Vision Inspection of Wire Bonding Position of Leadframe IC

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Abstract

In this paper, a vision system that can auto-inspect the correctness of the wire bonding position of leadframe ICs automatically was proposed. The proposed system can fully solve the overkill and missing problems that occur in wire bonding process. A new vision inspection method that integrates image processing and the bonding position check (BPC) technique was proposed. Experimental results show that the proposed system is robust and fast enough to be applied for inspecting the leadframe IC synchronously with the wire bonding process.

Keywords: Vision inspection, Bonding position check, Wrong bonding

1. Introduction

Wire bonding is a process that makes the connection between an IC chip and the base material. Each of the connections on an IC chip is called a pad. The interval between two adjacent pads is generally referred to as a pitch. The internal connector on the base material is called a lead. Typically, a gold wire is used to connect the pad and corresponding lead. A bonding ball is formed on the pad, while a bonding stitch is formed on the lead. But one lead might be formed more than one bonding stitch. The image of a sample chip is shown in Fig. 1. Fig. 2(a) is a single unit of a leadframe without the IC chip (before the die was attached). A part of the enlarged wire-bonded IC image is illustrated in Fig. 2(b).

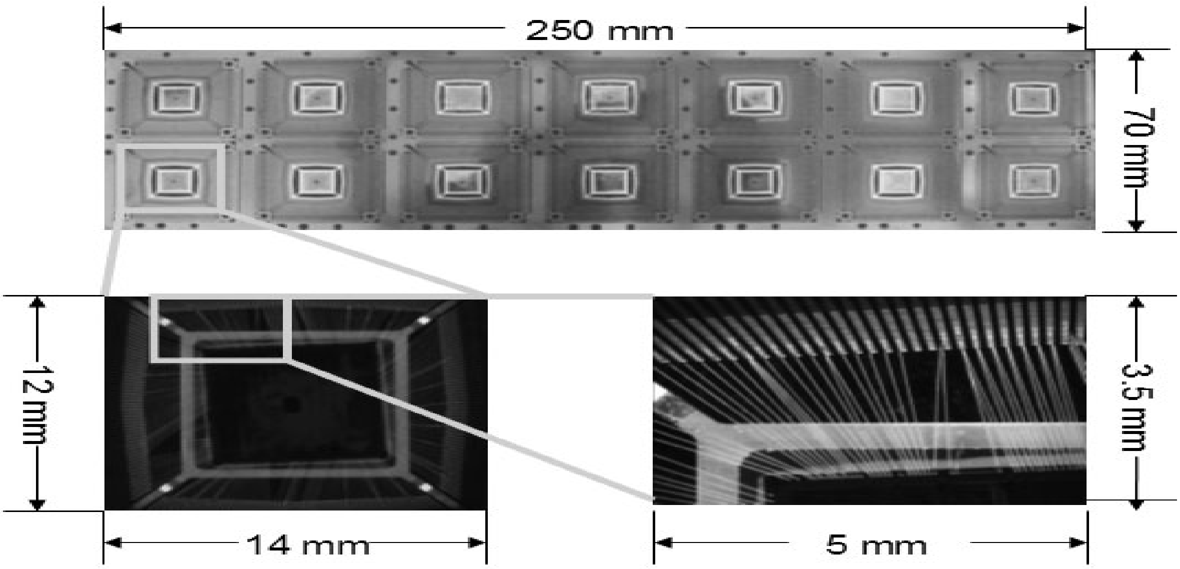
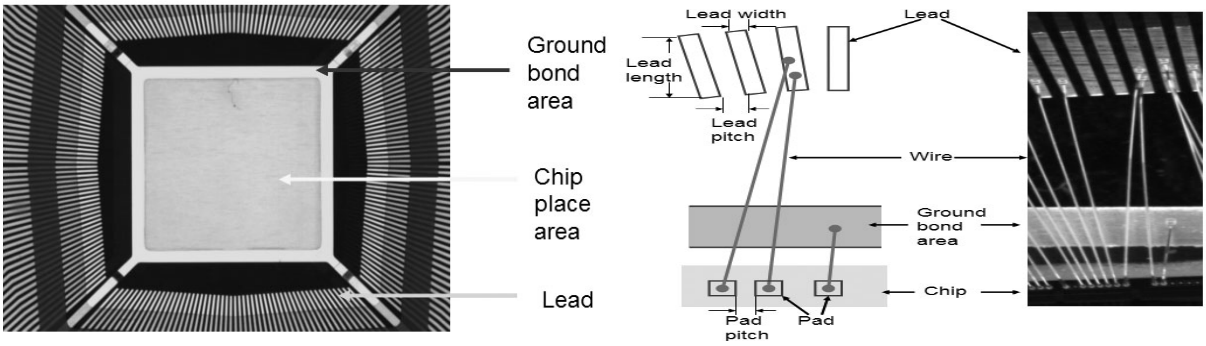


Fig. 1. Diagram of IC chips with bonding wires on the base material (leadframe)



(b) Single-unit leadframe before the die was attached. (c) Illustrative and enlarged wire-bonded IC image.

Fig. 2. Image of the single-unit leadframe and enlarged image of a wire-bonded IC.

Before the wire bonding process, the R&D department will generates the bonding diagram with the wire bonding position, as shown in Fig. 3(a). For each production order, the production engineers will firstly set up the wire bonder, in about 2 to 3 hours, with the correct wire bonding positions on the basis of the given bonding diagram as a referential machine (RM) after detailed verification. Subsequently, the engineer duplicates the RM’s bonding program in the other wire bonders. These wire bonders are the waiting verification machines (WVMs). In duplicating the bonding program, it is necessary to calibrate the bias of all the machines manually. During the tedious setup process, it is inevitable to mis-setup the wire bonding position, such as wire bonding position shifted away from the correct lead, and will result in the wrong bonding. Fig. 3(b) is an illustration of a magnified part of Fig. 3(a) that shows correct bonding. Fig. 3(c) shows an example of wrong bonding in which a wire shifts to the other lead—an incorrect position. Fig. 3(d) shows a wire bonded to a position that is slightly higher than the designed position. However, it is still on the same lead and is accepted as correct bonding. Fig. 3(e) shows a ground bond that shifts slightly to the right but is still in the correct position.

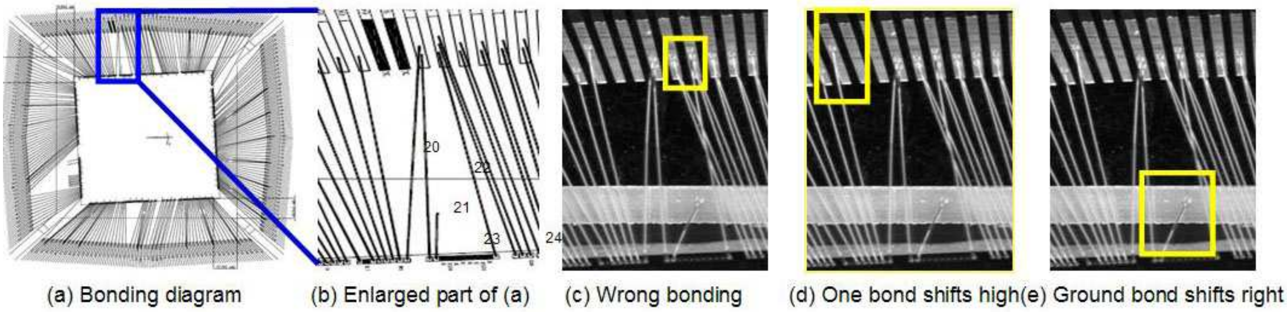


Fig. 3. (a) Diagram of a wire-bonded IC. (b) An enlarged image of a part of (a) magnified. (c), (d), (e) Enlarged images of some bonding samples.

Wrong bonding is a serious problem in the wire bonding process and it is non-reworkable – cannot be repaired to correct bonding. Therefore, it is very critical to ensure that all the wire bonding positions are correct. Most IC packaging foundries rely on human inspection and verification to ensure the wire bonding positions correctly. Such manual inspection is prone to error and cannot be synchronous with the machine’s throughput.

With the development of automatic optical inspection (AOI) technology, the IC packaging foundries attempted to improve the wire bonding position inspection by using an AOI system [1-7]. The recent researches on wire bonding inspection focused on the bonding position check (BPC) method [8]. The wire bonding position is checked as per the SEMI SECS/GEM communication protocol to obtain the bonding program from the wire bonder. The [X, Y] coordinate value for each wire can be obtained by decoding the bonding program. The obtained X and Y coordinate values of WVM are compared with the stored referential X and Y coordinates of RM. The shift distance (D) between the WVM and RM coordinates is then calculated (see Fig. 4). Theoretically, the ending point coordinates of a pair of corresponding wires in the two wire bonders should be equal. When the distance is greater than the pre-designed allowable range (R), this wire is marked as a wrong bonding. R is generally set to be as large as the lead pitch. The inspection speed is required to be fast enough that the inspection system can be implemented in and synchronous with the wire bonding system.

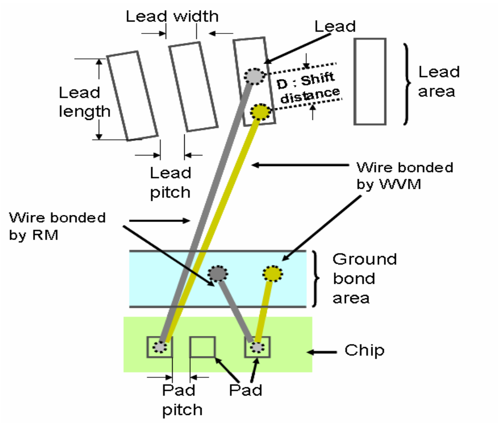


Fig. 4. Illustration of the pseudo-overlapping image of two pairs of corresponding wires. The two dark lines are the wires bonded by the RM. The other two bright lines are the wires bonded by the WVM.

However, for the IC product of leadframe base material, the base material is fabricated by punching or etching. Compared with the other IC products of substrate base material, which is fabricated by using a mask, the leadframe base material has the problem of high variation and low accuracy for each lead on it. This implies that the lead will be variably shifted in the punching or etching process. In practice, the allowable shift distance for each lead is less than 1 mil. It is important to calibrate the shift distance of each wire bonder before bonding because each wire bonder has a different mechanical bias, which will affect the accuracy of the lead location.

Therefore, the overkill problem might occur frequently when ordinary BPC method is implemented. The overkill problem is that the wire is bonded in the correct position but is recognized as a wrong bonding. The overkill problem for the “Ground Bond” wire is the most critical because the allowable shift in the ground bond is equal to the area of the entire chip place area. That is why the BPC method is implemented solely for the product of substrate base material in the past. Therefore, the objective of this study is to design and develop a vision inspection system that can capture the image of leadframe ICs and can verify the correctness of bonding position of each wire.

The rest of this paper is organized as follows. In section 2, a survey report on previous researches pertaining to wire bonding position inspection is presented. The approach and algorithm of the proposed vision inspection system is described in section 3. An inspection and the performance analysis of the proposed system along with the related experimentation are presented in section 4. Finally, in section 5, the conclusions are presented and further researches are suggested.

2. Literature Review

In the wire bonding inspection process, the inspectors focused on (a) the position of the bonding wire and (b) the contour and position of the bonding ball [9]. Khotanzad *et al*. [1, 2] presented an automatic system for evaluating the quality of the bonding ball. Their system could determine the location of the bonding ball from a 2D image of an IC wafer and it could extract geometrical information on the contour of the bonding ball.

Perng *et al*. [3–5] devised a vision inspection system equipped with a structured lighting system to highlight the bonding wire. Lim *et al*. [10] presented an auto-focusing technique to measure the height and diameter of the bonding ball. Their method can also be used for the inspection of missing bonds and for wire loop height measurements. Speed is the major concern and it took 7 seconds to inspect a single wire [11].

3. Vision System for Wire Bonding Position Inspection

Though the BPC method can meet the requirement of high speed for on-line inspection, some issues pertaining to mal-detection (overkill) and lost detection (missing) are yet to be solved. The mal-detection and lost detection problems are defined and described below.

Definitions:

Overkill: The ending point of a wire is actually bonded on the correct lead but is mal-detected as a wrong bonding case. When the shift distance D is greater than allowable range R, the system recognizes the bonded wire as having shifted to the other lead.

Missing: A wire is bonded on a wrong lead but is recognized as a correct bonding case. When R is set to be greater than or equal to D, the system incorrectly recognizes the shifting wire to be correctly bonded.

An example of overkill is illustrated in Fig. 3(d), in which the lead length is 26 mils. This means that the maximum possible shift distance of the wire is 26 mils and the bonded wire is still on the targeted lead. Comparing the image of the wire numbered 20 in Fig. 3(b) with that in Fig. 3(d) we can observe that the end point of the wire on the lead side shifts upward. In Table 1, we list the results obtained by applying the BPC method in the case in Fig. 3. The actual value of D for the wire numbered 20 is 11.88 mils. Because the lead pitch is 3.7 mils, R is set to be 3.7 mils. The BPC method will recognize this wire as a wrong bonding (11.88 > 3.7) and will cause overkill.

The overkill problem could be reduced if R could be considered to be equal to the maximum possible D. However, release R might cause the problem of missing. For example, the BPC method can correctly recognize the wire numbered 24, which shifts 8.45 mils and is not on the correct lead. If R is released to 11.88 mils, none of the overkill wires numbered 20 and 23 will be recognized as being incorrectly bonded. However, the wire numbered 24 that is incorrectly bonded will also be recognized as being correctly bonded and missing will occur

Table 1. An example of apply BPC method to the case in Fig. 3. In the last two columns on the right-hand side, “P” indicates system check passed and “F” denotes system check failed.

Wire Number	End point coordinates bonded by RM		End point coordinates bonded by WVM		Shift distance (D)	BPC Result for R=3.7	BPC Result for R=11.88
	X	Y	X	Y			
......							
19	315.29	48.17	316.54	48.07	1.25	P	P
20(Overkill)	**322.88**	**47.95**	**321.24**	**36.08**	**11.88**	**F**	**P**
21	344.22	42.71	345.5	42.14	1.4	P	P
22	344.95	46.52	346.17	46.02	1.32	P	P
23(Overkill)	**351.97**	**117.4**	**362.4**	**116.14**	**10.51**	**F**	**P**
24(Missing)	**351.01**	**38.1**	**359.45**	**37.72**	**8.45**	**F**	**P**
......							

The major drawback with the BPC method is that the bonding position of the wire is decided by comparing the positions, not utilize the actual information on the lead position.. We will extract more bonding positions of the wires on the lead and check for the correctness of the positions bonded by the RM and every WVM. Only when the wire positions bonded by the RM and WVMs are on the same lead can we guarantee that the wire bonding is correct. The entire process of wire bonding position inspection was illustrated in Fig. 5.

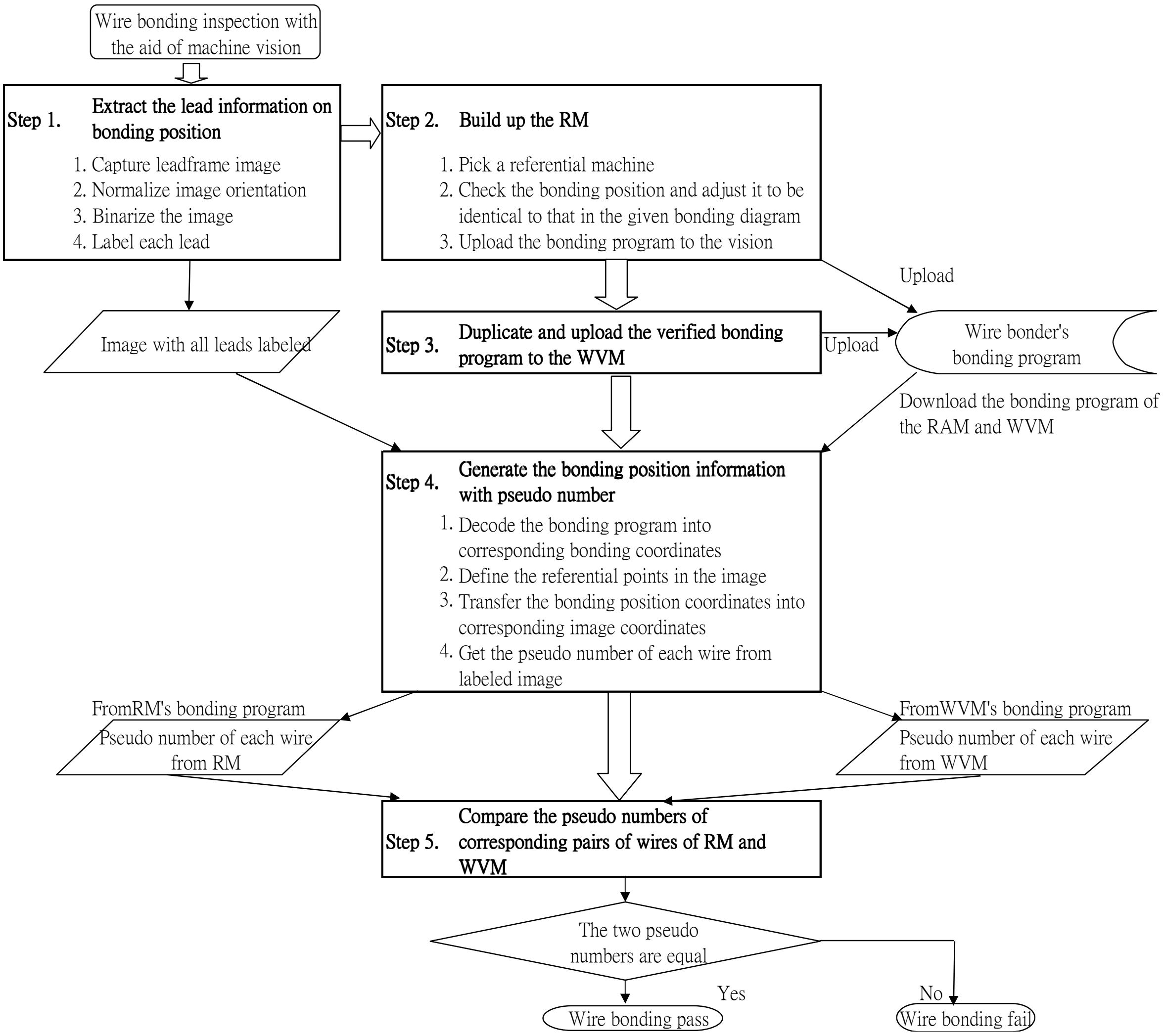
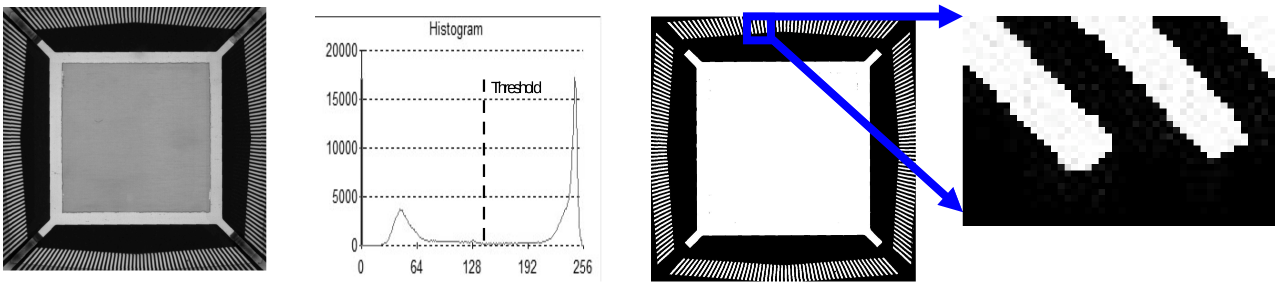


Fig. 5. Flow chart of wire bonding position inspection of the proposed machine vision approach

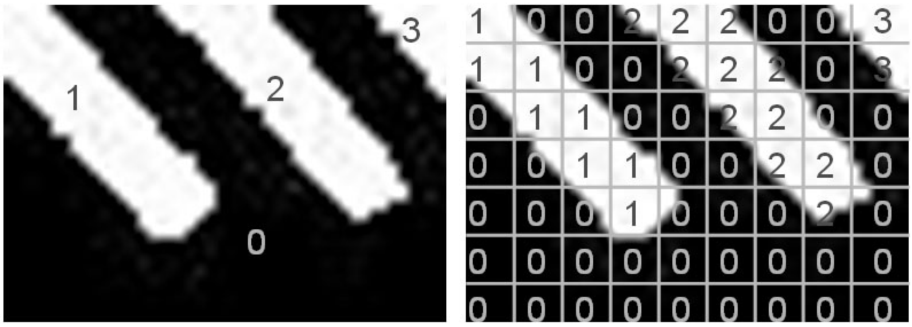
Step 1: Extract the lead information of the bonding position

Firstly capture the image of the leadframe as $I(l)$ and normalize the orientation of the captured image to align it in a predefined position. Then binarize $I(l)$ to be $I_b(l)$ so that each lead on $I_b(l)$ will be a solid line. A near-bimodal distribution of the gray-level histogram of $I(l)$ will be obtained and is showed in Figs. 6(a-d). The valley-emphasis method [12] is used to auto-select an optimal threshold value. Finally, label each solid line (lead) on the binary image $I_b(l)$ with a unique pseudo code. The pseudo number starts from 1, as shown in Fig. 6(e). All the pixels of the same solid line are given the same pseudo number. A labeled image $I_c(l)$ will then be derived from the binary image $I_b(l)$. Store the set of pseudo numbers in a 2D array $I_c(l)$[x, y], where [x, y] is the coordinate value of the pixels, as shown in Fig. 6(f).

Note: Such a pseudo number set is used for bonding position verification.



(a) Leadframe image $I(l)$ (b) Threshold selection (c) Binary image $I_b(l)$ (d) Enlarged sub-image of (c)



(e) Labeled image $I_b(l)$ (f) Store the pseudo number in array $I_c(l)$[x, y]

Fig. 6. Image binarize and labeling

Step 2: Build up the RM

The engineer randomly selects one wire bonder as an RM firstly and the engineer checks the bonding positions of the wires bonded by using the RM and adjusts them to ensure they are the same as those in the designed bonding diagram. Then the engineer uploads the bonding program of the RM to the vision inspection system via the SEMI SECS/GEM communication protocol.

Step 3: Duplicate and upload the verified bonding program to other WVMs.

The engineer duplicates and uploads the verified bonding program of the RM to other wire bonders, which are the WVMs, for mass production. Due to the machine bias, it is inevitable that the wire bonding position setup operation is mishandled during duplication. The wire positions bonded by all the WVMs have to be verified to make sure that they are identical to those bonded by the RM.

Step 4: Generate the wire bonding position information with pseudo code

A bonding program contains: (a) the bonding sequence of each wire and the coordinates of the starting point (pad side) and ending point (lead side) for each wire. (b) The coordinates of calibration marks on both the leadframe and IC chip. While attaching a die on an IC chip, varying shifts and rotations may occur with regard to the die. The calibration mark is used as a reference in such a case.

We decode the bonding program into the corresponding bonding coordinates firstly. In the case of the RM and WVMs, the XY coordinates of the ending point of each wire (j), $P_l(X_{RM(j)}, Y_{RM(j)})$ and $P_l'(X_{WVM(j)}, Y_{WVM(j)})$ on the lead side and $P_c(X_{RM(j)}, Y_{RM(j)})$ and $P_c'(X_{WVM(j)}, Y_{WVM(j)})$ on the pad side, are recorded and used as the referential coordinates and the waiting verification coordinates.

Secondly, define the calibration marks in the image. The XY coordinates of the two calibration marks on the lead side and the other two calibration marks on the pad side can be recorded as L1(X_{L1}, Y_{L1}), P1(X_{P1}, Y_{P1}), P2(X_{P2}, Y_{P2}), L2(X_{L2}, Y_{L2}) from the left to the right. If we define the upper left point of the image as the origin (X,Y) = (0,0) of this image, the coordinates of the four calibration marks in the image can then be determined accordingly, say IL1(X_{IL1}, Y_{IL1}), IP1(X_{IP1}, Y_{IP1}), IP2(X_{IP2}, Y_{IP2}), IL2(X_{IL2}, Y_{IL2}) from the left to the right, as shown in Fig. 7.

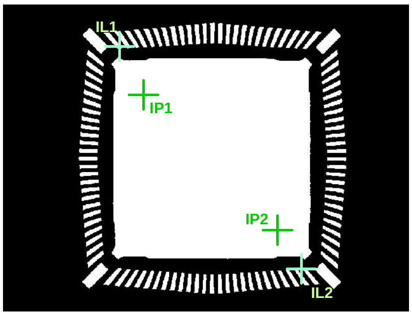


Fig. 7. Illustration of the calibration marks in the leadframe image generated from Step 1.

Thirdly, convert the coordinates of the actual bonding position into the corresponding image coordinates. Here, we use the lead side as the example. Assuming that there is a bonding position with coordinate (Xs, Ys) on the lead side, this position will be mapped into the image $I_c(l)$ with the coordinate (Xi, Yi) according to the equations (1). Δx = $X_{IL1} - X_{L1}$ and Δy = $Y_{IL1} - Y_{L1}$ are the shift distance in the x-axis and y-axis. ℓx = (X_{IL2} - X_{IL1}) / (X_{L2} - X_{L1}) and ℓy = (Y_{IL2} - Y_{IL1}) / (Y_{L2} - Y_{L1}) are the magnification in the x-axis and y-axis.

$$(Xi, Yi) = (\Delta x + (Xs - X_{L1}) \times \ell x,\ \Delta y + (Ys - Y_{L1}) \times \ell y) \qquad (1)$$

Fourthly, obtain the pseudo code of each wire from the labeled image. Based on the coordinate (Xi, Yi), the pseudo code of each pixel in the labeled image $I_c(l)$ can be obtained from the 2D array $I_c(l)$ [Xi, Yi]. For example, the end point $P_l(X_{RM(j)}, Y_{RM(j)})$ of a wire (j) on the lead side of the RM will be converted into new coordinates by equation (2) as follows.

$$[Xi, Yi] = [(\Delta x + (X_{RM(j)} - X_{L1}) \times \ell x), (\Delta y + (Y_{RM(j)} - Y_{L1}) \times \ell y)] \qquad (2)$$

All the pixels on this wire (j) will have the same pseudo code of

$$I_c(l)\,[(\Delta\mathrm{x} + (X_{RM(j)} - X_{L1}) \times \ell\mathrm{x}),(\Delta\mathrm{y} + (Y_{RM(j)} - Y_{L1}) \times \ell\mathrm{y})] \quad (3)$$

Step 5: Compare the pseudo codes of corresponding pair of wires of RM and WVM

On the lead side, we can compare the pseudo codes of a corresponding pair of wires of the RM and WVM to verify whether the wire position bonded by WVM is correct or not. On the pad side, every point of the IC chip is practically bonded with high accuracy and low variation so that the traditional BPC method can still be applied. Here, R is set to the same as the pad pitch. The algorithm for the wire bonding position comparison is given below:

Algorithm: Wire bonding position comparison

Input: The pseudo code of each wire on the lead side and the XY coordinate value of the starting point of every wire on the pad side

Output: The detected wire with wrong bonding

Procedure:

For j = 1 to N **do/* N is the total number of bonding wires */**

Case lead side :

If $(I_c(l)\,[(\Delta\mathrm{x} + (X_{RM(j)} - X_{L1}) \times \ell\mathrm{x}), (\Delta\mathrm{y} + (Y_{RM(j)} - Y_{L1}) \times \ell\mathrm{y})] - I_c(l)\,[(\Delta\mathrm{x} + (X_{WVM(j)} - X_{L1}) \times \ell\mathrm{x}),(\Delta\mathrm{y} + (Y_{WVM(j)} - Y_{L1}) \times \ell\mathrm{y})]) = 0$

/* If (the pseudo code of $P_l(X_{RM(j)}, Y_{RM(j)})$–the pseudo-code of $P_l'(X_{WVM(j)}, Y_{WVM(j)}) = 0$) ***/**

Then the wire bonding is passed

Else the wire bonding is failed

End if

End case

Case pad side :

If (D < = R) **then** the wire bonding is passed

/* $D = \sqrt{(X_{RM(j)} - X_{WVM(j)})^2 + (Y_{RM(j)} - Y_{WVM(j)})^2}$;

R = Shift tolerance range */

Else the wire bonding is failed

End if

End case

End for

End procedure

4. Experimentation and Result Analysis

The major problems concerned from high to low with the inspection of the bonding position in IC packaging foundries are (a) the overkill rate and missing rate, (b) the reliability in a mass production environment, and (c) the inspection speed. We used these parameters as the performance indicators to design the experiments to compare the performance of the BPC method with the proposed vision inspection method.

The first inspection experimentation involves an IC chip with 216 lead counts. The base material of this IC chip is a Cu leadframe. The lead width, lead length, and lead pitch of this IC chip, respectively, are 4, 26, and 3.7 mils. There are a total of 312 bonding wires, including 41 ground bonds. We randomly select three wires and adjust the bonding positions manually to let them shift from the original bonding position in the WVM, but still retain them on the same lead (i.e., to ensure correct bonding). Similarly, we randomly select the other wire and adjust its bonding position manually to let it shift from the original bonding lead so as to cause a wrong bonding in the WVM. Initially, the shift tolerance range R is set equal to the lead pitch (3.7 mils). We then repeat the wire bonding inspection steps as described in Section 3, by increasing the value of R by 2 mils each time when the BPC method is applied until no overkill can be found. The experimental results are recorded and a part of the image is shown in Fig. 8. The analyzed results are given in Table 2.

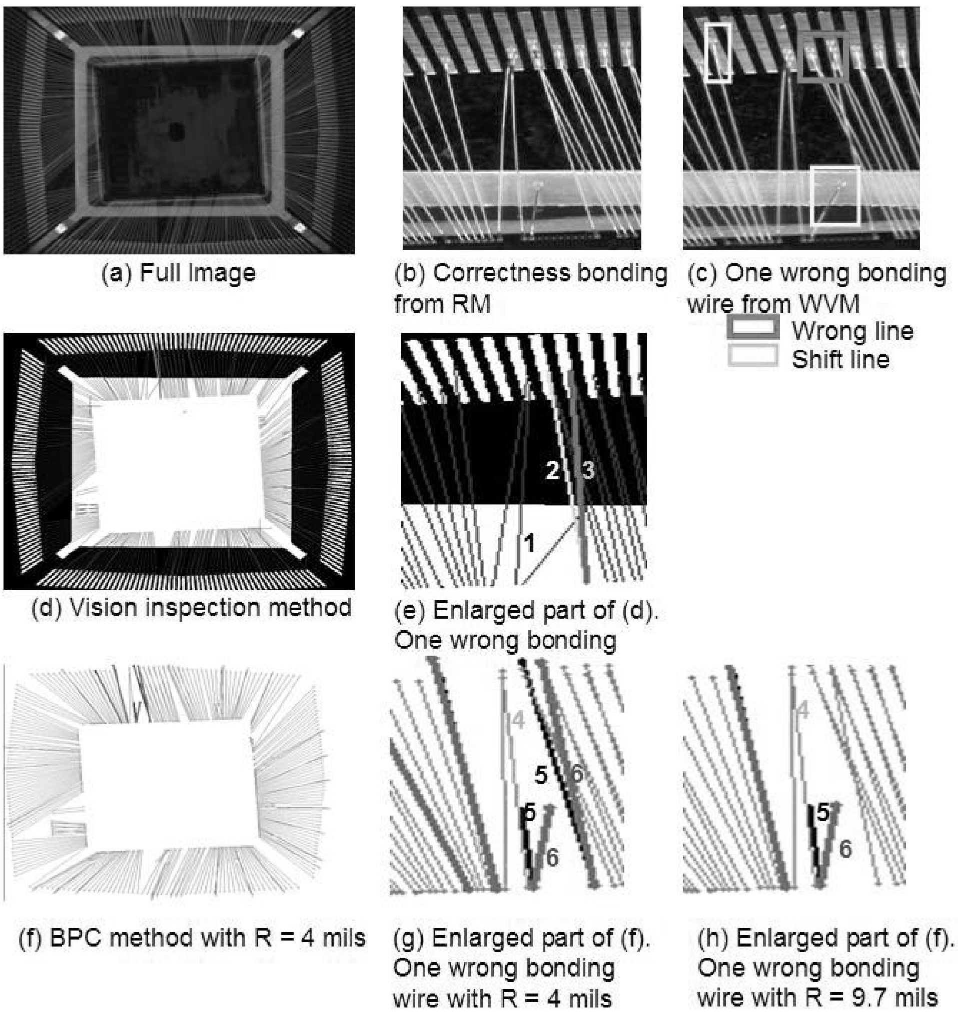


Fig. 8. Experimental results of inspecting IC.

Fig. 8(a) shows the full image of the chip. Fig. 8(b) is the partially enlarged image of the IC with the correct bonding wire in the RM. Fig. 8(c) depicts the partially enlarged image of the IC with a wrong bonding wire in the WVM. Figs. 8(d) and 8(e) are the results of applying the vision inspection method. In Fig. 8(e), the slim line (line 1) expresses the fact that the wire was identified as being correctly bonded by using the vision inspection method. Lines 2 and 3 represented the fact that they are wrong bonding wires (line 2 expresses the bonding position of the RM and line 3 expresses the bonding position of the WVM) that were identified by the vision inspection method. Figs. 8(f), 8(g), and 8(h) illustrate the results of applying the BPC method. The bright line (line 4) in Figs. 8(g) and 8(h) denote that this wire was identified as a correctly bonded wire by using the BPC method. The pair of dark lines (lines 5 and 6, where line 5 expresses the bonding position of the RM and line 6 expresses the bonding position of the WVM) in Figs. 8(g) and 8(h), respectively, represents the fact that they are wrong bonding wires; these wires were identified by the BPC method.

In Figs. 8(d) and 8(e), as a result of applying the proposed vision inspection method, no overkill or missing case can be found. On the other hand, the overkill case occured when the BPC method was applied. With regard to Figs. 8(f), 8(g), and 8(h), when the BPC method was applied, overkill occured. Comparing Fig. 8(c) with Fig. 8(g), we can find that line 6 is a shift wire and it is bonded on the correct lead, but the BPC method identified it as being incorrectly bonded. Moreover, when the shift tolerance range was increased to 9.7 mils (Fig. 8(h)), the missing case occured.

Table 2. Experimental results from the inspection of an IC with one man-made wrong bonding wire. The BPC method and vision inspection method about overkill rate and missing rate are compared by increasing the shift tolerance range by 2 mils each time. The initial shift tolerance range is set equal to the lead pitch (3.7 mils).

Tolerance range / Inspection method	3.7 mil		5.7 mil		7.7 mil		9.7 mil		11.7 mil		13.7 mil	
	Overkill	Missing	Overkill	Missing	Overkill	Missing	Overkill	Missing	Overkill	Missing	Overkill	Missing
BPC method	3	0	2	0	2	0	2	1	1	1	0	1
Vision inspection method	0	0	0	0	0	0	0	0	0	0	0	0

In Table 2, we can observe that when the BPC method was applied the missing case occured if the shift tolerance range was set at a value greater than or equal to 9.7 mils. Because the BPC method checks the correctness of wire bonding based on the shift distance, it does not have the actual information on the lead position and hence not all wrong bondings can be detected; some correct bonidngs may even be overkilled. When the vision inspection method was applied, because the actual information on the lead positions was utilized, no overkill or missing occured. All the bonding positions of the wires can be correctly identified.

To evaluate the feasibility of the proposed vision inspection method in a mass production environment, we implemented the proposed vision inspection method and the BPC method to a production line of 145 wire bonders. The overkill rate is the performance indicator that is focused upon. The selected production line produces the QFP (Quad Flatpack Package) product for wire bonding information collection. There are seven different lead counts for the QFP product to be inspected, as given in Table 3.

The results of applying the proposed vision inspection method and the BPC method to a mass production environment are listed in Table 3. We can observe that the overkill rate is very high for the BPC method, particularly for the products with the ground bond. On the other hand, no overkill occurs for the proposed vision inspection method.

Table 3. Experimental results from the application of the proposed vision inspection method and the BPC method in a mass production environment.

Type group / Inspection method				BPC method			Vision inspection method		
Lead Count	Wire Count	Machine Qty	Ground bond	Overkill rate	Max # of overkilled wires	Average # of overkilled wires	Overkill rate	Max # of overkilled wires	Average # of overkilled wires
64	116	4	Y	75%	8	2.75	0	0	0
100	100	54	Y	94.44%	12	5.48	0	0	0
128	131	7	N	42.86%	2	0.57	0	0	0
144	144	11	N	9.09%	20	1.82	0	0	0
176	183	20	N	10%	42	2.6	0	0	0
216	312	46	Y	95.65%	76	9.82	0	0	0
256	357	3	Y	66.67%	7	4.33	0	0	0

The proposed vision inspection method was implemented using Visual Basic and MIL 6.0. The computer hardware was a PC powered by Intel Celeron 1.6 GHz CPU. The proposed method takes only 3.4944 second to check an IC with 312 wires. In other words, it takes only approximately 0.0112 second to check a single wire. A brief comparison with other inspection methods is presented in Table 4.

Table 4. Wire bonding position inspection speed comparison of the proposed method and other inspection methods.

Algorithms	**Speed (second/per wire)**
BPC method	0.008
The proposed system	0.0112
The fastest commercial wire bonder	0.06
Machine Vision with lighting system [5]	0.08
Auto focusing [11]	7

At the present, the fastest commercial wire bonder needs about 0.06 second to bond a single wire [13]. The proposed method fast enough to be applied for inspecting the leadframe IC synchronously with the wire bonding production line.

5. Conclusions and Suggestions for Further Researches

In this paper, a novel vision system to auto-inspect the correctness of the wire bonding position was proposed and implemented. It is the first system that can automatically check the correctness of the wire bonding position of leadframe ICs. It can totally solve the overkill and missing problems that may occur in the BPC method. Experimental results showed that the proposed system was very efficient and effective, particularly good for the product that has ground bond.

The bonding program of the RM is used as the standard in inspecting the bonding balls and bonding wires. However, such a bonding program still has to be adjusted and modified by an operator. To enhance the inspection efficiency and prevent human errors, a program that can automatically check the bonding program with the original CAD file is required and is worth pursuing.

References

1. Khotanzad,A.,Banerjee,A.& Srinath,M.D. (1994). A Vision System for Inspection of Ball Bonds and 2-D Profile of Bonding Wires in Integrated Circuits. IEEE Transactions on Semiconductor Manufacturing. 7(4), 413-422

2. Khotanzad,A.,Banerjee,A.& Srinath,M.D. (1992). A Vision System for Inspection of Ball Bonds in Integrated Circuits. Proc. IEEE Workshop on App. of Comp. Vision. 290-297.

3. Perng,D.B., Chou,C.C.& Lee,S.M. (2003). A New Wire Bonding Inspection System by Machine Vision. 17th International Conference of Production Research, Blacksburg, Virginia.

4. Perng,D.B., Chou,C.C.& Lee,S.M. (March 2006 Accepted). Design and Development of a New Machine Vision Wire Bonding Inspection System. IJAMT.

5. Perng,D.B., Chou,C.C.& Lee,S.M. (September 2006 Accepted). A novel illumination system for wire bonding inspection. Applied Optics.

6. Ngan,K.N.,& Kang,S.B. (1988). Automated Inspection of IC Bonding Wires using Hough Transform. 14th Conference of Industrial Electronics Society. 4, 938-942.

7. Ye,Q.Z., Ong,S.H.,& Han,X. (2000). A Stereo Vision System for the Inspection of IC Bonding Wires. International Journal of Imaging System Technology. 11, 254-262.

8. Kulicke & Soffa Industries Inc., “Bonder Connectivity”, http://www.kns.com/Templates/ShowPage.asp?TMID=108&FID=123&PID=2326

9. Ahmed,M., Cole,C.E., Jain,R.C.,& Rao,A.R. (1990). INSPAD: A System for Automatic Bond Pad Inspection. IEEE Transactions on Semiconductor Manufacturing. 145-147.

10. Lim,H.O., Zhang,W.,& Koh,L.M. (1992). Automated Visual Inspection for IC Wire-bond using Auto-focusing Technique. IEEE/CHMT International Electronics Manufacturing Technology Symposium. 31-36.

11. KAIJO Corporation, WI-110 technical manual with Chinese version

12. Ng,H.F. (2004). Automatic Thresholding for Defect Detection. IEEE Proceedings of the Third International Conference on Image and Graphics. 532-535.

13. Kulicke & Soffa Industries Inc., “Datasheet”, http://www.kns.com/SendFile.asp?TID=61&FID=14873