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A Study on the Generation of Datasets for Applied AI to OLED Life Prediction

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Abstract

OLED displays cannot be used permanently due to burn-in or generation of dark spots due to degradation. Therefore, the time when the display can operate normally is very important. It is close to impossible to physically measure the time when the display operates normally. Therefore, the time that works normally should be predicted in a way other than a physical way. Therefore, if you do computer simulations based on artificial intelligence, you can increase the accuracy of prediction by saving time and continuous learning. Therefore, if we do computer simulations based on artificial intelligence, we can increase the accuracy of prediction by saving time and continuous learning. In this paper, a dataset in the form of development from generation to diffusion of dark spots, which is one of the causes related to the life of OLED, was generated by applying the finite element method. The dark spots were generated in nine conditions, such as 0.1 to 2.0 μm with the size of pinholes, the number was 10 to 100, and 50% with water content. The learning data created in this way may be a criterion for generating an artificial intelligence-based dataset.

Keywords : OLED, Dataset, Bigdata, AI, Machine learning

Major Classification Code : Artificial Intelligence

1. Introduction

Organic light emitting diodes (OLEDs) are at the cusp of becoming the dominant technology for high-quality flat panel display as well as for solid-state lighting owing to its unique disruptive features such as energy saving, wide view-angle, fast response, high contrast, and high color purity (Swayamprabha, 2021). Because of that, research areas and novel applications focusing on OLED have been rapidly developed, making OLED a rising and promising high-end technology for practical applications in the illumination field due to the advantages offered by organic over inorganic materials (Azrain, 2018). And Korea is the world's No. 1 powerhouse in the semiconductor and display industries. Among others, devices using organic electronic materials such as OLED displays, organic solar cells, and organic transistors have become the most notable technologies as they have become commercialized beyond the stage of

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development of original technologies. Devices that use organic electronic materials have many advantages, such as being lightweight, ultra-thin, low cost, etc., so innovative technology leadership will continue. Based on these advantages, Samsung and LG, Korea's leading companies, are leading the world's technology, and research on organic electronic materials and devices is being actively conducted in many institutions such as research institutes and schools.

An OLED (organic light-emitting diode) is a light-emitting diode (LED) in which the emissive electroluminescent layers a film of organic compounds which emit light in response to an electric current (Arnob, 2013). And, display made of OLED is a promising display technology that enables good image quality, low power consumption, and various designs. It began research on OLEDs in the early 1990s and it has now made remarkable advances in both their performance and life. However, the biggest weakness of OLED is its various problems related to life. In particular, the most basic problem with OLED is that it is extremely sensitive to moisture and oxygen. If even a very small amount of moisture and oxygen is continuously exposed, the organic materials that make up the OLED are damaged, resulting in a decrease in lifespan, unlike burn-in. If burn-in is a problem of reducing its own luminous efficiency while the device is driven, the degradation in life due to exposure to moisture and oxygen is accompanied by all-around destruction of organic matter due to external factors. <Figure 1> shows the diffusion of dark spots by exposure.

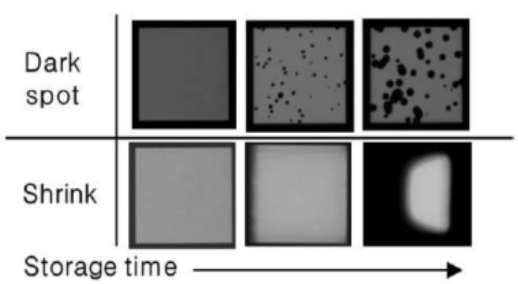

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Figure 1: OLED Dark spot growth (LT Material, 2018)

Therefore, the most important part of the OLED process that prevents exposure to moisture and oxygen is the encapsulation process. When encapsulation is not properly performed, it is difficult to expect a normal driving, and thus various discussions on an effective encapsulation process have been conducted, and a sophisticated encapsulation process may cause an increase in unit prices of the manufacturing process. Moisture and oxygen cause short-term or long-term damage to the OLED device, and essentially cause damage due to deformation or oxidation of the electrode material itself used as an organic material or an anode.

A major factor in the degradation mechanism of organic matter is the photolysis of organic matter in the atmosphere in which oxygen is present. Organic materials basically repeat the redox process during the driving process, and it is actually an redox reaction that occurs during the process of losing and obtaining electrons without oxygen involved. However, when oxygen is exposed to an organic material, light-enhanced oxidation occurs, and in the oxidation state, basic properties of the material change, and Quenching occurs, in which Luminescence wavelengths change or molecules react to degrade the properties. In addition, even if it is not a light emitting layer material, diffusion of oxygen into the electron transport layer and the hole transport layers (ETL, HTL) becomes a factor that hinders electric charge transfer characteristics. As another factor, oxygen and moisture penetrating into the interface between the anode itself and the anode and the organic material cause depression or pinholes of the organic materials by oxidation or swelling due to moisture, thereby inducing dark spots, thereby adversely affecting life.

In general, no matter how perfect the encapsulation process is, there is a certain amount of water permeability (WVTR, Water Vapor Transmission Rate), which even glass materials that seem to perfectly block moisture and oxygen have moisture permeability. OLED devices have comprehensive moisture permeability through various routes such as reliability problems, material problems, and defects of the encapsulation method itself. For stable device operation, they must have moisture permeability below the value for more than 10,000 hours (OLED Net, 2022).

Recently, flexible OLED displays have attracted attention, and if physical repetitive stress reliability of encapsulation materials is not secured as they are folded and bent, moisture and oxygen will be injected between damaged encapsulation materials to erode the life of OLED devices. The sealing process of OLED will continue to improve in the past, present, and future, and it will be carried out in various ways according to the purpose and manufacturing cost. The encapsulation process is a final process to compensate for weaknesses that are weak in moisture and oxygen of organic matter, which are the main materials of OLED. No matter how good materials or structures are made, organic materials that are exposed to moisture and oxygen immediately lose their properties (Jang, 2017).

Table 1: Encapsulation Requirements

Parameter	Minimum requirements
WVTR	10^-6g/m^2-day
OTR	10^-5cm^3(STP)/m^2-day
dark spot	300mm /dark spot under 5
wafer	20~30nm

The above requirement is calculated by measuring the time when a magnesium cathode, which is used as an electrode material for OLEDs, is oxidized and turned into magnesium oxide (MgO) in 2001 and becomes transparent. Therefore, with higher than this moisture permeability and oxygen permeability, oxygen and moisture continuously penetrate into the device within the life of the OLED device, and OLED device degradation due to external factors progresses faster than OLED device driving life.

Flexible organic light-emitting displays (OLEDs) require flexible permeation barrier films for their protection against atmospheric moisture and oxygen (Bhadri, 2015). However, moisture and oxygen will somehow penetrate, and dark spots of OLED will inevitably occur. Therefore, we set the requirements for this dark spot. The International Technology Roadmap for Semiconductors (ITRS) determines the standard for the maximum size of dark spots within the driving life of the display and stipulates that there should be five dark spots with a size of 20~30nm in an area for a wafer with a diameter of 300mm. Of course, we think leading panel manufacturing conglomerates such as Samsung Display and LG Display will set stricter requirements than this. However, information on mass production standards is of course, confidential, so it is not known.

Therefore, in this study, a method of generating a dataset for predicting the life of a display made of OLED with artificial intelligence was studied. Many methods are being attempted to predict the lifespan of OLEDs, but most of them are due to the interaction of materials, which requires a lot of budget and time.

2. Related research

In the field of OLED displays, research on the development of new materials or materials is constantly underway, and the process of synthesizing and evaluating molecular structures by changing the molecular structure to obtain desired physical properties is repeated, but significant results are not often obtained. In recent years, there have been an increasing number of cases of attempting a logical approach based on the theoretical background, away from this trial and error approach. Therefore, many studies on material informatics that can be accessed in terms of materials are being conducted. Therefore, many studies on cheminformatics that can be accessed in terms of materials are being conducted. Material informatics aims to drastically reduce the time required to develop and produce new materials and can be used in various ways, from process modeling to product lifecycle management, and new material development.

In this data-based study, a database containing characteristic values extracted through modeling and calculation is constructed based on the individual structure Pool. The database constructed in this way is used to establish a physical property prediction model through various statistical techniques such as machine learning or deep learning and predicts physical properties for individual substances based on the prediction model. The predicted results are verified through experiments, and the model is continuously updated so that the predicted results are similar to the actual physical property evaluation results. After the reliability of the prediction model is secured through the repetition of this process, some of the structures that are expected to have excellent physical properties are finally selected based on the prediction properties, and experiments and evaluations are performed. Through this process, it is possible to perform materials screening in the pre-experiment stage, and the effect of reducing research costs and increasing efficiency can be expected. In particular, as research on machine learning is activated, research on the establishment of databases and prediction models is increasing in numerous research institutes and schools at home and abroad.

Machine learning (ML) is a technology that makes a computer (algorithm) learn the relationship between inputs and outputs and predicts an output from new inputs based on the learned data (Akinori, 2020). Machine Learning provides a methodology to extract the information from the source data in the database as the primary technical-based data mining (Kim, 2016). And There have already been many machine learning algorithms for how to classify data. Decision trees, Bayesian networks, support vector machines (SVMs), artificial neural networks (ANNs), and clustering are examples (Kang, et al., 2017). So, data-based artificial intelligence research can be conducted on dark spot growth. In many cases, the growth of dark spots in OLEDs is attributed to morphological defects on cathode (e.g. pinholes) and unbalanced flow of hole and electron currents (Yoon-Fei, 2004). And according to "Extraction of the OLED Device Parameter Based on Randomly Generated Monte Carlo Simulation with Deep Learning" written by Seung Yeol You and two others, accelerated computational simulation and variable reverse design technology for efficient analysis between process variables and light emission performance of OLED are proposed. It is known that the dark spot is affected by the thickness (L), humidity (C0), temperature (T), pressure (P), degradation time (t), etc. Analyzing the results by performing performance experiments based on all indicators under process conditions costs a lot, so computer simulation results using each element were generated. The generated samples represent dark spot growth with different degradation times (t), the number of pinholes (N), and the size (r0). The growth of the dark spot may be expressed as Equation (1) with respect to the radius d and the degradation time t of the dark spot. The growth factor, D, is the organic layer diffusion factor.

$$\frac{\partial\, \mathrm{d}(t)}{\partial t} \cong \frac{\beta L D C_0}{4\pi \mathrm{L}/r_0} \cdot \frac{1}{d} \qquad (1)$$

Equation (1) is similar to that presented in the paper of "Dark spot growth and its acceleration factor in organic light-emitting diodes with single barrier structure" written by Takeru Okada and two others(2017). This paper using organic light-emitting diodes (OLEDs) without encapsulation, dark spot growth and its acceleration factor at high temperature and high humidity were measured and compared with those of edge shrink at the cathode edge.

In this paper, the water flux per unit length is LDC0=w when the diffusion coefficient of the organic layer is D and the thickness of the organic layer is L. Here, we assumed that D is a function of temperature but is independent of water concentration in the range of this experiment. Assuming that the growth rate of edge shrink is a product of the water flux per unit length and the coefficient β, the width of the edge shrink w is expressed in a rate equation of

$$\frac{dw}{dt} = \frac{\beta L D C_0}{w}. \qquad (2)$$

Solving this equation leads to

$$w = \sqrt{2\beta L D C_0 t}. \qquad (3)$$

In order to apply artificial intelligence like this, a well-organized dataset is needed.

3. Data Set Implementation

3.1 Finite element method

The Finite Element Method is a methodology designed to solve differential equations using computerized numerical methods. If a value is continuous in a finite interval, the number of values becomes infinite, and since it is impossible to calculate infinite values on a computer, the finite element method discretizes the time and space variables into small pieces of finite size.

In the generation of OLED data sets, the subject of this study, the Finite element method was used to calculate the moisture permeation of space spread based on 10,000 hours of flow and pinholes, and the variables of time and space that flow continuously are divided into frames and meshes and measured the area of the moisture permeation part. Using FEM Solver, the area of moisture spread was calculated as a finite value based on EL and pinholes, and it was verified whether the calculation was accurate in dividing the area into several parts through Mesh analysis, one of the integrity verification methods of the Finite element method. It can be used as a variety of machine learning and artificial intelligence datasets through image generation and GrayScale based on the calculated invasive area.

3.2 generate Data set

Dark spots are known to be affected by the thickness, humidity, temperature, pressure, and degradation time of the organic light-emitting layer. The FEM Solver was used to implement the dataset using FEM, and the factors that directly or indirectly affect the performance of OLED panels were determined as follows.

Table 2: Simulation Parameter

Parameter	Range
Initial Pinhole radius	0.1 ~ 2.0(μm)
Number of dark spots	10 ~ 100(Ea)
Degradation Time	10000(h)
Minimum humidity inflow (For edge detection)	0.01(%)
OLED Panel width/length	1000(μm)
Moisture	50%
Temperature	25 (℃)
Absolute pressure	1 ATM
diffusion coefficient	2.6e-5[μm^2/s]

In the case of the inner diameter and number of pinholes, it was designated based on "Extraction of the OLED Device Parameter Based on Randomly Generated Monte Carlo Simulation with Deep Learning" written by Yoo Seung-yeol and two others, and the minimum moisture content was used as a factor for threshold level criteria when processing images for big data. Temperature and humidity were maintained at 25°C and 50% respectively for the constant data set, and the atmospheric pressure was set at 1 ATM, which is atmospheric pressure. All datasets were built on a 10,000-hour basis, which was based on an OLED 1.0 structure that meets the minimum requirement of 10,000 hours of a lifetime for OLED substrates (Olednet, 2022). In the case of diffusion coefficient, the average free path and average speed values of molecules in the ideal gas in the Maxwell-Boltzmann distribution were calculated, and designated as the above factors.

4. Results

A total of 1,000 pieces of data were produced, and the image was set as a reference value by designating GrayScale among Colorables in the FEM Solver. Accordingly, the dataset is as follows.

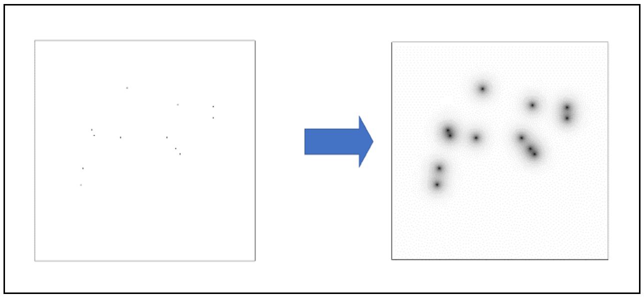

Figure 2. Dark spot data example (10,000h)

Based on the randomly distributed dark spots, the appearance of the water spread can be imaged through 'GrayScale', In the case of mesh work, various factors such as errors or measurement failures that may occur when divided by finite numbers in FEM are evaluated with accuracy and expressed in color, and this was processed together with integrity.

5. Conclusion

There are various variables in the life of OLED, and there are limitations in physical methods to predict this. So, applying artificial intelligence technology to make predictions could be a good way. In order to apply artificial intelligence technology, data to learn is needed. However, actual data, similar to the students is very low because data of three must be created. Therefore, a moisture diffusion dataset based on the dark spots, one of the causes related to OLED life, was generated by applying the Finite element method.

The generation of data calculating the diffusion of dark spots presented in this study may be helpful in generating a dataset of learning data for applying artificial intelligence technology to OLED production processes.

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