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Evaluation of Surface Roughness Using Interferometry – A Review

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***Abstract*: In this article we present a review of various method of interferometry principle for assessment of surface roughness. Techniques such as speckle, white light interferometry, digital holography, laser optical systems, microscopic shear and optical profiler have been presented. Images were captured by CCD and machine vision systems are used to carry out morphological operations and to perform analysis and for finding out surface roughness.**

***Keywords*: Speckle, White light, Digital holography, Laser techniques applications.**

1. Introduction

The Roughness measurement has a great importance in machining industries, as the end product of any machining operation is the smooth and good quality surface[1].Proper evaluations of statistical properties of surface and roughness measurement techniques play an important role in many engineering disciplines. Quality and reliability of components is dependent upon its surface texture. Surface evaluation techniques are divided into two types:1] Contact: contact stylus profiler, cmm, scanning probe microscope etc. 2] Noncontact: Laser scanning, White light interferometry, Digital holography etc [2].The development in the noncontact(nondestructive) type of measurement made it possible to take measurement without even touching the test objects .Comparison between contact and noncontact measurement techniques was done to find out the efficiency of those methods [3].

Speckle interferometry which generates speckle pattern when is object of rough surface is illuminated by a highly coherent light beam. When this speckle pattern is viewed in a camera it shows bright and spots called speckle. Many speckle interferometry techniques such as electronic speckle interferometry ,digital speckle interferometry ,speckle shear interferometry, speckle photography have been derived from speckle interferometry[4].Different paper sheet have different surface. Experiment for evaluation of surface roughness of silver nano particles sheet was conducted by using electronic speckle interferometry(ESI)[5],more ever ESI is also used for thermal strain measurement, displacement measurement etc. Digital speckle interferometry which is up gradation of electronic speckle pattern interferometry(ESPI) was used for measuring the surface profile of machined components[6]. Development of micro-electromechanical system takes place from micro fabrication method. For effective measurement of such components the metrology system should have the ability to measure the accuracy in microns. The contact measurement system cannot be used because they can damage the part. So white light interferometry(WLI) is best suited for such application. WLI is also used for 3D microstructure measurement ,tool wear measurement, nanometrology [2], [7]–[9].

Another type of noncontact measurement is digital holography. Mostly used for the precision measurement application such as roughness calculation of tensile specimen and transparent object[10]. The present method of measurement requires redundant conditions to reduce vibration and the further image analysis becomes difficult. So a new method based on microscopic shearing interferometry was proposed[11].Images processing techniques like segmentation, Thresholding, skeletoninzng , numbering are useful for analysis of fringes [12].

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2. Methodologies Used

A. Speckle Interferometry

1) ESP for nanoscale roughness

ESPI which has its roots in speckle interferometry was used for the calculation of roughness of silver nano particle sheet. One sheet sample was coated with silver nano particles and other was kept blank. He-Ne laser was used. Beam splitter splits the beam in two parts, one is used to illuminate the object and another after multiple reflection forms the reference beam. Combination of both beam gives rise to speckle interferograms which is captured by ccd. Unwraping algorithm was used to unwrap phase map. Results showed that sheets with silver nano particles had high roughness. Even the RMS values were calculated.

2) Digital Speckle for surface roughness assessment

Machines surface were assessed by DSI. A Michelson interferometer was used for the experiment. Piezoelectric

driven transducer was used to introduce phase shift via LabView software. He-Ne laser was used. The captured image had lot of noise, Gaussian filtering method was used. Phase extraction of fringes gave 3D profile of surface. Series of interferograms were recorded and analyzed by computer. Phase was unwrapped and by using Discrete cosine transformation (DCT) 3D profiles were constructed. At the end stylus type instrument was used for verification of Ra values.

3) ESPI for characterizing surface roughness speckle pattern analysis

Illumination of rough surface by coherent light source gives rise to grainy structure called. He-Ne laser exposed to rough surface. Five specimens were taken and one by one placed on a travelling micrometer and recording of images was done. Illumination was at a fixed angle. Visible pattern corresponding to each displacement was recorded. Again the object was rotated at some predetermined angles and pattern was recorded for each rotation. Digital Fourier transformation method was used to find roughness.

B. White light interferometry

1) White light for roughness measurement on semiconductor wafer

White light interferometry (WLI) is used for many applications mostly for precision measurement. Experiment consists of a Mirau type (WLI) and the objet was illuminated by coherent white light. The area was measured by objective lens. Lens is moved up and down by PZT (piezoelectric transducer) till brightest fringe is obtained. This results in creation of 3Dmap of sample. By using algorithm roughness was then calculated. Good agreement was shown in results of Atomic Force Microscopy and WLI.

C. Laser optical techniques

1) Surface measurement using laser optical imaging techniques

He-Ne laser was used to illuminate rough surface. Standard rough surface specimen of high and low values was taken. ccd camera was placed at a suitable distance for recording the images. It was observed that homogenous distribution of speckle pattern for smooth images and non-homogenous and incomplete for rough surface. The area was divided into ring like structures High pass filter and Gaussian filter were used to remove form and waviness and roughness value were calculated. Results showed that object has low value in middle and high outside

2) Optical profiler (lasered) vs. stylus instrument-A comparison

Samples of known value were taken. For experiment 3D with He-Ne laser installed in it was used. To find the interference peak, best focus was obtained by vertical scanning. Numerous algorithms were used for analysis of images taken by CCD. The data was then processed to make 3D profile.

For contact method a stylus profiler with suitable tip radius was used. Five samples were taken and Ra and Rz values were estimated. The same experiment was then performed with 3D laser profiler. The agreement between two methods was good for higher roughness values but for lower roughness the stylus instrument was unable to take measurements efficiently.

D. Digital holography

1) Digital holographic interferometry for surface measurement

Tensile specimen was conducted to evaluate, the roughness of tensile specimen. A reflective type Interferometer (holographic) was used and tensile testing machine for application tensile load. The specimen was ruptured with different tensile speed and area of ruptured part was measured. The images were captured by CCD and 3D surface profile was constructed. From the 3D profile roughness values can be calculated easily. Some other application includes microscopic shearing interferometery for roughness measurement. It uses phase shift analysis and recovery algorithm to built roughness profile[11].WLI is used for surface have roughness in nano/micro range. In the case of thin film each substrate is bound to have its own roughness and analysis is more difficult, so Helix Complex function(HCF) was used [13].

3. Conclusion

Sheets with silver nano particles had more surface roughness, as compared to blank sheets. Phase unwrapping and DCT has a potential use for calculation of roughness via DSI. Fourier transformation method was used to analyze image while travelling and rotation of object was performed. White light interferometry is best suited for precision metrology and for thin film measurement. Comparison between contact and non-contact measuring techniques was done and results showed that noncontact methods are best suited. Digital holography was sued for testing an object under tensile load.

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