Multiwavelength microscopy as inspection method for printed circuit boards

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Digital holographic microscopy is a powerful 3D imaging tool for industrial surface inspection and scientific experiment evaluation. As it provides similar lateral resolution as classical microscope and very fine axial resolution. This paper presents the results and the findings of the experimental holographic microscope development. The device construction is described. The emphasis of the research lays on multiwavelength interferometry combined with phase shifting. Phase shifting was done using acusto-optics modulators which allow precisely tune light frequency. A developed enhanced measurement procedure, which increases versatility by increasing dynamic range, is described. Developed algorithms for data evaluation are presented and measured experimental data visualised.

Keywords: microscope, interferometry, phase shifting, Bragg cell, acousto-optic modulator, multiwavelength interferometry

Introduction

Microscopy is a standard inspection method for surface quality evaluation. One of the disadvantages of the classical microscopy is the ability to sense only light intensity. This drawback can be overcome by using digital holographic microscopy (DHM). DHM bestows microscope ability to precisely measure surface height. In combination with a high lateral resolution of the microscopes, it forms superior measurement device.

Phase shifting

Standard holographic measurement approach uses phase shifting to solve the problem of the unknown light intensity offset and gain. A few methods can be used to introduce phase shifting to the system. Developed experimental microscope setup uses the set of the two fiber acusto-optics modulators so called Bragg cell in the reference and the illumination arm in order to introduce phase shifting between the object and the reference wavefronts. One of the properties of used acusto-optics modulators is that it allows light to pass only when a control signal is present. It allows switch off reference arm. As result the device can be used as classic microscope based on light intensity.

Experimental device

The developed holographic microscope in Fig. 1 uses epi-Illumination so it is intended to be used to inspect opaque samples. The device is equipped with microscope objective (5×) and a linear actuator to position sample to the focus.

Image 1: The experimental device

Two wavelength interferometry is based on measuring data at two known wavelengths. A tuneable laser Toptica with wavelength range from 629 nm to 636 nm was used to provide two stable wavelengths for increased axial range.

Measurement procedure

A measurement procedure has multiple steps. For each wavelength phase shifting is performed using the acusto-optics modulators and multiple frames are acquired from the camera. In order to increase the range of the measurable surface reflectivity, multiple frames are captured at the different level of the camera shutter settings. This approach increases dynamic range of the camera.

The captured frames are converted pixelwise using general algorithm of phase-shifting interferometry by iterative least-squares fitting to obtain phase for each wavelength. [1] A phase data from multiple wavelengths is then evaluated in order to get the synthetic phase and the surface shape.

Experimental data

This measurement method can be used for example for a printed circuit board (PCB) inspection when a production technology needs to be optimised. It can provide information about the height and the shape of each surface layer.

$$\lambda_s = \frac{\lambda_2 \cdot \lambda_1}{|\lambda_2 - \lambda_1|}. \qquad (1)$$

A presented experimental data was measured at two different wavelengths 631 nm and 632 nm. Based on equation (1), it means that synthetic wavelength was 398 µm. [2]

The used piece of the PCB is challenging sample as mostly dark surface is partially covered with highly reflective metal layers. Thanks to the dynamic range enhancing technique, it was possible to measure a whole visible area.

The phase and the OPD was evaluated from a multiple consecutive intensity images as presented in Fig. 2. General algorithm of phase-shifting interferometry by iterative least-squares fitting was used to obtain phase data from the intensity images. [1]

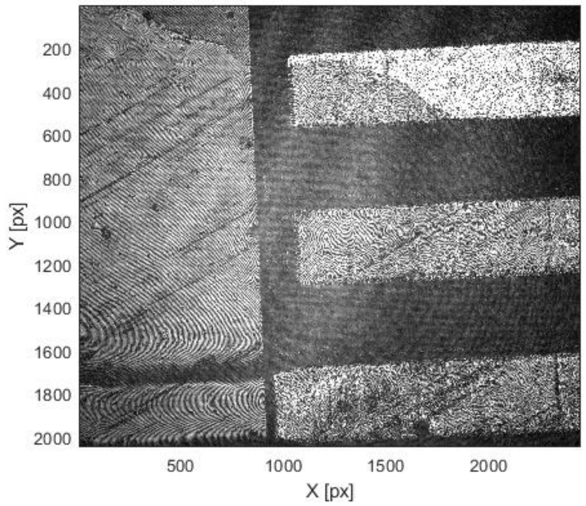

Image 2: Intensity image of part of the sample PCB

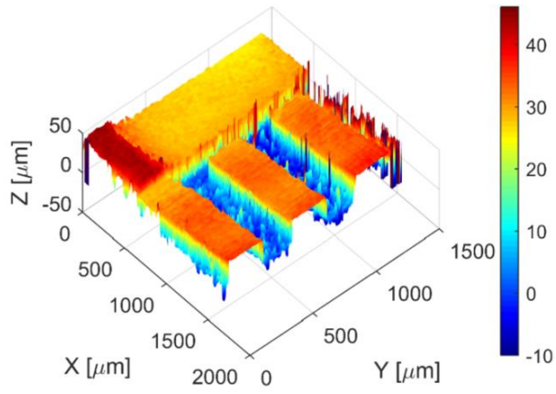

Image 3: Evaluated height data of the sample PCB

It is clearly visible in Fig. 3 how fine the lateral and the height resolution of measurement method is.

Conclusions

The assembled experimental device and the performed experiment helped to verify the theoretical principles of the DHM. The measurement procedure enhancement to increase dynamic range was devised and tested. The measured data were used to test and develop the data evaluation algorithms. It was proven that the acusto-optics modulators are relatively stable and can be used as the reliable source of the metrological grade phase shifting.

Acknowledgements

Tato práce byla podpořena z projektu Studentské grantové soutěže (SGS) na Technické univerzitě v Liberci v roce 2020.

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