Interactive Virtual Laboratories for Studying OLED Technology

Phillip I. Cherner

Abstract – The paper describes a virtual OLED laboratory designed to introduce young people to one of the most contemporary devices and technologies which is heavily used in many gadgets familiar to every teenager. In order to make learning science and engineering fun, such an introduction is made in an interactive multimedia-rich format. In the context of touch screen displays for mobile phones, tablets and TVs, the fundamental principles underlying the design, application, and production of OLEDs and OLED-based devices are demonstrated and explained. The lab enables students to practice preparing an OLED and operating an active matrix OLED (AMOLED) online in a virtual environment.

Keywords: OLED, e-Learning, Virtual Laboratory, Active Matrix

INTRODUCTION

The rapidly evolving OLED (Organic Light-Emitting Diode) is widely used today, appearing in ultra-thin TV screens, touch displays of mobile phones, tablets, and many other gadgets familiar to everyone. OLEDs are also used as military displays due to their flexibility, and as micro displays for gaming visitors due to their lightweight nature and the highly lifelike display quality that they provide. In addition, energy-efficient lighting is another area of OLED applications with a high growth potential. According to market researches [1] OLEDs are expected to form a mainstream market within the next five years in the area of consumer electronics, information technology, and industrial automation. The study [2] reveals that by 2012 cumulative sale of OLED based mobile phone reached 183 million units.

The main goal of this virtual OLED laboratory is to introduce young people to this contemporary and very exciting technology and help them understand its benefits and limitations, as well as the underlying concepts and principles behind their operation. In order to make learning more visual and less boring, we want to present information in an interactive multimedia-rich format that today’s students of the digital generation found engaging and that matches their everyday experience and habits in acquiring new information and knowledge. In addition to learning new concepts, students are able to prepare an OLED and operate an active matrix OLED (AMOLED) practice online.

The lab is comprised of the following major parts:

- A video clip that shows various applications of OLEDs in devices like TVs, cell phones, tablets, and flexible displays. Advantages and limitations of OLED vs. LCD and traditional technologies used for the same purposes are explained and discussed;
- A flash simulation that introduces students to a layered structure of an OLED, and then provides them with a task to assemble all of the layers together and explain the functions of each layer;
- An online experiment that requires students to prepare a simple OLED, by using virtual materials and tools;
- Simulations that visualize the physical processes behind the function of OLEDs, and help understand multicolored OLEDs;
- A little simulation-based game to learn the design and operation of Active Matrix OLEDs (AMOLED)

In addition, the lab will include interactive assessment tools to reinforce and evaluate students’ understanding.

VIRTUAL ACTIVITIES

The first part of the lab (Fig. 1) introduces the users to a few examples of common everyday devices where OLEDs are used today, including cell phone screens, televisions, and flexible displays. The videos is combined with flash
animations describing where and how the OLEDs are used in each device to show just how prominent OLED technology is even today. These materials help students comprehend advantages of OLED displays such as sharper images, a wider viewing angle, better contrast ratios and energy management, small thickness, no backlight, flexibility, etc. Performance characteristics of OLEDs and LCDs are compared in the Table 1 below. In comparison with semiconductor light-emitting diodes (LED), which are currently widely used in TV and computer screens, OLEDs provide brighter displays and consume less power.

![Virtual OLED Laboratory](image)

**Figure 1.** Screenshot of introductory part that presents students various applications of OLED technology in consumer electronics, information technology, industrial automation, and lighting, as well as in flexible displays for military and gaming devices.

**Table 1.** Comparison of OLED vs. LCD performance characteristics

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>OLED</th>
<th>LCD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Viewing Angle</td>
<td>175°</td>
<td>40-50°</td>
</tr>
<tr>
<td>Contrast Ratio</td>
<td>&gt;10,000</td>
<td>200</td>
</tr>
<tr>
<td>Power Consumption at 30% Lighting</td>
<td>110 mW</td>
<td>500 mW</td>
</tr>
<tr>
<td>Power Consumption at 100% Lighting</td>
<td>200 mW</td>
<td>500 mW</td>
</tr>
<tr>
<td>Response Time</td>
<td>0.2 ms</td>
<td>30 ms</td>
</tr>
</tbody>
</table>

The first part is also aimed to spark students’ interest and motivate them to learn more about the OLED technology and the underlying fundamental principles.

The second part of the lab is designed to assist students in understanding the layered structure of an OLED. The simulation allows users to split a diode into its component layers, which are easy to see, and then the student can explore each of them one by one. By clicking on a layer, the user is able pop-up a detailed description of the layer and its components, as well as explanations of the layer’s purpose, functions, and specific design features. Figure 2 below illustrates the splitting of an OLED on separate layers.
In a paper published in 2004, [3] H. Sevian, S. Müller, H. Rudmann and M. F. Rubner describe a hands-on experiment in which students make light-emitting devices by spin coating a thin film containing ruthenium (II) complex ions onto a glass slide coated with a transparent electrode on one side so that the light emitted by the film is visible through the electrode and the glass. The procedure involves making solutions of ruthenium (II) complex ions and a water-soluble polymer and then spin-coating a thin layer of a mixture of these onto the slide, using a spin-coater students have constructed. After drying the film to form a thin layer of ruthenium(II) complex ions embedded in the polymer matrix, droplets of a gallium–indium eutectic alloy are added to the top of the film to serve as the cathode. The same experiment was video recorded step by step at the University of Wisconsin [4].

The virtual experiment, which is the third part of the OLED lab, imitates the experiments described in [3 and 4]. The simulation enables the user to walk through the process step by step and prepare a very basic virtual OLED (Figure 3). All the materials necessary to make the OLED are in front of the user and all they will have to do is follow on screen instructions, interacting with the materials and tools that are required in creating a very simple OLED. First the student has to choose a plate, and then use a multimeter to measure the surface resistance to make sure that the conducting side is up. If the surface resistance is too high (considerably higher than 30 ohms), the user should click on the plate to flip it over. Using a cotton swab, the organic compound ([Ru(bpy)3](BF4)2 polyvinylalcohol solution) should be spread on the plate surface. This compound acts as the emissive layer of the OLED. A layer of liquid gallium-indium alloy will serve as an active metal electrode on the OLED. However, the electrode must be applied only onto a dry surface. To speed up drying process of the organic film, students may use a fan.

Before applying the gallium metal, a template mask must be put on top of the organic layer to act as a guide for the liquid metal. The guide will prevent the metal from spreading beyond the organic compound.

Finally, the prepared virtual OLED can be tested by applying electric power from a power supply device. The Figure 3 presents the interface of the virtual experiment.

Figure 2. Screenshot of the part presenting a layered structure of an OLED.
One of the most difficult concepts to understand and explain to high school students was the operation of an active matrix OLED (AMOLED) flat panel display which uses switching thin-film transistors (TTF) and storage capacitors for each pixel and line by line multiplex scanning.

To address this problem, a simulation that incorporates game-like elements was developed. Screenshot of its interface is shown in Figure 4. The simulation which represents a 6 x 7 pixels monochrome AMOLED can be run in two modes: in a manual pixel-by-pixel and row-by-row mode and in an auto scanning mode. It presents the user with a random digit. The user should reconstruct the digit using the OLED pixels, by applying the correct voltage. In the manual mode, the program selects a row and a pixel and the student should realize that the impulse should be applied to the corresponding data line. After that the program selects the next pixel. Selected pixels stay on or off until next refresh cycle (pixels are switched and shine continuously)

In the automatic mode, like in a typical computer games, the user has a limited time to make his/her decision. There are three levels of difficulty, ranging from easy to advanced, and for each mode, a score is calculated based on the student’s accuracy and elapsed time.

Figure 3. Screenshot of the virtual experiment, that enables students to prepare and test a simple OLED online. Students use mouse clicks and drag and drop options to manipulate the required virtual materials and equipment.
Currently, this virtual lab is being tested with students enrolled in the honors physics program at Swampscott High School.

The next part of the lab is where the fundamental scientific concepts behind the operation of OLEDs are explained. The core of this section is a simulation that shows the detailing of the electron transfer in OLEDs, delocalization of pi electrons, as well as other related processes. The animations will attempt to make the concepts easier to understand through clear visuals.

In the future, two more simulations will be added which will introduce the concept of multicolored OLEDs as well as show how a matrix can be used to operate multiple OLEDs simultaneously.

Preliminary testing has shown that students like the interactive simulations and find the embedded game engaging. The students believe that the simulations have given them a better understanding of the applications, benefits, shortcomings, and the great potential of OLED technology.

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REFERENCES


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