

Development of the In-Situ Thickness Monitoring and Feedback System for OLED Mass Production System

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Abstract

Canon Tokki has developed an in-situ monitoring (ISM) system that can measure the actual film thickness in OLED mass production deposition equipment. This has enabled them to successfully control the sheet to sheet film thickness in OLED mass production deposition equipment to within $\pm 1\%$.

Author Keywords

OLED, Deposition system, Thickness monitoring system

1. Introduction

Conventionally, a quartz crystal monitoring system (QCM) has been used to control the thickness of the deposited film in organic electroluminescence deposition equipment used to fabricate organic light-emitting diode (OLED) displays. QCM systems convert the accumulated weight of film deposited on a quartz crystal oscillator into a film thickness and displays it. QCM do not directly measure the film thickness applied to the substrate and is an indirect measurement method.

When the thickness of the film increases, measurement using this QCM can differ from the actual thickness. Therefore, when measuring the thickness of film deposited over a long period of time, as with mass production equipment, there is a problem of thickness deviation between the start film thickness and the film thickness after several hours.

Film thickness difference between sheet to sheet must be controlled for high-precision processes, including when forming microcavities. The difference in film thickness between the start of mass production, and the end of several tens of hours of production can affect the light-emitting characteristics of the OLED displays.

Measures can be taken to minimize film thickness deviation between sheet to sheet including taking film thickness measurements from dummy glass mass production. The actual film thickness of the dummy glass can be measured outside of deposition chamber vacuum, and the measured values can be used to calibrate the QCM control parameters.

Negatives of dummy glass thickness sampling include reduced process productivity. There is also a delay in acquiring the actual film thickness from the dummy glass and updating the QCM value.

To provide maximum throughput processing, plus fast application of QCM offsets, Canon Tokki has developed an ISM system that can measure actual film thickness within OLED mass production equipment.

2. In-situ Thickness Monitoring and Feedback System

FIG 1(a) shows a top-view illustration of an OLED mass production system. An ISM is installed in a pass chamber to provide feedback and control the film thickness in the preceding organic deposition chamber process.

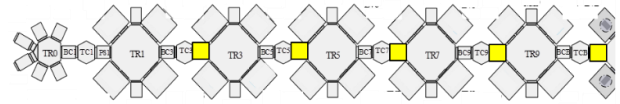


FIG. 1(a) Top View of G6H mass production system with ISM (ISM is installed in yellow areas)

FIG. 1 (b) shows an overview of the in-situ film thickness measurement system. OLED mass production systems are usually configured into cluster-type deposition equipment [1], and ISM can be installed in the substrate transfer line pass chambers.

In the pass chamber, the ISM system measures the actual thickness of the organic films formed on the glass substrate. The film thickness value is feedback to adjust the quartz monitor control parameters and the evaporation source scan speed. This makes it possible to successfully control the inter-surface film thickness to within $\pm 1\%$.

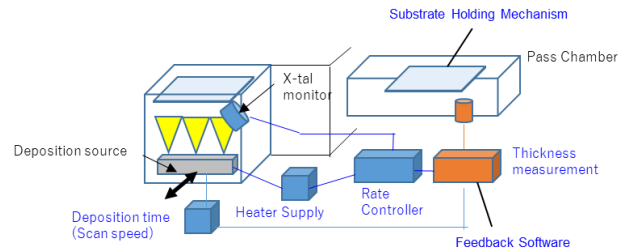


FIG. 1(b) ISM system

Table 1 shows the specifications of the ISM system developed by Canon Tokki. ISM System implementation allows sheet to sheet film thickness to be controlled within $\pm 1\%$. ISM also does not lengthen process time and the original equipment (without ISM) specification of 60 second tact time can be maintained.

Table 1 ISM Specifications

	Sheet to Sheet Film thickness	Tact time
Specification	$\pm 1\%$ (3σ)	60 s

3. ISM Measurement Equipment

The ISM system must be compact and provide good measurement repeatability. ISM hardware must be compact enough to measure film thickness inside a pass chamber that is designed with only enough space to facilitate substrate transport. The ISM system must also deliver accurate measurement repeatability to allow OLED deposition systems to control inter-surface film thickness variation to within 1%.

Table 2 shows a comparison of ISM system, with that of a spectroscopic ellipsometer. Although there are differences in the light irradiation angle and measurement data, both use optical constants as parameters for calculating film thickness values.

In ISM, light is introduced into a vacuum chamber using an optical fiber. Light irradiation onto the substrate, and light reflection intensity from the substrate are measured. The ISM measuring unit has a very compact configuration, with only an optical fiber inside the pass chamber.

Table 2 ISM system comparison with spectroscopic ellipsometer

Item	ISM	SE
	(Canon Tokki Custom)	(Spectroscopic Ellipsometer)
Light irradiation angle	Vertical	70 deg.
Measurement data	Reflectivity	ψ, Δ
Film thickness calculation parameters	Optical constants (nk)	
Repeatability 3σ	○	◎

4. ISM measurement Repeatability

SE and ISM were used to measure the thickness values of samples in which single layers of Alq3 and α -NPD were formed on a glass substrate.

The horizontal axis of Figure 2(a) shows the film thickness measured by SE, and the vertical axis shows the film thickness measured by ISM. Even for sublimation and molten materials, we confirmed that R^2 was at least 0.99 with good linearity. We believe that this is due to ISM’s ability to follow changes in film thickness.

FIG 2(b) shows the 3σ obtained when measuring a sample using the ISM measuring instrument. Regardless of the material and film thickness, the 3σ was within $\pm 1 \text{ \AA}$, confirming good measurement reproducibility.

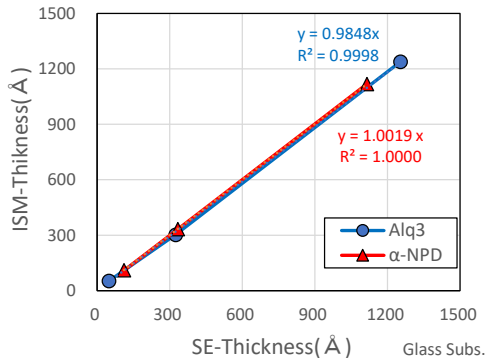


FIG. 2(a) ISM vs SE thickness measurements

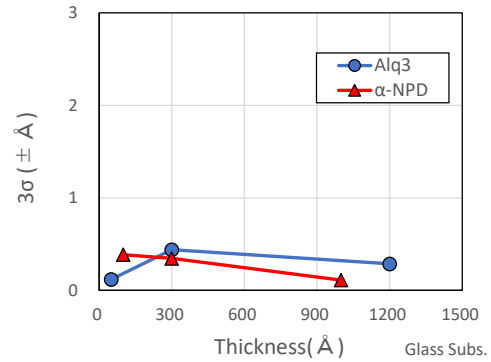


FIG. 2(b) 3σ measured with ISM (N=10)

5. Thickness Feedback

Validation of the deposition system was performed by depositing a single layer of Liq on a G6H-sized glass substrate. FIG. 3 shows the change in film thickness when the target thickness was set to 105 Å, and film thickness feedback was enabled.

The film thickness of the first substrate formed without feedback was measured using the ISM system. Based on the first substrate result, the deposition conditions were changed, and a film was deposited on a second substrate. The second substrate actual film thickness was measured by ISM, and the results were used to control the deposition conditions on a third substrate. The results confirmed that after 2 ISM feedback loops, the thickness converged to the target thickness.

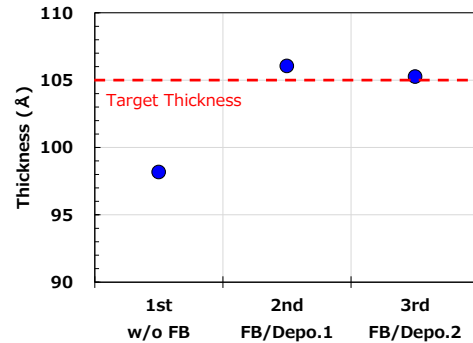


FIG. 3 OLED mass production equipment thickness control with in-situ film thickness monitor system.

6. References

[1] E. Matsumoto.; SID 2020 DIGEST. 61-4.