

A Method and a System for Creating
a Reference Image using unknown quality
patterns.

5 **FIELD OF THE INVENTION**

The present invention relates to the field of
automatic optical inspection systems and methods.
More specifically, the present invention relates
to a method and system for creating reference
10 image of a pattern.

BACKGROUND OF THE INVENTION

Automatic optical inspection systems use image
15 processing and dedicated algorithms to inspect
patterns that are located on a surface. The
present invention relates to this area and
particularly for inspection of circles on a PCB
or dice on a wafer in order to recognize, analyze
20 and classify defects.

Commonly, a reference image of a die is used to
inspect the on-wafer dice by comparison each die

with a reference image of the die. This reference image is acquired from the wafer, which unfortunately has production residues. Indeed, correction methods and techniques are used to
5 achieve better reference image but some of residues are still remained and interfere the inspection process.

The present invention provides a method and a
10 system that enables to achieve a clean reference image from unknown quality dice's images, which were acquired from a real unknown quality wafer.

SUMMARY OF THE INVENTION

15 The present invention is a method and a system for creating a reference image-model for inspecting patterns on a surface, useful particularly for inspection of dice on a wafer or repeatable circles on PCB.

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According to the teachings of the present invention there is provided a method for preparing a pattern's reference-model to be used

for automatic inspection of surface that includes a plurality such pattern, this method comprising:

- acquiring images of a plurality of the pattern;
- 5 ▪ aligning all of the images, in a common coordinate system;
- correcting the images; and
- creating a reference-model image, wherein each pixel in the created
- 10 reference-model image is made by choosing the best pixel of the same located and same coincident pixel of these images.

15 According to another aspect of the present invention the method is also provided wherein the pattern is a die, the surface is a wafer and the reference-model is made for inspecting dice on a wafer.

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According to another aspect of the present invention the method is also provided wherein the

images' correction includes geometrical-correction that optionally includes shift, rotation, scale, shrink, local distortion or any other geometrical-correction and radio-metrical-
5 correction of the gray level of each pixel by using plurality of well known technique.

According to another aspect of the present invention the method is also provided wherein the
10 choice of each pixel for creating the reference-model image includes the following steps:

- collecting the coincident pixels in same location from each of images;
- sorting the collected pixels by gray level
15 value; and
- choosing a pixel from the largest pixels-cluster in the sort distribution.

According to yet another aspect, the method
20 is also provided wherein a cluster is defined as a group of pixels' values that the distance

between each of its member is smaller than a predetermined value.

Moreover, the method is also provided wherein
5 the chosen pixel is the median pixel of the largest pixels-cluster.

According to another aspect, the mentioned method further includes additional calculation to
10 be stored corresponding to each pixel for use with the inspection algorithms, these calculations are:

- finding the median of the largest cluster;
- finding MIN value of the cluster and
15 applying cross kernel or 3x3 kernel or any other Min-Max kernel to find the MIN of gray level from pixels covered by kernel ; and
- finding MAX value of the cluster and
20 applying cross kernel or 3x3 kernel or any other Min-Max kernel to find the MAX of gray level from pixels covered by kernel.

According to another sequence of the provided method is further includes the step, before creating reference-model image:

- applying one of the Min-Max kernel on all
5 pixels of the images.

According to the mentioned sequence, the provided method is further includes additional calculation to be stored corresponding each pixel
10 for use with the inspection algorithms, these calculations are:

- finding the median of the largest cluster;
- finding MIN value of the cluster ; and
- finding MAX value of the cluster.

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According to another aspect of the present invention it is provided a system for preparing a pattern's reference-model to be used for automatic inspection of surface that includes
20 such patterns, this system comprising:

- imaging device that captured images of plurality of the patters;

- dedicated software that uses dedicated algorithms to correct and align the captured images; and
- a controller operative for:

- 50 collecting the same located and same coincident pixel of each of the images;
- o collecting the same located and same coincident pixel of each of the images;
- o choosing, according to predetermined
- 10 criteria, one of the collected pixels;
- o creating a new image with same dimensions as the captured images and locating the chosen pixel in the same place corresponding to the place of the collected pixels in the origin images;
- 150 repeating the process as defined above for each pixel of the captured images; and
- o providing the new created image as a reference model for inspecting the pattern.

20 According to a preferred embodiment of the present invention, the system is provided wherein the controller is further operative for choosing pixels from the collected pixels by the way of

sorting the collected pixels by gray level value and choosing a pixel of the largest pixels-cluster of the sorting distribution.

5 According to another preferred embodiment of the present invention, the system is provided wherein the chosen pixel is the median pixel of the largest pixels-cluster.

10 According to another preferred embodiment of the present invention, the system is provided wherein the cluster is defined as a group of pixels' values that the distance between each of its member is smaller than a predetermined value.

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 According to yet another preferred embodiment of the present invention, the system is provided wherein the controller is further operative for additional calculations to be stored
20 corresponding each pixel for use with the inspection algorithms, these calculations are:

- finding and storing the median of the largest cluster;
 - finding and storing MIN value of the cluster ; and
- 5 ▪ finding and storing MAX value of the cluster.

BRIEF DESCRIPTION OF THE FIGURES

The invention is herein described, by way of example only, with reference to the accompanying
10 drawings. With specific reference now to the drawings in detail, it is stressed that the particulars shown are by way of example and for purposes of illustrative discussion of the preferred embodiments of the present invention
15 only, and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made
20 to show structural details of the invention in more detail than is necessary for a fundamental understanding of the invention, the description

taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

In the figures:

5 Figure 1 illustrates a flow chart of the method according to the present invention.

Figure 2 illustrates the pixel's choosing method.

Figure 3 and 4 illustrate the cross-kernel and 3x3 kernel, and example of Min-Max operation.

10 Figure 5 illustrates the difference between a reference image that was acquired from the wafer and a reference image of the same die that "designed" by using the method of the present invention.

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DESCRIPTION OF THE PREFERED EMBODIMENTS

The present invention is a method and a system for creating a reference image-model for
20 inspecting patterns on a surface, useful particularly for inspection of dice on a wafer.

Usually, reference image is an improved image of a die that was improved by using correcting techniques and algorithms. The present invention provides, actually, a method and a system to
5 design a reference image. The designation is done by choosing the best pixel from the appropriate pixels of several image of same pattern.

Moreover, the method and the system are
10 calculating and storing values that can be used by the inspection algorithms.

The principles and operation of the method and the system according to the present invention may be better understood with reference to the
15 drawing and the accompanying description.

Referring now to the drawing, Figure 1 illustrates a flow chart of the method according to the present invention. Images of N patterns
20 are acquired **1, 2, , , N**. Starting from the first pixel of each image and collecting the coincident pixels - first pixel **11a** from the

first image **1**, second pixel **11b** from the second
image **2** and so on until the last pixel **11n** from
the last image **N**. All these pixels are from the
same location - e.g., from the bottom left corner
5 of the image (or X1Y1 coordination). According to
a predetermined criteria, selecting **13** the best
pixel of these collected pixels, for example
sorting the pixels by gray level value and
choosing a pixel from the most significant
10 cluster of the distribution e.g., the median
pixel.

The selected pixel **11** is used to design a
new reference image Ref. The selected pixel **11** is
15 embedded in the new image in the same location as
the location of the collected pixels (e.g., from
the bottom left corner of the image). The same
process is done for each pixel and a new image
Ref. Is built e.g., the coincident pixels **12a**
20 from first image **1**, **12b** from second image **2** and
so on until **12n** from last image - are collected

and one of them is selected **13** and located in the coincident place **12** in the new image **Ref.** - when the process is finished, a clean reference image-model **Ref.** is provided.

5 Figure 2 illustrates the pixel's choosing method. Ordering **14** pixels (1 to 7) according to ascending gray level values (1 is the smallest 7 is the biggest). Clustering **15** of pixels according to gray level distance between the
 10 pixels [$D = \text{GPixel}(i) - \text{GPixel}(i-1)$] where i indicates sample index.. A sub cluster **16** value based on the distance criteria $D \cdot C$ (where C is some selected factor). Both D and C are depicted as D **17** in based on gray level distance between
 15 pixels [$D = \text{GPixel}(i) - \text{GPixel}(i-1)$] where i indicates sample index and C **18** is a distance weight coefficient C (e.g. = 1.5)

Figure 3 and 4 illustrate the results of applying cross-kernel and 3x3 kernel. The neighbor pixels
 20 information is useful in the inspection process. By applying cross-kernel - Figure 3 - obtaining

information regarding four neighbors **19** and by applying 3x3 kernel - Figure 4 - obtaining information regarding nine neighbors **20**.

Figure 5 illustrates the difference between a reference image that was acquired from the wafer and a reference image of the same die that "designed" by using the method of the present invention. The reference image that was acquired from the wafer **21** suffers from defects and stains **22** and on the other hand the designed reference image **23** is clean and significantly better for automatic inspection.

Although the invention has been described in conjunction with specific embodiments thereof, it is evident that many alternatives, modifications and variations will be apparent to those skilled in the art, accordingly, it is intended to embrace all such alternatives, modifications and variations that fall within the spirit and broad scope of the appended claims.

WHAT IS CLAIMED IS:

1. A method for preparing a pattern's reference-model to be used for automatic inspection of surface that includes a plurality such pattern, said method comprising:
 - acquiring images of a plurality of said unknown quality pattern;
 - aligning all of said images, in a common coordinate system;
 - correcting said images; and
 - creating a reference-model image, wherein each pixel in said created reference-model image is made by choosing the best pixel of the same located and same coincident pixel of said images.
2. The method of claim 1, wherein said pattern is a unknown quality die, said surface is a wafer and said reference-model is made for inspecting dice on a wafer.
3. The method of claim 1, wherein said images' correction includes geometrical-correction that optionally includes shift, rotation,

scale, shrink, local distortion or any other geometrical-correction and radio-metrical-correction of the gray level of each pixel by using plurality of well known technique.

4. The method of claim 1, wherein the choice of each said pixel for creating said reference-model image includes the following steps:
 - collecting said coincident pixels in same location from each of said images;
 - sorting said collected pixels by gray level value; and
 - choosing a pixel from the largest pixels-cluster in said sort distribution.
5. The method of claim 4, wherein said cluster is defined as a group of pixels' values that the distance between each of its member is smaller than a predetermined value.
6. The method of claim 4, wherein said chosen pixel is the median pixel of said largest pixels-cluster.

7. The method of claim 4, further includes additional calculation to be stored corresponding to each pixel for use with the inspection algorithms, said calculations are:
- finding the median of said largest cluster;
 - finding MIN value of said cluster and applying cross kernel or 3x3 kernel or any other Min-Max kernel to find the MIN of gray level from pixels covered by kernel ; and
 - finding MAX value of said cluster and applying cross kernel or 3x3 kernel or any other Min-Max kernel to find the MAX of gray level from pixels covered by kernel.
8. The method of claim 1, further includes the step, before creating reference-model image:
- applying one of the Min-Max kernel on all pixels of said images.
9. The method of claim 8, further includes additional calculation to be stored corresponding each pixel for use with the inspection algorithms, said calculations are:

- finding the median of said largest cluster;
- finding MIN value of said cluster ; and
- finding MAX value of said cluster.

10.A system for preparing a pattern's reference-model to be used for automatic inspection of surface that includes such patterns, said system comprising:

- imaging device that captured images of plurality of said patterns;
- dedicated software that uses dedicated algorithms to correct and align said captured images; and
- a controller operative for:
 - o collecting the same located and same coincident pixel of each of said images;
 - o choosing, according to predetermined criteria, one of said collected pixels;
 - o creating a new image with same dimensions as said captured images and locating said chosen pixel in the same place

- corresponding to the place of said collected pixels in the origin images;
- o repeating the process as defined above for each pixel of said captured images; and
- o providing said new created image as a reference model for inspecting said pattern.

11. The system of claim 10, wherein said controller is further operative for choosing pixels from said collected pixels by the way of sorting said collected pixels by gray level value and choosing a pixel of the largest pixels-cluster of said sorting distribution.

12. The system of claim 11, wherein said chosen pixel is the median pixel of said largest pixels-cluster.

13. The system of claim 11, wherein said cluster is defined as a group of pixels' values that the distance between each of its member is smaller than a predetermined value.

14. The system of claim 11, wherein said controller is further operative for additional calculations to be stored corresponding each pixel for use with the inspection algorithms, said calculations are:

- finding and storing the median of said largest cluster;
- finding and storing MIN value of said cluster ; and
- finding and storing MAX value of said cluster.