Optical Microscanning X-ray Real-time Imaging System

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Abstract—As a new non-destructive testing technology, X-ray real-time imaging detection technology has been put into practical use in the field of industrial product testing. With the printed circuit boards, integrated circuits increasingly integrated, sizes of the circuit feature are smaller and smaller. The spatial resolution of X-ray imaging systems are increasingly high requirements on the circuit board defect detection. However, the spatial resolution of the existing system can not meet the need for high-resolution imaging. This paper proposes an approach to introducing international advanced optical microscanning technology into existing systems to improve the spatial resolution, thus completing the high-resolution X-ray imaging of fine structure. The definition, the component of the system, working principle, the microscanner and other theory were introduced. Moreover, the successful development of microscanning system can also be applied to other systems to improve the resolution, these systems include the X-ray imaging systems, visible imaging systems, infrared thermal imaging system.

Keywords: X-ray imaging; real-time imaging system; micro scanning; non-destructive testing; high resolution

I. INTRODUCTION

Ray detection is an important method of non-destructive testing and is widely used in aviation, aerospace, nuclear, defense, and other industrial sectors. It played an important role in industrial production and the national economy[1]. Currently, ray detection commonly used film radiography in the actual production. Higher image quality X-ray film photography can provide reliable information of defective test piece on the real situation. But it has some disadvantages such as complex operation, high operating costs, as a result it is not easy to save and the workers' eyes are vulnerable to X-ray[2]-[4] . To solve these problems, in the late 1990s there had been digital radiography detection technology. X-ray digital radiography system includes flat panel detector and its pixel size may be less than 0.1mm, so its image quality and resolution are almost comparable with film photography. Not only does it overcome the performance in the film out of the camera shortcomings, but also it provides a convenience to computer image processing. Therefore the digital imaging system based on X-ray flat panel detector has broad application prospects in non-destructive testing, evaluation (NDT / NDE), container scanning, circuit board inspection, and medical applications[5].

With the printed circuit boards, integrated circuits increasingly integrated, sizes of the circuit feature are smaller. The spatial resolution of X-ray imaging systems are increasingly high requirements on the circuit board defect detection. However, the spatial resolution of the existing system can not meet the need for high-resolution imaging[6]. This paper proposes an approach to introducing international advanced optical microscanning technology into existing systems to improve the spatial resolution, thus completing the high-resolution X-ray imaging of fine structure. Moreover, the successful development of micro-scanning system can also be applied to other systems which need to improve the resolution, including the X-ray imaging systems, visible imaging systems, infrared thermal imaging system.

II. COMPONENT OF THE SYSTEM

The proposed optical microscanning X-ray imaging system are composed of X-ray source, flat panel detector, optical microscanning systems, computer digital signal acquisition and processing (including software design and development) and monitors. The entire system block diagram is shown in Fig .1 The X-rays emitted by a radiation source penetrates the test piece, and then the X-ray that carries the message within the workpiece arrives the panel detector with little attenuation. And the flat panel detector is fixed to the micro-displacement of the platform. The flat panel detector can be controlled to move in the horizontal and vertical direction which is standard 2×2

micro-displacement. As a result, we can get multiple images with micro-displacement.Then we adopt oversampling reconstruction algorithm to complete high-resolution reconstruction to improve system spatial resolution.

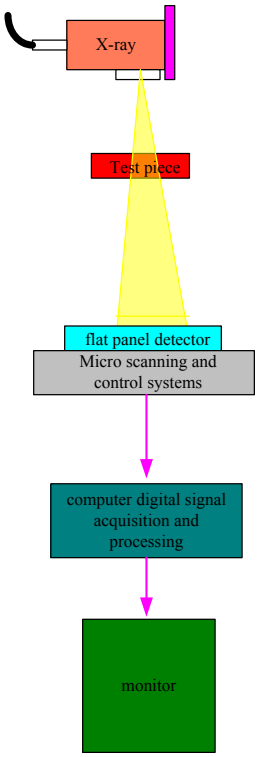

Figure 1. The block diagram of optical microscanning X-ray real-time imaging system

III. FLAT PANEL DETECTOR

With the development of microelectronics and materials science, digital flat panel detector has become a new kind of X-ray imaging devices in recent years. Flat detector imaging technology research is necessary because of its high spatial resolution and dynamic range. It can also provide means to acquire digital images rapidly to meet high quality detecting.

A. Principle and structure of the flat panel detector

Flat panel detector translates the X-ray photons into electrical charge and the two ways differ in the structure. The indirect mode has one more scintillator layer than the other. This scintillator can translate the incident X-ray photons into visible light photons. Direct way uses the photoconductor (generally use a-Se, GaSe and other materials) to translate the X-ray photons into electrical charge. And the indirect way uses a photodiode to translate visible light photons into charge. The following we take the PaxScan 2520V flat panel detector for example to describe structural principle of flat panel detector of indirect mode.

The internal structure of PaxScan 2520V flat panel detector is shown in Fig .2The uppermost layer is scintillator which is generally using Gd_2O_2S or GsI. Scintillator emitted wavelengths of visible light at 550 nm after being irradiated with X-rays, just to the optimum wavelength of the photodiode of the photoelectric effect. Under a layer of amorphous plane array is composed of amorphous silicon pixels which are arranged in rows and columns.The circuit behaves as a photodiode and a capacitor connected in series. Pixel pitch on PaxScan 2520V flat panel detector is 0.127 mm, capacitance of the pixel is 0. 7 pF and it can accumulate two ten million charge under reverse bias voltage of 5V. The bottom is the readout circuit that includes an amplifier, ADC and other integrated circuit chip.

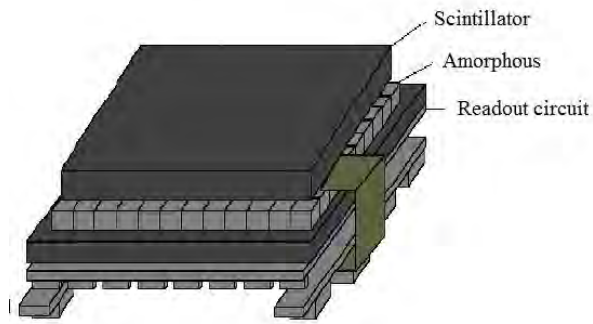

Figure 2. Internal structure of PaxScan 2520V flat panel detector

Circuit structure of PaxScan 2520V flat panel detector is shown in Fig .3 A pixel is composed of photodiode FET, the gate circuit, the bias voltage circuit and a read-out circuit. Detector scans a line every time in progressive scanning mode and reads the signal accumulated in each pixel to translate into digital signals, and finally sends the digital signal to the computer.

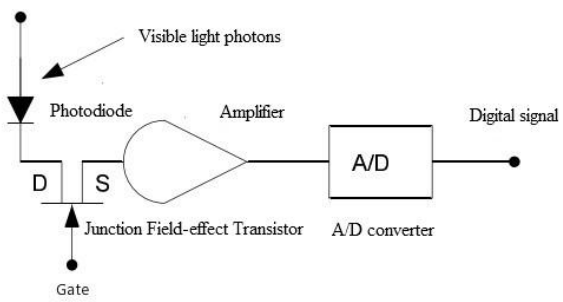

Figure 3. Circuit structure of PaxScan 2520V flat panel detector

B. Flat panel detector imaging process

First the scintillation crystal screen within the flat panel detector translates X-ray into visible light, and then produces and accumulates charge at each pixel after the photoelectric conversion. In addition to instant process of images readout, each pixel is constantly accumulating light charge. In the image read-out, the charge comes from capacitance of each pixel row by row; charge from the same line are amplified, digitized and then written to a first in first out (FIFO) queue; FIFO queues in the data connector transmits data via the network cable to the computer processing system.

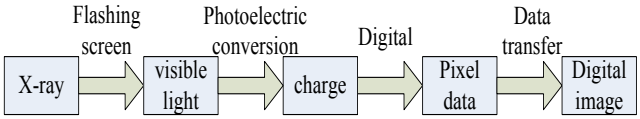

Figure 4. Digital imaging process of flat panel detector

IV. MICRO-DISPLACEMENT PLATFORM

In this paper,we choose PI-517.2CL series piezo scanning stage, product of Physik Instrumente (PI Shanghai)Co.,Ltd. as a micro displacement of the platform to achieve micro scanning. P-500 nanopositioning stages are equipped with the award winning PICMA® piezo drives,integrated into a sophisticated,single-module,parallel-kinematics,flexure guiding system.The flexures are FEA modeled for zero stiction, zero friction and exceptional guiding precision.The ceramic-encapsulated PICMA® drives are more robust than conventional piezo actuators, featuring superior lifetime and performance in both dynamic and static applications.Because guidance, actuators and sensors are all frictionless and maintenance-free, these nanopositioning systems achieve outstanding levels of reliability. P-500 series piezo stages feature a parallel-kinematics design with direct-measuring,non-contact capacitive position sensors (parallel, direct metrology).PI capacitive sensors are absolute-measuring devices that boast very high bandwidth and exhibit no periodic errors.Unlike conventional sensors,capacitive sensors measurethe actual distance between the fixed frame and the moving part of the stage. They detecterrors contributed by all componentsin the drive train from the actuator through the flexures to the platform. This results in higher motion linearity,long-term stability, phase fidelity, and because external disturbances are seen by the sensor immediately—a stiffer,faster-responding servo-loop.

Figure 5. Flexure-guided piezo-driven nanopositioning / scanning stage

- XY˘ θ_Z, XYZ and XY Versions
- Precision Trajectory Control
- Parallel-Kinematics/Metrology for Enhanced Responsiveness /Multi-Axis Precision
- Travel Ranges to 200 µm
- Clear Aperture to 66 x 66 mm
- PICMA® High-Performance Piezo Drives

V. DESIGN OF OPTICAL MICRO SCANNER

A. *Principle of standard 2 ×2 microscanning*

Micro scanning is a common way to reduce aliasing. It takes advantage of the X-ray image formed by the imaging system to implement 1 / N (N is an integer) of pixels from the displacement in x, y directions to achieve N × N frames sub-sampling images. It makes use of the multi-digital image processor to reconstruct the very frame image with sub-pixel displacement into an image so as to ultimately improve the image resolution[7]-[8].

0-3 in Fig .6 represents a 3 × 4 array of detectors staring imaging. The object imaging is on the flat panel detector and microscanner makes an image half the pixel pitch displacement in the horizontal and vertical directions[9]. The first frame image acquired by the focal plane is in the position 0, when the scanning device is fixed. After time T, the micro-scanning device makes the sample position move to right for half of a pitch detector and reach the position1. The first frame image sampled by the focal plane array is output to a digital memory. To acquire the second frame image when micro scanning device is stabilized at position 1.This frame image contains information in some non-sensitive region between the detector elements and is not acquired in the first frame. Acquiring the third frame image as soon as the sampled image is moved to position 2. This process is repeated until the fourth frame of the image is acquired and returns to the 0 position to begin the acquisition of the next frame image. Finally we can get a 6 × 8 pixels in the frame. As can be seen from the above process：throughout the imaging process, the micro-scan is a multiple sampling of the same scene, but the field remains unchanged. The displacement of the planar array is the same size, half of the pixel pitch of detector every time. As a result the number of pixels of the microscanned image is four times of the original .It obtains more information about the scene, thus greatly improving ability of the system to distinguish details on the scene namely spatial resolution[10].

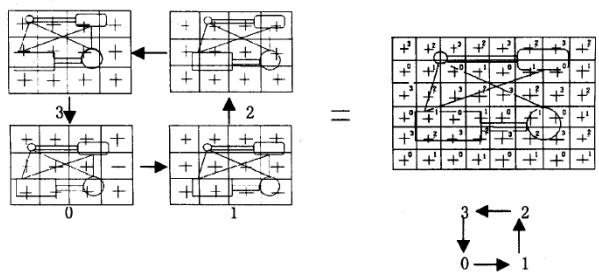

Figure 6. Schematic micro scanning reconstruction process with sub-pixel

B. *Optical microscanning implementations*

There are many methods to achieve microscanning. A variety of scanning mechanism were studied by many research institutions at home and on abroad, such as using a piezoelectric device to driver lens and rotary plate method to achieve micro scanning[11]-[12]. From the current data, basically using optical microscanning mechanism to achieve the micro-displacement relative to imaging device.

In this paper, the way to achieve micro scan is displacement of detector. Probes immobilized on micro-displacement platform and controlling the micro-displacement platform in the horizontal and vertical direction of movement can drive flat-panel detector to complete micro-displacement. As shown in Fig .7The black box represents the actual position of the detector, the imaginary box represents the original position of detector. Fig .1 denotes the location of the detector to the first frame, the micro-displacement of the platform is not moved and the dummy frame overlaps the black frame. "2" denotes the working position of the detector to the second frame, micro-displacement platform moved horizontally to the right to drive detector right."3" represents the working position to third frame detectors, the micro-displacement platform moved vertically downward to drive detector down on the basis of "2"."4" represents the working position to forth frame detectors, the micro-displacement platform moved horizontally to the left to drive detector left on the basis of "3". By precisely controlling the micro displacement amount of the platform in the horizontal and vertical direction, it can control the amount of displacement of the detector.

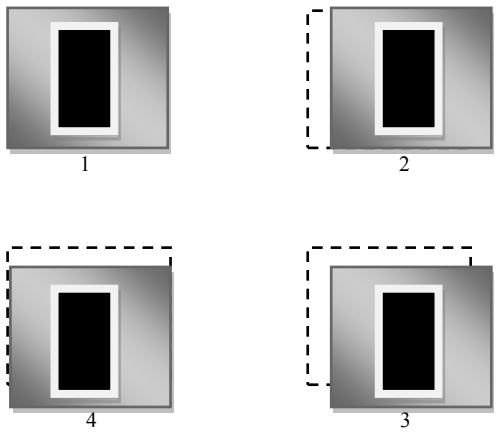

Figure 7. Micro-displacement platform sports to drive flat-panel detector schematic

C. *The actual composition of the microscanner*

In this paper, we choose PI-517.2CL series piezo scanning stage, product of Physik Instrumente (PI Shanghai)Co., Ltd., as a micro displacement of the platform to achieve micro scanning. Flat panel detector is Varian's PaxScan 2520D flat panel detector. Its amorphous silicon planar array size is 25cm × 20cm, pixel size of 127μm, the image gray depth of 14bit. PaxScan 2520D flat panel detector is a novel X-ray imaging device that can replace the image intensifier and a TV camera. The detector has the advantage of the following aspects: ① wide dynamic range, depth grayscale digital images for 14bit; ② low scattering losses, flat panel detector imaging mechanism determines the loss of scattering; ③ fast image acquisition, to reach 30 / s; ④ no images of geometric distortion and distortion. The flat panel detector is fixed to the micro-displacement of the platform and can be controlled to move in the horizontal and vertical direction which is standard 2×2 micro-displacement. As a result, we can get multiple images with micro-displacement. Then we adopt oversampling reconstruction algorithm to complete high-resolution reconstruction to improve system spatial resolution.

VI. CONCLUSION

This article provides an X-ray imaging system with microscanning. Systems can be applyed in printed circuit boards, integrated circuits and other areas of defect detection to improve the reliability of the integrated circuit chip and design level to ensure the performance and quality of microelectronic, optoelectronic devices and their products. If it applyed in the field of industrial radiography, it is possible to detect the damage of the workpiece quickly and accurately and avoid the machine breaking down due to the problems of the workpiece. When used in scientific research, it will provide new analytical tools for scientific and technical personnel and have good prospects and promotional value. After the successful development of microscanning system, it can also be applied to other systems to improve the resolution by changing some of the control parameters, these systems include the X-ray imaging systems, visible imaging systems, infrared thermal imaging system It has a wide range of applications.

TABLE I. THE EVALUATION PARAMETERS OF OPTICAL MICROSCANNING X-RAY REAL-TIME IMAGING SYSTEM

Parameters	**Specification**
pixel	1516×1900
resolution	63 μ m^2
Sensitivity	≤1.8%
Frame rate	50HZ
Pixel size	127 μ m^2

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