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Wavelength correction for thin film measurement in a microscopic white light spectral interferometer

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ABSTRACT

A film measuring method based on a new data model using a home-made microscopic white light spectral interferometer is proposed. It can improve the measuring accuracy of the thin film thickness at different OPDs. The influence of the effective thickness caused by the beam splitter prism in a Michelson interferometric objective is analysed and found not to be negligible while calculating the thin-film thickness. The linear relationship between the effective thickness and the optical path difference (OPD) can be removed by introducing a wavelength correction which made the effective thickness measurement more accurate. Some experiments on the film standard with calibrated film thickness showed that introducing a wavelength correction made the film thickness measurement more accurate at different OPDs.

1. Introduction

Compared with monochromatic interference, white light interference (WLI) measurement overcomes the problem of phase ambiguity, which is widely applied to the surface topography measurement of components with micro-structures. Its characteristic is that the interferogram would only appear when the optical path difference (OPD) is near zero, where the fringe visibility is maximum. However vertical scanning is needed in WLI, so it is time-consuming and sensitive to random noise. If the CCD camera of the WLI measuring system is changed to a spectrometer, white light spectral interferometry (WLSI) can be realised: this technique is widely used in the measurement of distance, displacement, film thickness, and so on [1–8].

A beam splitter prism is widely used in interferometers: they are made of dispersive material such as BK7 optical glass. Because different wavelengths have different optical paths in the dispersive material, the beam splitter in the interferometer will introduce dispersion error if not matched. Typical commercial beam splitter prisms do not guarantee that two optical beams match; the difference is about tens of microns and each piece is different. When the beam splitter prism is not matched, different wavelengths have different zero OPDs, which means that, when one wavelength is at the zero OPD, the OPD of other wavelengths are non-zero [9–11].

The aforementioned dispersive error affects the spectral signal analysis in WLSI. To decrease the error from the beam splitter, the manufacture error and misalignment error should be controlled [9]. In the measuring system, the mismatching must be accurately determined to quantify the dispersive error [12,13].

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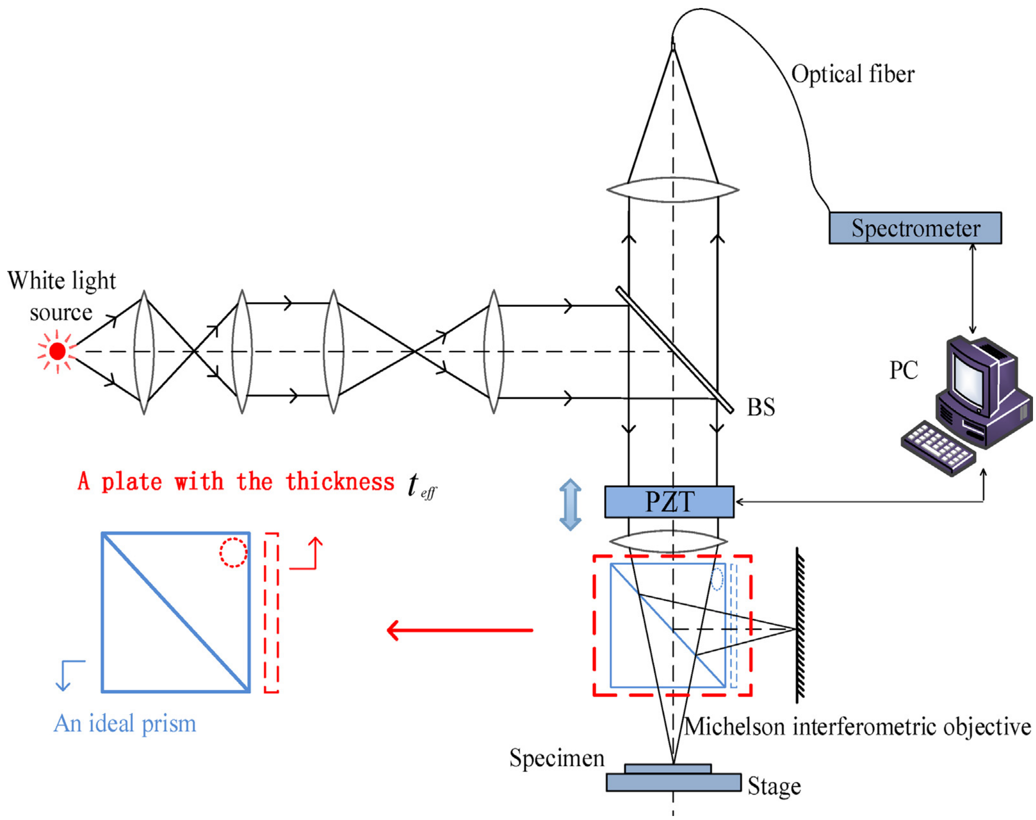

Fig. 1. Diagram of the microscopic white light spectral interferometer.

This research proposes a film thickness measuring method based on a new data model using a home-made microscopic white light spectral interferometer. The influence of the effective thickness caused by the beam splitter prism in a Michelson interferometric objective is analysed. Wavelength correction is applied to compensate the systematic error and improve the accuracy of the effective thickness. Some experiments on a film standard with calibrated thickness show that introducing a wavelength correction makes the film thickness measurement more accurate at different OPDs and it is not sensitive to external vibration.

2. System set-up

The measuring system is based on a Zeiss optical microscope. As shown in Fig. 1, the system includes: an optical microscope, a white light source, the Michelson interferometric objective, an optical fibre, spectrometer, PZT scanner, personal computer, *etc*. The light source is a halogen lamp which illuminates the Michelson interferometric objective after collimation. The beam splitter in the objective divides the incident light into two beams, including the measuring beam and the reference beam. The measuring beam is reflected by the sample surface and then interferes with the reference beam at the beam splitter. An optical fibre spectrometer (USB4000, Ocean Optics) is used to acquire the interferometric signal via the optical fibre and then the signal will be transmitted to the computer after A/D conversion. The detection range of the spectrometer is 200–850 nm, and the wavelength resolution is 1.33 nm. After data processing, some parameters, such as absolute distance and film thickness, can be obtained. The magnification of the Michelson interferometric objective (from Nikon) is 5 × and the numerical aperture (NA) is 0.13. The objective is driven by a PZT scanner (P-721.CL, PI), which can be used to change the OPD and realise phase-shifting measurement.

3. Thin-film measuring principle

The white light source in the white light spectral interferometry has a broad band. The interferometric signal only appears in a narrow region, which could be regarded as the incoherent superposition of a lot of incoherent monochromatic interferometric signals. It contains the amplitude and phase information at different wavelengths within the full spectrum of the light source. This information can be used to measure the characteristics of the thin film.