

Liquid Crystals (LCs) combine order and mobility on a molecular and supramolecular level. But while these remarkable states of matter are most commonly associated with visual display technologies, they have important applications for a variety of other fields as well.

Previously, other researchers had observed distinct color effects when cooling cholesterol derivatives just above the freezing point, but had not associated it with a new phenomenon. Reinitzer perceived that color changes in a derivative cholesteryl benzoate were not the most peculiar feature. Chemical structure of cholesteryl benzoate molecule He found that cholesteryl benzoate does not melt in the same manner as other compounds, but has two melting points. The phenomenon is reversible. Seeking help from a physicist, on March 14, 1828, he wrote to Otto Lehmann, at that time a Privatdozent in Aachen. They exchanged letters and samples. Lehmann examined the intermediate cloudy fluid, and reported seeing crystallites. The exchange of letters with Lehmann ended on April 24, with many questions unanswered. Reinitzer presented his results, with credits to Lehmann and von Zepharovich, at a meeting of the Vienna Chemical Society on May 3, 1828. After his accidental discovery, Reinitzer did not pursue studying liquid crystals further. The research was continued by Lehmann, who realized that he had encountered a new phenomenon and was in a position to investigate it: In his postdoctoral years he had acquired expertise in crystallography and microscopy. Lehmann started a systematic study, first of cholesteryl benzoate, and then of related compounds which exhibited the double-melting phenomenon. He was able to make observations in polarized light, and his microscope was equipped with a hot stage sample holder equipped with a heater enabling high temperature observations. The intermediate cloudy phase clearly sustained flow, but other features, particularly the signature under a microscope, convinced Lehmann that he was dealing with a solid. However, liquid crystals were not popular among scientists and the material remained a pure scientific curiosity for about 80 years. George William Gray, a prominent researcher of liquid crystals, began investigating these materials in England in the late 1800s. His group synthesized many new materials that exhibited the liquid crystalline state and developed a better understanding of how to design molecules that exhibit the state. His book *Molecular Structure and the Properties of Liquid Crystals* [4] became a guidebook on the subject. One of the first U.S. conferences marked the beginning of a worldwide effort to perform research in this field, which soon led to the development of practical applications for these unique materials. This led his colleague George H. Heilmeyer to perform research on a liquid crystal-based flat panel display to replace the cathode ray vacuum tube used in televisions. A material that could be operated at room temperature was clearly needed. In 1968, Joel E. Goldmacher and Joseph A. Castellano, research chemists in Heilmeyer group at RCA, discovered that mixtures made exclusively of nematic compounds that differed only in the number of carbon atoms in the terminal side chains could yield room-temperature nematic liquid crystals. This technique of mixing nematic compounds to obtain wide operating temperature range eventually became the industry standard and is still used to tailor materials to meet specific applications. Chemical structure of N-(4-Methoxybenzylidene) butylaniline MBBA molecule In 1971, Hans Kelker succeeded in synthesizing a substance that had a nematic phase at room temperature, MBBA, which is one of the most popular subjects of liquid crystal research. These molecules are rod-shaped, some created in the lab and some appearing spontaneously in nature. Since then, two new types of LC molecules have been discovered, both man-made: Despite significant differences in chemical composition, these molecules have some common features in chemical and physical properties. There are three types of thermotropic liquid crystals: Discotics are flat disc-like molecules consisting of a core of adjacent aromatic rings; the core in a bowlitic is not flat but like a rice bowl a three-dimensional object. Rod-shaped molecules have an elongated, anisotropic geometry which allows for preferential alignment along one spatial direction. Low-temperature mesomorphic behavior in general is technologically more useful, and alkyl terminal groups promote this. An extended, structurally rigid, highly anisotropic shape seems to be the main criterion for liquid crystalline behavior, and as a result many liquid crystalline materials are based on benzene rings. One can distinguish positional order whether molecules are arranged in any sort of ordered lattice and orientational

order whether molecules are mostly pointing in the same direction, and moreover order can be either short-range only between molecules close to each other or long-range extending to larger, sometimes macroscopic, dimensions. Most thermotropic LCs will have an isotropic phase at high temperature. That is that heating will eventually drive them into a conventional liquid phase characterized by random and isotropic molecular ordering little to no long-range order, and fluid-like flow behavior. Under other conditions for instance, lower temperature, a LC might inhabit one or more phases with significant anisotropic orientational structure and short-range orientational order while still having an ability to flow. This order extends up to the entire domain size, which may be on the order of micrometers, but usually does not extend to the macroscopic scale as often occurs in classical crystalline solids. However some techniques, such as the use of boundaries or an applied electric field, can be used to enforce a single ordered domain in a macroscopic liquid crystal sample. The ordering in a liquid crystal might extend along only one dimension, with the material being essentially disordered in the other two directions. Thermotropic crystal Thermotropic phases are those that occur in a certain temperature range. If the temperature rise is too high, thermal motion will destroy the delicate cooperative ordering of the LC phase, pushing the material into a conventional isotropic liquid phase. At too low temperature, most LC materials will form a conventional crystal. For instance, on heating a particular type of LC molecule called mesogen may exhibit various smectic phases followed by the nematic phase and finally the isotropic phase as temperature is increased. An example of a compound displaying thermotropic LC behavior is para-azoxyanisole. Biaxial nematic and Twisted nematic field effect Alignment in a nematic phase. Phase transition between a nematic left and smectic A right phases observed between crossed polarizers. The black color corresponds to isotropic medium. One of the most common LC phases is the nematic. Nematics also exhibit so-called "hedgehog" topological defects. In a nematic phase, the calamitic or rod-shaped organic molecules have no positional order, but they self-align to have long-range directional order with their long axes roughly parallel. Most nematics are uniaxial: However, some liquid crystals are biaxial nematics, meaning that in addition to orienting their long axis, they also orient along a secondary axis. Aligned nematics have the optical properties of uniaxial crystals and this makes them extremely useful in liquid-crystal displays LCD. The smectic A phase left has molecules organized into layers. In the smectic C phase right, the molecules are tilted inside the layers. The smectic phases, which are found at lower temperatures than the nematic, form well-defined layers that can slide over one another in a manner similar to that of soap. The word "smectic" originates from the Latin word "smecticus", meaning cleaning, or having soap-like properties. In the Smectic A phase, the molecules are oriented along the layer normal, while in the Smectic C phase they are tilted away from it. These phases are liquid-like within the layers. There are many different smectic phases, all characterized by different types and degrees of positional and orientational order. The chiral nematic phase exhibits chirality handedness. This phase is often called the cholesteric phase because it was first observed for cholesterol derivatives. Only chiral molecules i. This phase exhibits a twisting of the molecules perpendicular to the director, with the molecular axis parallel to the director. The finite twist angle between adjacent molecules is due to their asymmetric packing, which results in longer-range chiral order. The chirality induces a finite azimuthal twist from one layer to the next, producing a spiral twisting of the molecular axis along the layer normal. The pitch, p , typically changes when the temperature is altered or when other molecules are added to the LC host an achiral LC host material will form a chiral phase if doped with a chiral material, allowing the pitch of a given material to be tuned accordingly. In some liquid crystal systems, the pitch is of the same order as the wavelength of visible light. This causes these systems to exhibit unique optical properties, such as Bragg reflection and low-threshold laser emission, [27] and these properties are exploited in a number of optical applications. Cholesteric liquid crystals also exhibit the unique property that they reflect circularly polarized light when it is incident along the helical axis and elliptically polarized if it comes in obliquely. Blue phases have a regular three-dimensional cubic structure of defects with lattice periods of several hundred nanometers, and thus they exhibit selective Bragg reflections in the wavelength range of visible light corresponding to the cubic lattice. It was theoretically predicted in that these phases can possess icosahedral symmetry similar to quasicrystals. If the disks pack into stacks, the phase is called a discotic columnar. The columns themselves may be organized into rectangular or hexagonal arrays.

Chiral discotic phases, similar to the chiral nematic phase, are also known. Bowl-shaped LC molecules, like in discotics, can form columnar phases. Other phases, such as nonpolar nematic, polar nematic, stringbean, donut and onion phases, have been predicted. Bowl-shaped phases, except nonpolar nematic, are polar phases. Lyotropic liquid crystal and Columnar phase Structure of lyotropic liquid crystal. The red heads of surfactant molecules are in contact with water, whereas the tails are immersed in oil blue: A lyotropic liquid crystal consists of two or more components that exhibit liquid-crystalline properties in certain concentration ranges. In the lyotropic phases, solvent molecules fill the space around the compounds to provide fluidity to the system. A compound that has two immiscible hydrophilic and hydrophobic parts within the same molecule is called an amphiphilic molecule. Many amphiphilic molecules show lyotropic liquid-crystalline phase sequences depending on the volume balances between the hydrophilic part and hydrophobic part. These structures are formed through the micro-phase segregation of two incompatible components on a nanometer scale. Soap is an everyday example of a lyotropic liquid crystal. The content of water or other solvent molecules changes the self-assembled structures. At very low amphiphile concentration, the molecules will be dispersed randomly without any ordering. At slightly higher but still low concentration, amphiphilic molecules will spontaneously assemble into micelles or vesicles. These spherical objects do not order themselves in solution, however. At higher concentration, the assemblies will become ordered. A typical phase is a hexagonal columnar phase, where the amphiphiles form long cylinders again with a hydrophilic surface that arrange themselves into a roughly hexagonal lattice. This is called the middle soap phase. At still higher concentration, a lamellar phase neat soap phase may form, wherein extended sheets of amphiphiles are separated by thin layers of water.

Chapter 2 : Liquid crystal - Wikipedia

The chemistry, physics, and applications of liquid crystals beyond LCDs Liquid Crystals (LCs) combine order and mobility on a molecular and supramolecular level. But while these remarkable states of matter are most commonly associated with visual display technologies, they have important applications for a variety of other fields as well.

See Article History Alternative Title: Liquids can flow, for example, while solids cannot, and crystalline solids possess special symmetry properties that liquids lack. Ordinary solids melt into ordinary liquids as the temperature increases¹. Some solids actually melt twice or more as temperature rises. Between the crystalline solid at low temperatures and the ordinary liquid state at high temperatures lies an intermediate state, the liquid crystal. Liquid crystals share with liquids the ability to flow but also display symmetries inherited from crystalline solids. The resulting combination of liquid and solid properties allows important applications of liquid crystals in the displays of such devices as wristwatches, calculators, portable computers, and flat-screen televisions. Structure and symmetry Symmetries of solids and liquids Crystals exhibit special symmetries when they slide in certain directions or rotate through certain angles. These symmetries can be compared to those encountered when walking in a straight line through empty space. This is called continuous translational symmetry because all positions look identical. Figure 1A illustrates a crystal in two dimensions. Such a crystal lattice breaks the continuous translational symmetry of free space; starting at one molecule there is a finite distance to travel before reaching the next. Some translational symmetry is present, however, because, by moving the proper distance in the proper direction, one is guaranteed to locate additional molecules on repeated excursions. This property is called discrete translational periodicity. The two-dimensional picture of a crystal displays translational periodicity in two independent directions. Real, three-dimensional crystals display translational periodicity in three independent directions. Rotational symmetries can be considered in a similar fashion. From one point in empty space, the view is the same regardless of which direction one looks. There is continuous rotational symmetry²—namely, the symmetry of a perfect sphere. In the crystal shown in Figure 1A, however, the distance to the nearest molecule from any given molecule depends on the direction taken. Furthermore, the molecules themselves may have shapes that are less symmetric than a sphere. A crystal possesses a certain discrete set of angles of rotation that leave the appearance unchanged. The continuous rotational symmetry of empty space is broken, and only a discrete symmetry exists. Broken rotational symmetry influences many important properties of crystals. Their resistance to compression, for example, may vary according to the direction along which one squeezes the crystal. Transparent crystals, such as quartz, may exhibit an optical property known as birefringence. When a light ray passes through a birefringent crystal, it is bent, or refracted, at an angle depending on the direction of the light and also its polarization, so that the single ray is broken up into two polarized rays. This is why one sees a double image when looking through such crystals. In a liquid such as the one shown in Figure 1D, all the molecules sit in random positions with random orientations. This does not mean that there is less symmetry than in the crystal, however. All positions are actually equivalent to one another, and likewise all orientations are equivalent, because in a liquid the molecules are in constant motion. At one instant the molecules in the liquid may occupy the positions and orientations shown in Figure 1D, but a moment later the molecules will move to previously empty points in space. Likewise, at one instant a molecule points in one direction, and the next instant it points in another. Liquids share the homogeneity and isotropy of empty space; they have continuous translational and rotational symmetries. No form of matter has greater symmetry. As a general rule, molecules solidify into crystal lattices with low symmetry at low temperatures. Both translational and rotational symmetries are discrete. At high temperatures, after melting, liquids have high symmetry. Translational and rotational symmetries are continuous. High temperatures provide molecules with the energy needed for motion. The mobility disorders the crystal and raises its symmetry. Low temperatures limit motion and the possible molecular arrangements. As a result, molecules remain relatively immobile in low-energy, low-symmetry configurations. Symmetries of liquid crystals Liquid crystals, sometimes called mesophases, occupy the middle ground between crystalline solids and ordinary liquids with regard to symmetry, energy,

and properties. Not all molecules have liquid crystal phases. Water molecules, for example, melt directly from solid crystalline ice into liquid water. The most widely studied liquid-crystal-forming molecules are elongated, rodlike molecules, rather like grains of rice in shape but far smaller in size. A popular example is the molecule p-azoxyanisole PAA: Typical liquid crystal structures include the smectic shown in Figure 1B and the nematic in Figure 1C this nomenclature, invented in the 1930s by the French scientist Georges Friedel, will be explained below. The smectic phase differs from the solid phase in that translational symmetry is discrete in one direction—the vertical in Figure 1B—and continuous in the remaining two. The continuous translational symmetry is horizontal in the figure, because molecule positions are disordered and mobile in this direction. The remaining direction with continuous translational symmetry is not visible, because this figure is only two-dimensional. To envision its three-dimensional structure, imagine the figure extending out of the page. In the nematic phase all translational symmetries are continuous. The molecule positions are disordered in all directions. Their orientations are all alike, however, so that the rotational symmetry remains discrete. The orientation of the long axis of a nematic molecule is called its director. In Figure 1C the nematic director is vertical. It was noted above that, as temperature decreases, matter tends to evolve from highly disordered states with continuous symmetries toward ordered states with discrete symmetries. This can occur through a sequence of symmetry-breaking phase transitions. As a substance in the liquid state is reduced in temperature, rotational symmetry breaking creates the nematic liquid crystal state in which molecules are aligned along a common axis. Their directors are all nearly parallel. At lower temperatures continuous translational symmetries break into discrete symmetries. There are three independent directions for translational symmetry. When continuous translational symmetry is broken along only one direction, the smectic liquid crystal is obtained. At temperatures sufficiently low to break continuous translational symmetry in all directions, the ordinary crystal is formed. The mechanism by which liquid crystalline order is favoured can be illustrated through an analogy between molecules and grains of rice. Collisions of molecules require energy, so the greater the energy, the greater the tolerance for collisions. If rice grains are poured into a pan, they fall at random positions and orientations and tend to jam up against their neighbours. This is similar to the liquid state illustrated in Figure 1D. After the pan is shaken to allow the rice grains to readjust their positions, the neighbouring grains tend to line up. The alignment is not perfect across the sample owing to defects, which also can occur in nematic liquid crystals. When all grains align, they have greater freedom to move before hitting a neighbour than they have when they are disordered. This produces the nematic phase, illustrated in Figure 1C. The freedom to move is primarily in the direction of molecular alignment, as sideways motion quickly results in collision with a neighbour. Layering the grains, as illustrated in Figure 1B, enhances sideways motion. This produces the smectic phase. In the smectic phase some molecules have ample free volume to move in, while others are tightly packed. The lowest-energy arrangement shares the free volume equitably among molecules. Each molecular environment matches all others, and the structure is a crystal like that illustrated in Figure 1A. There is a great variety of liquid crystalline structures known in addition to those described so far. The Table relates some of the chief structures according to their degree and type of order. The smectic-C phase and those listed below it have molecules tilted with respect to the layers. Continuous in-plane rotational symmetry, present within smectic-A layers, is broken in the hexatic-B phase, but a proliferation of dislocations maintains continuous translational symmetry within its layers. A similar relationship holds between smectic-C and smectic-F. Crystal-B and crystal-G have molecular positions on regular crystal lattice sites, with long axes of molecules directors aligned, but allow rotation of molecules about their directors. These are the so-called plastic crystals. Many interesting liquid crystal phases are not listed in this table, including the discotic phase, consisting of disk-shaped molecules, and the columnar phases, in which translational symmetry is broken in not one but two spatial directions, leaving liquidlike order only along columns. The degree of order increases from the top to the bottom of the table. In general, phases from the top of the table are expected at high temperatures, and phases from the bottom at low temperatures. Selected phases characteristic of liquid-crystal-forming molecules phase.

Chapter 3 : Scientists developed a material for the new type of liquid crystal displays

*Liquid Crystals Beyond Displays: Chemistry, Physics, and Applications [Quan Li] on calendrierdelascience.com *FREE* shipping on qualifying offers. The chemistry, physics, and applications of liquid crystals beyond LCDs Liquid Crystals (LCs) combine order and mobility on a molecular and supramolecular level.*

March 7, , Lomonosov Moscow State University Illustration of color combination in time within a display pixel. Alexander Emelyanenko A team from the Faculty of Physics, MSU together with their foreign colleagues developed a new liquid crystal material with high potential as a basis for brighter, faster, energy saving displays with higher resolution. The results of the work were published in *Advanced Functional Materials*. LCD display images consist of many pixels, the smallest physical elements of a liquid crystal display. An LCD material within each pixel is, in fact, a color filter forming a sandwich-like structure, in which the "filling" is formed by the two layers with transparent electrodes inside and a liquid crystal between them, while the "bread" of the sandwich consists of the polarizers, which produce the linear polarization of light, but in perpendicular directions. Each pixel of an NLC has perpendicular molecule orientation on the opposite layers. The first polarizer produces the linear polarization of light in a particular direction. Without the electric field, the polarization plane of the light rotates by 90 degrees passing between the layers, so that the polarization plane on the output of the cell coincides with the polarization plane of the second polarizer. In this case, the light propagates through the cell, and the pixel is bright. When the electric field is applied, all molecules are oriented along the electric field see the picture on the right, there is no rotation of the polarization plane of the light between layers. Therefore, the second polarizer cuts off nearly all the light propagating through the cell, and the cell is dark. The color in conventional displays is formed by red, blue or green illumination of each particular sub-pixel, while the liquid crystal within each pixel is either transparent if the voltage is off or absorbing if the voltage is on for the light. In the end, the color image is formed by a particular combination of the red, blue and green subpixels. This principle was elaborated by the Soviet physicist Vsevolod Frederiks, and is currently used in the majority of LCD devices. FLC possesses the spontaneous electrical polarization that allows one to enlarge the order of the operation speed several times of magnitude. The material developed by the scientists has the stable FLC structure in a wide range of temperatures, which makes it resistant to temperature fluctuations. In new displays all three backlighting colors can be activated in a certain quick sequence across the whole screen, while each liquid crystal pixel can be "opened" and "closed" faster. Experiments have shown that the replacement of the three subpixels with the only one will allow the audience to enjoy a more realistic, contrast and bright images without the color blurring. Such displays require more powerful light sources. In new displays each pixel will be open for the light propagation during particular time, which is needed to mix the colors in time. This will also help save up to 70 percent of energy consumed by a display, as the source of light may be made much less bright without affecting the brightness of the screen," concludes Alexander Emelyanenko.

Chapter 4 : New liquid crystals prevent automobile touch screens from freezing

Read "*Liquid Crystals Beyond Displays Chemistry, Physics, and Applications*" by Quan Li with Rakuten Kobo. The chemistry, physics, and applications of liquid crystals beyond LCDs Liquid Crystals (LCs) combine order and mobility.

The CRT offers a high-quality, bright image at a reasonable cost, and it has been the workhorse of receivers since television began. However, it is also large, bulky, and breakable, and it requires extremely high voltages to accelerate the electron beam as a result. Electro-optical effects in liquid crystals Liquid crystals are materials with a structure that is intermediate between that of liquids and crystalline solids. As in liquids, the molecules of a liquid crystal can flow past one another. As in solid crystals, however, they arrange themselves in recognizably ordered patterns. In common with solid crystals, liquid crystals can exhibit polymorphism; i. LCDs utilize either nematic or smectic liquid crystals. The molecules of nematic liquid crystals align themselves with their axes in parallel, as shown in the figure. Smectic liquid crystals, on the other hand, arrange themselves in layered sheets; within different smectic phases, as shown in the figure, the molecules may take on different alignments relative to the plane of the sheets. For further details on the physics of liquid crystalline matter, see the article liquid crystal. The optical properties of liquid crystals depend on the direction light travels through a layer of the material. An electric field induced by a small electric voltage can change the orientation of molecules in a layer of liquid crystal and thus affect its optical properties. Such a process is termed an electro-optical effect, and it forms the basis for LCDs. Liquid crystal materials that align either parallel or perpendicular to an applied field can be selected to suit particular applications. The small electric voltages necessary to orient liquid crystal molecules have been a key feature of the commercial success of LCDs; other display technologies have rarely matched their low power consumption. Twisted nematic displays The first LCDs became commercially available in the late s and were based on a light-scattering effect known as the dynamic scattering mode. These displays were used in many watches and pocket calculators because of their low power consumption and portability. However, problems connected with their readability and the limited lifetime of their liquid crystal materials led to the development during the s of twisted nematic TN displays, variants of which are now available in computer monitors and flat-panel televisions. The substrate plates are normally transparent glass and carry patterned electrically conducting transparent coatings of indium tin oxide. The electrode layers are coated with a thin aligning layer of a polymer that causes the liquid crystal molecules in contact with them to align approximately parallel to the surface. In assembling the cell, the top and bottom substrate plates are arranged so that the alignment directions are perpendicular to each other. The whole assembly is then contained between a pair of sheet polarizers, which also have their light-absorption axes perpendicular to each other. In the absence of any voltage, the perpendicular alignment layers cause the liquid crystal to adopt a twisted configuration from one plate to the other. With no liquid crystal present, light passing in either direction through the cell would be absorbed because of the crossed polarizers, and the cell would appear to be dark. In the presence of a liquid crystal layer, however, the cell appears to be transparent because the optics of the twisted liquid crystal match the crossed arrangement of the polarizers. Application of three to five volts across the liquid crystal destroys the twisted state and causes the molecules to orient perpendicular to the substrate plates, giving a dark appearance to the cell, as shown in the diagram. For simple displays, the liquid crystal cell is operated in a reflective mode, with a diffuse reflector placed behind the display, and the activated parts of the electrode pattern appear as black images on a gray background provided by the diffuse reflector. By patterning the electrodes in segments or as an array of small squares, it is possible to display alphanumeric characters and very low-resolution images—for example, in digital watches or calculators. More-complex images can be displayed using a technique known as passive-matrix addressing described below. These supertwisted nematic STN displays achieve their high twist by using a substrate plate configuration similar to that of TN displays but with an additional optically active compound, known as a chiral dopant, dissolved in the liquid crystal. The display is activated using passive-matrix addressing, for which the pixels are arranged in rows and columns; selective application of a voltage to a particular row and column will activate the corresponding

element at their intersection. Colour STN displays have been produced for computer monitors, but they are being replaced in the market by more modern thin-film transistor TN displays described below, which have better viewing angles, colour, and response speed. Monochrome STN displays are still widely used in mobile telephones and other devices that do not require colour. Thin-film transistor displays The display of complex images requires high-resolution dot-matrix displays consisting of many thousands of pixels. For example, the video graphics array VGA standard for computer monitors consists of an array of by picture elements, which for a colour LCD translates to , individual pixels. Excellent images can be built up from arrays of this complexity by using thin-film transistor TFT TN displays, in which each pixel has associated with it a silicon transistor that acts as an individual electronic switch. A cutaway portion of a TFT display is illustrated in the figure. The use of a transistor for each pixel makes the TFT an active-matrix display, as opposed to the passive-matrix display described in the previous section. The TN effect produces black-and-white images, but, as shown in the diagram, colour images can be generated by forming three-pixel groups using red, blue, and green filters. The displayed image is bright by virtue of a flat backlight placed behind the liquid crystal panel. Basic architecture of an active-matrix thin-film transistor liquid crystal display Associated with each picture element, or pixel, of the display screen is a thin-film transistor, or TFT. The TFTs are subjected to varying voltages, which produce a varying orientation of molecules in the liquid crystal suspension. This varying orientation in turn varies the amount of light allowed to pass through the TFT matrix and colour filter, thereby changing the colour picture on the display screen. Introduced at the end of the s, TFT displays are now widely used in portable computers and as space-saving flat-screen monitors for personal computers. Some aspects of TFTs, such as viewing angle, speed, and the manufacturing cost of large-area displays, have slowed their full commercial exploitation. Nevertheless, these LCDs are increasingly entering the home television market. For example, in-plane switching IPS displays operate by applying a switching voltage to electrodes on a single substrate to untwist the liquid crystal. IPS displays have a viewing angle intrinsically superior to that of TFT TNs; however, the requirement for more electrode circuitry on their substrate can result in a less efficient use of the backlight. Twisted vertically aligned nematic TVAN displays utilize molecules that tend to orient with their long axes perpendicular to the direction of an applied electric field. A small quantity of an optically active material is added to the liquid crystal, causing it to adopt a twisted configuration upon the application of voltage. TVAN displays can show very high contrast and good viewing-angle characteristics. For mobile complex displays, battery lifetime is of great importance, and clearly the development of products that can be viewed in ambient light without recourse to backlighting is highly desirable. Such displays are known as reflective displays, and they can be realized in a number of ways. Some commercial reflective displays operate much like the transmissive STN. The liquid crystal again acts as an electro-optical layer between two polarizers. In place of a backlight, however, an aluminum mirror is used to reflect ambient light back toward the viewer when the liquid crystal is switched to a bright or transmissive state. Polarizers absorb about 50 percent of unpolarized light passing through them, and the removal of one or both polarizers can increase the brightness of the reflective displays. Indeed, active-matrix devices with single polarizers have begun to dominate the high-quality reflective display market—for example, in mobile phones and handheld electronic games. The dye molecules are selected to have a colour absorption that depends on their orientation. Variations in an applied electric voltage change the orientation of the host liquid crystal, and this in turn induces changes in the orientation of the dye molecules, thus changing the colour of the display. Guest-host devices may use one or no polarizers, but again they require a mirror. They can show high brightness, but generally they exhibit poorer contrast than optimized TN single-polarizer devices. Truly reflective displays not requiring a mirror have been manufactured using optically active liquid crystals known as chiral nematics or cholesteric liquid crystals. The first chiral nematics were based on derivatives of cholesterol, hence the now-obsolete term cholesteric. The molecules of such optically active liquid crystals spontaneously order into helical structures that are found to reflect light of a specific wavelength λ . Changing the orientation of the helices by an electric field can switch the liquid crystal from a coloured reflective state to a scattering or black state. The devices have a high resolution and acceptable contrast, but they are rather slow and are typically used in static displays. Transflective displays have been developed that combine some of the features of

polarizer-based reflective displays and transmissive displays. Transflective devices use a mirror that is partially reflective and partially transmissive, situated between the liquid crystal layer and a backlight. When ambient light levels are high, the backlight may be turned off and the display operated as a reflective device, saving battery power. When light levels are low, the backlight may be turned on to increase the brightness of the display. This clearly has advantages, although transflective displays by their nature represent a compromise and cannot readily match the reflectivity of a dedicated reflective display or the brightness of a transmissive device.

Projection displays The LCDs used in projection systems are typically small reflective or transmissive panels illuminated by a powerful arc lamp source. A series of lenses magnifies the reflected or transmitted image and casts it onto a screen. In front-projection systems the LCD is situated on the same side of the screen as the viewer, while in rear-projection systems the screen is illuminated from behind. Projectors of higher cost and performance may use three separate LCD panels, forming separate red, green, and blue images that combine to form a coloured image on the screen.

Smectic LCDs The increasing demand for video displays has placed a growing emphasis on the switching speed of liquid crystals. This has led to the development of devices employing smectic liquid crystals, certain of which have a faster electro-optical response than nematic liquid crystals. The surface-stabilized ferroelectric liquid crystal SSFLC display is currently the most developed smectic device. In it the liquid crystal molecules are arranged in layers perpendicular to the substrate planes, which are separated by one or two micrometres, and within the layers the molecules are tilted, as illustrated in the figure. The host liquid crystal contains optically active molecules, and a subtle consequence of the optical activity and the tilt of the molecules is the appearance of a permanent charge separation, or ferroelectric dipole, analogous to the ferromagnetic dipole of a magnet. The direction of this dipole is perpendicular to the tilt direction of the molecules and in the plane of the layers. Thus, there is a permanent charge separation across the liquid crystal layer in the SSFLC, and its sign is directly coupled to the tilt direction of the molecules. An applied voltage of the correct sign can reverse the direction of this dipole in tens of microseconds and hence reverse the tilt direction of the molecules. The corresponding change in optical properties can cause a change from light to dark when one or more polarizers are used. SSFLC devices have been commercialized for large passive-matrix displays, but their cost and complexity have prevented them from making any significant impact on the market. Small transmissive and reflective active-matrix SSFLC displays, however, show some promise for use as elements in projection systems or as viewfinders in digital cameras. Their fast response allows them to be used in time-sequential colour systems, in which costly colour filters are replaced by a coloured backlight that flashes red, green, and blue in rapid succession about cycles per second. For example, the liquid crystal can be switched to a transmissive state during the red and green periods and to a nontransmissive state during the blue period, with the result that the eye sees an average of red and green light, or the colour yellow.

Chapter 5 : Liquid Crystals Beyond Displays - Quan Li - Bok () | Bokus

The chemistry, physics, and applications of liquid crystals beyond LCDs Liquid Crystals (LCs) combine order and mobility on a molecular and supramolecular level. But while these remarkable states of matter.

What is an LCD? Courtesy of Shutterstock Courtesy of Shutterstock A liquid-crystal display is a type of electrically generated image shown on a thin, flat panel. The first LCDs, seen in the s, were tiny screens used mostly in calculators and digital watches displaying black numbers on a white background. Today, the latest LCD flat-panel TVs, which have largely replaced the traditional, bulky cathode-ray-tube kind, can produce high-definition colour images up to inches on the diagonal. LCDs are now found everywhere – in home-electronics systems, mobile phones, cameras and computer monitors, as well as watches and TVs. The technology is based on remarkable electrically sensitive materials called liquid crystals, which flow like liquids but have a crystalline structure. In crystalline solids, the constituent particles – atoms or molecules – sit in regular geometrical arrays, whereas in the liquid state they are free to move about randomly. Liquid crystals consist of molecules – often rod-shaped – that organise themselves in the same direction but are still able to move about. It turns out that liquid-crystal molecules respond to an electrical voltage, which changes their orientation and alters the optical characteristics of the bulk material. It is this property that is exploited in LCDs. They have become popular because they are thinner, lighter and have a lower voltage of operation than other display technologies, and they are perfect for battery-powered devices, for example. Physicists, chemists and technologists working together have had to solve many problems. The science Courtesy of Shutterstock Courtesy of Shutterstock Liquid crystals were discovered by accident in by Austrian botanist Friedrich Reinitzer. To seek an explanation, he passed his samples to physicist Otto Lehmann. It is understood that most liquid crystals, like cholesteryl benzoate, consist of molecules with long, rod-like structures. It is the combination of the attractive forces that exist between all molecules coupled with the rod-like structure that causes the liquid-crystal phase to form. However, the interaction is not quite strong enough to hold the molecules firmly in place. Many different kinds of liquid-crystal structures have since been discovered. Some organise further into layers, while others are even disc-shaped and form columns. Throughout the s and s, researchers studied the effects of electric and magnetic fields on liquid crystals. In , Russian physicist Vsevolod Fredericksz showed that liquid-crystal molecules, in a thin film sandwiched between two plates, changed their alignment when a magnetic field was applied. This was the forerunner of the modern voltage-operated LCD. The first patent for a liquid-crystal device was taken out by the UK Marconi Wireless Telegraph company in As physicists started to develop ever-smaller electronic devices and integrated circuits for everyday appliances, it became clear there was a need for a compatible display technology. LCDs became a candidate. The first devices, which were developed in the late s, consisted of a thin film of liquid crystal sandwiched between glass slides coated with transparent electrodes. An applied electric field disrupted the liquid-crystal alignment, transforming its appearance from transparent to opaque. These and subsequent devices were rather sensitive, for example, to temperature and did not last long. This interdisciplinary collaboration was crucial in advancing LCD technology. Current developments Courtesy of Shutterstock Courtesy of Shutterstock UK physics research groups have continued to work on improving liquid-crystal technology to produce faster, more stable LCDs with wider viewing angles. So-called ferroelectric liquid crystals promise to produce faster-responding displays, and liquid crystals are being combined with carbon nanotubes with the aim of creating new types of optical device, such as three-dimensional displays. Based on university research, Scottish company Exxelis has developed LCD back-lighting technology that is four times as efficient and will substantially improve picture quality and prolong battery life. Meanwhile, a Japanese electronics company is devising highly reflective LCDs that do not need backlighting at all. UK physicists have also played a major part in developing newer, competing display technologies. Richard Friend and his team at the Cavendish Laboratory at the University of Cambridge pioneered the development of polymer organic light-emitting diodes P-OLEDs in the late s while undertaking basic research into the physics of conducting organic polymers. They are currently used in small displays,

such as mobile-phone screens, but large TVs are on the horizon. They promise to be thinner and more efficient, though may not have the lifetime of LCDs. Impacts Courtesy of Shutterstock Courtesy of Shutterstock The technology behind the evolution of LCDs from simple displays for watches and calculators into fast colour displays for mobile phones, computer monitors and TVs has generated substantial revenue for the UK, through sales of materials and royalty income from device patents. The pace of technological development since the early s has been fast, and it continues to increase. LCD manufacture is truly global, with display production concentrated in the Far East and growing in central and eastern Europe. US firms lead the way in production technologies. LCDs now hold a dominant position in the displays market, challenged in only a few niche areas, and this is unlikely to change in the near future.

Chapter 6 : Liquid Crystals Beyond Displays - Advanced Science News

Liquid Crystals (LCs) combine order and mobility on a molecular and supramolecular level. But while these remarkable states of matter are most commonly associated with visual display technologies, they have important applications for a variety of other fields as well. Liquid Crystals Beyond Displays.

May 30, Liquid crystal is a state of matter " like liquid, solid, and gas. In order to understand what differentiates a liquid crystal phase from a liquid or solid phase, it is necessary to understand what defines these phases. The difference lies in the order of matter on a molecular, atomic or subatomic level. Order is a function of the energy stored within matter, and hence a function of the temperature of matter. Thus, one could say that temperature equals motion. There is no motion at absolute zero temperature 0 Kelvin. A little further away from absolute zero we have solids, which are characterized by limited motion of the molecules, atoms and ions that make up the material. This limited motion is a vibration within the molecule, and an oscillation around a fixed position. In a crystal for example, the centers of gravity within the molecules vibrate around fixed positions on a crystal lattice, while the general orientation of non-spherical molecules vibrates around a preferred orientation. When a solid melts, this long range order fixed average position, fixed average orientation many thousands of molecular units across breaks up. If both long range orders position and orientation dissipate at the same time as when the melting point is reached, a liquid phase is formed. In a liquid, there still is some level of order, but only in a short range. The hydrogen bonds between water molecules are a good example. When, with increasing temperature, this short range order gets lost and the molecules become completely independent in their motion, we speak about a gas or vapor. Finally, when electrons or other sub-atomic particles lose their order with respect to the rest of the molecule, we speak about plasma. Nature does not require that each phase is formed: Some materials can go from solid to gas without a liquid phase. Neither does nature require that positional and orientational order get lost in one step and at the same temperature. Depending on environmental conditions such as pressure or solvent concentration in a mixture, phases may be skipped or additional phases may appear when changing the temperature of a material. If positional order gets lost at the melting point, but orientational long range order is maintained up to a higher temperature, a liquid crystal phase is formed. The temperature at which all orientational long range order gets lost is called clearing point, as at such temperature a typically milky liquid crystal turns into a clear fluid. Positional long range order can get lost in steps while orientational order is maintained. As a result there can be many liquid crystal phases with different geometry and distinct phase transition temperatures between them. In some phases the liquid crystal is aligned in layers. They are called smectic phases and letters are used to differentiate different geometries smectic A, smC, smI. Columnar phases have molecules aligned in columns. The liquid crystal phase with no long range positional order is called a nematic phase and it is most widely used in displays. Liquid crystal phases are useful in displays because they interact with light and electric fields like crystals, but they can move flow like liquids, making it possible to use electric fields to change their effect on light. A typical temperature range of the liquid crystal phase s of a single material is only a few degrees. For most materials, that range is well above room temperature. In order to make liquid crystals practical for use in LCD displays , they need to be blended. Mixtures of liquid crystal materials can be formulated so that their temperature range is wide and falls within the operating temperature range requirements of modern electronics devices. Liquid Crystal Fluid suppliers engage in researching new material groups, synthesizing materials, and blending mixtures to achieve the physical properties defined by display manufacturers. Blends contain some single substances. In a volume model it would appear like this: Or simplified like a rod or cigar: Find out more here:

The chemistry, physics, and applications of liquid crystals beyond LCDs Liquid Crystals (LCs) combine order and mobility on a molecular and supramolecular level. But while these remarkable states of matter are most commonly associated with visual d.

General characteristics[edit] This section relies largely or entirely upon a single source. Relevant discussion may be found on the talk page. Please help improve this article by introducing citations to additional sources. October Learn how and when to remove this template message An LCD screen used as a notification panel for travellers. Each pixel of an LCD typically consists of a layer of molecules aligned between two transparent electrodes , and two polarizing filters parallel and perpendicular , the axes of transmission of which are in most of the cases perpendicular to each other. Without the liquid crystal between the polarizing filters, light passing through the first filter would be blocked by the second crossed polarizer. Before an electric field is applied, the orientation of the liquid-crystal molecules is determined by the alignment at the surfaces of electrodes. In a twisted nematic TN device, the surface alignment directions at the two electrodes are perpendicular to each other, and so the molecules arrange themselves in a helical structure, or twist. This induces the rotation of the polarization of the incident light, and the device appears gray. If the applied voltage is large enough, the liquid crystal molecules in the center of the layer are almost completely untwisted and the polarization of the incident light is not rotated as it passes through the liquid crystal layer. This light will then be mainly polarized perpendicular to the second filter, and thus be blocked and the pixel will appear black. By controlling the voltage applied across the liquid crystal layer in each pixel, light can be allowed to pass through in varying amounts thus constituting different levels of gray. Color LCD systems use the same technique, with color filters used to generate red, green, and blue pixels. Note that colors are inverted. The optical effect of a TN device in the voltage-on state is far less dependent on variations in the device thickness than that in the voltage-off state. Because of this, TN displays with low information content and no backlighting are usually operated between crossed polarizers such that they appear bright with no voltage the eye is much more sensitive to variations in the dark state than the bright state. As most of era LCDs are used in television sets, monitors and smartphones, they have high-resolution matrix arrays of pixels to display arbitrary images using backlighting with a dark background. When no image is displayed, different arrangements are used. Both the liquid crystal material and the alignment layer material contain ionic compounds. If an electric field of one particular polarity is applied for a long period of time, this ionic material is attracted to the surfaces and degrades the device performance. This is avoided either by applying an alternating current or by reversing the polarity of the electric field as the device is addressed the response of the liquid crystal layer is identical, regardless of the polarity of the applied field. Displays for a small number of individual digits or fixed symbols as in digital watches and pocket calculators can be implemented with independent electrodes for each segment. The general method of matrix addressing consists of sequentially addressing one side of the matrix, for example by selecting the rows one-by-one and applying the picture information on the other side at the columns row-by-row. For details on the various matrix addressing schemes see passive-matrix and active-matrix addressed LCDs. Castellano in Liquid Gold: Wild, can be found at the Engineering and Technology History Wiki. In , Charles Mauguin first experimented with liquid crystals confined between plates in thin layers. In , Georges Friedel described the structure and properties of liquid crystals and classified them in 3 types nematics, smectics and cholesterics. This effect is based on an electro-hydrodynamic instability forming what are now called "Williams domains" inside the liquid crystal. Heilmeyer , then working at the RCA laboratories on the effect discovered by Williams achieved the switching of colors by field-induced realignment of dichroic dyes in a homeotropically oriented liquid crystal. Practical problems with this new electro-optical effect made Heilmeyer continue to work on scattering effects in liquid crystals and finally the achievement of the first operational liquid-crystal display based on what he called the dynamic scattering mode DSM. Application of a voltage to a DSM display switches the initially clear transparent liquid crystal layer into a milky turbid state. DSM displays could be operated in transmissive and

in reflective mode but they required a considerable current to flow for their operation. The team at RRE supported ongoing work by George William Gray and his team at the University of Hull who ultimately discovered the cyanobiphenyl liquid crystals, which had correct stability and temperature properties for application in LCDs. The Gruen Teletime which was a four digit display watch. The same year, the first active-matrix thin-film transistor TFT liquid-crystal display panel was prototyped in the United States by T. Patent 4., and many more countries. In addition, Philips had better access to markets for electronic components and intended to use LCDs in new product generations of hi-fi, video equipment and telephones. Afterwards, Philips moved the Videlec production lines to the Netherlands. Years later, Philips successfully produced and marketed complete modules consisting of the LCD screen, microphone, speakers etc. The first color LCD televisions were developed as handheld televisions in Japan. One approach was to use interdigital electrodes on one glass substrate only to produce an electric field essentially parallel to the glass substrates. After thorough analysis, details of advantageous embodiments are filed in Germany by Guenter Baur et al. In , shortly thereafter, engineers at Hitachi work out various practical details of the IPS technology to interconnect the thin-film transistor array as a matrix and to avoid undesirable stray fields in between pixels. This is a milestone for implementing large-screen LCDs having acceptable visual performance for flat-panel computer monitors and television screens. In , Samsung developed the optical patterning technique that enables multi-domain LCD. Illumination[edit] Since LCD panels produce no light of their own, they require external light to produce a visible image. In a transmissive type of LCD, this light is provided at the back of the glass stack and is called the backlight. While passive-matrix displays are usually not backlit e. The common implementations of LCD backlight technology are: The LCD panel is lit either by two cold cathode fluorescent lamps placed at opposite edges of the display or an array of parallel CCFLs behind larger displays. A diffuser then spreads the light out evenly across the whole display. For many years, this technology had been used almost exclusively. A light diffuser is then used to spread the light evenly across the whole display. As of , this design is the most popular one in desktop computer monitors. It allows for the thinnest displays. Some LCD monitors using this technology have a feature called dynamic contrast, invented by Philips researchers Douglas Stanton, Martinus Stroomer and Adrianus de Vaan [52] Using PWM pulse-width modulation, a technology where the intensity of the LEDs are kept constant, but the brightness adjustment is achieved by varying a time interval of flashing these constant light intensity light sources [53] , the backlight is dimmed to the brightest color that appears on the screen while simultaneously boosting the LCD contrast to the maximum achievable levels, allowing the Since computer screen images usually have full white somewhere in the image, the backlight will usually be at full intensity, making this "feature" mostly a marketing gimmick for computer monitors, however for TV screens it drastically increases the perceived contrast ratio and dynamic range, improves the viewing angle dependency and drastically reducing the power consumption of conventional LCD televisions. LCDs that use this implementation will usually have the ability to dim the LEDs in the dark areas of the image being displayed, effectively increasing the contrast ratio of the display. As of , this design gets most of its use from upscale, larger-screen LCD televisions. This implementation is most popular on professional graphics editing LCDs. Today, most LCD screens are being designed with an LED backlight instead of the traditional CCFL backlight, while that backlight is dynamically controlled with the video information dynamic backlight control. The combination with the dynamic backlight control, invented by Philips researchers Douglas Stanton, Martinus Stroomer and Adrianus de Vaan, simultaneously increases the dynamic range of the display system also marketed as HDR, high dynamic range television. Connection to other circuits[edit] A pink elastomeric connector mating an LCD panel to circuit board traces, shown next to a centimeter-scale ruler. The conductive and insulating layers in the black stripe are very small, click on the image for more detail. A standard television receiver screen, an LCD panel today in , has over six million pixels, and they are all individually powered by a wire network embedded in the screen. The fine wires, or pathways, form a grid with vertical wires across the whole screen on one side of the screen and horizontal wires across the whole screen on the other side of the screen. To this grid each pixel has a positive connection on one side and a negative connection on the other side. So the total amount of wires needed is 3 x going vertically and going horizontally for a total of wires horizontally and vertically. For a

panel that is. These same principles apply also for smart phone screens that are so much smaller than TV screens. It is usually not possible to use soldering techniques to directly connect the panel to a separate copper-etched circuit board. Instead, interfacing is accomplished using either adhesive plastic ribbon with conductive traces glued to the edges of the LCD panel, or with an elastomeric connector, which is a strip of rubber or silicone with alternating layers of conductive and insulating pathways, pressed between contact pads on the LCD and mating contact pads on a circuit board. The commercially unsuccessful Macintosh Portable released in 1988 was one of the first to use an active-matrix display though still monochrome. Passive-matrix LCDs are still used in the 2000s for applications less demanding than laptop computers and TVs, such as inexpensive calculators. In particular, these are used on portable devices where less information content needs to be displayed, lowest power consumption no backlight and low cost are desired or readability in direct sunlight is needed. A comparison between a blank passive-matrix display top and a blank active-matrix display bottom. A passive-matrix display can be identified when the blank background is more grey in appearance than the crisper active-matrix display, fog appears on all edges of the screen, and while pictures appear to be fading on the screen. They exhibit a sharper threshold of the contrast-vs-voltage characteristic than the original TN LCDs. This is important, because pixels are subjected to partial voltages even while not selected. Individual pixels are addressed by the corresponding row and column circuits. This type of display is called passive-matrix addressed, because the pixel must retain its state between refreshes without the benefit of a steady electrical charge. As the number of pixels and, correspondingly, columns and rows increases, this type of display becomes less feasible. Rewriting is only required for picture information changes. That changed when in the "zero-power" bistable LCDs became available. After a page is written to the display, the display may be cut from the power while that information remains readable. This has the advantage that such ebooks may be operated long time on just a small battery only. High-resolution color displays, such as modern LCD computer monitors and televisions, use an active-matrix structure. Each pixel has its own dedicated transistor, allowing each column line to access one pixel. When a row line is selected, all of the column lines are connected to a row of pixels and voltages corresponding to the picture information are driven onto all of the column lines. The row line is then deactivated and the next row line is selected. All of the row lines are selected in sequence during a refresh operation. Active-matrix addressed displays look brighter and sharper than passive-matrix addressed displays of the same size, and generally have quicker response times, producing much better images.

Chapter 8 : Liquid-crystal displays

LCD or Liquid Crystal Display is a flat electronic display which is very commonly used in digital watches, calculators, laptops, televisions etc. It make use of light modulating properties of liquid crystal and polarization of light for its operation.

Chapter 9 : Liquid-crystal display - Wikipedia

Integrating nanotechnology and liquid crystals (LCs) opens up a new area of hybrid research, which enables the realization of novel photonic devices and displays []. A study by Yeung et al. [1] showed the possibility of using nano-structured alignment surfaces based on a random distribution of.