DOWNLOAD PDF ORGANIC LIGHT-EMITTING MATERIALS AND DEVICES VI

Chapter 1 : Organic Light-Emitting Materials and Devices VI | () | Publications | Spie

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many newcomers have invested heavily in OLED research and development. As a result, a stream of new OLED products has reached the marketplace and a number of large-scale manufacturing facilities are under construction. Though the field is growing rapidly and its impact is both pervasive and far-reaching, major challenges still remain, especially the lack of highly efficient, stable organic light-emitting materials, the insufficient operational lifetimes of the devices, and technical hurdles in large-scale manufacturing yields of the OLED displays. Overcoming these drawbacks will require further multidisciplinary studies. In recent years, several books on related topics have provided the readers with essential information in the field of organic electroluminescence. However, none of these could serve as a comprehensive guide. Our aim is to provide readers with a single source of information covering all aspects of OLEDs, including the systematic investigation of organic light-emitting materials, device physics and engineering, and so on.

Chapter 2 : OLED - Wikipedia

PROCEEDINGS VOLUME Organic Light-Emitting Materials and Devices VI. Editor(s): Zakya H. Kafafi; Homer Antoniadis. Format Member Price organic light-emitting.

The device includes an anode, a cathode, and an emissive layer disposed between the anode and the cathode. The emissive layer includes material having the structure: A material including the photoactive ligand of the above material is also provided. Many of the materials used to make such devices are relatively inexpensive, so organic opto-electronic devices have the potential for cost advantages over inorganic devices. In addition, the inherent properties of organic materials, such as their flexibility, may make them well suited for particular applications such as fabrication on a flexible substrate. Examples of organic opto-electronic devices include organic light emitting devices OLEDs , organic phototransistors, organic photovoltaic cells, and organic photodetectors. For OLEDs, the organic materials may have performance advantages over conventional materials. For example, the wavelength at which an organic emissive layer emits light may generally be readily tuned with appropriate dopants. Small molecules may include repeat units in some circumstances. Small molecules may also be incorporated into polymers, for example as a pendent group on a polymer backbone or as a part of the backbone. Small molecules may also serve as the core moiety of a dendrimer, which consists of a series of chemical shells built on the core moiety. The core moiety of a dendrimer may be an fluorescent or phosphorescent small molecule emitter. OLEDs make use of thin organic films that emit light when voltage is applied across the device. OLEDs are becoming an increasingly interesting technology for use in applications such as flat panel displays, illumination, and backlighting. OLED devices are generally but not always intended to emit light through at least one of the electrodes, and one or more transparent electrodes may be useful in an organic opto-electronic devices. For example, a transparent electrode material, such as indium tin oxide ITO , may be used as the bottom electrode. A transparent top electrode, such as disclosed in U. For a device intended to emit light only through the bottom electrode, the top electrode does not need to be transparent, and may be comprised of a thick and reflective metal layer having a high electrical conductivity. Where an electrode does not need to be transparent, using a thicker layer may provide better conductivity, and using a reflective electrode may increase the amount of light emitted through the other electrode, by reflecting light back towards the transparent electrode. Fully transparent devices may also be fabricated, where both electrodes are transparent. Side emitting OLEDs may also be fabricated, and one or both electrodes may be opaque or reflective in such devices. For example, for a device having two electrodes, the bottom electrode is the electrode closest to the substrate, and is generally the first electrode fabricated. The bottom electrode has two surfaces, a bottom surface closest to the substrate, and a top surface further away from the substrate. One application for phosphorescent emissive materials is a full color display. In particular, these standards call for saturated red, green, and blue pixels. Color may be measured using CIE coordinates, which are well known to the art. CIE coordinates are described in H. B London , , , , which are incorporated by reference. Another application for phosphorescent emissive materials is a display, full color or otherwise, that is intended to be powered by battery, such as the display of a cellular telephone or a digital camera. Lighting is another application where efficiency is of particular importance, because of the sheer volume of power used for lighting applications. Efficiency is also important for many other applications. Moreover, a high efficiency may lead to a longer lifetime, because inefficient devices generally lose power to heat instead of emitting light, and heat may adversely affect device lifetime. The emissive layer includes a material having the structure: When a current is applied, the anode injects holes and the cathode injects electrons into the organic layer s. The injected holes and electrons each migrate toward the oppositely charged electrode. Light is emitted when the exciton relaxes via a photoemissive mechanism. In some cases, the exciton may be localized on an excimer or an exciplex. Non-radiative mechanisms, such as thermal relaxation, may also occur, but are generally considered undesirable. Fluorescent emission generally occurs in a time frame of less

than 10 nanoseconds. As a result, phosphorescence generally occurs in a time frame exceeding at least 10 nanoseconds, and typically greater than nanoseconds. If the natural radiative lifetime of phosphorescence is too long, triplets may decay by a non-radiative mechanism, such that no light is emitted. Organic phosphorescence is also often observed in molecules containing heteroatoms with unshared pairs of electrons at very low temperatures. Non-radiative decay mechanisms are typically temperature dependent, such that a material that exhibits phosphorescence at liquid nitrogen temperatures may not exhibit phosphorescence at room temperature. But, as demonstrated by Baldo, this problem may be addressed by selecting phosphorescent compounds that do phosphoresce at room temperature. Generally, the excitons in an OLED are believed to be created in a ratio of about 3: See, Adachi et al. In a fluorescent device, the energy of triplet excitons is generally lost to radiationless decay processes that heat-up the device, resulting in much lower internal quantum efficiencies. OLEDs utilizing phosphorescent materials that emit from triplet excited states are disclosed, for example, in U. Phosphorescence may be preceded by a transition from a triplet excited state to an intermediate non-triplet state from which the emissive decay occurs. For example, organic molecules coordinated to lanthanide elements often phosphoresce from excited states localized on the lanthanide metal. However, such materials do not phosphoresce directly from a triplet excited state but instead emit from an atomic excited state centered on the lanthanide metal ion. The europium diketonate complexes illustrate one group of these types of species. Phosphorescence from triplets can be enhanced over fluorescence by confining, preferably through bonding, the organic molecule in close proximity to an atom of high atomic number. This phenomenon, called the heavy atom effect, is created by a mechanism known as spin-orbit coupling. Such a phosphorescent transition may be observed from an excited metal-to-ligand charge transfer MLCT state of an organometallic molecule such as tris 2-phenylpyridine iridium III. The figures are not necessarily drawn to scale. Device may include a substrate , an anode , a hole injection layer , a hole transport layer , an electron blocking layer , an emissive layer , a hole blocking layer , an electron transport layer , an electron injection layer , a protective layer , and a cathode Cathode is a compound cathode having a first conductive layer and a second conductive layer Device may be fabricated by depositing the layers described, in order. Substrate may be any suitable substrate that provides desired structural properties. Substrate may be flexible or rigid. Substrate may be transparent, translucent or opaque. Plastic and glass are examples of preferred rigid substrate materials. Plastic and metal foils are examples of preferred flexible substrate materials. Substrate may be a semiconductor material in order to facilitate the fabrication of circuitry. For example, substrate may be a silicon wafer upon which circuits are fabricated, capable of controlling OLEDs subsequently deposited on the substrate. Other substrates may be used. The material and thickness of substrate may be chosen to obtain desired structural and optical properties. Anode may be any suitable anode that is sufficiently conductive to transport holes to the organic layers. Anode and substrate may be sufficiently transparent to create a bottom-emitting device. A preferred transparent substrate and anode combination is commercially available ITO anode deposited on glass or plastic substrate. A flexible and transparent substrate-anode combination is disclosed in U. A reflective anode may be preferred for some top-emitting devices, to increase the amount of light emitted from the top of the device. The material and thickness of anode may be chosen to obtain desired conductive and optical properties. Where anode is transparent, there may be a range of thickness for a particular material that is thick enough to provide the desired conductivity, yet thin enough to provide the desired degree of transparency. Other anode materials and structures may be used. Hole transport layer may include a material capable of transporting holes. Hole transport layer may be intrinsic undoped , or doped. Doping may be used to enhance conductivity. Other hole transport layers may be used. Emissive layer may include an organic material capable of emitting light when a current is passed between anode and cathode Preferably, emissive layer contains a phosphorescent emissive material, although fluorescent emissive materials may also be used. Phosphorescent materials are preferred because of the higher luminescent efficiencies associated with such materials. Emissive layer may comprise a single material that combines transport and emissive properties. Whether the emissive material is a dopant or a major constituent,

emissive layer may comprise other materials, such as dopants that tune the emission of the emissive material. Emissive layer may include a plurality of emissive materials capable of, in combination, emitting a desired spectrum of light. Examples of phosphorescent emissive materials include Ir ppy 3. Examples of emissive and host materials are disclosed in U. Emissive material may be included in emissive layer in a number of ways. For example, an emissive small molecule may be incorporated into a polymer or dendrimer molecule. Other emissive layer materials and structures may be used. Electron transport layer may include a material capable of transporting electrons. Electron transport layer may be intrinsic undoped , or doped. Alq3 is an example of an intrinsic electron transport layer. An example of an n-doped electron transport layer is BPhen doped with Li at a molar ratio of 1: Other electron transport layers may be used. Cathode may be any suitable material or combination of materials known to the art, such that cathode is capable of conducting electrons and injecting them into the organic layers of device Cathode may be transparent or opaque, and may be reflective. Metals and metal oxides are examples of suitable cathode materials.

Chapter 3 : Organic electronics - Wikipedia

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For a device intended to emit light only through the bottom electrode, the top electrode does not need to be transparent, and may be comprised of a thick and reflective metal layer having a high electrical conductivity. Where an electrode does not need to be transparent, using a thicker layer may provide better conductivity, and using a reflective electrode may increase the amount of light emitted through the other electrode, by reflecting light back towards the transparent electrode. Fully transparent devices may also be fabricated, where both electrodes are transparent. Side emitting OLEDs may also be fabricated, and one or both electrodes may be opaque or reflective in such devices. As used herein, "top" means furthest away from the substrate, while "bottom" means closest to the substrate. For example, for a device having two electrodes, the bottom electrode is the electrode closest to the substrate, and is generally the first electrode fabricated. The bottom electrode has two surfaces, a bottom surface closest to the substrate, and a top surface further away from the substrate. Where a first layer is described as "disposed over" a second layer, the first layer is disposed further away from substrate. There may be other layers between the first and second layer, unless it is specified that the first layer is "in physical contact with" the second layer. For example, a cathode may be described as "disposed over" an anode, even though there are various organic layers in between. One application for phosphorescent emissive materials is a full color display. Industry standards for such a display call for pixels adapted to emit particular colors, referred to as "saturated" colors. In particular, these standards call for saturated red, green, and blue pixels. Color may be measured using CIE coordinates, which are well known to the art. CE coordinates are described in H. B London , ,, Another application for phosphorescent emissive materials is a display, full color or otherwise, that is intended to be powered by battery, such as the display of a cellular telephone or a digital camera. Lighting is another application where efficiency is of particular importance, because of the sheer volume of power used for lighting applications. Efficiency is also important for many other applications. Moreover, a high efficiency may lead to a longer lifetime, because inefficient devices generally lose power to heat instead of emitting light, and heat may adversely affect device lifetime. Photoactive ligands bearing a benzimidazole group are not disclosed. Summary of the Invention The present invention is directed to an organic light emitting device according to claim 1, comprising an anode, a cathode and an emissive layer disposed between the anode and the cathode, the emissive layer including a material according to claim 8 having the structure: According to a embodiment at least one of A and B includes a substituent. According to a further embodiment the emissive material is incorporated into a polymer. According to a further embodiment the emissive material is incorporated into a dendrimer. According to a further embodiment the emissive layer further comprises a host material. According to a further embodiment the emissive material is a dopant in the host material. According to a further embodiment the emissive material consists essentially of a neat film of the emissive material. The present invention is further directed to an emissive material having the structure: According to an embodiment at least one of A and B includes a substituent. Brief Description of the Drawings Fig. Figure 3 shows plots of luminous efficiency v. Detailed Description Generally, an OLED comprises at least one organic layer disposed between and electrically connected to an anode and a cathode. When a current is applied, the anode injects holes and the cathode injects electrons into the organic layer s. The injected holes and electrons each migrate toward the oppositely charged electrode. When an electron and hole localize on the same molecule, an "exciton," which is a localized electron-hole pair having an excited energy state, is formed. Light is emitted when the exciton relaxes via a photoemissive mechanism. In some cases, the exciton may be localized on an excimer or an exciplex. Non-radiative mechanisms, such as thermal relaxation, may also occur, but are generally considered undesirable. The initial OLEDs used emissive molecules that emitted light from their singlet states "fluorescence" as disclosed, for example, in U. Fluorescent emission generally occurs

in a time frame of less than 10 nanoseconds. More recently, OLEDs having emissive materials that emit light from triplet states "phosphorescence" have been demonstrated. Phosphorescence may be referred to as a "forbidden" transition because the transition requires a change in spin states, and quantum mechanics indicates that such a transition is not favored. As a result, phosphorescence generally occurs in a time frame exceeding at least 10 nanoseconds, and typically greater than nanoseconds. If the natural radiative lifetime of phosphorescence is too long, triplets may decay by a non-radiative mechanism, such that no light is emitted. Organic phosphorescence is also often observed in molecules containing heteroatoms with unshared pairs of electrons at very low temperatures. Non-radiative decay mechanisms are typically temperature dependent, such that a material that exhibit phosphorescence at liquid nitrogen temperatures may not exhibit phosphorescence at room temperature. But, as demonstrated by Baldo, this problem may be addressed by selecting phosphorescent compounds that do phosphoresce at room temperature. Generally, the excitons in an OLED are believed to be created in a ratio of about 3: See, Adachi et al. In many cases, singlet excitons may readily transfer their energy to triplet excited states via "intersystem crossing," whereas triplet excitons may not readily transfer their energy to singlet excited states. In a fluorescent device, the energy of triplet excitons is generally lost to radiationless decay processes that heat-up the device, resulting in much lower internal quantum efficiencies. OLEDs utilizing phosphorescent materials that emit from triplet excited states are disclosed, for example, in U. Phosphorescence may be preceded by a transition from a triplet excited state to an intermediate non-triplet state from which the emissive decay occurs. For example, organic molecules coordinated to lanthanide elements often phosphoresce from excited states localized on the lanthanide metal. However, such materials do not phosphoresce directly from a triplet excited state but instead emit from an atomic excited state centered on the lanthanide metal ion. The europium diketonate complexes illustrate one group of these types of species. Phosphorescence from triplets can be enhanced over fluorescence by confining, preferably through bonding, the organic molecule in close proximity to an atom of high atomic number. This phenomenon, called the heavy atom effect, is created by a mechanism known as spin-orbit coupling. Such a phosphorescent transition may be observed from an excited metal-to-ligand charge transfer MLCT state of an organometallic molecule such as tris 2-phenylpyridine iridium III. The figures are not necessarily drawn to scale. Device may include a substrate , an anode , a hole injection layer , a hole transport layer , an electron blocking layer , an emissive layer , a hole blocking layer , an electron transport layer , an electron injection layer , a protective layer , and a cathode Cathode is a compound cathode having a first conductive layer and a second conductive layer Device may be fabricated by depositing the layers described, in order. Substrate may be any suitable substrate that provides desired structural properties. Substrate may be flexible or rigid. Substrate may be transparent, translucent or opaque. Plastic and glass are examples of preferred rigid substrate materials. Plastic and metal foils are examples of preferred flexible substrate materials. Substrate may be a semiconductor material in order to facilitate the fabrication of circuitry. For example, substrate may be a silicon wafer upon which circuits are fabricated, capable of controlling OLEDs subsequently deposited on the substrate. Other substrates may be used. The material and thickness of substrate may be chosen to obtain desired structural and optical properties. Anode may be any suitable anode that is sufficiently conductive to transport holes to the organic layers. The material of anode preferably has a work function higher than about 4 eV a "high work function material". Anode and substrate may be sufficiently transparent to create a bottom-emitting device. A preferred transparent substrate and anode combination is commercially available ITO anode deposited on glass or plastic substrate. A flexible and transparent substrate-anode combination is disclosed in United States Patent No. A reflective anode may be preferred for some top-emitting devices, to increase the amount of light emitted from the top of the device. The material and thickness of anode may be chosen to obtain desired conductive and optical properties. Where anode is transparent, there may be a range of thickness for a particular material that is thick enough to provide the desired conductivity, yet thin enough to provide the desired degree of transparency. Other anode materials and structures may be used. Hole transport layer may include a material capable of transporting holes. Hole

transport layer may be intrinsic undoped , or doped Doping may be used to enhance conductivity. Other hole transport layers may be used. Emissive layer may include an organic material capable of emitting light when a current is passed between anode and cathode Preferably, emissive layer contains a phosphorescent emissive material, although fluorescent emissive-materials may also be used. Phosphorescent materials are preferred because of the higher luminescent efficiencies associated with such materials. Emissive layer may comprise a single material that combines transport and emissive properties. Whether the emissive material is a dopant or a major constituent, emissive layer may comprise other materials, such as dopants that tune the emission of the emissive material. Emissive layer may include a plurality of emissive materials capable of, in combination, emitting a desired spectrum of light. Examples of phosphorescent emissive materials include Ir ppy 3. Examples of emissive and host materials are disclosed in U. Emissive material may be included in emissive layer in a number of ways. For example, an emissive small molecule maybe incorporated into a polymer or dendrimer molecule. Other emissive layer materials and structures may be used. Electron transport layer may include a material capable of transporting electrons. Electron transport layer may be intrinsic undoped , or doped. Doping may be used to enhance conductivity.

Chapter 4 : Organic Light-Emitting Materials and Devices - Google Books

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Ligter; Eric Meulenkamp ; Simone Vulto ; Peter van de Weijer Show Abstract An overview of the requirements for full color passive matrix displays and their implications for the light emitting materials will be presented. Using the performance of light emitting polymers tested in Philips devices the status of the light emitting polymers is reviewed. It will be shown that the performance of light emitting polymers is at the edge of being acceptable for practical applications. Red and green light emitting polymers can already be used for certain monochrome applications. However, for the high-resolution displays used in mobile telecom applications the efficacy for red and the lifetime for green are still somewhat low. Optimization routes for further improvement in terms of efficacies and lifetimes for red and green are identified. The peformance of blue light emitting polymers has rapidly improved over the last year, but the lifetime is still too short for full color applications. Improvement routes for the blue light emitting polymers and its device structure are outlined. A first generation of polymers phenyl-PPVs is now being commercially exploited in first monochrome polymer LED displays. Nevertheless, due to market interest, there is a huge demand for materials for full-color OLED displays. Our main focus here lies on the improvement of the properties of various polymers derived from the spiro-bifluorene core. Depending on the color, the main issues vary strongly: For RED materials, in contrast, the operational lifetime is already excellent, whereas the efficiency and the driving current still need to be improved. For GREEN acquiring saturated emission, whilst maintaining the other properties high efficiency, long operational lifetime , is still challenging. Also, we will report on advances in full-color patterning, especially techniques based on Ink-Jet Printing. Haskal Show Abstract To explore the practical size limits of passive-matrix polymer light emitting displays, a 4-inch diagonal monochrome QVGA display was simulated, fabricated and tested. To design this display, a simulation program was developed which takes into account the multiplex rate, aperture ratio of the pixels, parasitic capacitance in the display, series resistance of the anodes and cathodes, and the decrease in efficiency at higher applied voltages. The effects of these parameters on the power consumption will be addressed. In addition, technological aspects of introducing a shunt metal in the pixels will be presented. Finally, the measurements of the fabricated display are compared to the simulation and discussed. Baynes Show Abstract The fabrication of high resolution light emitting polymer LEP OLED displays using ink jet printing to deposit the hole conducting and conjugated polymer electroluminescent components has required the development of both printing and ink technology. We review the issues associated with meeting the technology requirement and split these into the areas of ink delivery, getting the correct volume out of ink jet nozzles with well defined velocity and direction; surface energy considerations to maximize aperture ratio and display resolution; solution drying to form flat films and solution formulation to create polymer films that perform as well as films created by conventional spin coating. In addition we will describe the current status of the technology both in terms of polymer performance for both passive and active matrix applications, printing technology and polymer ink performance. The panel consisted of x pixels, and each pixel had three sub-pixels of red, green and blue emission in line. The panel contained stripe-shaped ITO lines, multi layers of organic materials, and cathode lines orthogonal to ITO lines. The organic layers of the electroluminescence panels were fabricated by vacuum evaporation method. Full-color emission was performed by patterning directly the emitting layers of red, green and blue color through metal mask in order to take most advantage of the luminous efficiency of electroluminescence. Pixel size of 0. This simple-structured panel was driven with passive matrix drive method. Dual scan drive method was adopted to lower the duty ratio, which made the peak luminance lower. Total thickness of the module was only 2. We started pilot production of the 2. Chwang ; Raymond C. Brown

Show Abstract We describe the performance of mixed-layer, small molecule organic light-emitting devices OLEDs that are step-graded from a mostly hole transporting layer HTL to a mostly electron transporting layer ETL from anode-side to cathode-side, respectively. These efficiencies are significantly higher than those of a uniformly mixed device, i. Operating lifetime of the graded mixed OLEDs, however, is much improved over the heterostructure device. We then compare the performance of fluorescent OLEDs at high current drive to that of phosphorescent OLEDs at high current drive in the context of passive matrix driven display suitability. Duggal ; Joe J. Shiang ; Christian M. In order to realize this, significant advances have to be made in device efficiency, lifetime at high brightness, high throughput fabrication, and the generation of illumination quality white light. In this talk, a down conversion method of generating white light is demonstrated and shown to be capable of generating illumination quality white light over the full range of color temperatures required for lighting. It is also demonstrated that, due to the presence of light scattering, the down-conversion method can actually increase the overall device power efficiency. Jabbour ; Steve G. Johnson ; John B. Kerr Show Abstract Besides display application, organic light emitting diodes OLED have great potential for the application of thin film light sources. The new device is designed to have a self-healing mechanism against electrical shorts. The entire device can be prepared in a vacuum chamber equipped with plasma treater, monomer evaporators, radiation curing units and inorganic deposition stations. A blend of small electron-donor organic molecules and radiation polymerizable monomers is flash evaporated to provide a molecular-level vapor-phase mixture, which is then condensed and cured on a flexible ITO coated substrate. The procedure is repeated with an electron-acceptor organic substance, which is deposited over the electron-donor layer. A metallic cathode is then deposited over the electron-acceptor layer and the composite OLED product is packaged. The flash evaporation vacuum deposition technique with in-line radiation cross-linking allows the mixing of small OLED molecules with monomers or oligomers at any ratio. Using this technique, a heterogeneous blend can be flash evaporated and molecularly mixed in the vapor phase, re-condensed as a homogeneous film, and then quickly cross-linked before any phase separation occurs. This creates a unique polymer chemistry that is not possible by conventional coating techniques. The electrical characteristics and the thickness of the metallic cathode and the composition of the polymer layers are selected to produce a self-healing mechanism via gasification of elemental carbon generated by dielectric breakdowns and the oxidation of any exposed cathodic surface, thereby providing a self-healing mechanism to prevent propagation of the damage caused by electrical shorts. Hany Aziz ; Zoran D. To this effect, the role of 5,6,11,tetraphenylnaphthacene rubrene , a widely dopant for HTLs, in increasing OLED stability has been widely investigated. However, significant disagreements between various explanations for the increased stability, ranging from rubrene being a charge injection promoter, to its being a charge trap, still exist. We conducted an in-depth study on the influence of rubrene doping of HTL on device stability. The study was carried out on OLEDs of structure: Ag cathode, in which different portions of the HTL were doped with rubrene. In addition, for a fixed thickness of the doped portion, device stability was found to be essentially independent of the thickness of the undoped portion. Popovic ; George Vamvounis; Hany Aziz ; Nan-Xing Hu Show Abstract Temperature dependence of electroluminescence degradation is studied in organic light emitting devices containing an emitting layer composed of a mixture of different hole transport molecules and tris 8-hydroxyquinoline aluminum ALQ3 electron transport and emitter molecule. The emitting layer is sandwiched between hole and electron transport layers. Activation energies for device degradation were determined for devices with different hole transport molecules and it was found that devices with higher activation energy show better high temperature stability. These results are consistent with the recently proposed degradation mechanism based on the unstable cationic AlQ3 species. Brenden Carlson ; Gregory D. Jen ; Larry Raymond Dalton Show Abstract Novel luminescent materials based on europium-cored complexes have been synthesized and incorporated into light emitting diodes using poly N-vinyl-carbazole and poly vinyl naphthalene blends as doping hosts. Excitation of the ligands and efficient transfer of energy from the excited ligands to the metal core results in the emission of optically pure red light. The ligands were designed such

that they include a polycyclic aromatic compound, phenanthrene, and a second substituent to improve processibility. Phenanthrene is used to so that the ligand energy will match with the energy of the metal center. Partially fluorinated substituents were also used to help improve the efficiency and charge transfer capability of the resulting metal complex. The complex consisted of one equivalent of europium and three equivalents of the ligand. One equivalent of either 1,phenanthroline or 4,7-diphenyl-1,phenanthroline was also chelated to enhance the stability of the complex. The double layer devices made with a polymer blend of PVN outperformed the devices made from PVK as the emission bands of the PVN better match the absorption bands of the ligands. Hassenkam Show Abstract Although polyaniline PAni has been proposed for use as a hole injection layer HIL in organic light emitting diodes OLEDs and polymeric light emitting diodes PLEDs from very early on, the material does not seem to have found widespread use on a pre commercial scale. Recent results will be presented showing that PAni can be efficiently used as HIL, and that it even has some advantages over the often preferred poly[ethylenedioxy-thiophene] PEDT. Intensive investigations on the influence of conductivity, morphology and especially the work function onto device performance have led to a commercially available water-borne PAni dispersion. Shu-jen Lee ; Joseph R. Gallegos; Julien Klein ; M. Jen Show Abstract Polyfluorenes are a class of very efficient conjugated polymers used in the development of LEDs that exhibit very high hole mobility. In order to balance the charge transport and enhance quantum efficiency of the LEDs, fluorene-based copolymers were synthesized based on the statistic copolymerization between fluorene and 2,5-dicyanobezene. By attaching two electron-withdrawing cyano groups onto the phenylene ring, both the electron affinity and the electron conduction of these copolymers are greatly enhanced comparing to the fluorene homopolymer. LED devices using the cyano-containing fluorene copolymers show very bright emission and low turn-on voltages. The emission color of these polymers could be also tuned by exciplex formation between the polymers and amine-containing hole transporting materials. Liu ; Alex K. Jen Show Abstract Copolymers based on fluorene and benzothiadiazole exhibit high brightness and quantum efficiencies when incorporated into polymer light-emitting diodes PLEDs. Their emission wavelength is strongly dependent on the benzothiadiazole-containing segment of the polymer. However, the chain structure and charge-transport and -transfer processes in these materials are not well studied. We have systematically investigated the effect of structure on their photoluminescence PL and electroluminescence EL properties. Furthermore we have also studied the effect of molecular weight and its distribution on the performance of the material in PL and EL. We have found that the absorption and emission spectra PL and EL of these polymers are quite independent of their structures, molecular weights, and polydispersity. However, the PL and EL efficiencies do vary with the materials studied. These materials were fabricated into a series of double-layer devices. Their external quantum efficiencies ranging from 0. The higher the molecular weight and the narrower the distribution are, the higher the efficiency and brightness of the devices. Likewise, the structure of the polymer also influences the efficiency. It was found that the structural-random copolymer r-PF3B exhibits higher efficiencies and brightness when compared with the structural-defined one s-PF3B in the same molecular weight range. Heike Riel ; Tilman A. A combinatorial approach that allows the simultaneous fabrication of 10 x 10 individual devices was used to vary the thicknesses of CuPc and NPB over a broad range from 0 to 45 nm and from 10 to nm, respectively.

Chapter 5 : EPB1 - Organic light emitting materials and devices - Google Patents

Organic Light-Emitting Materials and Devices provides a single source of information covering all aspects of OLEDs, including the systematic investigation of organic light-emitting materials, device physics and engineering, and manufacturing and performance measurement techniques.

Iridium complexes [54] such as Ir mppy 3 [52] are currently the focus of research, although complexes based on other heavy metals such as platinum [53] have also been used. The heavy metal atom at the centre of these complexes exhibits strong spin-orbit coupling, facilitating intersystem crossing between singlet and triplet states. By using these phosphorescent materials, both singlet and triplet excitons will be able to decay radiatively, hence improving the internal quantum efficiency of the device compared to a standard OLED where only the singlet states will contribute to emission of light. OLED devices are classified as bottom emission devices if light emitted passes through the transparent or semi-transparent bottom electrode and substrate on which the panel was manufactured. Top emission devices are classified based on whether or not the light emitted from the OLED device exits through the lid that is added following fabrication of the device. Top-emitting OLEDs are better suited for active-matrix applications as they can be more easily integrated with a non-transparent transistor backplane. The TFT array attached to the bottom substrate on which AMOLEDs are manufactured are typically non-transparent, resulting in considerable blockage of transmitted light if the device followed a bottom emitting scheme. TOLEDs can greatly improve contrast, making it much easier to view displays in bright sunlight. Graded heterojunction Graded heterojunction OLEDs gradually decrease the ratio of electron holes to electron transporting chemicals. Stacked OLEDs Stacked OLEDs use a pixel architecture that stacks the red, green, and blue subpixels on top of one another instead of next to one another, leading to substantial increase in gamut and color depth, [59] and greatly reducing pixel gap. Metal sheet with multiple apertures made of low thermal expansion material, such as nickel alloy, is placed between heated evaporation source and substrate, so that the organic or inorganic material from evaporation source is deposited only to the desired location on the substrate. Almost all small OLED displays for smartphones have been manufactured using this method. Such defect formation can be regarded as trivial when the display size is small, however it causes serious issues when a large display is manufactured, which brings significant production yield loss. To circumvent such issues, white emission device with 4-sub-pixel color filter white, red, green and blue has been used for large television. Other color patterning approaches[edit] There are other type of emerging patterning technologies to increase the manufacturabiltiy of OLED. Patternable organic light-emitting devices use a light or heat activated electroactive layer. Using this process, light-emitting devices with arbitrary patterns can be prepared. The gas is expelled through a micrometre -sized nozzle or nozzle array close to the substrate as it is being translated. This allows printing arbitrary multilayer patterns without the use of solvents. Like ink jet material depositioning , inkjet etching IJE deposits precise amounts of solvent onto a substrate designed to selectively dissolve the substrate material and induce a structure or pattern. This trapped light is wave-guided along the interior of the device until it reaches an edge where it is dissipated by either absorption or emission. IJE solvents are commonly organic instead of water-based due to their non-acidic nature and ability to effectively dissolve materials at temperatures under the boiling point of water. It takes advantage of standard metal deposition, photolithography , and etching to create alignment marks commonly on glass or other device substrates. Thin polymer adhesive layers are applied to enhance resistance to particles and surface defects. Microscale ICs are transfer-printed onto the adhesive surface and then baked to fully cure adhesive layers. An additional photosensitive polymer layer is applied to the substrate to account for the topography caused by the printed ICs, reintroducing a flat surface. Photolithography and etching removes some polymer layers to uncover conductive pads on the ICs. Afterwards, the anode layer is applied to the device backplane to form bottom electrode. OLED layers are applied to the anode layer with conventional vapor deposition , and covered with a conductive metal electrode layer. As of [update]

transfer-printing was capable to print onto target substrates up to mm X mm. Lower cost in the future OLEDs can be printed onto any suitable substrate by an inkjet printer or even by screen printing, [69] theoretically making them cheaper to produce than LCD or plasma displays. Roll-to-roll vapor-deposition methods for organic devices do allow mass production of thousands of devices per minute for minimal cost; however, this technique also induces problems: Lightweight and flexible plastic substrates OLED displays can be fabricated on flexible plastic substrates, leading to the possible fabrication of flexible organic light-emitting diodes for other new applications, such as roll-up displays embedded in fabrics or clothing. If a substrate like polyethylene terephthalate PET [70] can be used, the displays may be produced inexpensively. Furthermore, plastic substrates are shatter-resistant, unlike the glass displays used in LCD devices. This also provides a deeper black level , since a black OLED display emits no light. Better power efficiency and thickness LCDs filter the light emitted from a backlight , allowing a small fraction of light through. Thus, they cannot show true black. However, an inactive OLED element does not produce light or consume power, allowing true blacks. Emission intensity is enhanced when the IML thickness is 1. The refractive value and the matching of the optical IMLs property, including the device structure parameters, also enhance the emission intensity at these thicknesses. Due to their extremely fast response time, OLED displays can also be easily designed to be strobed, creating an effect similar to CRT flicker in order to avoid the sample-and-hold behavior seen on both LCDs and some OLED displays, which creates the perception of motion blur. Each currently is rated for about 25,â€”40, hours to half brightness, depending on manufacturer and model. It is said that the chemical breakdown in the semiconductors occurs in four steps: This variation in the differential color output will change the color balance of the display and is much more noticeable than a decrease in overall luminance. More commonly, though, manufacturers optimize the size of the R, G and B subpixels to reduce the current density through the subpixel in order to equalize lifetime at full luminance. Considerable research has been invested in developing blue OLEDs with high external quantum efficiency as well as a deeper blue color. Therefore, improved sealing processes are important for practical manufacturing. Water damage especially may limit the longevity of more flexible displays. However, with the proper application of a circular polarizer and antireflective coatings, the diffuse reflectance can be reduced to less than 0. With 10, fc incident illumination typical test condition for simulating outdoor illumination , that yields an approximate photopic contrast of 5: However, an OLED can use more than three times as much power to display an image with a white background, such as a document or web site. Portable displays are also used intermittently, so the lower lifespan of organic displays is less of an issue. Applications in flexible signs and lighting are also being developed. DuPont also states that OLED TVs made with this less expensive technology can last up to 15 years if left on for a normal eight-hour day. Flexible OLED displays are already being produced and these are used by manufacturers to create curved displays such as the Galaxy S7 Edge but so far there they are not in devices that can be flexed by the consumer. The hope is to combine the comfort and low cost properties of textile with the OLEDs properties of illumination and low energy consumption. Although this scenario of illuminated clothing is highly plausible, challenges are still a road block. In addition, the company adopted active matrix-based technology for its low power consumption and high-resolution qualities. The drive circuit was formed by low-temperature polysilicon TFTs. Also, low-molecular organic EL materials were employed. The contrast ratio is , The panel has a contrast ratio of 1,, The device features a p screen, measuring 5. The corporation has promoted the following advantages: A new feature called "Round Interaction" that allows users to look at information by tilting the handset on a flat surface with the screen off, and the feel of one continuous transition when the user switches between home screens. The project involves one laboratory and 10 companies including Sony Corp. Eventually, bendable, see-through displays could be stacked to produce 3D images with much greater contrast ratios and viewing angles than existing products.

Chapter 6 : USB1 - Organic light emitting materials and devices - Google Patents

PROCEEDINGS VOLUME Technology and materials for full-color polymer light-emitting displays Synthesis and design of organic light-emitting devices.

These problems require the creation of revolutionary display materials and devices, and the invention of visual system technologies. Breakthroughs needed in display technology for defense and security personnel may be organized into the following technical challenge areas: The improved film properties are meeting many of the desired needs and specifications for display and process applications as they are understood today. Processing the plastic substrate through the OLED device making process can contribute to small changes in the substrate dimensions. Photolithography process is a critical part of the OLED device making process, knowing to compensate for substrate size does address technical challenges in overlay registration. While monochrome operation is sufficient for some applications, ultimately multi-color devices such as signs or even RGB red, green, blue matrix displays will be requested by the customer in the future. So far, this goal has been achieved with small-molecule devices fabricated by vacuum deposition. In contrast, electroluminescent EL polymers, which are commonly deposited by solution processing, seemed to be only poorly suited for this purpose owing to the lack of high-resolution patterning processes. Recent attempts, therefore, focus on the adaptation of common printing techniques such as screen printing and ink jetting, both having severe technical difficulties and drawbacks, such as limited resolution in the former and wetting issues in the latter case requiring extensive pre-treatment of the substrates. We demonstrate the use of a new class of EL polymers, which can be applied similar to a standard photoresist. Soluble polymers with oxetane sidegroups were crosslinked photochemically to yield insoluble polymer networks in the desired areas. The resolution of the process is sufficient to fabricate common pixelated matrix displays. Consecutive deposition of the three colors yielded a RGB device with efficiencies comparable to state-of-the-art EL polymers, even slightly reduced onset voltages, and improved efficiencies at high luminance levels. The improved thermal and morphological stability promises better performance in passive-matrix displays requiring high drive currents. The new method potentially allows efficient manufacturing of high-resolution multi-color polymer-based displays on large area using common lithography techniques. However, the key challenges that still remain are improving luminance efficiency for lower power consumption and better stability. Applying a co-dopant into the EML is an effective way to adjust device performance. A large proportion of power is consumed in red sub-pixels in full-color displays with RGB sub-pixels. Previously we found that rubrene doping of red emitting layer improved the luminance efficiency and operational stability by enhancing the energy transfer from host material to emitting dopant. To increase the efficiency, a phosphorescent material as a red emitter was studied. We review the requirements for and characteristics of RGB OLEDs and the impact of co-doping systems on the performance of full-color displays. Vulto ; Michael Buechel; Paul C. Meulenkamp ; Jan-Eric J. Rubingh; Peter van de Weijer; Suzanne H. The focus of current materials research is on state-of-the-art red, green, and blue light-emitting polymers LEP with high efficiency, optimum color points, low driving voltages and long lifetimes in devices. A general overview of the progress of red, green and blue LEP lifetimes and efficiencies will be given and compared to requirements for both full-color passive and active matrix-displays for mobile display applications. Further, the status of ink-jet printing of LEPs for the industrialization of full-color displays will be discussed, and a comparison of the performance of spin coated and inkjet printed devices will be presented. In addition, two material-related topics studied recently will be discussed; namely, the lifetime of blue light-emitting devices correlated to processing, anodes, cathodes and the blue polymers themselves, and second, the consequences of pulsed-driving schemes on efficiency and lifetime. Anthopoulos ; Ebinazar B. Here we demonstrate a modular approach allowing highly efficient fluorescent and phosphorescent emissive chromophores to be used to make red, green and blue solution-processed light emitting diodes. The choice of a common dendritic architecture ensures good solubility and film forming properties irrespective of

the choice of core unit. In addition, this architecture allows blending of dendrimers with different cores without phase separation. We show that blending provides a simple but powerful way of tuning the color of dendrimer LEDs from deep blue to blue-green, and from green to red with little impact on the device properties. The emission of light via the conductive transparent top-contact is considered necessary in terms of integrating OLED-technology to standard Si-based driver circuitry. To obtain low series resistance the overlying transparent electrode was realized employing low-power radio-frequency magnetron sputter-deposition of indium-tin-oxide ITO. The devices introduce a two-step sputtering sequence to reduce damage incurred by the sputtering process paired with the buffer and hole transporting material pentacene. Systematic optimization of the organic growth sequence focused on device performance characterized by current and luminous efficiencies is conducted. PSS as anode buffers is presented. These effects are similar to those reported for anthracene single crystals suggesting a large triplet-triplet annihilation TTA component for the EL in Alq3. However, transient EL studies fail to definitively identify a delayed luminescence component with a time scale appropriate for TTA in Alq3. We discuss this and other questions concerning the origin of MFE in this system. Choudhury; Ruth Shinar ; Joseph Shinar Show Abstract A new platform for luminescent chemical and biological sensors, integrating the excitation source, an OLED, with the sensing component, is described. The utility of the platform is demonstrated for an oxygen sensor and its potential is demonstrated for antibody-antigen immunoassays. The oxygen sensor is operable in two modes, i. In the lifetime mode, the need for sensor calibration, which remains a challenge in real-world sensing applications, is eliminated. Attributes and issues related to sensor performance, including design and stability, are discussed. The technique is based on monitoring the resistance of a degrading Ca sensor in situ, inside a climate chamber. The benefits of the method are demonstrated for single- and double-sided barrier foils, and the temperature and humidity dependence of the transport through PET is analyzed in detail. The method is also applied to obtain permeation rates for a barrier-coated substrate after as well as during bending. Theoretical simulations are used to evaluate the influence of a defect-dominated transport mechanism on the experimental results and to model the time evolution of the concentration profile in a double-barrier stack. Implications for the development of barrier-enhanced substrates for flexible OLED applications are discussed. Moro ; Todd A. Rutherford; Olga Philips; Robert J. Visser ; Mark E. Gross ; Wendy D. In this paper results on encapsulation of OLED test pixels and passive matrix displays will be shown. Lifetime and permeability tests conducted at high temperature and humidity demonstrate that this thin film coating can meet the necessary performance requirements for commercial OLED displays. Processing parameters, layer architecture and manufacturing techniques are analyzed and discussed. Thin film encapsulated displays are used to demonstrate the utility of the encapsulation technique. Bazan ; Daniel Moses ; Alan J. The results demonstrate that high performance electrophosphorescence can be obtained from conjugated polymer-based LEDs that are fabricated by processing the active materials directly from solution. Yeh-Jiun Tung ; Michael M. Weaver ; Michael Hack ; Julie J. Hartmut Yersin Show Abstract This contribution focuses on triplet emitters. They represent attractive OLED materials, since their efficiencies can in principle be by a factor of four higher than of small singlet emitter molecules. On the basis of introductory models, it is discussed how the exciton formation process can be visualized, how the emitter states are populated, and why the excitation energy is finally harvested in the lowest triplet state. Further, it is shown that essential photophysical properties of organometallic emitters depend systematically on the metal participation in the triplet states and on the effective spin-orbit coupling that control the amount of zero-field splitting ZFS of the triplet state into substates. Increase of ZFS corresponds to more metal character in the triplet state. High metal character reduces the energy difference between excited singlet and triplet states, enhances the singlet-triplet inter-system crossing rate, lowers the emission decay time, changes the vibrational satellite structure, decreases the excited state reorganization energy, etc. These effects will be discussed by referring to well characterized compounds. Based on a new ordering scheme presented for triplet emitter materials a controlled development of compounds with pre-defined photophysical properties becomes possible. Mari Ishihara; Kenji Okumoto; Yasuhiko Shirota

Show Abstract Effects of the method of preparation of organic thin films and chemical doping on charge injection from electrodes were investigated. It was found that charge injection from electrodes and the performance of organic electroluminescent EL devices are affected by the method of preparation of organic thin films, depending on the kind of materials. Theo Kreouzis; Donal D. Bradley ; Alasdair J. It also undergoes irreversible increases when the samples are annealed. These results can be related to PFOs complex phase behavior and show the importance of understanding and controlling the polymer film structure for device applications. We also present new TOF measurements on the green emitting electroluminescent polymer poly 9,9-dioctylfluorene-co-benzothiadiazole BT. Previous TOF measurements have shown that BT exhibits dispersive electron transport and that holes are very heavily trapped, no hole transport signal being measurable using this technique. This new batch therefore exhibits the highly desirable property of both good electron and hole transport in the same electroluminescent polymer. TOF measurements of the variation of the hole and electron mobility with temperature are examined within the framework of the Gaussian disorder model. We have shown that very low operating voltages can be achieved in small-molecule OLED by intentional electrical n- and p-type doping. Even more important than the reduction of the voltage is the fact that doping of the charge carrier transport layers improves charge injection, making it basically independent on the actual contact work-functions. Organic light emitting diodes OLEDs with electrically doped transport layers show significantly improved properties: With phosphorescent emitter dopants, high quantum and power efficiency of OLEDs with doped transport layers can be achieved: Inverted and fully transparent devices with parameters comparable to standard bottom-emitting OLED have been demonstrated as well. PSS , were either spin-cast from aqueous dispersions or pre-coated on plastic substrates courtesy Agfa Gevaert N. Recent investigations on hole transport mechanism in polyaniline systems now show the necessity of a minimum conductivity and an optimum work function for hole injection. Otherwise, a decrease in maximum efficiency and an increase in driving voltage in dependence on coating thickness occurs. Work function investigations on water-free, highly conductive polyaniline dispersions emphasize the theory of an optimum range for hole injection from the anode into the light emitting polymer. The work function of highly conductive, non-aqueous PAni dispersion 0. Bradley Show Abstract Here we report the observation of ohmic hole injection from a conducting polymer anode into poly 9,9-dioctylfluorene PFO in a polymer light-emitting diode LED structure. Although initially non ohmic, the contact can be made locally ohmic by electrically conditioning the device at voltages higher than the electroluminescence EL onset voltage. The ohmic nature of the contact in selected regions is confirmed by the appearance of dark injection space-charge-limited transient currents, which yield hole mobilities in good agreement with those measured by the time-of-flight method. The appearance of ohmic injection is discussed within a model that assumes the existence of electron traps near the anode interface. When the sample is conditioned electrons are injected from the cathode and are trapped near the anode inducing an interfacial dipole that reduces the barrier for hole injection. Scanduicci de Freitas; M. First, conditions that facilitate photo-oxidation of PF are investigated. We show that dense chain packing and addition of hole-trapping moieties lead to increased defect formation.

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Organic light-emitting diodes are rapidly taking over display technology, from smartphones to roadside billboards. This big book, in its second edition, provides a single source of information about OLEDs: their synthesis, compositions, properties and applications.

History[edit] One class of materials of interest in organic electronics are electrical conductive , i. Traditionally, conductive materials are inorganic. Classical and still technologically dominant conductive materials are metals such as copper and aluminum as well as many alloys. Heeger , Alan G. MacDiarmid , and Hideki Shirakawa jointly for their work on conductive polymers. In the s, a second class of electric conductors were discovered based on charge-transfer salts. Early examples were derivatives of polycyclic aromatic compounds. For example, pyrene was shown to form semiconducting charge-transfer complex salts with halogens. Conductive plastics have undergone development for applications in industry. In , the first organic diode was produced at Eastman Kodak by Ching W. Tang and Steven Van Slyke. Moving from molecular to macromolecular materials solved the problems previously encountered with the long-term stability of the organic films and enabled high-quality films to be easily made. Molecular solids and salts[edit] Conductive polymers[edit] Conductive polymers are often typically intrinsically conductive or at least semiconductors. They sometimes show mechanical properties comparable to those of conventional organic polymers. Both organic synthesis and advanced dispersion techniques can be used to tune the electrical properties of conductive polymers, unlike typical inorganic conductors. The most well-studied class of conductive polymers include polyacetylene , polypyrrole , polyaniline , and their copolymers. Poly p-phenylene vinylene and its derivatives are used for electroluminescent semiconducting polymers. Poly 3-alkythiophenes are also a typical material for use in solar cells and transistors. Organic light-emitting diode[edit] An OLED organic light-emitting diode consists of a thin film of organic material that emits light under stimulation by an electric current. Emission of radiation, 4. Tang, [11] reported fabrication of an OLED device in The OLED device incorporated a double-layer structure motif consisting of separate hole transporting and electron -transporting layers, with light emission taking place in between the two layers. Their discovery opened a new era of current OLED research and device design. Classification and current research[edit] OLED organic materials can be divided into two major families: Fluorescent dyes can be selected according to the desired range of emission wavelengths ; compounds like perylene and rubrene are often used. By modifying the structure of Br6A, scientists are attempting to achieve a next generation organic light emitting diode. Devices based on small molecules are usually fabricated by thermal evaporation under vacuum. While this method enables the formation of well-controlled homogeneous film ; is hampered by high cost and limited scalability. Common polymers used in PLEDs include derivatives of poly p-phenylene vinylene [15] and polyfluorene. The emitted color can be tuned by substitution of different side chains onto the polymer backbone or modifying the stability of the polymer. Compared to thermal evaporation, solution based methods are more suited to creating films with large dimensions. Organic field-effect transistor[edit] Main article: Organic Field-Effect Transistor Rubrene-OFET with the highest charge mobility An Organic field-effect transistor is a field-effect transistor utilizing organic molecules or polymers as the active semiconducting layer. A field-effect transistor FET is any semiconductor material that utilizes electric field to control the shape of a channel of one type of charge carrier, thereby changing its conductivity. Two major classes of FET are n-type and p-type semiconductor, classified according to the charge type carried. Lilienfeld [17] first proposed the field-effect transistor in , but the first OFET was not reported until , when Koezuka et al. Other conductive polymers have been shown to act as semiconductors, and newly synthesized and characterized compounds are reported weekly in prominent research journals. Many review articles exist documenting the development of these materials. Current research focuses more on thin-film transistor TFT model, which eliminates the usage of conductive materials. Very recently, two studies conducted by Dr. By controlling the formation of crystalline

TFT , it is possible to create an aligned as opposed to randomly ordered charge transport pathway, resulting in enhanced charge mobility. Organic electronic devices[edit] Organics-based flexible display Five structures of organic photovoltaic materials Organic solar cells could cut the cost of solar power by making use of inexpensive organic polymers rather than the expensive crystalline silicon used in most solar cells. Transport and installation of lightweight flexible solar cells also saves cost as compared to cells on glass. Inexpensive polymeric substrates like polyethylene terephthalate PET or polycarbonate PC have the potential for further cost reduction in photovoltaics. Protomorphous solar cells prove to be a promising concept for efficient and low-cost photovoltaics on cheap and flexible substrates for large-area production as well as small and mobile applications. One ink must not damage another, and low temperature annealing is vital if low-cost flexible materials such as paper and plastic film are to be used. Sony reported the first full-color, video-rate, flexible, plastic display made purely of organic materials ; [28] [29] television screen based on OLED materials; biodegradable electronics based on organic compound and low-cost organic solar cell are also available. Fabrication methods[edit] There are important differences between the processing of small molecule organic semiconductors and semiconducting polymers. Small molecule semiconductors are quite often insoluble and typically require deposition via vacuum sublimation. While usually thin films of soluble conjugated polymers. Devices based on conductive polymers can be prepared by solution processing methods. Both solution processing and vacuum based methods produce amorphous and polycrystalline films with variable degree of disorder. Common examples of solvent-based coating techniques include drop casting, spin-coating , doctor-blading, inkjet printing and screen printing. Spin-coating is a widely used technique for small area thin film production. It may result in a high degree of material loss. The doctor-blade technique results in a minimal material loss and was primarily developed for large area thin film production. Vacuum based thermal deposition of small molecules requires evaporation of molecules from a hot source. The molecules are then transported through vacuum onto a substrate. The process of condensing these molecules on the substrate surface results in thin film formation. Wet coating techniques can in some cases be applied to small molecules depending on their solubility. Organic solar cells[edit] Bilayer organic photovoltaic cell Compared to conventional inorganic solar cell, organic solar cells have the advantage of lower fabrication cost. An organic solar cell is a device that uses organic electronics to convert light into electricity. Organic solar cells utilize organic photovoltaic materials, organic semiconductor diodes that convert light into electricity. Figure to the right shows five commonly used organic photovoltaic materials. Typically, the band gap lies in the range of eV. Different forms of solar cells includes single-layer organic photovoltaic cells, bilayer organic photovoltaic cells and heterojunction photovoltaic cells. However, all three of these types of solar cells share the approach of sandwiching the organic electronic layer between two metallic conductors, typically indium tin oxide. Generally, a field-effect transistor has two plates , source in contact with drain and the gate respectively, working as conducting channel. Different types of FETs are designed based on carrier properties. Thin film transistor TFT , among them, is an easy fabricating one. In a thin film transistor , the source and drain are made by directly depositing a thin layer of semiconductor followed by a thin film of insulator between semiconductor and the metal gate contact. Such a thin film is made by either thermal evaporation, or simply spins coating. In a TFT device, there is no carrier movement between the source and drain. After applying a positive charge , accumulation of electrons on the interface cause bending of the semiconductor and ultimately lowers the conduction band with regards to the Fermi -level of the semiconductor. Finally, a highly conductive channel is formed at the interface. Printed electronics Conductive polymers are lighter, more flexible , and less expensive than inorganic conductors. This makes them a desirable alternative in many applications. It also creates the possibility of new applications that would be impossible using copper or silicon. Organic electronics not only includes organic semiconductors , but also organic dielectrics , conductors and light emitters. New applications include smart windows and electronic paper. Conductive polymers are expected to play an important role in the emerging science of molecular computers.