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## Implementation of line-scan dispersive interferometry for defect detection

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### Abstract

Surface assurance is one of the main concerns for advanced manufacturing technologies such as Roll-to-Roll (R2R) technique. The undesired defects present on the barrier films make R2R products suffer from a low efficiency and short life span. In order to enhance the performance and the yield of the products, an inspection system enabling in-line metrology of functional surfaces in production lines is desirable to optimise the manufacturing processes. This paper reports an instantaneous line-scan dispersive interferometry which has sufficient resolutions and nano-scale measurement repeatability to detect defects on flexible PV films. Free from any mechanical scanning and obtaining a surface profile in a single shot allows this setup to minimise environmental effects and to be used on the shop floor. The captured spectral interferogram is analysed using a FFT based algorithm, and the process time can be accelerated through data parallelism using a graphics processing unit (GPU). The performance of the developed system was evaluated experimentally by measuring the polyethylene naphthalate (PEN) films provided by the Centre for Process Innovation (CPI). The experimental details and results are presented in this paper.

**Keywords:** dispersive interferometry, defect detection, photovoltaic film, phase slope.

### 1. Introduction

R2R technology has been adopted to fabricate multi-layer flexible devices for a reduction in product costs and throughput time. Such flexible Photovoltaic (PV) films technology is widely used in integrated field for offering particular design option and extends its applications to Building-Integrated-Photovoltaic products [1]. An effective barrier such as a thin coating of Aluminium oxide ( $\text{Al}_2\text{O}_3$ ) by atomic layer deposition (ALD), is used to protect the active elements from environmental degradation due to water and oxygen ingress. However, the function-affecting defects are inevitably generated during the R2R manufacturing processes. It has been found that defects especially present on the barrier film during  $\text{Al}_2\text{O}_3$  ALD process are significant in the deterioration of the PV module's efficiency and lifespan [2]. Therefore, one of the biggest challenges faced by industry when using R2R is characterising the functional surface during the manufacturing process to detect the significant defects and finally guarantee the barriers with good condition.

The surface metrology in production lines requires inspection of the film surface with a sufficient resolution and a production speed. Many optical techniques such as machine vision [3], scatterometry [4] and optical interferometry [5] were investigated for defect assessment in the flexible electronics industry. In this paper, an instantaneous line-scan dispersive interferometry (LSDI) is developed for characterisation of the defects present on R2R products. By obtaining a surface profile in a single shot without any mechanical scanning, the developed metrology device has great potential to be used for in-line R2R metrology in terms of quality assurance.

### 2. LSDI principle

LSDI is capable of performing surface profile measurement in a single shot without the well-known  $2\pi$  phase ambiguity

problem. Additionally, the mechanical scanning in height can be eliminated by spatially dispersing the interference beam along the chromaticity axis of the camera.

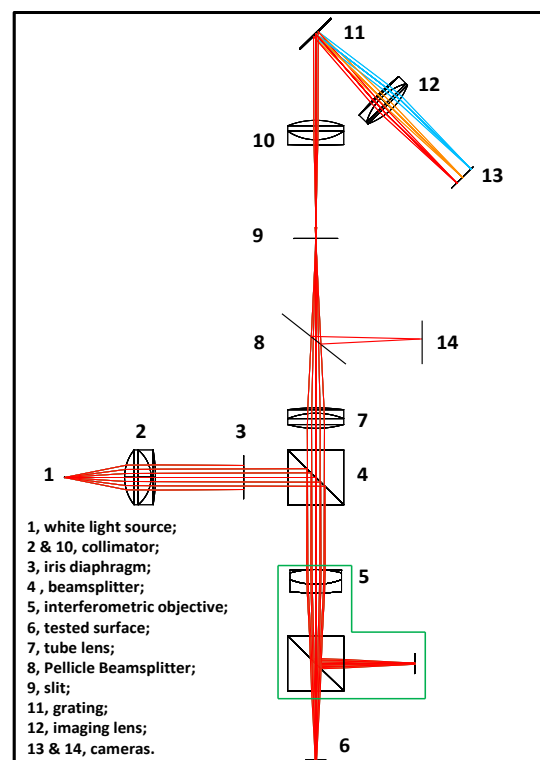


Figure 1. Optical configuration of the LSDI

The basic configuration of the LSDI system is illustrated in Figure 1. A halogen bulb with broadband spectrum provides the white light illumination for the system. A 4X Michelson interferometric objective is used to resolve the features on the

tested surface. Interference occurs when the two light beams reflected from the reference arm and the measurement arm are brought together. Then this interference beam is focused by a spherical tube lens and split into two parts by a pellicle beamsplitter. A CCD camera is set at the reflected optical branch to provide real-time images of the tested surfaces. The other optical branch is brought to a spectrometer to produce spectral interferogram for surface profile measurement. The slit is used to block the light redundant for measurement and is set to be parallel to the columns of camera pixels, therefore the dispersion axis is along the rows of the pixels. Finally, the height information of the profile is registered in the two-dimensional interferogram with lateral information in vertical direction and chromaticity axis in horizontal direction. A FFT based algorithm [6] is used to analyse the obtained fringes pattern. In-line surface inspection is then performed by translating the sample along horizontal direction.

### 3. Measurement results

A detailed defect classification was described by Rebeggiani et al. [7] and the work in this paper is to investigate the possibility to detect these defects using the LSDI. A PEN film from CPI was measured. In order to better understand the performance of the developed metrology device, an area with some significant defects has been selected for inspection. Additionally, the commercial instrument Talysurf CCI 3000 was also used to measure almost the same area on the sample surface to provide a reference.

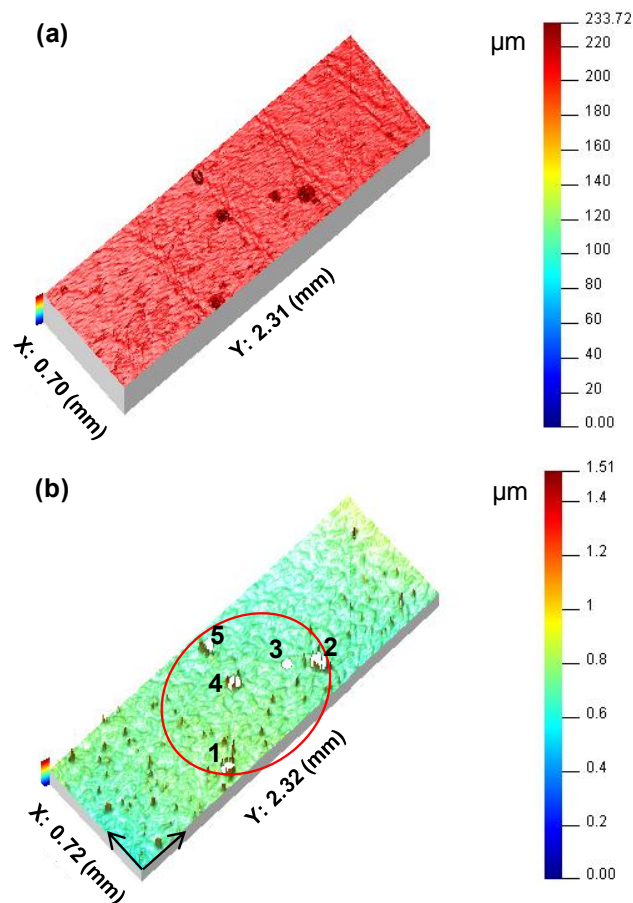


Figure 2. Surface inspection results: (a) LSDI result, (b) CCI result.

The measurement results acquired by LSDI (a) and CCI (b) are shown in Figure 2. The scales in Figure 2 do not represent the actual heights of the defects. Such factors as numbers of invalid

data points in the defect areas (CCI) and spiky errors due to the irregularity of interference fringes from the defect surface (especially for LSDI) lead to the discrepancies between the defects' heights in both measurement results. The surface map shown in Figure 2(a) is constructed by 1400 surface profiles which represents a scanning length of 2.31 mm. It can be observed that LSDI is capable of detecting most of the defects detectable by CCI. Five function-affecting defects were selected and labelled for approximately investigating their locations, as shown in Figure 2(b). The position of defect 1 was set as the reference point to calculate the relative locations of other four defects, as listed in Table 1. Considering the effects such as different fixed modes of the sample, different measuring principles (profile measurement versus areal measurement) and scanning errors from the linear translation stage, the slight differences of the relative positions are tolerated and do not affect the validation of LSDI's performance because only successful defect detection is concerned for this measurement. On the whole, the locations of the defects correlate well between the CCI measurement results and the LSDI results.

Table 1 Defects specifications in terms of relative locations

Defects	Relative locations (x,y)(mm)	
	LSDI	CCI
1	Reference point (0, 0)	
2	(0.02, 0.71)	(0.01, 0.70)
3	(0.18, 0.58)	(0.16, 0.58)
4	(0.29, 0.28)	(0.26, 0.27)
5	(0.56, 0.21)	(0.53, 0.29)

### 4. Conclusions

We have demonstrated a fast line-scan dispersive interferometer with good performance in detecting the defects present on the PEN film surface. Obtaining a surface profile in a single shot enables the metrology device to be environmentally robust for use on shop floor. The developed system offers an attractive solution for quality assurance in R2R manufacturing processes and will consequently enhance the performance as well as the yield of the PV film products.

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