is low.
- The effect of the signal processing at a later stage can easily appear for that some pattern signals have been reduced by the polarized light differential method at the initial stage. Although we were unable to reduce the initial leading edge of the signal, in the actual signal processing, its effect is reduced, because rectangular signals are slightly reduced by the polarized light differential method.

Conclusion

As explained above, obtaining the effect of reducing the pattern signal regardless of the various pattern configurations possible, from the coarse pattern like Figure 6(b) to the dense pattern like Figure 6(a) has been achieved as well as reducing the possibility of missed particle detection.

This paper describes the signal processing only, without mention of the system details.

For other specifications of the system, refer to:
http://global.horiba.com/semicon_e/