Application of 3D surface profilometer in single cut sample inspection

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Abstract: As a non-contact measuring instrument, 3D surface profilometer has many advantages such as high precision, good repeatability and high visualization, and has become the mainstream measuring equipment in the field of micro and nano detection. Single cut line sample, multi cut line sample and step sample have important applications in micro/nano calibration field. In this paper, 3D surface profilometer is used to measure two kinds of samples. The results are compared with those obtained by National Institute of Metrology. The results show that the results are similar to those obtained by other measuring equipment, which proves the powerful function of 3D surface profilometer.

1. Introduction

Surface topography plays a crucial role in the properties and functions of materials and components [1]. In the past, contact 2D measurements were mainly used in manufacturing, such as shipbuilding, steel mills and automobile manufacturing. In most cases, only a line or curve profile was measured to obtain enough information to control production, but only to identify process changes.

Nowadays, many changes have taken place. In high precision optical systems, the surface roughness accuracy of optical components has been required to reach the nanometer level. Because the surface roughness of optical components will affect the propagation characteristics of optical components, light absorption characteristics and scattering characteristics. The lack of measuring accuracy and machining accuracy of the surface topography of optical components often limits its application. In the field of aerospace, precious metal fatigue strength of titanium alloy and its surface quality are closely linked, with research told the milling titanium alloy surface to improve the fatigue life of high speed milling machining has very important significance, northwestern polytechnical university du as more studies have found that with the increase of spindle speed milling surface quality will get better, cutter once walked through the area, The center surface is of better quality than the edge surface. In the medical field, the World Health Organization studies that osteoporosis is characterized by reduced bone mass and changes in bone microstructure. Therefore, the detection of three-dimensional microscopic morphology of bone can effectively predict and prevent the disease. In addition, in the surgical treatment of children with developmental dislocation of the hip, accurate positioning of anatomical markers of the femur can be achieved through preoperative CT scan and digital 3D reconstruction, so as to accurately measure the anterior Angle of the femoral neck, which can guide the operation [2]. In metallurgical production, coal is an indispensable fuel for blast furnace
ironmaking. Guo Wentao [3] from University of Science and Technology Beijing studied the relationship between the evolution of coal microstructure and macroscopic properties under three different gas conditions of traditional blast furnace, full oxygen blast furnace and blast furnace with injection coke oven gas, and put forward the suggestion of selecting coal with different microstructure according to different gas conditions. In the field of microelectronics, the surface roughness of silicon chip in integrated circuit has a great influence on the performance of resistance and capacitance. In the field of laser research, there are higher and higher surface quality requirements for laser mirror window, X-ray component and laser gyro component.

In this paper, the data of two different depths of single cut line samples are analyzed by 3D surface profilometer. It is found that the 3D surface contour measuring instrument is suitable for measuring single cut line sample, and has the advantages of fast measurement speed and high visualization degree.

2. 3D surface profilometer

2.1 Introduction and Composition

3D surface profilometer is an instrument used to measure the surface of various precision devices and materials at sub-nanometer level. It is based on the principle of white light interference technology, combined with precision Z-scanning module and 3D modeling algorithm to conduct non-contact scanning on the surface of the device and establish a 3D image of the surface. Data processing and analysis on the 3D image of the surface of the device are carried out by system software, and 2D and 3D parameters reflecting the quality of the surface of the device are obtained. In order to realize the device surface topography 3D optical detection instrument.

3D surface profiler is mainly composed of a measuring head, a loading platform, a tilt knob, a computer, a vibration isolation base and a workbench. The measuring head is the core part of 3D surface profilometer, which mainly consists of motion motor, scanning module and optical system. The 3D surface profiler is also equipped with a dual-channel air floating vibration isolation system, which can be connected to a stable air source or a standard mute air compressor, and can work stably without an external air source.

2.2 The principle and Measurement Steps

The white light scanning interferometry adopted by 3D surface profilometer is a non-contact measurement method, which compares the deviation between sample test surface and project reference surface through interference fringe. White light interferometric scanning is very useful for measuring rough and discontinuous surfaces. Because the test results of white light scanning are analyzed separately based on the light intensity signal at each pixel, the results are based on the absolute physical height. Single wavelength laser interference systems do not have this advantage when measuring rough samples. The phase shift method combines the phase results of neighboring pixels when processing the data of each pixel, and the original result is based on phase rather than physical distance. This gives white light interferometric scanning a great advantage in measuring rough sample surface data, it can measure rough or step jump structure surface. When measuring the smooth sample surface, the monochromatic phase shift method has the advantage of high speed.

When measuring, first place the sample under the lens of the loading platform, check the motor connection and environmental noise, and confirm the state of the instrument. Use the joystick to adjust the Z-axis and find the interference fringes on the sample surface. After completing scanning Settings and naming, click start measurement. Enter the data processing module, click leveling, the default leveling is adopted for the plane sample, click the lower right corner to apply the save operation. Enter the analysis tool module and click Parameter Analysis to directly obtain surface roughness data. Click parameter standard on the right to change parameter standard and add or delete parameter type. If you want to obtain the measured data, you need to extract the profile line. Enter the data processing interface, click the extraction profile icon, select the oblique line, and extract the profile line along the
2.3 Application Fields
3D surface profilometer can be widely used in semiconductor manufacturing and packaging process testing, 3C electronic glass screen and its precision accessories, optical processing, micro and nano materials and manufacturing, auto parts, MEMS devices and other ultra-precision processing industries and aerospace, national defense, scientific research institutes and other fields. It can measure all kinds of surfaces from ultra-smooth to rough, low reflectance to high reflectance, roughness, flatness, microscopic geometric contour and curvature of workpiece from nanometer to micron level. It provides more than 300 kinds of 2D and 3D parameters as evaluation standards according to ISO/ASME/EUR/GBT standards at home and abroad.

3. Application of 3D surface profilometer
3D surface contourgraph measurement system function more powerful, can be a variety of products, parts and materials on the surface of the flatness and roughness, waviness and surface outline, surface defect, wear, corrosion, pore space, bench height, bending deformation situation, the processing conditions of surface topography measurement and analysis of the characteristics. Feng Hui et al. applied 3D surface profilometer to the surface test of metal materials, and the test results showed that 3D surface profilometer could accurately measure the two-dimensional and three-dimensional morphology and depth distribution of wear spots and corrosion pits [4]. Shi Wei et al. applied 3D surface profilometer in ball bearing measurement, and found that the resolution of finish could reach the nanometer level and the curvature could reach the micron level [5].

3.1 Measurement of single cut sample
The single-notch sample is a standard measuring instrument with a certain groove depth and groove bottom shape, which can verify the vertical magnification of palpation surface roughness measuring instrument, the indication error of surface roughness interference measuring instrument and optical cutting measuring instrument [6]. Single cut plate is a standard measuring instrument with working size of height difference between two measuring surfaces. The groove depth of the single notch sample refers to the height difference between the bottom surface of the groove of the main notch and the base surface [7]. Single cut line sample mainly has flat bottom single cut line sample and round bottom single cut line sample.

Figure 1 shows the 3D scanning diagram of a single line sample, which has clear scanning pattern and clear image color. The whole measurement process is fast, because the bottom surface of the measured sample groove is relatively deep, the medium 20 times lens is used for scanning. In the process of data collection, automatic focusing and automatic brightening, due to the relatively small measurement interval, there is no image Mosaic in the measurement. It can be seen from Figure 1 that the measurement interval is 979 μm in length direction and 979 μm in width direction. In the process of data acquisition, four positions are selected to level the image, which is convenient and quick.

Figure 1. Three-dimensional scanning of single cut sample 1
Figure 2 shows the analysis interface of measurement. It can be seen from Figure 2 that the groove bottom of the single cut line sample is not smooth enough, and the groove shape is like the arc groove surface. The groove surface of single - cut sample is rough. The scale value of the single cut sample was 46 μm, and the result of groove 1 measured by 3D surface contouring instrument was 50254.872 nm, and the measurement data of China Metrology Institute was 50.4 μm. The error between the measurement results and the indication value of China Metrology Institute is 0.145 μm, and the difference between the measurement results is in nanometer level.

Figure 3 shows a 3D scan of another single cut sample. The single-cut sample has a shallow cut depth and is measured with a 10-fold lens at 979 μm in length and 979 μm in width. The measurement interface has the same window as the analysis interface. There is no need to switch, and the measurement data can be counted automatically. The measurement interface has a visual window, and the whole scanning process can be easily observed. The 3D surface contorer is also equipped with double anti-collision protection measures, including anti-collision protection at the lower limit of z-direction displacement. In addition, an electronic sensor is designed on the Z-axis. When the lens touches the sample surface, the instrument can automatically enter a stop state, which can maximize the protection of the instrument and reduce the risk of manual operation.

Figure 4 shows the measurement analysis diagram of single cut line sample 2. The calibration value of single cut line sample two is 9 μm, and the values measured by 3D contour measuring instrument are 8919.744 nm and 8885.688 nm respectively. The measurement value of China Metrology Institute is 9.1μm, and the error between the measurement result and the indication value of China Metrology Institute is 0.180 μm and 0.214 μm, and the measurement result is good.
3.2 Other Measurements

In addition to single cut line sample, 3D contour measuring instrument can also measure step sample, multi-cut line sample, penetration test block and so on. Step sample is represented by the structure shape of step surface collection, which can reproduce or provide one or more physical measuring tools with vertical height values between datum level. The depth of the step sample refers to the height difference between the step surface in the direction of the positioning index line and the datum level [7]. Step pattern mainly includes convex step pattern and concave step pattern. The standard sample of micro/nano step height (depth) is mainly used to calibrate the vertical displacement of micro/nano measuring instruments such as scanning probe microscope, step meter, stylus profilometer and optical surface topography meter. The measurement instrument to be calibrated is compared with the step height (depth) value measured by the series of samples and the calibration value of the samples, so as to evaluate the vertical displacement characteristics of the measured instrument [8].

A multiline pattern is an integration of a single line pattern, which consists of many parallel lines in a certain area. Multi-line sample of surface roughness is used to verify Ra indication error of stylus electric profilometer, as well as the variability and stability of instrument indication error [9]. Test block refers to test block with artificial defect or natural defect. It is used to measure the sensitivity of penetration detection equipment, also known as sensitivity test block. Due to space limitations, analysis of other samples measured by 3D surface profilometer will be described in a later article.

4. Conclusions

3D surface profilometer, as a micro/nano structure observation and measurement instrument, will help us to better understand the micro/nano world. In this paper, two kinds of single-line samples with different depths were used to carry out experiments. By comparing and analyzing the data from The National Institute of Metrology of China, it is proved that 3D surface profilometer can meet the requirements of measurement, and it has many advantages such as high precision and visualization. 3D surface profilometer will be widely used in the future.

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