MS4602 Materials and Processes for Electronic Displays

[Lectures: 26 hours; Tutorials: 13 hours; Pre-requisites: MS3012@; Academic Unit: 3.0]

Learning Objective

Flat panel displays, especially active matrix liquid crystal displays, have emerged as an economically important multi-disciplinary subject at the confluence of materials engineering, physics and chemistry, and microelectronics engineering. This course brings together all these elements to form a cohesive introduction to all relevant aspects of liquid crystal displays, with an emphasis on active matrix transmissive displays and amorphous silicon thin film transistors as switching elements. Other flat panel technologies are also introduced in class assignments.
The course is applications-oriented, focusing on two highly specialized areas: liquid crystal materials and display engineering. The materials section covers liquid crystal chemistry, phase structures and morphology, and the molecular origin of anisotropic electro-optic properties. The display engineering section introduces the human vision system and color science as they relate to display formats and attributes. Introductory treatment on the electro-optics of liquid crystals leads to the design of the twisted nematic liquid crystal cell, where the properties of optical and dielectric anisotropy are engineered to produce spatial light modulation. The next topic is addressing, the necessity and limitations of multiplexing, and the design requirements of active matrix addressing. The thin film transistor is introduced as the switching component of choice for an active matrix, with a review of device physics and introduction to amorphous semiconductors. Course focus then shifts to the fabrication of amorphous silicon thin film transistors, emphasizing the considerations behind the co-design of a device structure and a fabrication sequence. The course concludes with cell assembly operations and the origin of defects in displays.

Content

Introduction. Liquid Crystals. Color Science. Electro-Optics of Liquid Crystals. Addressing. Thin Film Transistors. TFT-LCD Manufacturing Processes. Other Display Materials and Devices.

Learning Outcome

At the end of the course, the student will be able to:

- describe phase structures and morphologies of various types of liquid crystal materials, and principles used to formulate liquid crystal mixtures used in LCDs.
- stipulate tests to identify liquid crystal phases and measure phase transition temperatures.
- explain relations between liquid crystal properties and LCD performance.
- describe basic operating principles of twisted nematic and super-twisted nematic LCDs.

- calculate radiometric and photometric quantities from spectral data, calculate color coordinates from color-matching functions and perform cordinate transformations. Interpret CIE color charts.
- distinguish between physical and perceptual attributes of vision, color and motion.
- identify the electrical and optical components within a twisted nematic liquid crystal cell and calculate important design parameters governing the performance of the cell. Interpret a transmission-voltage curve and define contrast ratios.
- construct waveforms for addressing liquid crystal cells, derive the limits of multiplexing, and calculate contrast loss in multiplexed displays.
- describe the operation of a thin film transistor, its IV characteristics, and its charging behavior for driving display pixels.
- relate the performance of a thin film transistor to display attributes
- construct the processing sequence for fabricating thin film transistors, and identify thin film material properties critical to its performance
- design elementary pixel architectures, and evaluate alternatives in terms of performance versus complexity.

Textbooks/ References

1. E. Lueder, *Liquid Crystal Displays: Addressing Schemes and Electro-Optical Effects*, John Wiley and Sons Ltd, England, 2001.
2. T. Tsukada, *TFT/LCD Liquid-Crystal Displays Addressed by Thin-Film Transistors*, Gordon and Breach Science Publishers, Netherlands, 1996.
3. P. Yeh and C. Gu, *Optics of Liquid Crystal Displays*, John Wiley and Sons Inc, 1999.
4. G. W. Gray, *Thermotropic Liquid Crystals*, John Wiley & Sons, New York, 1987
5. V. G. Chigrinov, *Liquid Crystal Devices: Physics and Applications*, Artech House, New York, 1997.