Available online at www.sciencedirect.com
ScienceDirect
Expert Systems with Applications 35 (2008) 1771–1779
Expert Systems with Applications
www.elsevier.com/locate/eswa

The feature extraction and analysis of flaw detection and classification in BGA gold-plating areas

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Abstract

In this paper, the measurements along with color image segmentation to detect all possible defects in BGA (ball grid array) type PCB (printed circuit boards) were presented. We use feature extraction and analysis as well as BPN (back-propagation neural) network classification to classify the detected defects. There are variable defects to be detected and classified including stain, scratch, solder-mask, and pinhole. The experimental results show that the proposed algorithm is successful in detecting and classifying the defects on gold-plating regions. The recognition speed becomes faster and the system becomes more flexible in comparison to the previous system. The proposed method, using unsophisticated and economical equipment, is also verified in providing highly accurate results with a low error rate.

Keywords: Color image segmentation; BGA; Neural network; Flaw detection/classification

1. Introduction

A color change on a bond finger or a ball pad usually indicates an anomaly that occurs in the bond finger or the ball pad. For example, a scratch on the bond finger may expose nickel underneath causing a change in color. Accordingly, the research of flaw detection on the bond finger can be conducted based on color machine vision.

The items of BGA board normally to be inspected include subtract surfaces, gold-plating regions, metal traces, via holes, burrs, chip out, and discoloration. The gold-plating regions include bond regions and ball pads. Furthermore, the bond regions consist of ground rings, power rings, and bond fingers. However, we focus on the inspection of bond fingers and ball pads within the gold-plating regions. Moreover, the detected defects will be classified as stain, scratch, pinhole, or residual solder-mask. Fig. 1 shows the images containing defects that occur in the bond finger and ball pads.

Color machine vision is becoming more useful for online industrial applications as it makes color measurements and color recognition more feasible than grayscale images. Referring to Fig. 2, in contrast to grayscale images, color[1] images provide more detailed information for anomaly detection, classification, and verification. As shown in Fig. 2a, the color of a metal trace is green, whereas the color of a bond pad is golden. Accordingly, it is easy to distinguish one from the other. However, the image shown in Fig. 2a is transformed into a grayscale image, in which the metal traces and the bond pads are difficult to be distinguished because their colors look extremely close. Thus, color information is much more appropriate than grayscale information for the detection and classification of flaws. In view of this problem, this research applied color machine vision to inspect BGA substrates. Although there are many techniques involved in flaw inspection, we mainly focus on the color image segmentation and the flaw classification.

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[1] For interpretation of color in Figs. 2, 5–7 and 10 the reader is referred to the web version of this article.

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doi:10.1016/j.eswa.2007.08.085

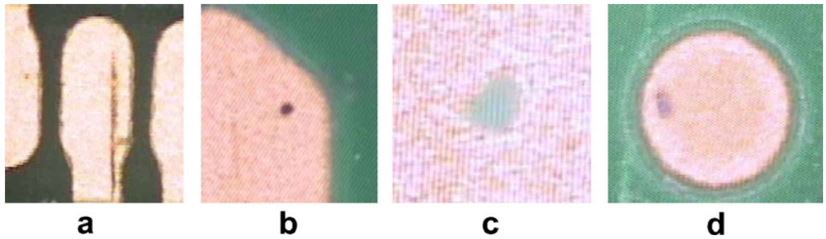

Fig. 1. Defective BGA images: (a) scratch; (b) pinhole; (c) residual solder-mask; (d) stain.

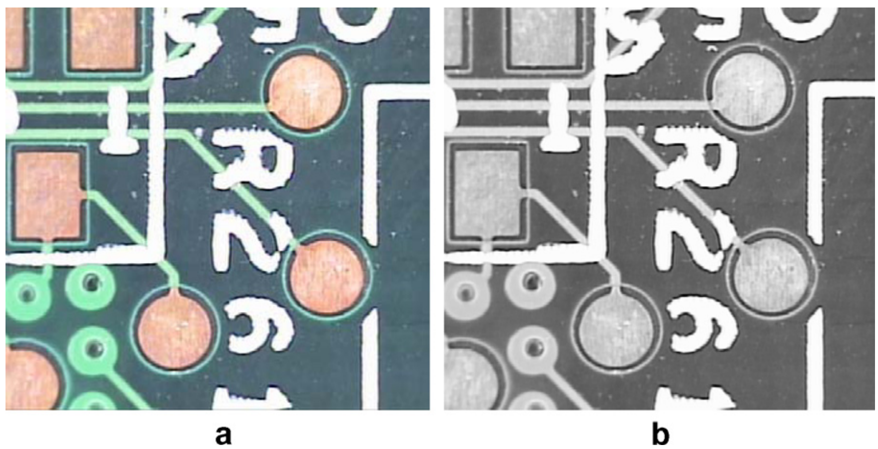

Fig. 2. Comparison of color and grayscale PCB images: (a) color image; (b) grayscale image.

As to the color image segmentation, a few color-based image segmentation techniques were developed to subdivide an image into regions with specific colors. These techniques include neural network color segmentation (SOM (self-organizing map), ART (adaptive resonance theory), BPN) (Darwish & Jain, 1988; Francisco, 1998; Jiang & Zhou, 2004; Lin, Lay, Huan, Chang, & Hwang, 2003; Lin & Lue, 2001), watershed color segmentation (Lezoray, Elmoataz, & Cardot, 2003; Lin, 1997), histogram thresholding (1-D, 2-D, 3-D) (Schuster & Ahmad, 1999), and Bayesian classifier. Jiang and Zhou (2004) adopted SOM neural network to segment an image into several regions. The five-dimensional feature vector inputting to the SOM network consists of x and y positions and R, G, and B components of each pixel. An ensemble-based SOM neural network was used to segment an image into several different regions. Francisco (1998) proposed a neural network architecture, which integrated ART, COS (color opponent system), CSS (chromatic segmentation system); and BCS/FCS (boundary and feature contour system), for the segmentation and classification of colored and textured images. Color segmentation techniques are also used for the segmentation of facial regions. A simple method can coarsely segment the input image into regions and the skin color is learned by using a back-propagation learning algorithm. At the final stage, they use a Gaussian-based Bayesian classifier to distinguish skin from non-skin. Lezoray et al. (2003) first use a gradient-based color watershed segmentation to segment the cell from an image. Then, distinguishable features used for the subsequent classification of cells are extracted. Finally, a multiple ordinate neural network architecture (MONNA) is used to classify the cell into different kinds. The method can roughly locate the facial regions even if with the occurrence of over-segmentation. Schuster and Ahmad(1999) partitioned an RGB space using a 3-D RGB histogram. They tried three mathematical models, i.e., ellipsoid model, cylinder model, and mixed density model, to describe a 3-D color histogram. The experimental results show that the mixed density model is the most suitable for approximating the 3-D histogram of a color image.

Other techniques are also used to segment an image into regions (Breen, 1994; Capson & Tsang, 1990; Geren & Lo, 1997; Hara, Doi, Karasaki, & Iida, 1988; Moganti & Ercal, 1995; Xiang, 1997). Breen (1994) employed regression methods to automated segment images. Xiang (1997) segmented a color image by minimizing the maximum-discrepancy between original pixel colors and the corresponding quantized colors. There are several techniques of color-based classification including neural networks, statistical methods (nearest neighbors, Bayesian classifier, scatter measured by variances and standard deviation), decision trees, and normalized correlations (Lin, Ho, Wu, Miau, & Lin, 2004; Tao, 1996; Tragesser, 1998). The fruit sorter invented by Tao (1996) used color space transformation to transform input color images from RGB model to HSI model. Then, the H component is used to grade the fruits. They adopted different formulas for calculating the Hue