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# Visual Inspection System of the Defect of Collets for Wafer Handling Process

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***Abstract***

*Pick up and placement tools (collet) are one of important tools for semi-conduct manufacturing process. It should have acceptable precision and reliability of shape to pick the piece of wafer and chip without damages. To defect detection of pick up tools such as wrong size of hole and flaw in collet surface plays an important role in tool manufacturing process. In this study, we propose a visual inspection system to defect detection based on pattern matching algorithm. Experiments were performed to evaluate the proposed visual inspection system and showed 99.3% of success rate to detect defection.*

***Keywords****: Collet, Visual inspection, Auto focus, Defect inspection*

## 1. Introduction

Machine Vision inspection plays an important role in quality control, reducing costs and ensuring a high level of customer satisfaction in the semi-conduct manufacturing processes. In the semi-conductor manufacturing, tiny and precise pick up tools shown in Figure 1 are used to pick and place tiny wafer and chip for assembly process.

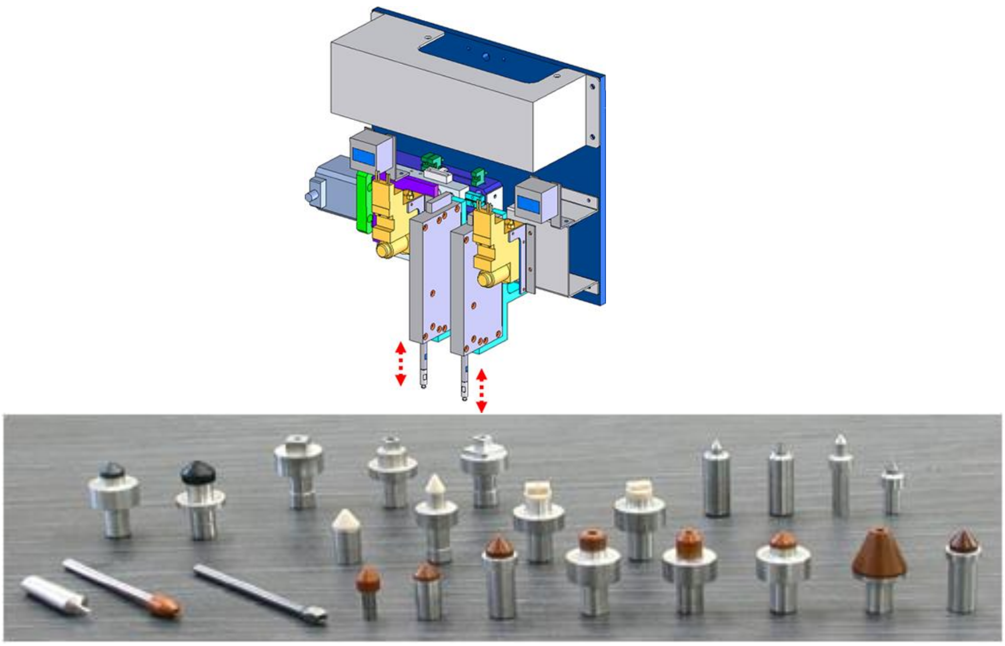

**Figure 1. Pick and Place Tools and Various Types of Collets**

These tools are produced from various materials, such as: plastics, ceramics and metal based, depending on the different applications. Most important quality of the collets such

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as shape, outer size, hole and surface of tools are very important to achieve high reliability to pick and place of sawed wafer in semiconductor packaging process. The size of the tools are under 100um. The human inspectors are inspecting these tools with microscopes and it takes 2~ 3mins to inspect one collet and it is one of big obstacle against mass products. We propose automatic defect detection system based on machine vision and its image processing algorithm[1] to reduce the inspection time and increase the reliability of inspection result.

## 2. Visual Inspection System

Proposed automatic visual inspection system consists of 3 axis motion system and two different FOV vision systems. X and Y axis are driving by servo motors with the resolution of 1um. Camera is mounted on Z axis which is driving by stepper motor with 1um resolution. Two 2M cameras are used to acquire the image of collets. Depending on the size of collet, 2X, 4X and 10X magnification lens to be chosen to capture tiny collet image. Figure2 shows our inspection system.

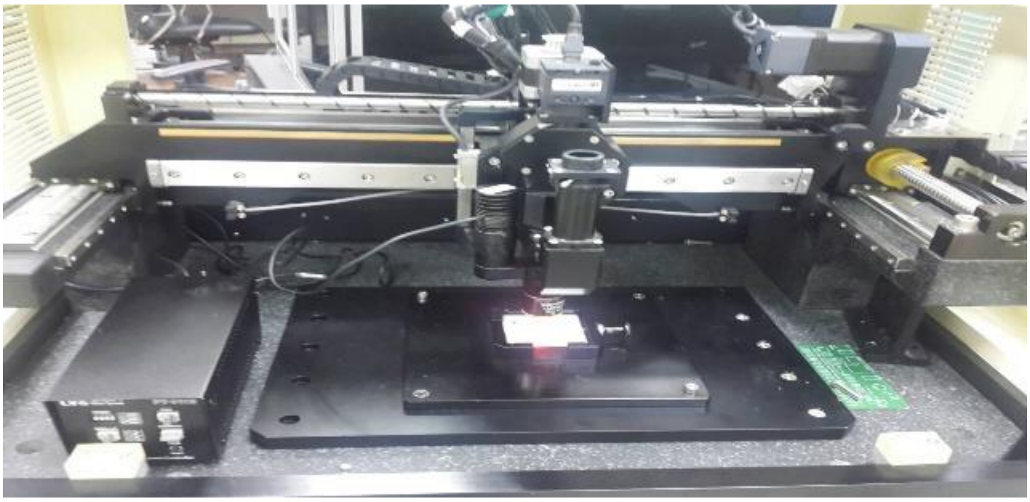


**Figure 2. Proposed Visual Inspection Machine**

### 2.1. Camera Calibration

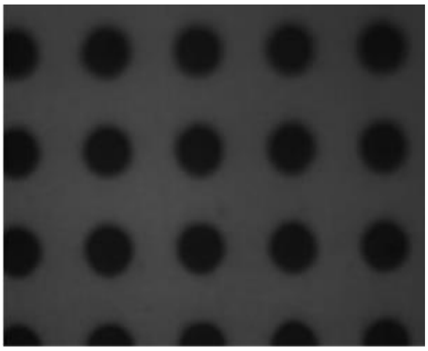
Camera calibration is to find the relationship of camera pixel (u,v) coordinate and (X.Y,Z) world coordinate and considering distortion of imaging system. Distortion is caused by either a characteristic of the lens or the position of the camera in relation to the subject. and it make an error on an image. Geometric correction is undertaken to avoid geometric distortion from a distorted image, and is achieved by establishing the relationship between the image coordinate system and geometric coordinate system using calibration data of the sensor[3]. A dotted calibration target is used. This calibration dot space as shown in Figure 3 is 125 um and the relation between image coordinate (u,v) and world coordinate (x y), is expressed as equation (1) and (2). The equation (2) is expressed by matrix form (3) and A matrix can be calculated by pseudo inverse matrix $A^{-1} = A^T \cdot A \cdot A^T$ .

$$x = a_1 u^3 + b_1 u^2 v + c_1 u v^2 + d_1 v^3 + e_1 u^2 + f_1 v^2 + g_1 uv + h_1 u + i_1 v + j_1$$

$$y = a_2 u^3 + b_2 u^2 v + c_2 u v^2 + d_2 v^3 + e_2 u^2 + f_2 v^2 + g_2 uv + h_2 u + i_2 v + j_2 \quad (1)$$

$$\begin{bmatrix} x_1 & y_1 \\ \vdots & \vdots \\ x_n & y_n \\ \vdots & \vdots \\ x_N & y_N \end{bmatrix} = \begin{bmatrix} u_1^3 & u_1^2 v_1 & u_1 v_1^2 & v_1^3 & u_1^2 & v_1^2 & u_1 v_1 & u_1 & v_1 & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ u_n^3 & u_n^2 v_n & u_n v_n^2 & v_n^3 & u_n^2 & v_n^2 & u_n v_n & u_n & v_n & 1 \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ u_N^3 & u_N^2 v_N & u_N v_N^2 & v_N^3 & u_N^2 & v_N^2 & u_N v_N & u_N & v_N & 1 \end{bmatrix} \begin{bmatrix} a_1 & a_2 \\ b_1 & b_2 \\ c_1 & c_2 \\ d_1 & d_2 \\ e_1 & e_2 \\ f_1 & f_2 \\ g_1 & g_2 \\ h_1 & h_2 \\ i_1 & i_2 \\ j_1 & j_2 \end{bmatrix} \tag{2}$$

$$X = A \cdot x \quad \text{and} \quad x = A^{-1} \cdot X \tag{3}$$



**(a) 4X (b) 10X**

**Figure 3. Calibration Chart**

After calibration, average error of 4X lens is under 1um and error of 10X is under 0.5um.

## 2.2. Auto Focus

Focus is one of the important function to get clear images. In order to focus with high speed and automatically, we define the quality of focus to be measured in a pre-defined image at ROI, on the focused image, sharpness of edge in image should be maximum. The operator must produce maximum response when image area is perfectly focused. We chose the Laplacian operator often used [2] as equation (4).

$$\Delta^2 I = \left|\frac{\partial^2 I}{\partial x^2}\right| + \left|\frac{\partial^2 I}{\partial y^2}\right| \tag{4}$$

The focus measure at a point (i, j) is computed as the average of the Laplacian, in a the predefined window at (i, j) that are greater than a threshold value expressed by equation (5):

$$F(i,j) = \sum_{x=i-N}^{i+N} \sum_{y=i-N}^{j+N} L(x,y) \text{ for } L(x,y) \geq T_i \tag{5}$$

where, the parameter N determines the window size is used to compute the focus measure value. In contest to focus automatically and with high seed, we typically use a small window of size 3x3 or 5x5. The best focus image has maximum focus measure value under 30 unfocused images. To increase speed of focus, the robot motion continuously moving and at every 2um trigger pulse is generated into camera to capture images

**Figure 4. Camera Trigger at Every 2um for Auto Focus**

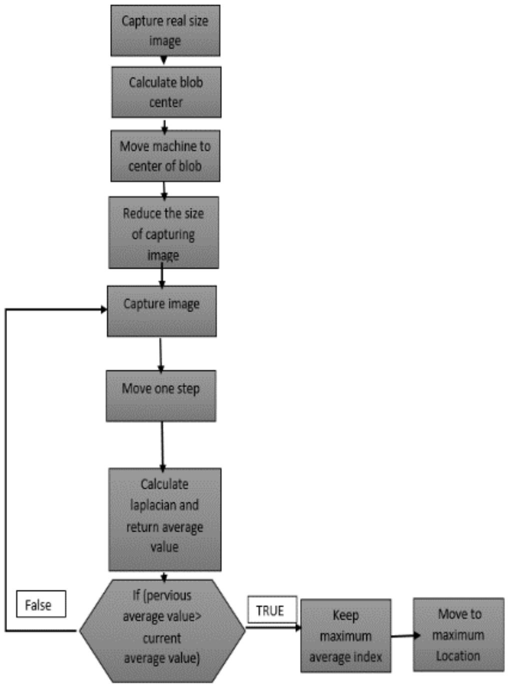



**Figure 5. Auto Focusing Algorithm and Result**

Figure 6 shows the result of auto focus. The initial search to find best focal plane is downward and if focus value (edge sharpness) cannot be increased, the focal plane must be placed higher position then initial location and the search direction is changed upward to find focal plane successfully.

## 3. Image Processing Algorithm

Our proposed image processing algorithm consists of three main steps. The first step is to capture images from image acquisition system after autofocus procedure and image correction. The second step is rotation correction between model and input image. The final step is matching and calculation error between model image from cad data and captured input image. The Figure 7 show the image correction result.

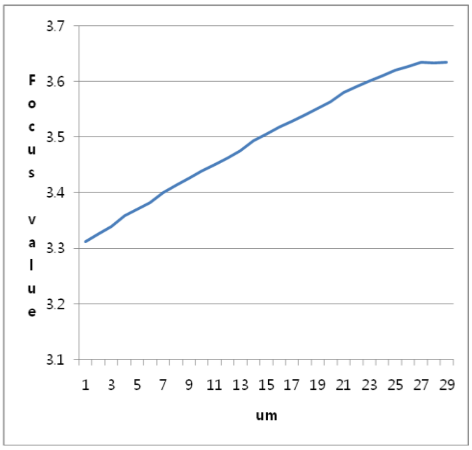



**Figure 6. The Auto Focus Result**

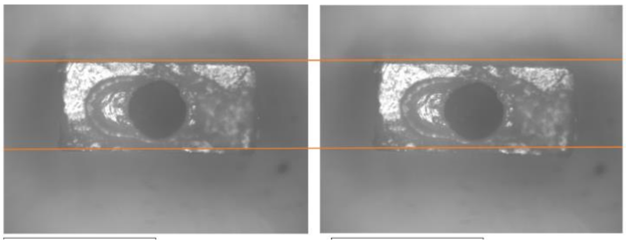


**Figure 7. Image Correction Result**

The reference image is generated by CAD file (dxf file) and converted to image coordinates to detect the difference of image and CAD. The Figure 7 shows generated reference images.

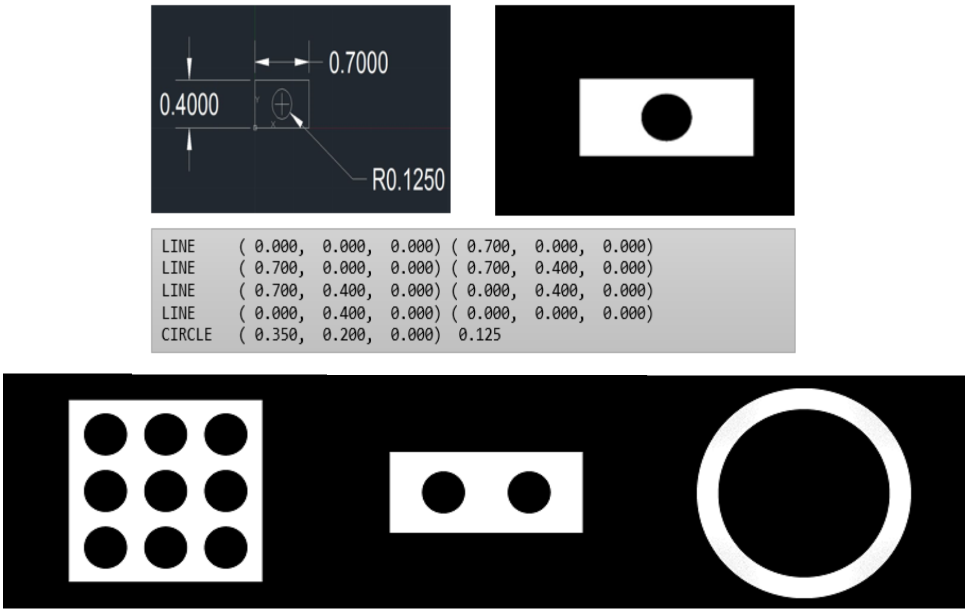



**Figure 7. Reference Image Generated from CAD Data**

The collet is consists of line and circle. The circle is one of most important geometrical feature to location of center of collet. The circle can be detected by blob area and also Hough circle transform. Figure 8 shows the calculated circle by two methods. These circle centers are used to locate collet to center of image.

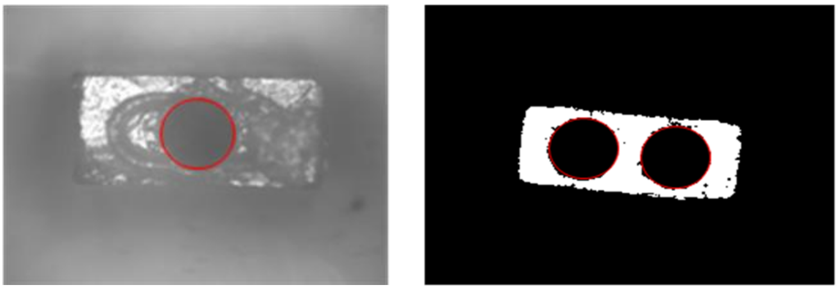


**Figure 8. Circle Detection by Circle Hough Transform**

When the number of circle is single, one of circle center is used as reference of image center. In case of even number of circle, the average value of center location of circles are used as reference of image center.

The all line edges in captured image are calculated by Hough transfrom. These line edge information were used firstly to correct rotation angle of the collet to compare to reference image and were also used to calculate the outer size of every collet. The final image processing algorithm is shown in Figure 8.

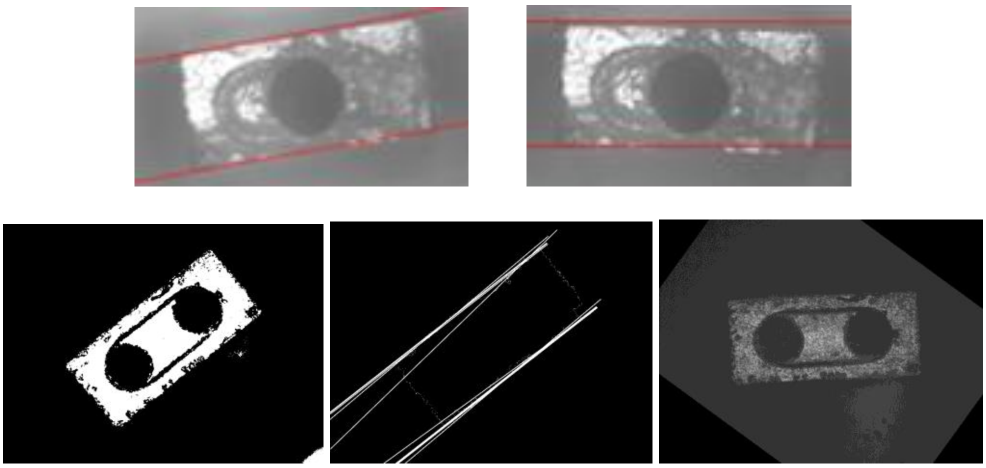


**Figure 9. Rotation Correction by line Hough transform**

## 4. Experimental Results

Finally, defect is detected by subtraction of calibrated image and reference image. The result of our proposed algorithm is shown in Figure 9. The size difference of rectangle and hole are detected by comparing the reference image generated by CAD data. The size error of hole can be calculated by counting number of pixel of circle part, and the size of error of rectangular also calculated as same way. If the number of pixel exceeds the threshold, it can be error of size. The total image algorithm is shown in Figure 10.

The 6 different types of collets are used to test the performance of proposed vision system. Each of collet has 100 samples. Our proposed defect inspection algorithm is simple pattern matching based algorithm but fast with reasonably high accuracy of 99.33% success rate. Table 2 shows our inspection results.

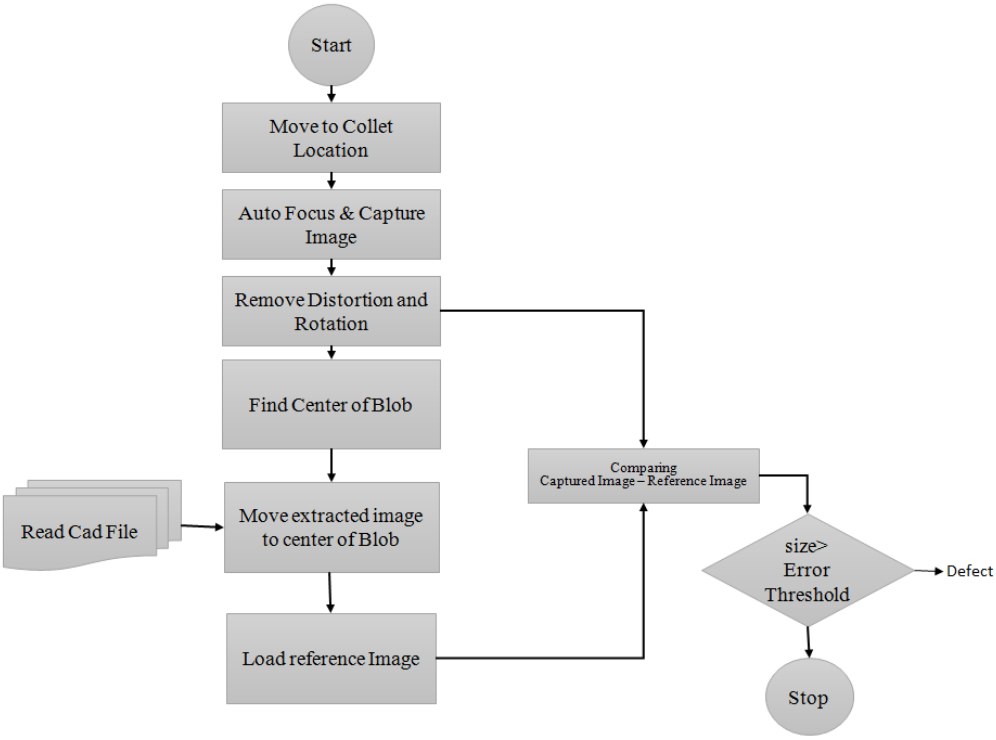
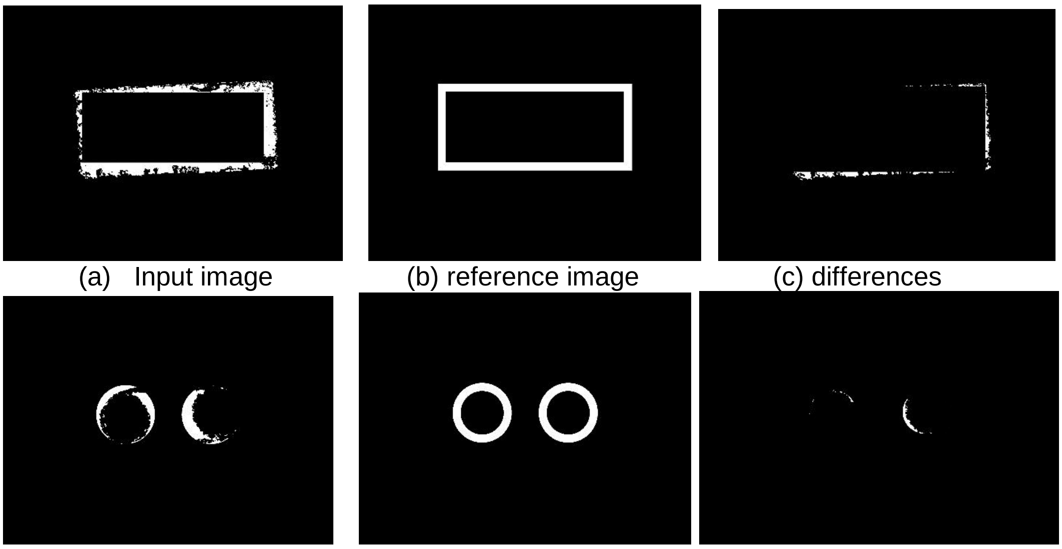



**Figure 8. Image Processing Algorithm**



(a) Input image (b) reference image (c) differences

(d) Input image (e) reference image (f) differences

**Figure 9. Image Comparison Method**

**Table 1. Inspection Results**

| *Inspection system* | *Number of Total trial* | *Number of Success* | *Number of Fail* | *Ratio (%)* |
|---|---|---|---|---|
| Collet type 1 | 100 | 99 | 1 | 99% |
| Collet type 2 | 100 | 99 | 1 | 99% |
| Collet type 3 | 100 | 100 | 0 | 100% |

| | | | | |
|---|---|---|---|---|
| Collet type 4 | 100 | 99 | 1 | 99% |
| Collet type 5 | 100 | 99 | 1 | 99% |
| Collet type 6 | 100 | 99 | 0 | 99% |
| Total | 500 | 596 | 4 | 99.33% |

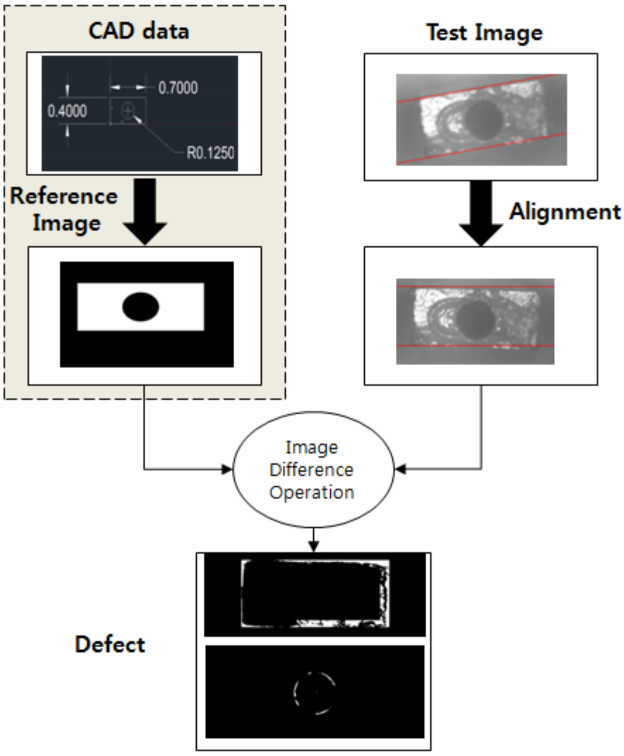



**Figure 10. Image Processing Algorithm**

## 5. Conclusion

The experimental result shows that our algorithm is very effective to inspect defects of collet image. The requested minimum size of error is within 4um and we can easily detect the size defect of collet. We analyze the image of unsuccessful results. The collet surface is contaminated and good images can be not acquired.  They make difficult to match and identify defect of collet. The total speed of inspection is maximum 3.5 sec per one collet. 1~2 sec is required for auto focus and 0.3 sec for inspect image and 1~1.5sec to move next collet position. We must increase the performance of image acquisition system

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