APPLICATION OF MACHINE VISION TECHNOLOGY IN DEFECT DETECTION OF HIGH-PERFORMANCE PHASE NOISE MEASUREMENT CHIPS

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ABSTRACT

The problem of chip defects has always existed in industrial production, and since there are more and more environmental problems caused by chip defects, people have attached greater importance to the identification and detection of chip defects. Pursuant to the ecological environmental problems caused by chip defects in the process of chip production, this paper uses machine vision technology to detect the defects of high-performance phase noise measurement chips. The results suggest that the accuracy of machine vision technology for the identification of chip defects reaches up to 98%. The production volume of organic waste gas decreases from 5968.0t/a to 4000t/a. The yield of organic wastewater decreases from 5496m3/d to 4600m3/d. The production amount of solid waste reduces from 8000t/a to 6500t/a. The aforementioned data all confirm that machine vision technology has the advantages of automation, high detection efficiency, and high accuracy of defect identification for the defect detection of high-performance phase noise measurement chips. And also, by improving the chip defects, the discharge volume of waste gas, wastewater, and solid waste in the chip production process is reduced, and thereupon the ecological environment is ameliorated.

KEYWORDS

Machine vision technology; Chips; Defect detection; Environmental pollution; Ecological environment

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1. INTRODUCTION

In the process of chip production and manufacturing, the processes are interlinked. The technology is complex, and slight variations in materials, environment, process parameters, and other factors often lead to defects in the chip and affect the product yield. The problem of chip defects has always existed in industrial production [1]. And there are more and more environmental problems due to chip defects [2]. Therefore, more and more attention has been paid to the identification and detection of chip defects. The traditional chip defect identification and detection approach relies on the manual operation of professional technicians. This method is not only inefficient but also relies on the subjective judgment of the operator, and the accuracy of detection is difficult to be guaranteed. The combination of non-destructive testing equipment and industrial production lines not only ensures the quality of products but also reduces the cost of manual inspection and improves the efficiency of production. Later, along with the rapid rise of machine vision technology, many scholars gradually extended the application of this technology in the field of chip defect detection, making the chip defect detection method more and more mature and perfect [3].

The traditional chip defect detection technology is usually used to detect and identify the defect information such as cracks, white spots, defects, and internal defects contained in the target chip sample by inspection methods such as magnetic particle inspection method, penetrant inspection method, eddy current inspection method, ultrasonic inspection method, and X-ray inspection [4-10]. Despite the achievements of traditional chip defect detection methods, there are some drawbacks. First, the chip and shape of the sample under inspection are demanding, and second, the professional requirements for the operator are high. For example, the detection results of penetrant flaw detection by the operator's influence, X-ray flaw detection if improper operation will produce radiation hazards to the operator, etc. Third, the traditional chip defect identification method is difficult to achieve the multiple requirements of intelligence, automation and high accuracy, low detection efficiency, etc. [11-13].

Machine vision technology plays an important role in chip defect detection technology. Features are mainly a combination of nondestructive testing, automation, and intelligence. Not only is it safe and efficient, but also has high detection accuracy [14]. Machine vision inspection technology is composed of three aspects: image acquisition, software image processing, and image analysis [15-17]. The image acquisition part is mainly to select a suitable light source, professional camera, and lens to realize the picture acquisition of the sample. The principle is mainly to use the image sensor to convert the light converged by the lens into an electrical signal, and then into a digital signal, and pass it to the software processing part for analysis. The software processing part mainly covers measures such as image denoising, image enhancement, and edge detection [18-20]. The image analysis part includes three parts: extraction of feature information, screening of effective features, and recognition of images using classifiers. Mainly based on the extraction of effective feature information from the pixels of the image, algorithms such as PCA are often used to

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compress the image pixel data and reduce the high-dimensional image data to obtain the features [21-22]. This makes it easier for the classifier to recognize feature information during image recognition, thus improving the accuracy of classification and more correct classification recognition [23-24].

Machine vision techniques are used in a large number of applications for defect detection and target classification. In the literature [25], the location of the damage appearance and identification of the damage type was roughly calculated using the YOLOv3 detection network based on the image dataset of untouchable damage. Using the designed level set algorithm, more accurate damage locations are obtained in the image blocks. In the literature [26], a machine vision system based on a recorder and image signal processing was proposed for automatic assessment. The machine vision system consists of four modules, including a video acquisition module, an image extraction module, an image processing module, and a trajectory state evaluation module. Three classical edge detection methods were used and compared. The literature [27] provides an overview of the application of machine vision models in the field of fish classification and then discusses in detail the specific applications of various classification methods. In addition, the challenges and future research directions in the field of fish classification are discussed. The literature [28] reviews the application of machine vision techniques for 3D dimensional and morphological measurements of high-temperature metal components. In addition, two aspects are described in detail, based on the principles and methods of measuring device construction: laser scanning measurement and multi-view stereo vision techniques. Through comparison and analysis, special attention is given to each method to provide the necessary technical references for subsequent researchers. The literature [29] presents a multi-defect stereo inspection system for magnetic rings based on multi-camera vision technology to accomplish the automatic inspection of magnetic rings. The system can simultaneously detect surface defects and measure ring height. Two image processing algorithms are proposed, namely the image edge removal algorithm (IERA) and the magnetic ring localization algorithm (MRLA). Based on these two algorithms, a connected-domain filtering method for cracks, fibers, and large-area defects is established to accomplish defect detection. The results show that the system achieves a 99% recognition rate for defects such as cracks, adhesion, hanger adhesion, and pitting. The literature [30] reviewed the principles, cameras, and thermal data of infrared imaging-based machine vision and discussed the application of deep learning in infrared imaging machine vision. Case studies of IR imaging-based machine vision and deep learning on various platforms such as unmanned vehicles, cell phones, and embedded systems are also reported. Machine vision techniques have been rapidly developed in recent years for the detection of defects in high-performance phase-noise measurement chips. By combing and analyzing chip defect detection methods, the traditional machine vision problem of requiring different image processing algorithms for classifying different tasks is solved, and the further development of machine vision technology in the field of high-performance phase noise measurement chip defect detection is promoted.

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The environmental problems caused by chip defects have been a hot issue of great concern. To improve the correct rate and detection rate of high-performance phase noise measurement chip defect detection, and improve the ecological environment pollution caused by the chip production process. In this paper, based on the ecological environments problems such as waste gas, wastewater, and solid waste caused by chip defects in the chip production process, we build a machine vision inspection technology for detecting defects contained in high-performance phase noise measurement chips using three aspects: image acquisition, software image processing, and image analysis.

2. ENVIRONMENTAL POLLUTION CAUSED BY CHIP DEFECTS

The environmental pollution caused by chip defects mainly comes from the three wastes generated in the manufacturing process, namely wastewater, exhaust gas, and solid waste. The exhaust gas, wastewater, and solid waste generated during the chip manufacturing process contain high concentrations of organic pollutants as well as fluorinated pollutants and other pollution factors that are seriously harmful to the environment. A large number of gases are produced during the manufacturing process of chips due to defects. For example, PH3, BF3, Cl2, SF6, CF4, C4F8, BCl3 and other organic substances, ammonia nitrogen, fluorine-containing pollutants, and other factors. If these gases are directly discharged without treatment, they will cause great pollution to the environment and direct harm to human health.

With the continuous improvement of air pollution control, the concentration of flue gas emissions is becoming more and more strict, and as far as the enterprises themselves are concerned, the urgency of waste gas treatment is much greater than that of wastewater treatment. The more harmful components of the exhaust gas produced in the manufacturing process are hydrogen sulfide, fluorinated dust, and sulfur dioxide. These harmful substances can cause acute and chronic diseases of the human respiratory system. The wastewater produced in the chip manufacturing process contains a large amount of organic pollutants. Once these pollutants enter the surrounding water bodies, they will cause the microorganisms in the water bodies to multiply rapidly. This causes a dramatic decrease in dissolved oxygen in the water, which leads to the death of aquatic organisms in the water body due to lack of oxygen. Ammonia nitrogen is an important nutrient in the environment of water bodies, and its random discharge will lead to eutrophication of water bodies. At the same time, ammonia nitrogen is also a major oxygen-consuming pollutant, and when dissolved oxygen reacts with ammonia nitrogen in the water body, it will bring great toxic effects to other kinds of aquatic organisms in the water body. In addition, if ammonia nitrogen is ingested by the human body for a long time through the food chain, it will be transformed into ammonium nitrite in the human body under specific conditions, and the long-term accumulation of this substance in the human body will make the risk of cancer rise sharply. Fluorine is an essential element for the human body and is one of the main components of human bones and teeth. It also plays an important role in the

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formation of bone tissue and tooth enamel and participates in metabolic processes by activating or inhibiting the activity of various enzymes. Lack of fluoride in the body or excessive fluoride inhalation can have serious health consequences. The cavities we usually see formed by erosion of tooth enamel, muscle atrophy, thickening of joints, and other large bony conditions are all unfavorable lesions due to the lack of fluoride in the body. Excess fluoride, on the other hand, can likewise bring about unfavorable some lesions, including bone deformation, back and leg pain, loss of labor force, and even worse, death. Fluorine is not only harmful to humans but also to the natural environment we live in. Some plants absorb some fluorine dissolved in water through the soil, and the excess fluorine can have a serious toxic effect on plants, which are eventually eaten by animals and humans.

2.1. EXHAUST GAS AND SOLID WASTE GENERATION DUE TO CHIP DEFECTS

Acid exhaust gas mainly comes from the exhaust gas generated by the volatilization of acidic raw materials from the wet etching of the array production process and the medium gas periodically emitted from the excimer laser annealing device. The main pollutants are acid mist such as HCL and fluoride. The alkaline exhaust gas mainly comes from the alkaline volatile substances generated from the development process of the array and color film production process, and the main pollutants are NH3. dry etching and chemical vapor deposition exhaust gas mainly come from some gas raw materials in the dry etching process to produce a certain amount of reaction exhaust gas and unreacted raw material gas. The main pollutants are N2O, SiH4, NH3, NF3, PH3, BF3, Cl2, SF6, CF4, C4F8, BCl3 and reaction waste gas fluoride and chloride, etc. Organic waste gas mainly comes from the volatilization of organic gases from organic raw materials in the production process, and the main pollutants are non-methane total hydrocarbons. Solid waste mainly comes from the waste of various raw materials used in the production process of array, color film, organic vapor deposition, and box formation. This includes their packaging containers, organic wiping materials, residual liquids, and expired unusable materials. Chip manufacturing waste gas as well as solid waste generation is shown in Table 1.

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Table 1. Generation of chip defect waste gas and solid waste

Pollution category	Pollution source	Major pollutants	Emission method	Production (t/a)	Yield concentration (mg/m^3)
Acid waste gas	Acidic volatile gases from array wet etching	Fluoride	Continuous	28.26	40
		NOX		83.79	120
Alkaline waste gas	Volatile alkaline gases emitted from developing production processes such as arrays and color filters	NH3	Continuous	20.56	65
		HCL		118.02	350
		Fluoride		201.7	520
Dry etching and chemical vapor depositio n exhaust	Unreacted gas and reaction waste gas discharged from vapor deposition, dry etching, doping, etc.	NOX	Continuous	48.01	128
		SO2		37.67	1500
		Cl2		198.70	600
Organic waste gas	Organic waste gas generated by coating, peeling, evaporation, etc. from arrays, color filters, organic evaporation, and box formation	Total non-methane hydrocarbon s	Continuous	5968.0	6000
Solid waste	Waste reagent containers, organic wiping materials, expired raw materials, residual liquids	Chemical reagents containing acids, bases, alcohol esters, ethers, etc.	Regular	8000	

2.2. CHIP DEFECT WASTEWATER GENERATION

The main pollutants of acid-base wastewater are pH, COD, BOD5, SS, F-, NH3-N. The fluorinated wastewater mainly comes from the PECVD deposition and dry etching process waste gas POU purification system discharge, and the array process fluorinated cleaning wastewater. purification device for treatment. The main pollutants in the discharged wastewater are F-, pH, COD, BOD5, SS, NH3-N. The phosphorus-containing wastewater mainly comes from wet etching using phosphoric acid, sulfuric acid, nitric acid, and other raw materials. Organic wastewater mainly comes from the production process of film, organic vapor deposition, box formation, etc., glue

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application, glue stripping, detergent cleaning, etc. The production processes all use organic materials as raw materials and ultra-pure water is used for cleaning after the processes. Therefore, organic wastewater mainly comes from the cleaning wastewater of production processes such as array, color film, organic vapor deposition, and box formation, and organic wastewater is discharged from alkaline and etching exhaust gas washing and purification system. The main pollutants are COD, BOD5, SS, NH3-N, pH, etc. The wastewater generation situation of the chip manufacturing industry is shown in Table 2.

Table 2. Wastewater generation of chip defect

Pollution category	Pollution source	Major pollutants	Emission method	Wastewater volume(m^3/d)
Acidic wastewater	Acid-base waste gas treatment system discharge waste water pure water preparation of waste water	PH, COD, BOD5, SS、F⁻ , NH3-N	Continuous	4202
Fluorinated wastewater	Wastewater from exhaust gas purification systems for ECVD deposition and dry etching processes	PH, COD, BOD5, SS、F⁻ , NH3-N	Continuous	2518
Phosphorus-containing wastewater	Array wet etching discharge cleaning wastewater	PH, COD, BOD5, SS, Phosphate	Continuous	683
Organic wastewater	Equipment circulating cooling water system sewage, boiler sewage, etc.		Continuous	5496

3. APPLICATION OF MACHINE VISION-BASED TECHNOLOGY FOR HIGH-PERFORMANCE PHASE NOISE MEASUREMENT CHIP DEFECT DETECTION

Machine vision technology plays an important role in chip defect detection. Features are mainly non-destructive testing, automation, and intelligence combined, not only good safety, and high efficiency, but also high detection accuracy.

Machine vision inspection technology is composed of three aspects: image acquisition, software image processing, and image analysis. The image acquisition part is mainly to choose the appropriate light source, professional cameras, and lenses, to achieve the picture acquisition of chip samples. The principle is mainly to use the image sensor to convert the light converged by the lens into electrical signals, and then into digital signals, and pass to the software processing part for analysis. The software processing part mainly covers measures such as image denoising,

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image enhancement, and edge detection. The image analysis part includes three parts: extraction of feature information, screening of effective features, and recognition of images using classifiers. It is mainly based on the extraction of effective feature information from the pixels of the image. Algorithms such as PCA are often used to compress the image pixel data and reduce the high-dimensional image data to obtain features. This makes it easier for the classifier to recognize feature information during image recognition, thus improving the accuracy of classification and more correct classification recognition. The detection workflow diagram is shown in Figure 1.

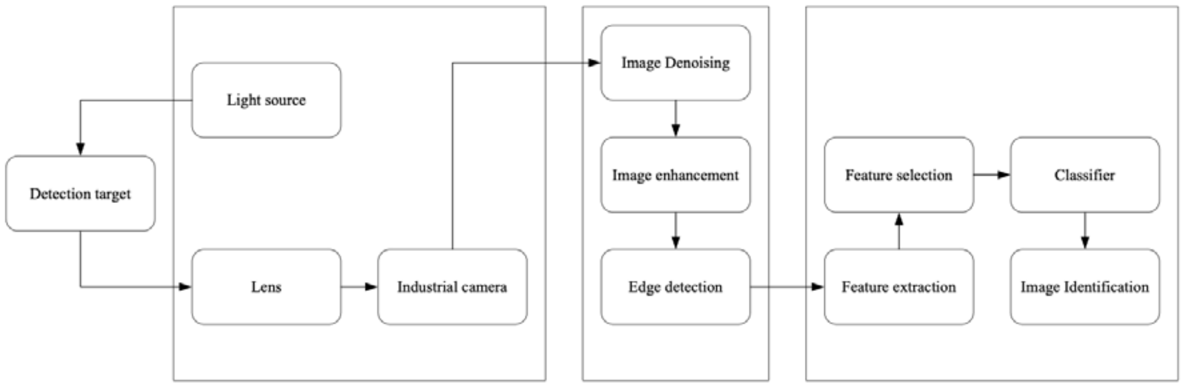

Figure 1. Detection workflow diagram

4. RESULTS AND ANALYSIS

Machine vision technology for chip defect identification detection has the advantages of automation, high detection efficiency, and high accuracy of defect identification. With the rapid development of machine vision technology in recent years, machine vision inspection technology has been used in a large number of applications in chip defect detection. Selected 100 high-performance phase noise measurement chips containing different kinds of defects, through the application of machine vision technology detection, two cases of false detection occurred. Once a foreign object on the chip surface was not detected and once a metallic contaminant present on the chip was not detected. This resulted in a 98% correct rate of chip defect detection. By fixing the chip defect problem, the environmental problems caused by chip defects were improved in three ways.

1. Acidic emissions from the manufacturing process due to chip defects mainly come from the volatilization of acidic raw materials from the wet etching process of the array manufacturing process, and the periodic emission of dielectric gases from the excimer laser annealing unit. The main pollutant is "fluoride". The alkaline exhaust gas mainly comes from the alkaline volatile substances generated from the development process of the array and color film production process. The main pollutant is "NH3". Dry etching and chemical vapor deposition waste gas mainly come from some gas raw materials in the dry etching process to produce a certain amount of reaction waste gas and unreacted raw material gas. The main pollutant is "NOX". Organic waste gas

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mainly comes from the volatilization of organic gases in the organic raw materials during the production process, and the main pollutant is non-total methane hydrocarbon. The application of machine vision technology in the detection of defects of chips with high-performance phase noise measurement has improved the defects of chips and reduced the amount of acidic exhaust gas "fluoride" from 28.26t/a to 20.53t/a. The amount of "NH3", the main pollutant of dry etching and chemical vapor deposition waste gas, is reduced from 48.01t/a to 35.23t/a. The amount of "NOX", the main pollutant of organic waste gas, is reduced from 20.56t/a to 15.2t/a. The amount of "non-methane total hydrocarbons", the main pollutant of organic waste gas, was reduced from 5968.0t/a to 4000t/a.

2. The wastewater generated in the manufacturing process due to chip defects mainly includes acid and alkali wastewater, phosphorus-containing wastewater, fluorine-containing wastewater, and organic wastewater. Acid-base wastewater mainly comes from acid-base cleaning wastewater discharged from the production system, acid exhaust gas scrubbing and purification system discharge wastewater, and regeneration backwash wastewater discharged from the pure water preparation system. Fluorine-containing wastewater mainly comes from wastewater discharged from PECVD deposition and dry etching process exhaust gas POU purification system, and fluorine-containing cleaning wastewater from array process. Phosphorus-containing wastewater mainly comes from wet etching using phosphoric acid, sulfuric acid, nitric acid, and other raw materials, and the cleaning wastewater after etching mainly contains pH, COD, BOD5, SS, phosphate, and other pollutants. Organic wastewater mainly comes from the array, color film, organic vapor deposition, box formation, and other production process cleaning wastewater, and organic wastewater discharged from alkaline and etching exhaust gas scrubbing and purification systems. Through the application of machine vision technology in the detection of defects of chips with high-performance phase noise measurement, the defects of chips are improved, so that the wastewater volume of acidic wastewater from the chip manufacturing process is reduced from 4202m^3/d to 3500m^3/d. The wastewater volume of phosphorus-containing wastewater is reduced from 683m^3/d to 552m^3/d. The wastewater volume of fluorine-containing wastewater is reduced from 2518m^3/d to 2208m^3/d. The wastewater volume of organic wastewater is reduced from 5496m^3/d to 4600m^3/d.

3. The solid waste generated in the manufacturing process due to chip defects mainly comes from the waste of various raw materials used in the production processes of the array, color film, organic vapor deposition, and box formation. This includes their packaging containers, organic wiping materials, residual liquids, expired unusable materials, etc. Through the application of machine vision technology in the detection of defects in high-performance phase noise measurement chips, the defects of chips have been improved and the amount

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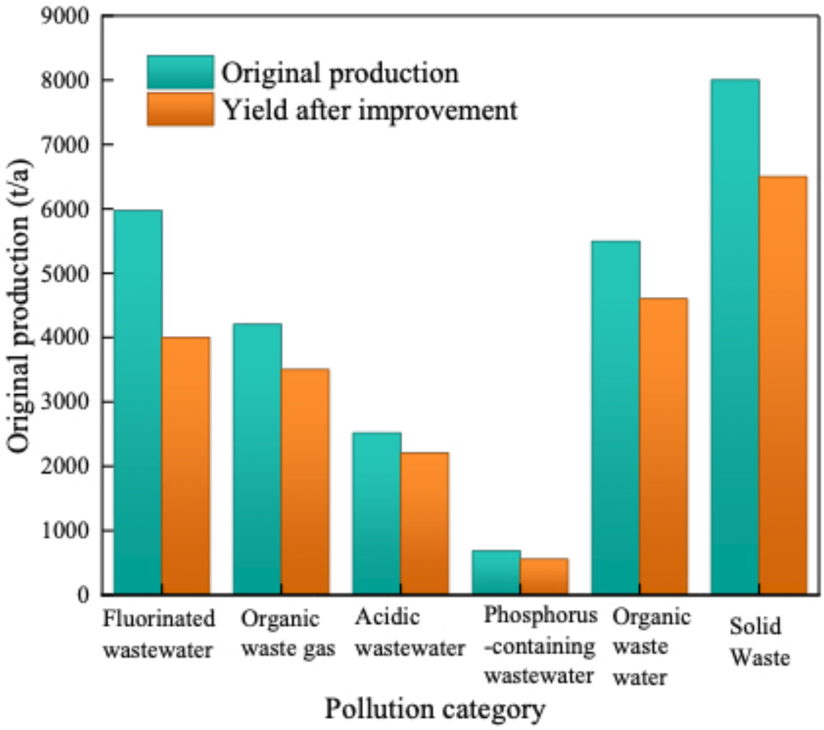
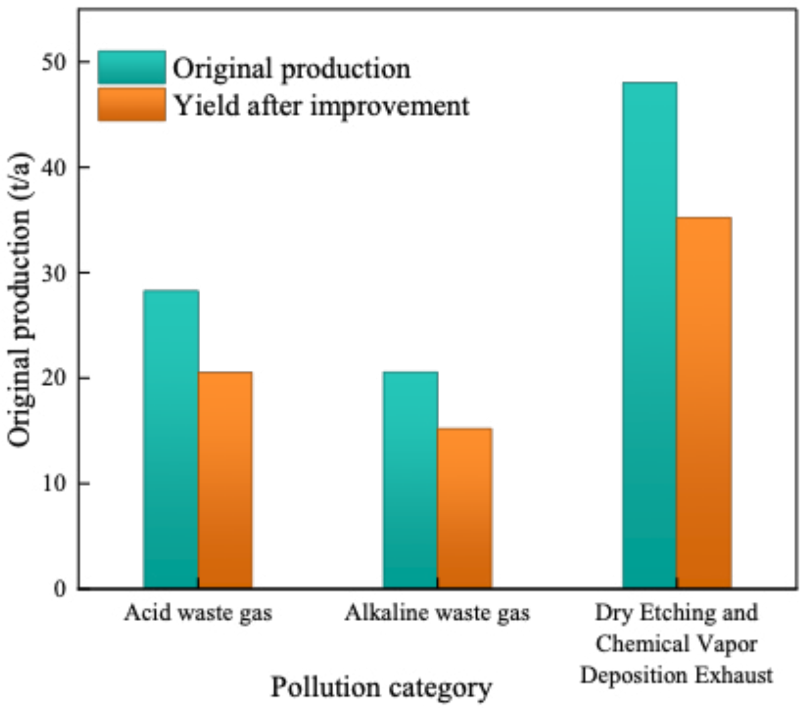
of solid waste generated from the chip manufacturing process has been reduced from 8000t/a to 6500t/a. See Figure 2 for details.



(a) Organic waste gas, wastewater, and solid waste



(b) Acid and alkaline waste gas, dry etching, and chemical vapor deposition waste gas

Figure 2. Quantification of waste generation

Inspection using machine vision technology is an important step in the chip production process. Geometric measurement is the key technology for automatic inspection in traditional automated inspection. Although this technology can achieve automatic inspection, in terms of detection accuracy, speed is relatively poor, and has gradually failed to meet the automation efficiency to further enhance the requirements. The application of machine vision technology in automatic inspection can use CT, laser scanning, and other technologies to synchronize automatic inspection, which can not only effectively improve the speed of automatic inspection, but also further improve the accuracy of automatic inspection. Secondly, the biggest advantage of machine vision technology in automatic inspection is that automatic inspection technology can realize the detection of chip appearance. The traditional geometric inspection method cannot realize the processing of chip appearance information and can only deal with geometric dimensions. Machine vision technology, on the other hand, can effectively realize the processing of the chip surface, thus further enhancing the accuracy of the detection. Based on the generation and emission of major pollutants before and after chip defect detection, it can be seen that the use of machine vision technology to detect chip defects not only helps to repair chip defects promptly but also greatly reduces the amount of waste gas, wastewater and solid pollutants generated by chip defects, alleviating the degree of harm caused to the surrounding environment. In summary, machine vision-based chip defect detection technology is of great importance to improve the ecological level.

5. DISCUSSION

Machine vision technology is not only the core of artificial intelligence technology, but also has a very important significance for the current social production efficiency improvement. In the future machine vision technology is bound to achieve further development. Extraction of chip defect information characteristics, not only can achieve high precision detection of high-performance noise measurement chip defects but also can directly achieve end-to-end chip defect detection, reducing the complexity of engineering. Also, the scope of application in social production will be further promoted. Most of the current methods for chip defect detection are based on two-dimensional images. Such methods can only obtain limited flat feature information, and cannot obtain the spatial feature information of material defects. Therefore, how to capture and use three-dimensional defect information more accurately to detect defects is also a direction worthy of future research.

6. CONCLUSION

This paper is based on the ecological environmental problems caused by chip defects in the chip production process. Choose the appropriate light source, professional camera, and lens to achieve the picture acquisition of chip samples. Through image denoising, image enhancement, edge detection, and other measures, image processing is completed. After three parts: extraction of feature information,

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screening of effective features, and recognition of images using classifiers, high-performance phase noise measurement chip defects are detected. The conclusions of the obtained study are as follows.

1. Through the comparison of traditional chip defect detection technology and machine vision technology, it is concluded that machine vision technology for chip defect identification and detection has the advantages of automation, high detection efficiency, and high accuracy of defect identification. The biggest advantage of machine vision technology in automated inspection is that the automatic detection technology can achieve the detection of chip appearance. Traditional geometric inspection methods can not achieve the processing of chip appearance information, only geometric size, while machine vision technology can effectively achieve the processing of the chip surface, thereby further enhancing the accuracy of detection.

2. Chip defect identification detection by machine vision technology has the advantages of automation, high detection efficiency, and high accuracy of defect identification. Machine vision inspection technology has been applied in a large number of chip defect detection, and the correct rate of chip defect detection is as high as 98% through the application of machine vision technology detection.

3. Analysis of the type of environmental pollution caused by chip defects, and the use of machine vision technology for chip defect detection. By dealing with chip defects promptly, the amount of waste gas, wastewater, and solid waste generated is reduced. The amount of organic waste gas generated was reduced from 5968.0t/a to 4000t/a, the amount of organic wastewater generated was reduced from 5496m^3/d to 4600m^3/d, and the amount of solid waste generated was reduced from 8000t/a to 6500t/a. The ecological environment around the enterprise was improved.

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