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Flexible Organic Displays Under Long-Term Irradiation☆

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Abstract

Flexible displays based on OTFT matrices are one application for the enormous potential of organic semiconductor materials.Environmental influences for example sunlight exposure or temperature heating regarding those displays are inevitable for daily use.To study the display stability and reliability long-term irradiation measurements for about 1500 hours at constant temperatures and radiation conditions adapting sunlight exposure were performed with several display samples.Display grey level shifts were spectroscopically measured, used to calculate the lifetimeproperties via Weibull reliability analyses and to develop a Black equation like model including the activation energy Q_a and the irradiation factor exponent m.

Keywords: organic elcetronics; flexible displays; long-term irradiation; Weibull analysis; Black modelling

1. Introduction

Flexible organic electronic devices offer an enormous potential of new applications.[1] That is why an increasing number of products are using organic electronic devices like thin film transistors (OTFT) or light emitting diodes (OLED) especially in their displays.[2] Organic electronics consists of components and substrates of conducting polymers like pentacene, polythiophens or polyfluorenes due to their conjugated π-electron systems.[3;4] Compared to conventional silicon based electronics these flexible organic devices captivate through their high variety of size

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and easy processing and handling, i.e. via printing techniques, spin coating or physical vapor deposition.[5] The consumer requirements for organic electronic products in daily use are very similar to regular electronic and the customer expects the same performance and full product lifetime. Thus the reliability investigation under regular environmental conditions is key for creating a successful product or organic devices. It is well known, that organic devices by its nature have a low withstanding against moisture and high energetic sun light. To study environmental influences like sun light exposure or temperature heating flexible organic displays were tested regarding their stability and reliability under long-term irradiation measurements. The failure mechanisms of the products are statistically evaluated using known reliability methods like Weibull technique.[6;7] For life time calculation the exaggerated temperature and irradiation stress condition have to be extrapolated to regular product use conditions. The standard equation for modeling drift processes in non-organic electronics is a Black like equation. It is the goal to find a similar model for the organic failure distributions, to convert the mean time to failure from stress to use conditions.[8]

Nomenclature

E	irradiance
L*	brightness/luminosity
MTTF	mean time to failure
OTFT	organic thin film transistor

2. Experimentals

The investigated samples are based on an organic thin film transistor matrix imprinted on a PET substrate and include a two pigment electrophoretic display. This enables the opportunity to trigger different grey levels from black to white which were determined via a spectrophotometer. Quantifying the sun light influence and substrate temperature with respect to the stability of the grey level performance of the investigated organic electrophoretic displays, the brightness L* of the screen is evaluated over a stress sequence. The L* value is a parameter out of the standardized CIELab color space system, representing the luminosity on a scale from 0 (black) to 100 (white).

Therefore non-shielded display samples were divided into irradiated and non-irradiated parts. 12 different positions spread all over the display were chosen to be irradiated. Additionally three positions were used as dark reference to distinguish between light induced display changes. The area of the illuminated spots is 3x3cm. Optical filter were used to classify the light range of the incoming light with respect to UV, VIS and near IR. As a light source a high power xenon lamp by Hamamatsu was used providing a broad and continuous white light spectrum comparable to AM 1.5 solar spectrum. Different irradiances were obtained by changing the distance between the light source and the irradiated samples. Additionally a vacuum thermo chuck system with a planar micro porous textured surface serves for clamping and tempering flexible substrates. This novel thermo chuck was built by HorstWitte GerätebauBarskamp KGand contains a micro porous composite material made of aluminiumgranules and epoxy resin with an airpermeable system and an overall porosityof 20%. The micro pores sizes vary between 10-12µm.[9]Heating and cooling is generated via a meander structure underneath the vacuum panel connected to a thermostat including a silicon oil thermofluid. Figure 1 shows the display preparation using alignment points to identify the irradiated spots and the used experimental setup.

The lifetime and reliability analyses were performed via a two parametric Weibull distribution $W(\beta,t_{63})$. Here t_{63} is the sample dependent characteristic lifetime and β the shape parameter describing the failure type with respect to the bathtub curve. A $\beta<1$ indicates premature sample failures, while a $\beta>1$ stands for belated failures. Random failures can be identified with a characteristic parameter equal to one.[10]