Shortening Time of Life-Time Evaluation for QD-OLED Through Low Gray Observation Condition

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Abstract

Image sticking problem has been considered a last obstacle of QD-OLED in terms of technical field. There are several ways to expend life time of image sticking including modeling advanced. However life time of light source itself is essential. Durable material causes long evaluation time. Accelerated evaluation has been used to shorten time until now. Extremely high brightness evaluation makes unnecessary noise such as pixel shrinkage. It brings errors of modeling like brightness coefficient inaccurate. To solve the problem we found low observation gray shows decay shape of QD-OLED faster than high gray observation. Also decay shape was quite similar among different observation grays except very low observation grays. In this paper we introduce method which we could reduce evaluation time by using low gray observation data.

Author Keywords

QD-OLED, Roll-off, Life time, Observation gray

1. Introduction

QD-OLED has launched in 2022. Pure spectrum of QD-OLED improved color gamut. Lambertian radiation of QD improved viewing angle called WAD. In spite of these merits Burn-in has been issue of all OLED display including QD-OLED. Every year QD-OLED has expanded burn-in life time. It has been reached the goal through advanced modeling and image sticking prevent IP and so on. However long life time light source itself is essential and fundamental development way. Durable material also causes long evaluation time. It brings long development time of product of QD-OLED. Accelerated evaluation has been used to reduce time for extraction acceleration factor regarding brightness or temperature. It was quite useful so far.

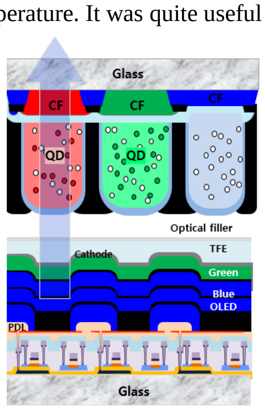

Figure 1. QD-OLED Structure and 2 color OLED

We could gather enough data within product specification. As material was improved, we needed more accelerated conditions to meet the time. Sometimes we had to choose such a condition which was far from real using condition. It brought risk possible such as pixel shrinkage. It caused inaccurate modeling factor. Acceleration test needed wide evaluation scope as well. Of course it cost time and money. In this paper we introduce method possible to save time without acceleration test of QD-OLED.

2. Roll-off and time dependency

Fig.2 shows 31.5" QD-OLED efficiency change according to aging time. It is about blue observation condition. But Red and Green have same trend as well.

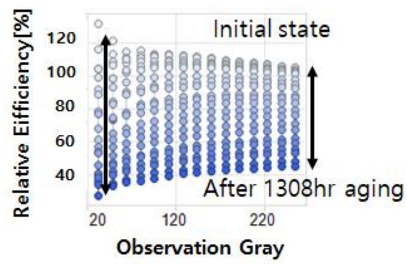

Figure 2. QD-OLED initial efficiency and time dependency

At first we can see that lower gray makes higher efficiency at initial state. We call this roll-off. As time goes by relative efficiency totally changes. Low gray shows low efficiency after certain time aging. So it makes different aging speed. Even if we age QD-OLED under same brightness and temperature, observation gray condition makes different degradation. It means low gray observation condition can make aging faster. Actually from Fig.3 we can see different degradation speed. At 255 observation gray shows only 25% degradation but 64 gray indicates 45% degradation under same aging condition. We gathered 31.5" QD-OLED life time data of red pixel. Other colors had same trend.

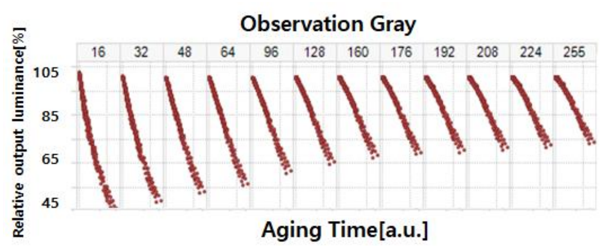

Figure 3. Degradation speed according to observation gray

2.1 Different life time of two light sources

In 2023, some newspaper reported OLED structure of QD-OLED. Fig.1 shows that structure. We call that 4T. T means

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tandem. 4T consists of 3 blue and 1 green light source. Two different light source have different life time each. Blue have better durability than green light source. Fig. 4 shows 4T itself color change regarding observation gray initial and after aging. Before degradation 4T have higher color coordinate y as we see lower gray. It means green light have more portion than blue at low gray. After degradation it is changed a lot. Low gray have low color coordinate y. It means blue light portion have increased during aging. Green light source decays faster than blue. Of course we did cross check degradation speed from spectra change initial and after aging.

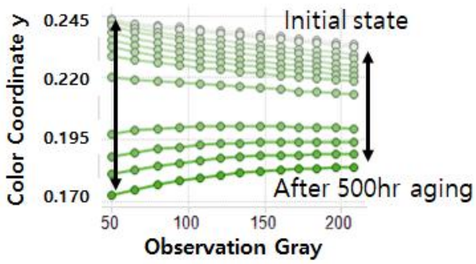

Figure 4. QD-OLED color without QD initial & after aging

Fig.2 and Fig.4 are very similar. We think Roll-off feature of QD-OLED is related to green OLED highly.

3. Decay shape of QD-OLED

So far, we have seen low observation gray condition make degradation faster. And it comes from Roll-off feature change after aging. Also we could guess Roll-off feature is related to green light source. From now we present decay shape. Fig.5 is decay shape of QD-OLED at green pixel from 16 gray to 255 gray of observation. In fig.5 to compare decay shapes themselves we compensated time scale. Except very low gray, decay shapes of different observation gray are very similar. Low gray observation shows decay route earlier than high gray observation. We thought we could predict high gray observation data by using low gray data gathered earlier.

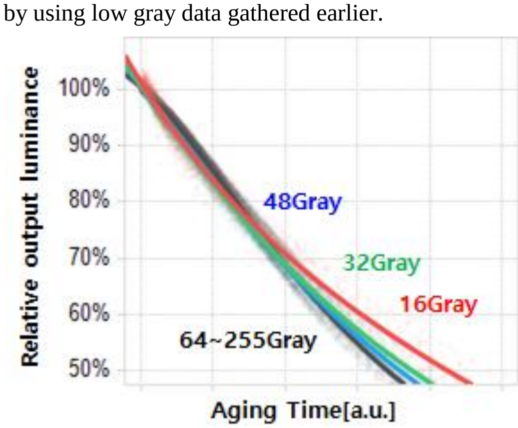

Figure 5. Decay shape according to observation gray

4. Prediction data of high gray observation

We chose 64 gray observation gray data to predict higher gray data. 31.5" QD-OLED life time data was used. From Fig.6 we could know green pixel data showed under 1% error from 0% to 50% degradation. Error means gap between evaluated data and prediction data. On the other side error was about 5% at blue pixel up to 50% degradation. Red pixel had smaller error than blue pixel. It was around 3%. Also we found that error was getting bigger after 30% degradation at red and blue pixel in common.

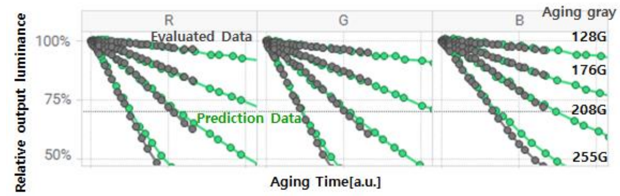

Figure 6. QD-OLED evaluated data and predicted data

4.1 Decay shapes according to light source ratio

Stretched Exponential Decay (SED) is well known model for OLED decay. But we could not fit the raw data of 4T with SED. After around 30%, degradation decay shape starts to split. 4T has long tail shape. It comes from blue OLED. Because blue OLED of 4T has longer life time than green OLED of 4T in QD-OLED.

$$SED(t) = e^{\wedge}[-(t/\tau)^{\wedge}\beta\ ] \qquad (1)$$

It means blue has small β from SED Eq (1). And inflection point is 30% degradation time same as red, blue pixel prediction data error point in fig.6. Also error occurs prediction data has bigger value than real data. It matches low observation gray decay has more portion of blue OLED after aging. However the reason which blue pixel makes bigger error than red pixel still remains.

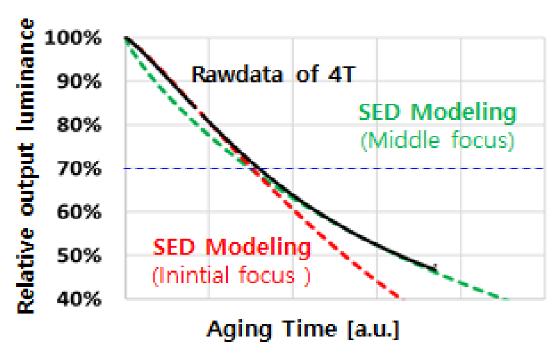

Figure 7. 4T Modeling with different focusing SED

Table 1 is simulation result. We used QD-OLED structure for simulation including pixel design and QD thickness and so on. Details can be changed depending on pixel size and color filter etc. However trends are same. It shows green pixel makes light using green OLED than blue OLED. It comes from low absorption ratio of QD at long wavelength. Also green color filter cannot cut green OLED light. But in green pixel blue OLED makes light by using green QD. Leakage blue light not absorbed by QD will be cut by green color filter. Red pixel has more portion of blue light than green pixel as well. Leakage green OLED light in red pixel is cut by red color filter. Of course blue pixel makes most light with blue OLED but not 100%. Previously we mention about error between prediction data and real data. When we predicted blue pixel data, the error was big. And we could predict green pixel decay data quite precisely. Error could match with ratio of blue OLED. Higher blue OLED ratio makes higher error when we predict high observation gray data.

Table 1. Blue/Green-EL contribution ratio of QD-OLED

	Contribution ratio [%]		
	B-EL On	**G-EL On**	**BG-EL On**
Red	52.7	47.3	100.0
Green	42.2	57.8	100.0
Blue	84.6	15.4	100.0

4.2 Decay shape of RGB pixel and application

Now we can tell that each color pixel of QD-OLED has different contribution of blue OLED and green OLED on 4T OLED. And life time of blue and green OLED are different. So each pixel should have their own decay curve. It means low gray observation data might be different depending on sub pixel color when we predict high observation gray data through low observation gray decay shape. Fig 8 shows decay shape of QD-OLED sub pixel. Instead of QD-OLED TV, we used QD-OLED monitor life time data when we compared decay shape of each color. Because monitor has thinner color filter than TV. It makes decay shape sensitive according to blue and green OLED ratio change. From fig.8 we can notice several features of QD-OLED life time curve regarding observation gray. In fig.8 to compare decay shapes themselves we compensated time scale as well like fig.5 First, as we go lower observation gray decay shape has smaller β tail shape in common.

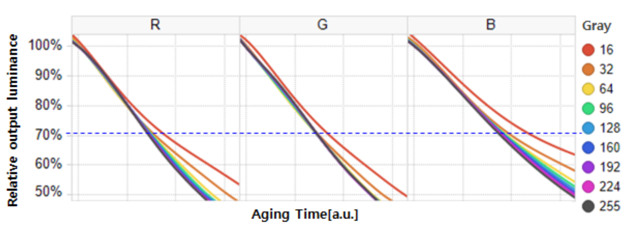

Figure 8. Decay shape of each sub pixel color

Second, tail shape is well distinguished after 30% degradation in common. Third, blue pixel which has maximum blue OLED ratio shows the strongest small β tail shape. Also small β tail shape feature of each color accurately follows portion ratio of blue OLED. Lastly these decay curve differences of each color are well explained with fundamental properties of 4T and simulation result. Now we can properly change the way how to use low observation gray data of each color to predict high observation gray data. Applying offsets among observation grays of each color is easy way to think.

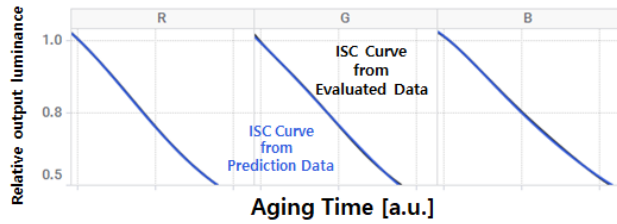

Figure 9. ISC curves from evaluated data and prediction data

Prediction data has same count of aging condition. It means we can make Image Sticking Compensation (ISC) curve under same aging condition with prediction data. So we made two curves with evaluation data and prediction data. Fig.9 is example of two curve comparison. It is 127 observation gray. As you can see two curves are very similar. For your information, gap between two curves was under 0.5% until 50% degradation.

5. Conclusion

Durable light source material needs long evaluation time. Accelerated test causes unnecessary noise from time to time such as pixel shrinkage. We introduce method possible to save time without acceleration test of QD-OLED through low observation gray data. Low observation gray condition make degradation faster. And it comes from Roll-off feature change after aging. Also except very low gray, decay shapes of different observation gray are very similar. Also there is a difference of decay shape similarity according to sub pixel color. That difference can be explained by blue, green OLED decay feature and ratio according to sub pixel color. By using decay shape difference according to observation gray we could make relatively accurate prediction data of each color. Also we present that ISC curve from prediction data under 0.5% error until 50% degradation. 50% degradation means QD-OLED product life time. It means we could compensate burn-in until product life time. Through presented method we could shorten around 50% life time evaluation to make ISC curve.

6. Reference

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