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Research paper

A Study on a Focus Value Quantification Algorithm Applicable to the Vision System

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Abstract

Background/Objectives: Recent development of the IT industry has led to active convergence among industries, and the field of semiconductors has especially shown decreasing size and weight of products. As smaller products are resulting in management of production processes using the vision system, this paper proposes a focus value quantification algorithm to acquire images for the detection of defects in semiconductor packages.
Methods/Statistical analysis: An active focus measurement method that uses an image processing technique to improve autofocusing efficiency of camera lenses by enhancing the detection of defects in semiconductor packages was applied. After acquiring images of target packages, the SMD(Sum Modules Difference), Tenengrad, SML(Sum Modified Laplacian) and LOG(Laplacian of Gaussian) algorithms were used on the acquired images to calculate focus values. Quantification was performed on a large quantity of focus values.
Findings: Camera is a very important device in the vision system, and adjusting focus of camera lenses is essential in acquiring accurate images to detect defects in semiconductor packages. In general, time required for focus adjustment is determined as the sum of time taken to calculate the focus value for moving a camera to the image acquisition position and time taken to calculate the focus value from the acquired image. It would be necessary for users and hosts at industrial sites to perform interpretation of the focus value quickly and accurately. However, since various existing algorithms have extremely large focus values and are difficult to interpret, this paper proposes an algorithm that can interpret focus values quickly through quantification. Based on the comparison of information before and after quantification, the position of maximum focus value was measured to be the same. The proposed algorithm can increase efficiency of semiconductor package testing by shortening time required to interpret the focus value in the device configuration stage.
Improvements/Applications: Future studies should be conducted on an algorithm to improve speed of focus value calculation and an algorithm to acquire image according to wavelength of lighting and conditions of lenses.

Keywords: *Vision System, Focus Value, Semiconductor Package, Calibration Plate, Focus Control*

1. Introduction

With the development of IT, industries are diversifying and undergoing active and rapid convergence. Especially, the development of semiconductor fields has a great impact on the electronic industry. As electronic products are becoming increasingly smaller and lighter, systematic and efficient production management is required to produce core semiconductor parts. Defects in semiconductor parts are factors that can have significant effects on performance of products. It is important to identify defects in parts during the production process to detect defected products. The vision system has been introduced to resolve this issue. The field of machine vision appeared with sensors made of devices like CMOS (Complementary Metal Oxide Semiconductor) a CCD (Charge Coupled Device) in early 1970s, which allowed for digital image processing on computers [1]. When producing electronic products, they must be inspected consistently. Soldering condition was inspected with unaided eyes in the early stage, but this method increases the number of parts attached and results in a tolerance limit compared to the automated system. The development of machine vision, image processing and digital computing resulted in the need for automation of the inspection process using various cameras and lighting systems [2].

There have been studies on lighting technologies [3,4] and studies on algorithm and semiconductor package inspection systems for efficient image processing [5,6]. In addition, the development of reliable and accurate inspection equipment is required to satisfy the demand for equipment and inspection. There are increasing cases of using the vision system to promptly detect defects in parts such as BGA (Ball Grid Array) in the semiconductor production process. Camera is a very important device in the vision system, and adjustment of camera focus is an important and essential element to accurately acquire images for the detection of defects. In general, time taken to adjust focus is determined as the sum of time to calculate the focus value for movement of a camera to the image acquiring position and time to calculate the focus value in the acquired image. The methods of adjusting focus are divided into the manual focus measurement method that uses additional infrared or ultrasound equipment and the active focus measurement method that only uses the image processing technique. In the semiconductor production process, an optimal measurement method appropriate for the environment can be applied to detect defects. The user at the production site must accurately adjust and inspect positions of the camera and lens to apply the focus value calculated for optimal image acquisition, but a large amount of time is needed for the vision system user and host to identify the focus value due to the massive focus value.

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This paper proposes an algorithm that calculates the focus values of an image acquired from a camera of the vision system using SMD (Sum Modules Difference), Tenengrad, SML (Sum Modified Laplacian) and LOG (Laplacian of Gaussian) algorithms, performs quantification of the massive focus value, and determines the position of the focus. The proposed quantification algorithm is expected to increase efficiency of production by quickly determining defects in semiconductor packages through the vision system.

2. Related Work

2.1 Focus Value Measurement Algorithm

The basic principle of autofocusing by image processing is to define the focus value that increases with increasing accuracy of the focus in the acquired image, analyze the focus values obtained from images coming in from various camera positions within the search range, and determine the in-focus position based on the camera position that returns the maximum focus value. In general, if an image is clear and in focus, it means that objects in the image have distinct boundaries and the image contains many high frequency components.

2.2. Tenengrad

The Tenengrad method is an energy slope function based on the space domain. The idea is to use the Sobel operator, considering the fact that accuracy of the focus affects sharpness of the edge. As in (Eq. 1) below, the total accumulated value of square of the edge slope greater than a specific threshold value is used as the focus value [7]. Here,T is the threshold value and (x, y) is size of the slope calculated using the Sobel mask.

$$F_{Tenengrad} = \sum_x \sum_y G(x,y)^2 \, , G(x,y)^2 > T \qquad (1)$$

2.3. Smd (Sum Modules Difference)

The SMD method is similar to the Tenengrad method, but it does not use 2-dimensional mask and shows faster computation speed. SMD calculates the differences in shade of pixels in horizontal and vertical directions of the image and determines the focus value as the sum of accumulated absolute values, as shown in the equation below [8,9].

$$SMD_x = \sum_x \sum_y |f(x,y) - f(x,y+1)| \qquad (2)$$

$$SMD_y = \sum_x \sum_y |f(x,y) - f(x+1,y)|$$

$$F_{SMD} = SMD_x + SMD_y$$

2.4. Sml (Sum Modified Laplacian)

The SML method proposed by Nayer measures high frequency components of an image using the modified Laplacian operator. As expressed by (Eq. 3) below, absolute values are used to resolve the problem in which the 2nd gradient values in horizontal and vertical directions have opposite signs and offset one another [10].

$$FV_{SML} = \sum_x \sum_y \left(\left| \frac{\partial^2 g(x,y)}{\partial x^2} \right| + \left| \frac{\partial^2 g(x,y)}{\partial y^2} \right| \right) \qquad (3)$$

2.5. LOG (Laplacian of Gaussian)

Since the Laplacian filter is greatly affected by noise, the Gaussian filter can be used to reduce noise. Therefore, the LOG operator applies the Gaussian filter first and then performs the Laplacian operation. This combination can reduce noise of high frequency components. Accordingly, sensitivity to noise is reduced by combining the Gaussian function and Laplacian mask. (Eq. 4) below is a log function for convolution [11]. Here,(x, y) indicate horizontal and vertical pixels of the image and σ is the standard deviation.

$$\mathrm{LOG}(x,y) = \frac{1}{\pi\sigma^2}\left(1 - \frac{x^2+y^2}{2\sigma^2}\right) e^{\frac{x^2+y^2}{2\sigma^2}} \qquad (4)$$

3. Proposed System

3.1. System Configuration

[Figure 1] is the overall configuration of the proposed system, largely divided into three parts. The first part is a probe comprised of a CCD camera, lens and LED light. The second part is a vision system to calculate the focus value of the image received from the probe and send the result to the host system. The third part is a host system that receives the result from the vision system, determines the in-focus position and controls the optical axis.

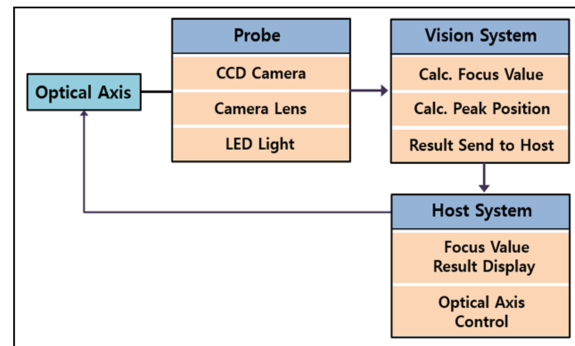


Figure 1: System Configuration

3.2. System Process

[Figure 2] illustrates the process of the proposed system, largely divided into three parts. First, the optical axis is moved to acquire the target image according to package type. Second, the focus value is calculated for the target designated by the user, the calculation result is quantified, and the result of quantification is sent to the host system. Third, the quantification value received is used to decide the in-focus position. If the given position is not the in-focus position, the optical axis is controlled to acquire the image at another position.

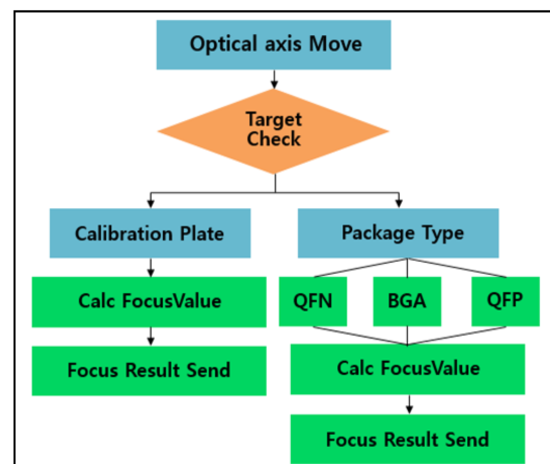


Figure 2: System Process

3.3. Focus Value Measurement Process

[Figure 3] is the process of calculating and quantifying the focus value according to the calibration plate and semiconductor packages. In the case of the calibration plate, if the user has not defined the ROI (Region of Interest), 80% of the image is defined as the ROI to calculate the focus value. In the case of semiconductor packages (QFN, BGA and QFP), package alignment is performed to find out total number and position of packages. A mask image is generated to only extract information inside the packages, and the AND operation is performed on the mask image and original image.

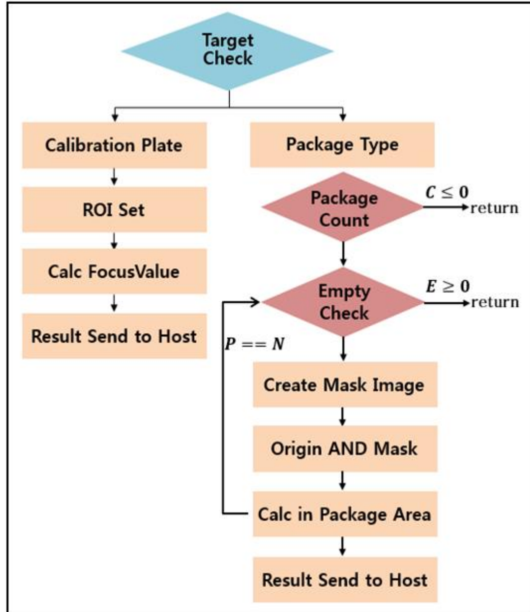
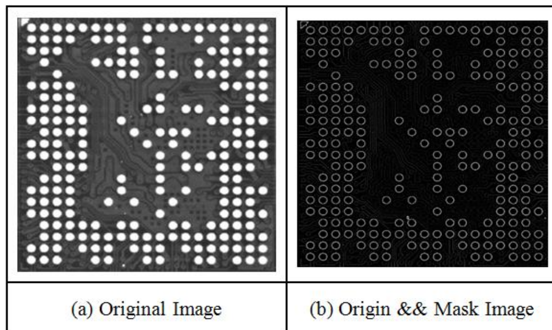


Figure 3: Measurement Focus Value Process

[Figure 4] shows the resultant image after performing the AND operation on the mask image and original image.



(a) Original Image (b) Origin && Mask Image

Figure 4: Measurement Focus Value Process

Since packages need to measure the focus value only using information inside the packages unlike the calibration plate, the brightness value of pixels in the area that corresponds to package size is changed into 255 to generate the mask image for the AND operation with the original image. In [Fig. 4] above, (a) is a portion of the original image after completing package alignment and (b) is the resultant image after performing the AND operation on the mask image generated by changing the brightness value to 255. The background was completely removed from the resultant image of (b) except in the measurement area, and the SML algorithm was applied to measure the focus value. The focus value of the resultant image after the AND operation measured using the SML algorithm returns an extremely large focus value, requiring a large amount of time for the user to check the focus value. Accordingly, (Eq. 5) was applied to quantify the focus value

$$.B_p = \sum_{i=1}^{N} I_{vmax} \text{ , } V = \frac{F_v}{B_p} \quad (5)$$

The brightness value in a gray image has a range from 0 to 255, and I_{vmax} is a pixel of the resultant image after the AND operation that has a brightness value of 255. $B_p$is the accumulated number of pixels that have a brightness value of 255, F_v is the measured focus value, and V is the quantified focus value. Therefore, the SML algorithm was applied to the original image to measure the focus value and quantification was performed on the measured focus value using internal package information.

4. Test and Result

[Figure 5] is the overall screen of the vision measurement system that receives the image form the probe and calculates the focus value.

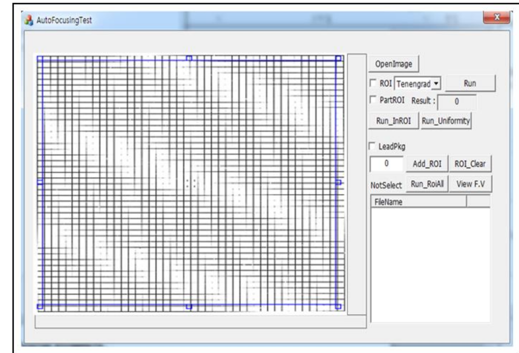
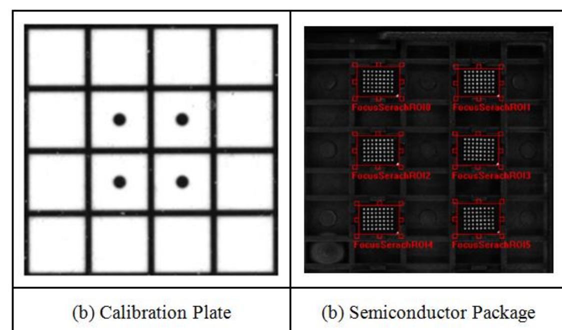


Figure 5: Focus Value Measurement System

To experiment and measure the proposed system, the probe was configured using a CCD camera with 30x30 FOV (Field of View) and 20μm resolution and the LED ring light of company A. The software program was developed using MFC based on the dialog box of Visual Studio 2012 for the vision host system and the iPP library of intel for increased focus value computation speed. The center of the screen displays the image acquired. The top right corner of the screen has buttons that allow the user to select an image and choose the ROI and algorithm for manual calculation of the focus value. The list on the bottom right side of the screen can show and manage the image selected by the user. Package images can be controlled using segmented ROI[12-15]. [Figure 6] shows the calibration plate and package images used to measure the focus value.



(b) Calibration Plate (b) Semiconductor Package

Figure 6: Measurement Screen

[Figure 6] (a) is the image of the calibration plate used for measurement, which requires ROI the same as image size. Since [Figure 6] (b) uses information inside packages, the ROI was designated according to quantity of packages. [Table 1] below presents a portion of the result of measuring the focus value after acquiring 73 images while controlling height of the optical axis. The measured focus values were very massive, requiring a large amount of time for analysis by the user.

Table 1: Before Quantification of Focus Value

Probe Z	Tenengrad	SML	LOG	SMD
0	294675566	27571199	34662283	48377634

1500	401407920	28297509	54232077	61067220
5300	628728784	85223648	159241262	90762545
6400	616989214	67371159	136238671	90304071
7300	579076118	54624736	101321955	89262853

[Table 2] presents the focus values quantified using the quantification algorithm. The massive focus values were quantified to values within three digits. The maximum focus value is found in the same position before and after quantification. The focus values were below 100 after quantification. Although decimal values were obtained, gaps between the values were significantly reduced for convenience of the user.

Table 2: After Quantification Focus Value

Probe Z	Tenengrad	SML	LOG	SMD
0	44.96392	4.207031	5.289045	7.381841
1500	61.24999	4.317857	8.275158	9.318118
5300	95.9364	13.0041	24.29829	13.84927
6400	94.14508	10.28002	20.78837	13.77931
7300	88.36	8.335073	15.4605	13.62043

5. Conclusion

Industries are actively converging with the development of the IT industry, and the field of semiconductor production has a trend of increasing use of the vision system for the detection of defects in semiconductor packages. Core parts of the vision system include the camera, lens and lighting. Accurate images can be acquired by improving focus of the lens. The system proposed in this paper measures the focus value using an existing focus value measurement algorithm after acquiring an image according to height of the optical axis. In the step of comparing the measured focus values to find the position of the maximum focus value, there is a difficult for the user in checking the massive focus values. The proposed system introduces a quantification algorithm to quantify the massive focus values and increase convenience of the user. When the quantified values were compared to analyze the maximum focus value before and after quantification, the position of the maximum focus value was found to be the same. Autofocusing is an important factor in the vision system that requires precise measurement, expected to help increase production efficiency by shortening time taken for device configuration. However, it is difficult to acquire the same image in the same position due to computation speed of the focus value measurement algorithm, heating of the camera, conditions of the lens and wavelength of the light. Therefore, future studies must be conducted on algorithms that can increase computation speed and acquire images while accounting for wavelength of the light and conditions of the lens.

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