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Original Citation

Muhamedsalih, Hussam, Blunt, Liam, Martin, Haydn, Jiang, Xiang and Elrawemi, Mohamed (2014) An interferometric auto-focusing method for on-line defect assessment on a roll-to-roll process using wavelength scanning interferometry. In: Proceedings of EUSPEN 14th International Conference 2014. EUSPEN, Dubrovnik, Croatia, pp. 177-180. ISBN 978-0-9566790-3-1

An interferometric auto-focusing method for on-line defect assessment on a roll-to-roll process using wavelength scanning interferometry

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Keywords: auto focus, wavelength scanning, embedded metrology and PV defect

Abstract

The quality and lifetime of flexible photovoltaic (PV) modules is dependant on having an effective vapour barrier layer which protects active elements from environmental degradation. An effective flexible barrier layer can be produced by employing a thin film of Al_2O_3 (40-100 nm thick) on a polymer substrate using atomic layer deposition (ALD). By measuring the surface of the barrier coating critical defects that will result in excess vapour transmission can be detected and minimised. Such, knowledge of defect size, type and distribution forms a crucial dataset for informing process control. This paper reports on a practical embedded inspection technique to measure the surface topography of the thin ALD deposited Al_2O_3 barrier film on a roll-to-roll manufacturing platform. The method combines wavelength scanning interferometry (WSI) along with an auto-focus method. Example measurements are given and discussed.

1 Introduction

Flexible PV cell degradation due to water ingress can be minimised and controlled by implementing a thin (40-100 nm thick) barrier coating of Al_2O_3 using atomic layer deposition technique (ALD). However, it has been found in previous studies that there is a correlation between surface defects in the film barrier and the water vapour transmission rate (WVTR) [1]. In order to guarantee the barrier condition, surface inspection needs to be carried out during the roll to roll manufacturing process. However, measuring the entire surface topography of barrier coatings over a large area substrate, under laboratory conditions, is impractical and very time consuming. Current instrumentation suffers from the inability to perform embedded (on-line) measurement and is only able to sample of very small selected zones, effectively batch sampling. In this paper the authors introduce a concept system using that combines wavelength scanning interferometry (WSI) together with an interferometric auto-focusing method in order realise the possibility of measuring surface topography of a vapour barrier film across a large area on a roll-to-roll manufacturing platform.

2 The Wavelength Scanning Interferometer (WSI)

WSI is employed to measure the surface topography of the barrier coating and is capable of generating surface maps with unambiguous height, without the well-known 2π phase ambiguity limitation, figure 1. The interferograms are produced with no mechanical movement but by scanning the wavelength of a halogen light in the visible region (683.4 nm-590.9 nm) using an acousto-optic tuneable filter (AOTF). Such a measurement methodology can provide significant enhancements in speed compared to comparable methods such as white light interferometry. In addition, WSI can be stabilised against environmental disturbances by using an active control of the reference arm, thus enabling nanometre scale measurements with large amounts of environmental isolation [2]. This active control consists of a reference interferometer which provides positional feedback and a piezo-electric transducer which moves the reference mirror.

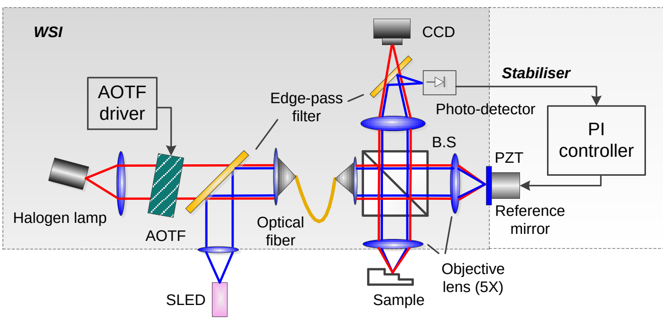
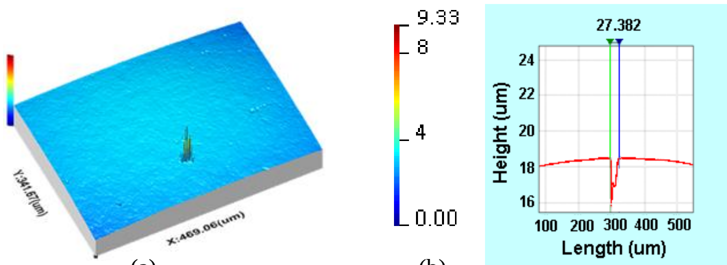


Figure 1: Configuration of the WSI

The system can compensate for disturbances in the optical path length up to a few microns at 10^2 Hz. The reference interferometer is sourced by a super luminescent diode (SLED) light source having a central wavelength of 820 nm and sharing the same optical path as the rest of the WSI. The intensity of the generated fringes is detected by a photo-detector which monitors the SLED light only, via a dichroic filter that allows the scanned visible light to pass through to the CCD. During the measurement process, 256 interferograms are captured over a field of view of 640x480 pixels. A periodic interference pattern produced for each captured pixel is analysed individually using Fourier transform algorithm. The full analysis of all the pixels is accelerated by parallelising the computation with a many-core graphic processing unit (GPU). The WSI can capture and generate a full areal topography in 3.7 seconds. Figure 2 shows a defect of 1.85 µm amplitude and 27.4, µm width captured using 5X objective lens.



(a) (b)

Figure 2: (a) Surface topography and defect on Al_2O_3 film (b) defect profile section

3 Auto-Focusing interferometric method

An effective auto-focusing methodology is crucial to the successful implementation of the WSI for large flexible substrate measurement. The flexible substrate is held by an air-bearing system but surface undulation is still substantial across the 500 mm web width. Fast, automated positioning of the WSI head so its focal point is at the top layer of Al_2O_3 barrier is needed which must also be robust against the possibility of mis-focusing due to the multilayer structure of the web. The auto-focus method is based on tracking the peak of the coherence envelope of the reference interferometer sourced by the SLED while the head is moved normal to the web. Figure 3 shows a proof-of concept experiment which uses a sample of the web mounted statically. The substrate of Al_2O_3 coated film barrier is attached to a stepper motor in order to translate the film through the focal plane of the WSI objective lens. Simultaneously the intensity response is monitored by the reference interferometer, with the maximum intensity (coherence envelope peak) being found to be the point of focus. Throughout the translation, the position of the film is acquired continuously from the encoder of the stepper motor in order to map the physical position of the translation stage to peak position of the coherence envelope. This information allows the stage to move to the precise point of focus after the scan. The speed of the auto-focusing method is dependent on the speed of motorised translation stage. For the reported proof-of-principle experiment, the the auto-focus routine, using a 1 mm translation distance, took approximately 0.6 second.

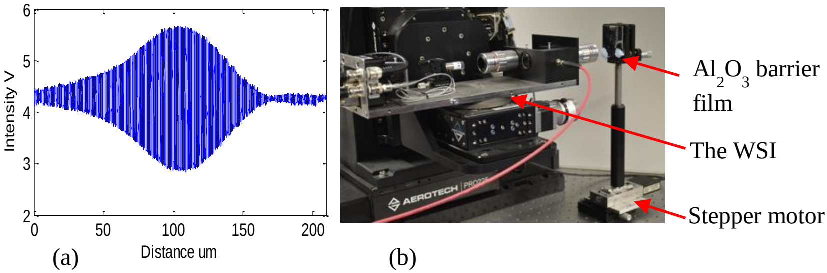


Figure 3: (a) The coherence envelop (b) The WSI along with auto-focus method

4 Summary

This paper reports a practical implementation of wavelength scanning interferometry and an interferometric autofocusing technique that will be used to measure surface topography of the barrier film within a roll-to-roll manufacturing platform. The finalised system will provide rich data on critical defects in vapour barrier layers produced using a roll-to-roll ALD process. The speed of throughput and scope for substrate coverage is improved substantially over off-line techniques for generating surface topography information.

Acknowledgements

To EPSRC for grant EP/I033424/1 and EU FP7 programme for NanoMend project NMP4 LA-2011-280581.

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