The Liquid Crystal Display – What's in Your T.V.?

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Abstract

This module provides an introduction to liquid crystal display technology and some of the key components of the LCD: the glass substrates, liquid crystals, and polarizer filters. Hands on activities have been incorporated to demonstrate some of the key concepts at work in LCD materials technology.

Module Objective

Develop an understanding about the manufacture of and the components used in liquid crystal display panels; how an LCD works.

Student Learning Objectives

The student will be able to:
Explain how liquid crystals (LCs) relate to other phases of matter (liquid, solid, gas)
Explain how changes in optical properties occur in an LC (temperature changes, induced electrical/magnetic field)
Describe the purpose of each component of an LCD system
Describe the type of glass used in LCD panels (borosilicate)
Describe the process for forming glass used in LCD panels (float glass)
Discuss the applications of liquid crystal displays

MatEdU Competencies Covered

6C Apply concepts of electricity (energy is required to "direct" the liquid crystals and change its optical properties)
6D Apply concepts of light (polarization, reflection)
7E Illustrate the general nature of glass (amorphous structure, chemical composition)
14A Distinguish structure, properties and behavior of glass (glassy, stress and strain properties)
16A Distinguish effects of processing and manufacturing variables on material properties (heating and cooling, an induced current or field)

Nano Concepts Covered

Self-assembly (helical alignment of the LCs)
Sense of scale
Nature/structure of matter (fourth state of matter)

Key Words

Liquid crystal, liquid crystal display, glass, glass processing, glass structure, polarizers,

polarizability

Type of Module
Guided discussion with hands-on activities

Time Required
90 minutes – 45 minutes for each activity and discussion.

Pre-requisite Knowledge Required
None

Target Grade Levels
Advanced high school, introductory college

Table of Contents

Equipment and Supplies Needed
Computer with Internet access
Projector
Slideshow, "Liquid Crystal Displays – What's in Your T.V.?"
Supplies (see lists provided with each activity)

Curriculum Overview and Instructor Notes
A PowerPoint presentation is provided to guide discussion. Suggestions for discussion

around each of the topics/concepts illustrated on each slide are provided.

Two hands-on activities are described to help illustrate some of the key concepts in the module: Liquid crystal structure, properties, and self-assembly; and polarizers.

Module Procedures

Slide – Introduction
This slide is a verbal pre-evaluation to assess how much students know about LCDs.

Ask: "What is actually IN an LCD Display?"
Discuss:

- Definition of LCD – Liquid Crystal Display
- What makes it work – integrated circuits
- What are some of the components for the system – glass, liquid crystals, etc.

Slide – Disrupting Liquid Crystals
This slide provides a graphic explanation of what happens in Hands-on Activity One.

Explain that: Liquid crystals exist somewhere in a “fourth state” between a liquid and a solid. When “disrupted” they go through a “phase” change. This change can be observed through differing optical properties of the material (change in color) based on temperature, an induced electric current or magnetic field, or absorption of chemicals.

In this activity: Three types of temperature-sensitive liquid crystal material (thermotropic) are boiled and then cooled down to observe the effect of temperature change on the material.

LC molecules are generally considered to be rod shaped and depending on what state they are in, can be aligned in layers in an organized parallel pattern.

When environmental conditions change, layers of LCs orient themselves in directions at an angle (generally a 90°angle) from the one above and below it, like a spiral staircase, and change the spacing between them (called the pitch). This causes light to refract at different wavelengths. Different wavelengths create different visible colors:

- As the crystals heat up, the spiral staircase of molecules tighten and the spiral reflects light in the blue spectrum (shorter wavelengths).
- As the crystals cool, the spiral staircase of molecules loosen/relax and the spiral reflects light in the red spectrum (longer wavelengths).

Hands-on Activity One
Full explanation and video of the activity from University of Wisconsin WISC online: http://education.mrsec.wisc.edu/274.htm

Slide – Light Selectivity (by altering the wave and polarizing)
This slide provides a graphic explanation of what happens in Hands-on Activity Two.

Explain that: Molecules are free to form however they want. However, they tend to organize themselves around a direction.

In this activity: an LCD, induced electrical current is used to “disrupt” the LCs. LCs are considered a dipole molecule. Dipoles exist when one end of a molecule has a net positive charge while the other end has a net negative charge. When an electric field is applied to the liquid crystal, the dipole molecules tend to orient themselves along the direction of the field. This is what occurs in the case of an LCD. (NOTE: When a magnetic field is applied, the molecules will tend to align with or against the field.)

This behavior pattern at the molecular level can be referred to as self-assembly. With self-assembly, molecules arrange themselves in a specific structure to form a specific material with specific properties. When the structure is “disrupted” by a change in condition/environment molecules can change from one self-organized structure to another as they bind to certain ions or atoms (through non-covalent interaction). In nature we observe many examples of this: DNA (helix), chlorophyll, etc.

Light is a wave. Different colors of light are characterized by a different wavelength, which is on the order of 400 to 700 hundred nanometers in the visible spectrum. LCs selectively reflect light of wavelengths equal to their pitch length. The effect is based on the gradual change in director orientation between the layers of LCs, which modifies the pitch length.

Hands-on Activity Two

NOTE: this is the “trick” described in the Homemade LCD video referenced

Supplies for each student/team:

- ☐ Two 2” x 2” squares of polarizer filters
- ☐ One 2” x 3” strip of plastic (overhead projector film works best, available at office supply stores)
- ☐ Overhead projector/light source

Steps:

1. Have students layer the 2 filters first aligned then at right angle to each other.
2. Apply the light source.
3. Discuss observations: Light is blocked when parallel/aligned, light is not blocked when at right angle.
4. Repeat with plastic inserted in the middle of the two filters.
5. Discuss observations. Small changes in color occurred.
6. Discuss why this is important to our LCD discussion and that this observation led to the experimentation with LCs by RCA and current experimentation with plastic in LCDs for a lighter, cheaper product. NOTE: this is discussed in the Homemade LCD video.

Slide – Manufacturing an LCD (cell)

This slide introduces a video of a homemade manufacturing process of an LCD cell. Play the video while discussing the multi-step process, the components and their purpose:

1. The glass substrates are cut to specifications. Glass is an insulator and the two pieces are the substrate of the assembly.
2. The surface of the glass substrates are first polished, washed, and coated with silicon dioxide (SiO_2). The silicon dioxide acts as a barrier to moisture and unwanted particles that may influence the LCs.
3. Next, a layer of indium tin oxide is sputtered onto the glass. ITO is a transparent conducting material into which the electrodes are etched.
4. Electrode patterns are etched into the desired pattern (using a masking/photoresist process).
5. A layer of a long chain polymer is then applied. Polyamides are the most popular agent. NOTE: in the video this step is skipped.

6. The polymer is then gently stroked to create small “grooves” in the surface. These grooves help the liquid crystals align (orient) properly, in a parallel pattern. NOTE: other methods used cause different specific LC orientations but we don’t go into those here. This step is followed with a resin seal. NOTE: in the video this step is substituted.
7. The spacers (5 – 25 micrometers thick) are put into place and the glass sandwich is filled with the liquid crystal material, the frame is then glued. Spacers used are glass balls.
8. The entire assembly is set between two polarizers, optical filters that allow light of only one specific plane of polarization to pass. A PVA film is typically used, but in the video polarizers are glass.
9. Finally the display assembly is attached to circuit boards with the necessary electronic components to drive the device and a power source.

Slides – Behind the Glass in Electronics

These slides illustrate the amorphous structure and processing of glass for use in electronics. Each can be discussed in terms of what the students know and what their questions are on each of the subjects. Students who want to know more about glass manufacture should be referred to references.

Slide – The Future of LCDs

This slide wraps up the module, assesses what was learned and student’s motivation to pursue further learning about LCDs.

Ask: "What is actually IN an LCD Display?"
Discuss:

- Definition of LCD – Liquid Crystal Display
- What makes it work
- What are some of the components for the system
- Applications of LCs – Liquid crystals are used in cell phone, laptop and other electronics monitors/screens, an electric field changes the alignment of the liquid crystal molecules and affects the polarization of light passing through them. LCs can detect changes made by chemicals, electrical fields, and temperature.

References

Websites

Two introductions to many of the liquid crystal display concepts covered in this module (last visited June, 2016):
http://plc.cwru.edu/tutorial/enhanced/files/lc/Intro.htm
http://education.mrsec.wisc.edu/147.htm

(with animations)
“How LCDs work,” from How Products are Made website (last visited June, 2016):
http://www.madehow.com/Volume-1/Liquid-Crystal-Display-LCD.html

Video

Discussion that demonstrates some of the key concepts such as chiral nematic, phase changes, polarization, surface treatments and materials used in LCDs, and self-assembly. Parts of the demonstrations can be done in the classroom and are described in this module. Other parts of the LCD manufacture require special equipment. From Applied Science YouTube channel (last visited June, 2016):
https://www.youtube.com/watch?v=d4QFNWBSZYg

Homemade LCD manufacturing process:
https://www.youtube.com/watch?v=_zoeeR3geTA

“All About Glass” from the Corning Museum of Glass (last visited June, 2016):
http://www.cmog.org/research/all-about-glass

Corning’s Eagle 2000 and EagleXG lightweight, thin glass specifically developed for use in liquid crystal displays (last visited, June 2016):
https://www.corning.com/worldwide/en/products/display-glass/products/eagle-xg-slim.html

Float glass manufacturing covers some of the chemistries and properties of glass, from Pilkington of North America (last visited June, 2016):
https://www.youtube.com/watch?v=ig4G5WbOMLc

Corning’s presentation on applications of LCDs (last visited June, 2016):
http://www.corning.com/r_d/technology_exploration/consumer_electronics.aspx

Evaluation Packet

1. How do liquid crystals (LCs) relate to other phases of matter (liquid, solid, gas)?

ANSWER: LCs are considered the “fourth state” of matter. They exist in both the liquid state when heated like ice and the solid state when cooled like crystals. LCs can exist in over 100 phases making LC properties extremely sensitive to many externally applied forces/environmental conditions.

2. How are changes in optical properties of LC made (as illustrated in this module)?

ANSWER: Molecular structure and orientation is disrupted through temperature changes, induced electrical/magnetic field. This changes the alignment and spacing of the molecules (they twist) and when light of selective wave length xxx.)

3. Describe the purpose of each component/material used in an LCD system:

ANSWER:

- Glass – insulator and as a substrate for the system
- Polarized filters – filter light
- LCs – filter light
- Indium tin oxide – conduct electrical current (base for the electrodes)
- Polymer – set the direction of the LC molecules
- Silicon dioxide – barrier to moisture and other elements

4. What is Borosilicate glass and why was it selected for use in electronic devices?

ANSWER: XXX

5. What is the float glass process and how does it apply to making an LCD?

ANSWER: The float glass processes glass to produce a flat, defect free, light and durable glass. Precise control is required. Molten glass is poured onto a flat surface then xxx.

6. List the applications of liquid crystal displays:

ANSWER: Should include monitors and displays on electronic devices.

7. Did the module load properly (including the video portions)?

8. Were you able to understand the information provided on the videos?

Instructor evaluation questions:
1. At what grade level was this module used?
2. Was the level and rigor of the module what you expected? If not, how can it be improved?
3. Did the discussion/PowerPoint work as presented? Did they add to student learning? Please note any problems or suggestions.
4. Was the background material on LCDs sufficient for you to be able to deliver this module? Comments?
5. Tell us about how the discussion/PowerPoint/activities generated interest among the students.
6. Please provide your input on how this module can be improved, including comments or suggestions concerning the approach, focus and effectiveness of this module in your context.

Course evaluation questions (for the students):
1. Was the discussion/PowerPoint clear and understandable?
2. Was the instructor's explanation comprehensive and thorough?
3. Was the instructor interested in your questions?
4. Was the instructor able to answer your questions?
5. Was the importance of materials made clear?
6. What was the most interesting thing that you learned?