

Reclaim wafer defect classification using SVM

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Abstract. Silicon wafer is the most important material in semiconductor manufacturing. Due to the limited resource, the reclamation of monitor wafers and dummy wafer to refurbish can dramatically lower the running cost of a factory, and become the competitive edge in this industry. If any defects such as void, scratches, particles, and contamination found on the surface of reclaim wafers. Due to previous study, we found reclaim wafers can be re-polished if its defect is not fatal and thickness is enough for a re-polish. Currently, those NG reclaim wafers must be screened by experienced human inspectors to determine re-usability through its defective mapping. This screening task is tedious, costly, and unreliable. This study proposed an artificial intelligent system to construct an automated reclaim wafer defect classification system, which incorporated a support vector machine (SVM) with digital image process (DIP) techniques to analyze the pattern of defective mapping, and determined whether reclaim wafers can be re-polished or not. Experiments showed the SVM gave excellent performance in identifying NG and Good wafers. The proposed method was successfully increase the reusability of RM, and currently serves as important module in the MIS system of case-study company.

Keywords: Reclaim wafer, wafer defect detection, defect analysis, SVM, digital image process

1. INTRODUCTION

Wafer is the most essential and important semiconductor material and thus a main resource in semiconductor industry. It may benefit the profit and increase the competence the competence when utilizing the wafers properly for integrated circuit (IC) foundries. Wafer can be divided into two categories: prime wafers and test wafer. Test wafers are then of two types: control wafer and dummy wafer. The prime wafers are used to manufacture IC and the test wafers are mainly used to monitor parameter and to maintain machines in the manufacturing process. Since the wafer is a limited and precious resource, it is desired to recycle or reclaim the wafers through which a cost down in manufacturing can be achieved. Higher reusability results in higher profit and thus higher competence among IC foundries. The prime wafer has been produced as integrated circuit chips. Consequently, only test wafers can be reclaimed, Categories of wafers as shown in Fig. 1. (Hong,2008).

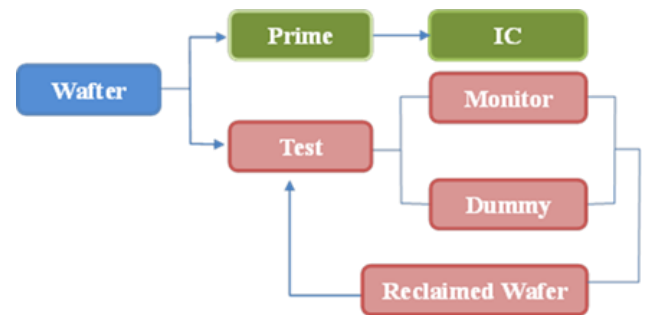


Figure 1: Categories of wafers.

To reuse the test wafers, a reclaim wafer process is conducted as in Fig.2. The key processing steps include sorting, stripping, lapping and grinding, polishing, cleaning, and inspection (MT Sytem.Inc). Since not all processed test wafers can be reclaimed, an inspection system should be sought to classify the test wafers into two types: 'Go (G)' and 'No Go (NG).' For G type, the wafers can be reused in the manufacturing process. For NG type, the wafers are discarded. Among key steps, to determine reusability of reclaim wafers is the most critical task which heavily depends on an inspection

system to classify the processed test wafers appropriately.

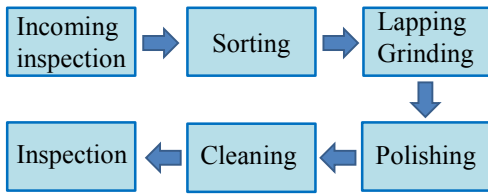


Figure 2: The reclaim wafer processing step.

Since the crucial step in the reclaim wafer process is the inspection, an inspection system with machine vision and automatic inspection will be considered in this paper. The paper is organized as follows: Section 2 gives brief reviews on the automated visual inspection. Then the proposed inspection system with SVM in Section 3 which is followed by experimental results to show the performance of the proposed inspection system in Section 4. Finally, Section 5 concludes this paper.

2. Review

Automated visual inspection (AVI) is an image-processing technique for quality control and production automation. It has been widely applied in the production line of manufacturing industries, such as for electronic, electrical and mechanical parts, vehicles, food, and the garment industry. Huang and Pan (2015) clearly surveyed the applications of AVI in the semiconductor industry. AVI can solve the problem of quality engineer require time to training, and instability of inspection quality. Compared to machines, the working hours of quality engineer are relatively short and the cost of labor is a main consideration factor for manufacturers as well.

In practice, using circuit probe test to inspect dies of wafer is the main approach to represent the defect distribution of wafer in bin maps, so called WBM (Wafer Beam Map). However, most of companies heavily rely on experienced human inspectors to analyze WBM (Liu and Chien, 2013). In order to effectively identify the possible candidate of re-polishing, many researches such as Ooi et al. (2012) 、 Chien et al. (2010, 2007) 、 Wang (2008) 、 Chien and Chen (2007) 、 Wang et al. (2006) 、 Palma et al. (2005) 、 Chen et al. (2000) etc. have applied different data mining techniques in this area.

There is very limited reference related to reclaim wafer. Most of the research described the cleaning techniques of reclaim wafers (Abadi et al., 2004). Besides, the reclaim wafer maps generated by AVI (G-sorter and SP1/SP2) machine, which projects a laser spot on the surface of reclaim wafer and collect height information. This information can depict the defect including: Epi spikes, mounds, voids, dislocations, slurry burns, particles, and contamination (Zoroo et al., 2001).

Support Vector Machine (SVM) is a popular classification technique, and successfully applied to regression and pattern recognition of the machine learning tool (Cortes and Vapnik, 1995). It is a good tool for the two classifications, widely to use in various fields as feature selection to hypertension diagnosis (Chao-Ton Su, Chien-Hsin Yang, 2008). Mohamed KHELIL et al. (2006) classification of defects by the SVM method and the principal component analysis. In addition, it has also been applied to handwritten characters and digit recognition (Cortes & Vapnik, 1995; Scholkopf, 1997; Vapnik, 1995), face detection (Osuna et al., 1997) and speaker identification (Schmidt, 1996).

Ooi et al. (2013) pointed out that there were a variety of different defects on the wafer surface, and the causes of difficulty in detection includes: variations in defect cluster size, shape, location and orientation, on the wafer for the same class of defects, Non-symmetrical geometry, Low signal-to-noise ratio, insufficient quality historical data for training, a-priori unknown best feature sets and/or best classifiers etc. In their study, they used Polar Fourier Transformation and Invariant Moment to obtain invariant characteristics of surface defects, and then applied Bayesian classifier and Top-down induction decision tree for classification. Finally, their system adopted an ADTree classifier that achieves classification accuracy up to 95% for different product types. Hsu and Chien (2007) proposed a hybrid data mining approach that integrated spatial statistics and adaptive resonance theory neural networks to quickly extract patterns from WBM. Liu and Chien (2013) integrated the geometric information of distributed WBM, and used cellular neural network, adaptive resonance theory (ART) and moment invariant etc. for classification. The proposed system recognized specific failure patterns efficiently and also traced the assignable root causes. Li and Tsai (2012) used wavelet transform techniques in defect inspection of multi-crystalline solar wafer for fingerprint, contamination, saw-mark difficult, and so forth. Li and Tsai (2011) developed a machine vision-based scheme to automatically detect saw-mark defects in solar wafer surfaces. First, they used Fourier image reconstruction to remove the multi-grain background of a solar wafer image, and then the Hough transform was used to detect low-contrast saw-mark defects. Sun et al. (2011) develop HJPOS algorithm solved MIC problem, and combine vision machine use in wafer re-polish. Wang (2008) proposed a spatial defect diagnosis system to identify wafer surface defect. This method used entropy fuzzy means to eliminate noise of wafer map, and then used decision tree in classification according to feature of clusters. Chang et al. (2009) used median filter to remove noises, and the defect clustering into blocks, according to the spatial information of blocks. The wafer image was classified into four clusters.

Shankar and Zhong (2005) developed a template-based vision system for the 100% inspection of wafer die surfaces. Su et al. (2002) used BPN, RBFN, and LVQ three kind of neural network in wafer detect of post-sawing. Su and Tong (1997) proposed a neural network-based procedure for the process monitoring of clustered defects in integrated circuit fabrication. This method can be effective to reduce warning errors caused by cluster defect. Chang et al. (2007) developed an automatic inspection system, which recognizes defective patterns automatically. The Radial Basis Function (RBF) neural network was adopted for inspection processing. The results show the proposed RBF neural network successfully identifies the defective dies on LED wafers images with good performance.

3. RESEARCH METHOD

The objective of this study is to build up an artificial intelligent system to identify the reclaim wafer which can be polished again such that the human inspector can be relieved from the tedious and laborious task.

3.1 Ten typical defect maps in reclaim wafers

In the reclaim wafer process, defect maps can be divided into ten typical types, which are summarized and described in Table 1. The related patterns of ten typical defects are listed in Table 2. The ten types of defects will be classified as G (Go) or NG (No Go) types for further processing.

3.2 Proposed Method

In order to achieve effective defect classification, the proposed process of research is shown as Fig.3.

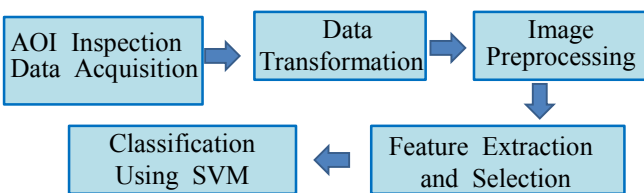


Figure 3. Process of Research.

3.2.1 AOI Inspection and Data Acquisition

The AOI instrument (G-sorter) were used to derive the 3D information of the reclaim wafer surface. The derived information includes the geometry, flatness, the position of particles etc. However, the amount of acquired data is huge and presented in a digital form, which cannot be perceived by a

human inspector.

3.2.2 Data Transformation

The purpose of data transformation is to convert the numerical data, which derived from G-sorter and SP1/SP2, into graph map (Fig. 4) such that a human inspector can classify the reclaim wafer into good and no good based on the distribution of particle. Figure 4 show different maps of defect, in which the different colors represent height (3D) of the corresponding location.

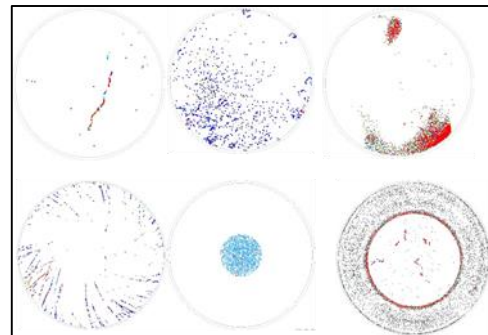


Figure 4. Defect distribution map.

3.2.3 Image Preprocessing

Image preprocessing is to remove the unrelated information and enhance the defective area. First, the edge of the defective feature map was removed and the boundary of the image as well. Secondly, the image is converted into a gray scale image and defective blobs are grouped and enhanced through morphological operations such that the scratches, or isolated defects can be visualized easily.

3.2.4 Feature Extraction and Selection

After image preprocessing, the defective feature can be extracted based on the attribute of defects such as the number of particles, position, color, area, distribution and so forth. The feature must be representative for the different types of defective maps described in Table 1. Besides, the extracted feature must be scale, position, and orientation invariant. By using the statistical blob analysis, we obtained the thirteen invariant features, which can be learned by SVM.

3.2.5 Classification using SVM

The extracted invariant features were fitted into the SVM. In order to avoid the large scale data dominating the impact of classification process, a normalization of data usually is a crucial process. Some parameters such as C, Nu, K-fold, SVM kernel, number of iterations, and error must be specified with some trial and error.

T4										
T5										
T6										
T7										
T8										
T9										
T10										

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