

Article

A Method to Improve the Lifetime of Microcapsule Electrophoretic Display Modules

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Abstract: Microcapsule electrophoretic display (MED) is a kind of display with the properties of reflectivity and low power consumption. It is widely used in electronic book readers, but some new applications have appeared in the Internet of Things (IoT) products. Long working time is required in IoT products because it is not easy to replace or install such displays. The main failure phenomenon is the mura that will appear after about 1 to 2 years of use. The root cause of the failure is analyzed, and the lifetime prediction models for MED are introduced. The high temperature and high humidity (HTHH) test is used to evaluate the protective effect of the packaging structure. The HTHH test result is reported for the new MED structure; it shows that the MED with the new structure involves a longer working time.

Keywords: electronic paper display (EPD); microcapsule electrophoretic display (MED); Internet of Things (IoT); lifetime prediction models; HTHH; RH (RH relative humidity)



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1. Introduction

An EPD is a type of display technology that shows the pictures in reflected mode; there are a lot of technologies that could be applied for an EPD such as Cholesterol LCD, Memory LCD, Electronic Wetting display, MEMS, and Clear ink, and an electrophoretic display is a technology that could lead to mass production. It has many advantages such as eye protection, low power consumption, and flexibility [1–3]. This technology is widely used in e-reader products, such as Amazon's kindle. Nevertheless, the electrophoretic display could be used in many IoT products, such as price tags in the supermarket [4–6]. A long lifetime is necessary for these applications because it is not easy to install them, and the repair cost is high. The warranty time for the price tag is over five years, which is longer than the warranty for the reader product. The failure phenomenon after prolonged use is presented and the root cause for this failure is also discussed [7–11]. The models for predicting an MED's lifetime are studied; the purpose is to determine a fast way to verify the lifetime of the product [12]. Additionally, the HTHH (the temperature is 60 °C, and the relative humidity is 80%) storage test is used to evaluate the capability of the panel structure of the package. A new method for improving the lifetime of an MED is introduced, and the storage time is longer with this new method.

2. MED Panel Structure Failure Phenomenon

Microcapsule electrophoretic display is a technology that controls the charged nanoparticles moving up and down with an electrical field; microcapsules enwrap the particles, the cross-section of MED is showed in Figure 1.

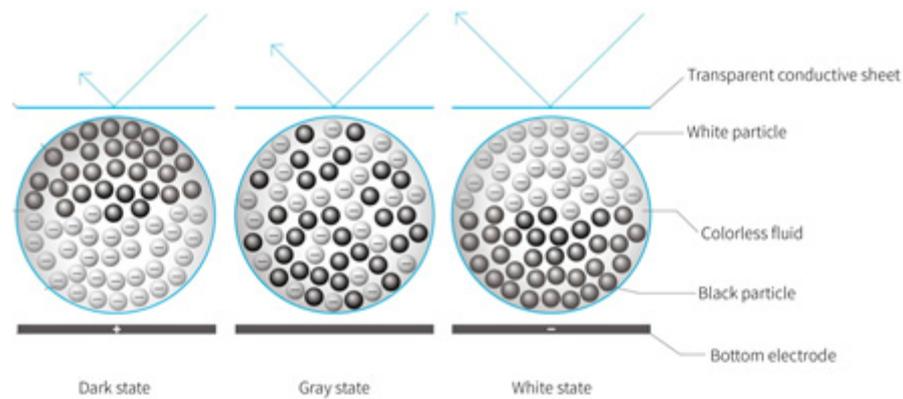


Figure 1. This is a cross-section of microcapsule electrophoretic display.

The optical performance of MED material has a direct relation to driving time and the addition of an electronic field to the material. As such, the electric resistance of microcapsule electrophoretic material between electrodes is significant. The electric resistance will change if water invades the panel. Consequently, the microcapsule electrophoretic material is packaged using TFT glass, moisture barrier film, and sealing glue, the cross-section of MED module is showed in Figure 2.

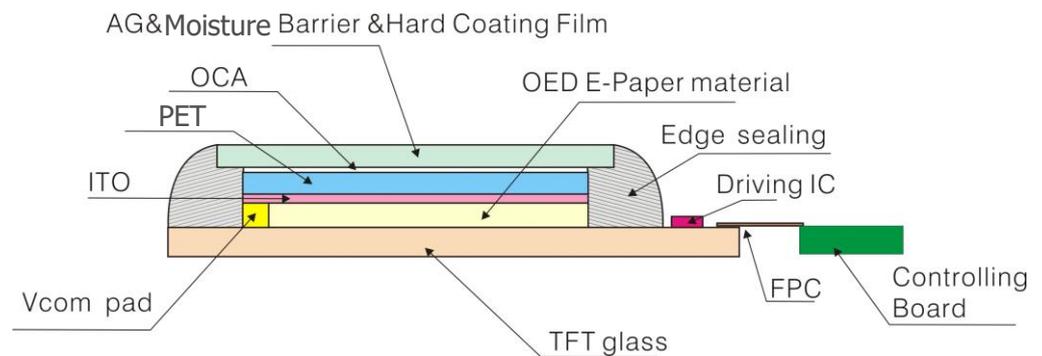


Figure 2. The cross-section for electrophoretic display.

Even with this packaging, some defects appear after a long duration of use. The main defect is mura at the edge of the panel after about 1 to 2 years of use in the customer's application. Mura is one defect that normally comes up in displays; the picture in the mura area is different to the picture in other areas of the display. There is no mura effect when the displays have just been manufactured (Figure 3). However, there are mura effects after 15 days of HTHH (60 °C, 80% RH) testing (Figure 4).

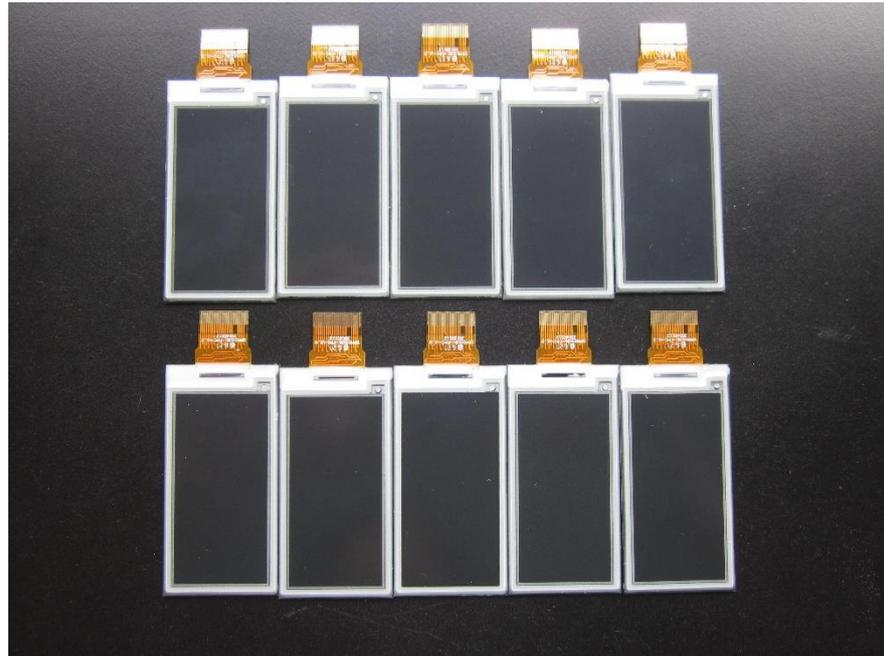


Figure 3. The samples before HTHH test.



Figure 4. There is mura after 15 days of HTHH testing.

3. Failure Analysis and Working Time Prediction Models

The main reason for this mura is water invading the microcapsule electrophoretic display material at the edge of the display. The pathway for water invading the display is shown in Figure 5. The main pathway is on the top of the panel. A barrier file is necessary to protect the microcapsule electrophoretic display material. Another pathway is at the contact area between the protective film and the glue. The contact area will exhibit peeling when the long-time temperature fluctuates because the thermal contraction coefficients are different.

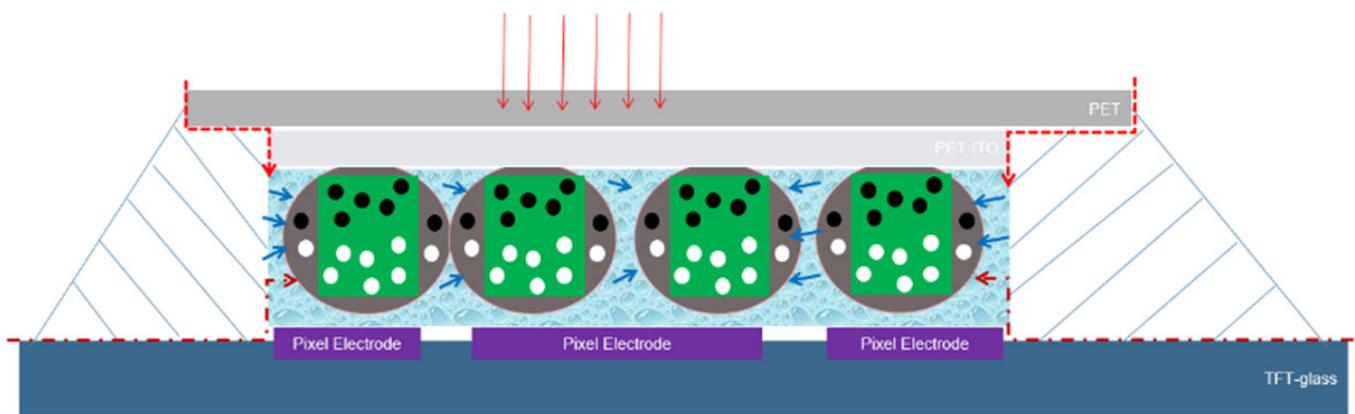


Figure 5. The pathway of moisture invading.

The package structure is the primary factor influencing the lifetime of an MED.

There are three lifetime prediction models for this kind of failure mode: the Peck model, the Eyring model, and the LWW model [10]. The LWW model is a newly developed model and is more suitable for predicting the lifetime of a microcapsule electrophoretic display.

The lifetime can be calculated by the LWW model, and the HTHH (60 °C, 80% RH) is used for evaluating the capability of the panel structure of the package.

4. New Package Method and Test Results

The main reason for the MED failure is water invading the top barrier film and the sealing glue contact area during conditions of thermal shock. The substrate used for the barrier films is polyethylene terephthalate (PET). The water vapor transmittance rate of this material is about 10^{-2} – 10^{-3} g/day/m² (60 °C, 80% RH); as such, water could invade into the panel. Furthermore, the thermal contraction coefficient of PET is 1.2–2.0%; it is more sensitive than glass. Consequently, when the temperature changes, the sealing glue between the PET and the glass will peel. Water will invade if this peeling happens.

As PET is not a good substance for protecting MED material, we changed this protective film to transparent glass. The new package method is showed in Figure 6. The water transmission rate and the thermal contraction coefficient are very low for glass, so it is very suitable for MED protection.

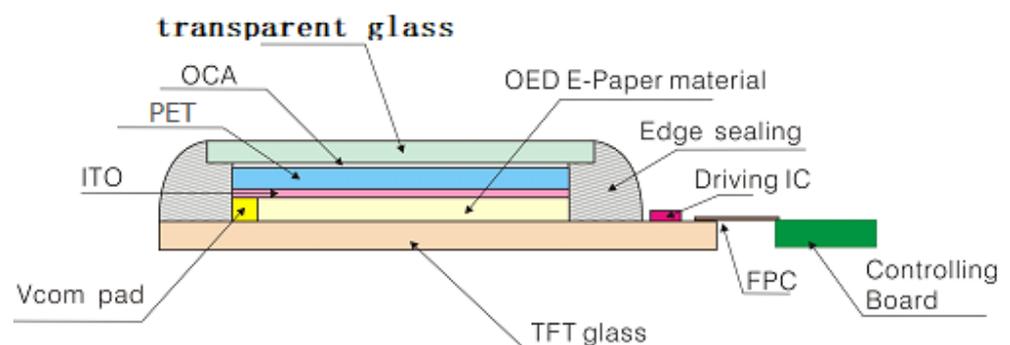


Figure 6. New method for microcapsule electrophoretic display package: change the protective sheet to glass.

The lifetime of the MED panel with this new method is evaluated with HTHH (60 °C, 80% RH) tests (Table 1). The MED panels are assembled with the same set of MED materials with two different methods. The samples are tested in high-temperature and high-humidity incubators under the same conditions.

Table 1. The HTHH storage test result with two methods.

Test Condition	The Failure Time (Hours)	
	PET Package	Transparent Glass Package
60 °C 80% RH	312	1128

5. Discussion

The new structure of the MED panel has a longer lifetime, but the assembly process is a little different. It has been proved that the cost of panels with the new packaging method is lower because the glass is cheaper than the barrier film. If the new method is used, the main passageway for water invasion is the sealing glue area. The moisture permeability is about 4~6 g/m²/day (the thickness of the sample is 1 mm), and the coefficient of thermal expansion is about 60~70 ppm/dC. If the characteristics of this sealing glue can be improved, it will be possible to extend the lifetime of the MED panel.

6. Conclusions

Long working time is required in IoT products for MED, and the current structure of MEDs cannot meet this requirement. As a result, a new method has been developed, and the HTHH testing demonstrates that this method helps to improve the MED's lifetime.

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Conflicts of Interest: The authors declare no conflict of interest.

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