Encapsulated Organic Light Emitting Diode Devices Characterization by Spectroscopic Ellipsometry

Ikuko Tsuda, Nataliya Nabatova-Gabain, HORIBA Japan

OLED devices, which are considered as the display technology of the future, are currently used as displays for MP3 players, cell phones and other small/mid-sized applications. Compared to LCD devices, they combine superior viewing angles and response times with lower power consumption, higher color saturation and can also be more efficiently manufactured. However, OLED devices degrade when exposed to air and water and hermetic sealing from the environment is required. Conventional methods to protect OLED devices are based on applying a metal or glass cap filled with inert atmosphere and a desiccant.

In this Application Note Spectroscopic Ellipsometry, a standard optical characterization technique used to measure multi-layered thicknesses and optical constants (n,k), has been successfully used to characterize such encapsulated OLED devices. This report also investigates the aging process of an OLED.

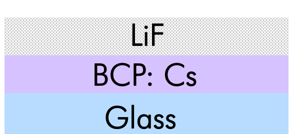
OLED Sample Description and Experimental Measurement Procedure

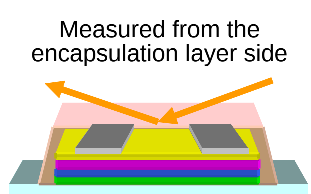
Three OLED samples have been characterized using the HORIBA Jobin Yvon Spectroscopic Phase Modulated Ellipsometer.

- The **first sample** consists of a layer of Caesium (Cs) doped bathucuproine (BCP) deposited on glass and encapsulated by a lithium fluoride LiF layer.

  Ellipsometric measurements are possible through the encapsulation dielectric layer as incoming ellipsometric light can pass through the transparent LiF layer and then into the BCP layer.

  The sample structure used for ellipsometric modelling is shown below:

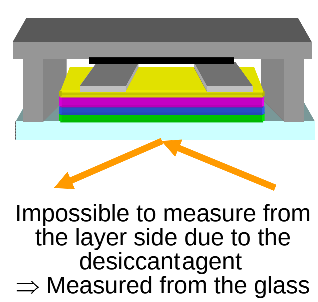


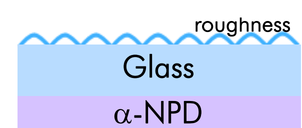


- The **second sample** is composed of a N, N'-bis(1-naphtyl)-N, N'-diphenyl-1, 1'-biphenyl-4, 4'diamine (α-NPD) film deposited on glass and encapsulated with a glass cap that integrates a dessicating agent in its inner part.

  Ellipsometric measurements are impossible from the cap side as the incoming light is totally absorbed by the dessicant and cannot penetrate through to the OLED device to be measured.

  However, it is possible to make measurements through the glass substrate, and this approach was taken here. The sample structure used is presented below. The DeltaPsi2 software, which is the common software platform controlling all HORIBA Jobin Yvon ellipsometers, enables the modelling of sample structures with substrates on the top or on the back of the structure.





- The **third sample** is a non-encapsulated 50nm α-NPD layer on glass.

  Three ellipsometric measurements performed at day 1 (immediately after the sample preparation), day 17 and day 27 allow investigation of the aging process of the α-NPD layer exposed to air in the laboratory environment.

Optical Characterization of Encapsulated OLED Samples by Spectroscopic Ellipsometry

Accurate characterization of the three OLED samples was successfully carried out using the UVISEL Spectroscopic Phase Modulated Ellipsometer from HORIBA Jobin Yvon. Ellipsometric measurements were collected at an angle of incidence of 60° across the spectral range 250-830nm (1.5-5 eV).

The proven sensitivity and accuracy of UVISEL Spectroscopic Phase Modulated Ellipsometer for very thin multi-layered films deposited on glass substrate makes the UVISEL the most suitable optical instrument for OLED device measurement.

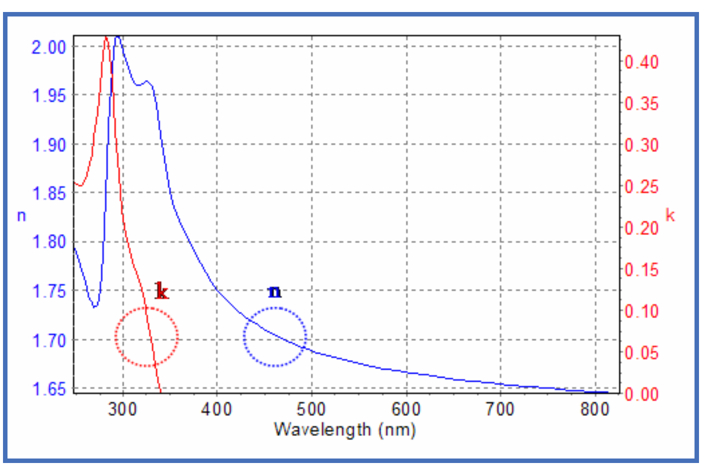
Sample 1 Results

The table below shows ellipsometric results obtained for sample 1.

Ellipsometric characterization	Thickness (nm)	n@633nm
BCP:Cs	63.6	1.661
LiF	74.4	1.327
Total thickness by ellipsometry	138	

Excellent correlation was obtained with a stylus profilometer where a total thickness of 135 nm was measured.

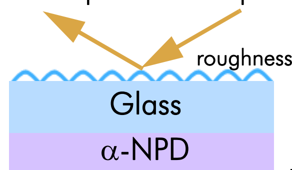
Optical constants - refractive index (n) and extinction coefficient (k) as function of wavelength - for the Cs doped BCP layer are displayed below.



Sample 2 Results

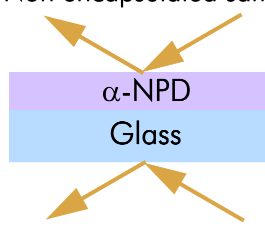
The results for the encapsulated α-NPD sample measured from the glass substrate side are summarized in the table below.

Encapsulated sample



	Thickness (nm)	n@633nm
α-NPD measured from backside	54.1	1.793

Non encapsulated sample



	Thickness (nm)	n@633nm
α-NPD measured from backside	54.2	1.790
α-NPD measured from front side	52.6	1.792

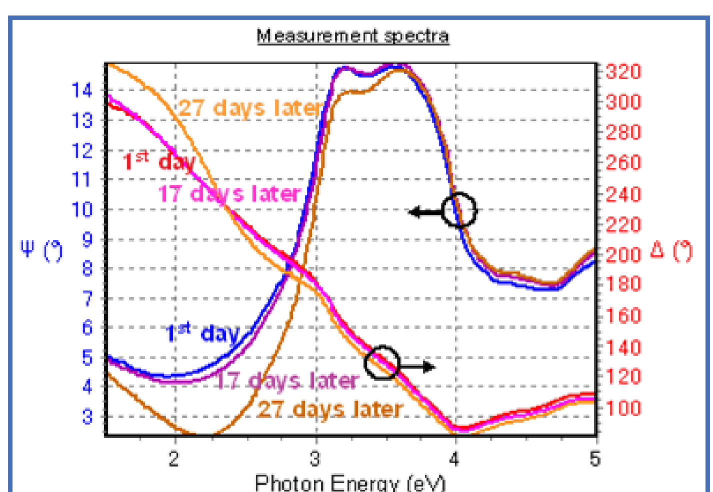
To prove the reliability of the measurement via the glass substrate for the case of the non transparent encapsulation cap, the same sample with no encapsulation was measured from both sides i.e. from the α-NPD side (front side) and the glass side (backside).

One can observe that the thicknesses obtained for both non encapsulated and encapsulated samples measured from backside are very close.

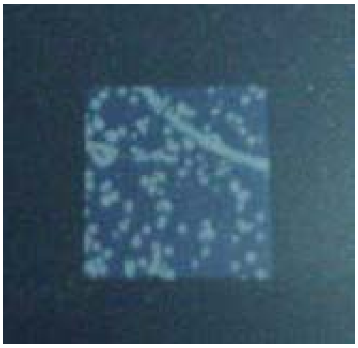
Sample 3 Results

The results found for the investigation of the aging effect of α-NPD film exposed to the air are presented below.

Ellipsometric (Ψ,Δ) curves measured the 1st, 17th and 27th day show a relevant shift after 27 days.



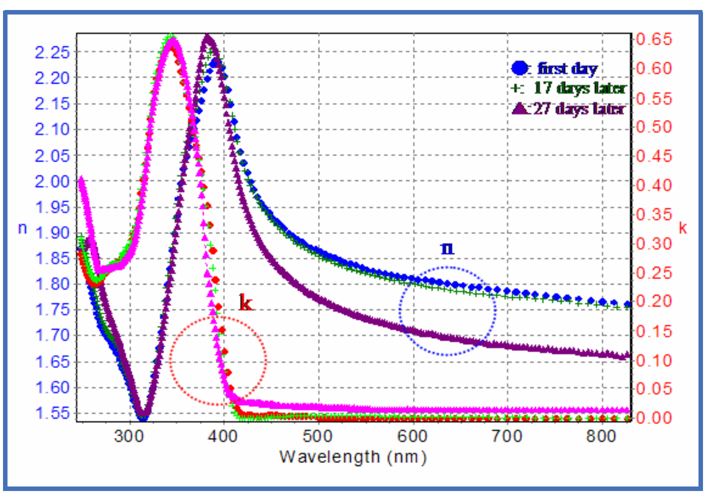
At day 27, the sample exhibited white grains formed at the surface.



Picture of OLED sample taken at day 27

The thickness and refractive index determined by ellipsometry show that the thickness of α-NPD layer increases from 52.0 to 61.6 nm, while the refractive index decreases from 1.803 to 1.698 (values at 633 nm) suggesting a decrease in material density.

	Thickness (nm)	n@633 nm
1st day	52.0	1.803
17 days	54.3	1.790
27 days	61.6	1.698



Conclusion

Spectroscopic ellipsometry is a powerful technique to characterize the thickness and optical constants of encapsulated OLED devices.

For the case of non-transparent encapsulation the combination of ellipsometric measurements via the glass substrate and the powerful modelling features of DeltaPsi2 software make it possible to analyze "this reverse sample".

Ellipsometric investigation of a 1-month aging process for an α-NPD film show a significant decrease of the refractive index, suggesting a decrease in the material density.

Acknowledgments

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