**Organic LED**

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[](http://en.wikipedia.org/wiki/File:OLEDScreen.jpg)[](http://en.wikipedia.org/wiki/File:Sony_oled.jpg)[](http://en.wikipedia.org/wiki/File:Sony_XEL-1.jpg)

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A 3.8 cm (1.5 in) OLED display

[http://1.1.1.3/bmi/bits.wikimedia.org/skins-1.5/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:Sony_oled.jpg)

[Sony XEL-1](http://en.wikipedia.org/wiki/Sony_XEL-1), the world's first OLED TV.[[1]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-xel1-0) (front)

[http://1.1.1.3/bmi/bits.wikimedia.org/skins-1.5/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:Sony_XEL-1.jpg)

Sony XEL-1 (side)

An **organic light emitting diode** (**OLED**), also **organic electro luminescent device** (**OELD**), is a [light-emitting diode](http://en.wikipedia.org/wiki/Light-emitting_diode) (LED) whose [emissive](http://en.wikipedia.org/wiki/Emission_%28electromagnetic_radiation%29) [electroluminescent](http://en.wikipedia.org/wiki/Electroluminescence) layer is composed of a film of [organic compounds](http://en.wikipedia.org/wiki/Organic_compound). This layer of organic semiconductor material is formed between two electrodes, where at least one of the electrodes is transparent.

Such devices can be used in [television](http://en.wikipedia.org/wiki/Television) screens, [computer monitors](http://en.wikipedia.org/wiki/Computer_monitor), small, portable system screens such as cell phones and [PDAs](http://en.wikipedia.org/wiki/PDAs), watches, advertising, information and indication. OLEDs can also be used in light sources for general space illumination, and large-area light-emitting elements. Due to the younger stage of development, OLEDs typically emit less light per unit area than inorganic solid-state based LEDs which are usually designed for use as point-light sources.

In the context of displays, OLEDs have certain advantages over traditional [liquid crystal displays](http://en.wikipedia.org/wiki/Liquid_crystal_display) (LCDs). OLED displays do not require a [backlight](http://en.wikipedia.org/wiki/Backlight) to function. Thus, they can display deep [black levels](http://en.wikipedia.org/wiki/Black_level) and can be thinner and lighter than LCD panels. OLED displays also naturally achieve higher [contrast ratios](http://en.wikipedia.org/wiki/Contrast_ratio) than either LCD screens using [cold cathode fluorescent lamps (CCFLs)](http://en.wikipedia.org/wiki/Cold_cathode) or the more recently developed [LED](http://en.wikipedia.org/wiki/LED) backlights in conditions of low ambient light such as dark rooms.

## History

A. Bernanose and co-workers at the [Nancy-Université](http://en.wikipedia.org/wiki/Nancy-Universit%C3%A9), first produced [electroluminescence](http://en.wikipedia.org/wiki/Electroluminescence) in organic materials in the early 1950s by applying high-voltage [alternating current](http://en.wikipedia.org/wiki/Alternating_current) (AC) fields in air to [acridine orange](http://en.wikipedia.org/wiki/Acridine_orange) and [quinacridine](http://en.wikipedia.org/w/index.php?title=Quinacridine&action=edit&redlink=1) either deposited on or dissolved in cellulose or cellophane thin films. They proposed a mechanism of either direct excitation of the dye molecules or excitation of electrons.[[2]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-1)[[3]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-2)[[4]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-3)[[5]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-4)

In 1960,[[6]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-5)[[7]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-6) [Martin Pope](http://en.wikipedia.org/wiki/Martin_Pope) and his group made the seminal discovery of ohmic, dark injecting electrode contacts to organic crystals,[[8]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-7) and described the necessary energetic requirements (work functions) for hole and electron injecting electrode contacts. Dark injecting hole and electron injecting electrode contacts are the basis of all current OLED devices, molecular and polymeric, as will be pointed out in the description of the requirements for the construction of successful OLEDs.

In 1963, Martin Pope and his group made the first observation of direct current (DC) electroluminescence, under vacuum, on a pure, single crystal of [anthracene](http://en.wikipedia.org/wiki/Anthracene), and also on anthracene crystal doped with tetracene.[[9]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-8) The injecting electrode was a small area silver electrode, at 400 V DC, and the proposed mechanism was field accelerated electron excitation of molecular fluorescence.

In 1965,[[10]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-9) Martin Pope and his group refined their experiment and showed that in the absence of an external electric field, the electroluminescence in anthracene single crystal was caused by the recombination of a thermalized electron and hole. This paper proved conclusively that the conducting level of anthracene is higher in energy than the exciton energy level.

Also in 1965,[[11]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-10) W. Helfrich and W.G. Schneider produced double injection recombination electroluminescence for the first time, in an anthracene single crystal using hole and electron injecting electrodes whose work functions satisfied the requirements specified by Pope's group. Electroluminescent materials can be insulators or doped insulators.[[12]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-11) The Helfrich and Schneider paper is the forerunner of all double injection induced OLED devices.

In 1965, researchers at [Dow Chemical](http://en.wikipedia.org/wiki/Dow_Chemical) developed high voltage (500–1500 V) AC-driven (100–3000 Hz), electrically insulated thin (1 millimeter) layers of a melted phosphor consisting of ground anthracene powder, tetracene, and graphite powder.[[13]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-12) Their proposed mechanism was electronic excitation at the contacts between the graphite particles and the anthracene molecules.

Conductivity of such materials limited light output until more conductive organic materials became available, especially the [polyacetylene](http://en.wikipedia.org/wiki/Polyacetylene), [polypyrrole](http://en.wikipedia.org/wiki/Polypyrrole), and [polyaniline](http://en.wikipedia.org/wiki/Polyaniline) "Blacks". In a 1963 series of papers, Weiss *et al.* first reported high conductivity in iodine-[doped](http://en.wikipedia.org/wiki/Doping_%28semiconductor%29) oxidized polypyrrole.[[14]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-13)[[15]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-14)[[16]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-15) They achieved a conductivity of 1 [S](http://en.wikipedia.org/wiki/Siemens_%28unit%29)/cm. Unfortunately, this discovery went unnoticed, as was a 1974 report[[17]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-16) of a melanin-based bistable switch with a high conductivity "ON" state. This material emitted a flash of light when it switched.

In 1977, [Hideki Shirakawa](http://en.wikipedia.org/wiki/Hideki_Shirakawa) *et al.* reported high conductivity in similarly oxidized and iodine-doped polyacetylene.[[18]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-17) [Alan J. Heeger](http://en.wikipedia.org/wiki/Alan_J._Heeger), [Alan MacDiarmid](http://en.wikipedia.org/wiki/Alan_MacDiarmid) & Hideki Shirakawa received the 2000 [Nobel Prize in Chemistry](http://en.wikipedia.org/wiki/Nobel_Prize_in_Chemistry) for "The discovery and development of conductive organic polymers". The Nobel citation made no reference to the earlier discoveries.[[19]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-18)[[20]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-19)

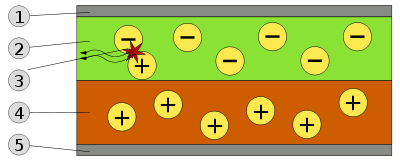
The first attempt to create a polymer LED was by Roger Partridge at the UK's [National Physical Laboratory](http://en.wikipedia.org/wiki/National_Physical_Laboratory_%28United_Kingdom%29). The project succeeded, being patented in 1975[[21]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-20) though publication was delayed until 1983.[[22]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-21)[[23]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-22)[[24]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-23)[[25]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-24)

The first diode device was invented at Eastman Kodak by Ching W. Tang and [Steven Van Slyke](http://en.wikipedia.org/wiki/Steven_Van_Slyke) in the 1980s.[[26]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-ApplPhy87-25) This diode, giving rise to the term "OLED" used a novel two-layer structure with separate hole transporting and electron transporting layers such that recombination and light emission occurred in the middle of the organic layer. This resulted in a reduction in operating voltage and improvements in efficiency, and started the current era of OLED research and device production. Later, this concept was adapted for use with polymers culminated in the Burroughes *et al.* 1990 paper reporting a very-high-efficiency green-light-emitting polymer.[[27]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-26)

## [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=2)] Working principle

A typical OLED is composed of an emissive layer, a conductive layer, a [substrate](http://en.wikipedia.org/wiki/Substrate_%28materials_science%29), and both [anode](http://en.wikipedia.org/wiki/Anode) and [cathode](http://en.wikipedia.org/wiki/Cathode) terminals. The layers are made of organic molecules that conduct electricity. The layers have conductivity levels ranging from insulators to conductors, so OLEDs are considered [organic semiconductors](http://en.wikipedia.org/wiki/Organic_semiconductor).

The first, most basic OLEDs consisted of a single organic layer, for example the first light-emitting polymer device synthesised by [Burroughs](http://en.wikipedia.org/wiki/Burroughs_Corporation) *et al.* involved a single layer of [poly(p-phenylene vinylene)](http://en.wikipedia.org/wiki/Poly%28p-phenylene_vinylene%29). Multilayer OLEDs can have more than two layers to improve device efficiency. As well as conductive properties, layers may be chosen to aid charge injection at electrodes by providing a more gradual electronic profile,[[28]](http://en.wikipedia.org/wiki/Organic_LED" \l "cite_note-27) or block a charge from reaching the opposite electrode and being wasted.[[29]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-28)

[](http://en.wikipedia.org/wiki/File:OLED_schematic.svg)

[http://1.1.1.3/bmi/bits.wikimedia.org/skins-1.5/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:OLED_schematic.svg)

Schematic of a 2-layer OLED: 1. Cathode (−), 2. Emissive Layer, 3. Emission of radiation, 4. Conductive Layer, 5. Anode (+)

A voltage is applied across the OLED such that the anode is positive with respect to the cathode. This causes a current of [electrons](http://en.wikipedia.org/wiki/Electron) to flow through the device from cathode to anode. Thus, the cathode gives electrons to the emissive layer and the anode withdraws electrons from the conductive layer; in other words, the anode gives [electron holes](http://en.wikipedia.org/wiki/Electron_hole) to the conductive layer.

Soon, the emissive layer becomes negatively charged, while the conductive layer becomes rich in positively charged holes. Electrostatic forces bring the electrons and the holes towards each other and they recombine. This happens closer to the emissive layer, because in organic semiconductors holes are more [mobile](http://en.wikipedia.org/wiki/Semiconductor_carrier_mobility) than electrons. The recombination causes a drop in the energy levels of electrons, accompanied by an emission of [radiation](http://en.wikipedia.org/wiki/Radiation) whose [frequency](http://en.wikipedia.org/wiki/Frequency) is in the [visible region](http://en.wikipedia.org/wiki/Visible_spectrum). That is why this layer is called emissive.

The device does not work when the anode is put at a negative potential with respect to the cathode. In this condition, holes move to the anode and electrons to the cathode, so they are moving away from each other and do not recombine.

[Indium tin oxide](http://en.wikipedia.org/wiki/Indium_tin_oxide) is commonly used as the anode material. It is transparent to visible light and has a high [work function](http://en.wikipedia.org/wiki/Work_function) which promotes injection of holes into the polymer layer. Metals such as [aluminium](http://en.wikipedia.org/wiki/Aluminium) and [calcium](http://en.wikipedia.org/wiki/Calcium) are often used for the cathode as they have low [work functions](http://en.wikipedia.org/wiki/Work_function) which promote injection of electrons into the polymer layer.[[30]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-29)

Just like [passive-matrix](http://en.wikipedia.org/wiki/Passive_matrix_addressing) LCD versus [active-matrix LCD](http://en.wikipedia.org/wiki/Active-matrix_LCD), OLEDs can be categorized into passive-matrix and active-matrix displays. Active-matrix OLEDs ([AMOLED](http://en.wikipedia.org/wiki/Active-Matrix_OLED)) require a [thin-film transistor](http://en.wikipedia.org/wiki/Thin-film_transistor) backplane to switch the individual pixel on or off, and can make higher resolution and larger size displays possible.

## [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=3)] Material technologies

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=4)] Small molecules

Efficient OLEDs using small molecules were first developed at [Eastman Kodak](http://en.wikipedia.org/wiki/Eastman_Kodak) by Dr. Ching W. Tang. The production of small-molecule displays often involves [vacuum deposition](http://en.wikipedia.org/wiki/Thin_film), which makes the production process more expensive than other processing techniques. Since this is typically carried out on glass substrates, these displays are also not flexible, though this limitation is not inherent to small-molecule organic materials. The term OLED traditionally refers to this type of device, though some are using the term SM-OLED.

Molecules commonly used in OLEDs include organo-metallic [chelates](http://en.wikipedia.org/wiki/Chelation) (for example [Alq3](http://en.wikipedia.org/wiki/Tris%288-hydroxyquinolinato%29aluminium), used in the first organic light-emitting device)[[26]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-ApplPhy87-25) and conjugated [dendrimers](http://en.wikipedia.org/wiki/Dendrimer).

Contrary to polymers, small molecules can be evaporated and therefore very complex multi-layer structures can be constructed. This high flexibility in layer design is the main reason for the high efficiencies of the SM-OLEDs.

Coherent emission from a laser dye-doped tandem SM-OLED device, excited in the pulsed regime, has been demonstrated.[[31]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-30) The emission is nearly diffraction limited with a spectral width similar to that of broadband dye lasers.[[32]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-31)

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=5)] Polymer light-emitting diodes

[](http://en.wikipedia.org/wiki/File:Light_Emitting_Polymer_display_partially_failed.jpg)

[http://1.1.1.3/bmi/bits.wikimedia.org/skins-1.5/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:Light_Emitting_Polymer_display_partially_failed.jpg)

LEP display showing partial failure

[](http://en.wikipedia.org/wiki/File:Oled_display_alterung.jpg)

[http://1.1.1.3/bmi/bits.wikimedia.org/skins-1.5/common/images/magnify-clip.png](http://en.wikipedia.org/wiki/File:Oled_display_alterung.jpg)

An old OLED display showing wear

Polymer light-emitting diodes (PLED), also light-emitting polymers (LEP), involve an [electroluminescent](http://en.wikipedia.org/wiki/Electroluminescence) [conductive polymer](http://en.wikipedia.org/wiki/Conductive_polymer), that emits [light](http://en.wikipedia.org/wiki/Light) when connected to an external voltage source. They are used as a [thin film](http://en.wikipedia.org/wiki/Thin_film) for [full-spectrum](http://en.wikipedia.org/wiki/Full-spectrum) colour displays and require a relatively small amount of power for the light produced. No vacuum is required, and the emissive materials can be applied on the [substrate](http://en.wikipedia.org/wiki/Substrate_%28printing%29) by a technique derived from commercial [inkjet](http://en.wikipedia.org/wiki/Inkjet_printer) printing.[[33]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-32)[[34]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-33) The substrate used can be flexible, such as [PET](http://en.wikipedia.org/wiki/Polyethylene_terephthalate).[[35]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-34) Thus flexible [PLED](http://en.wikipedia.org/wiki/PLED) displays, also called Flexible OLED (or FOLED), may be produced inexpensively.

Typical polymers used in PLED displays include derivatives of [poly(*p*-phenylene vinylene)](http://en.wikipedia.org/wiki/Poly%28p-phenylene_vinylene%29) and [polyfluorene](http://en.wikipedia.org/wiki/Polyfluorene). [Substitution](http://en.wikipedia.org/wiki/Substitution_reaction) of side chains onto the polymer backbone may determine the colour of emitted light[[36]](http://en.wikipedia.org/wiki/Organic_LED" \l "cite_note-35) or the stability and solubility of the polymer for performance and ease of processing.[[37]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-36)

Applications of OLEDs in solid state lighting require the achievement of high brightness with good CIE coordinates (for white emission). The use of macromolecular species like polyhedral oligomeric silsesquioxanes (POSS) in conjunction with the use of phosphorescent species such as Ir for printed OLEDs have exhibited brightnesses as high as 10,000 cd/m2.[[38]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-37)

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=6)] Phosphorescent materials

Phosphorescent OLED ([PHOLED](http://en.wikipedia.org/wiki/PHOLED)) uses the principle of electrophosphorescence to convert electrical energy in an OLED into light in a highly efficient manner.

## [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=7)] Patterning technologies

Patternable organic light-emitting device (POLED) uses a light or heat activated electroactive layer. A latent material ([PEDOT-TMA](http://en.wikipedia.org/wiki/PEDOT-TMA)) is included in this layer that, upon activation, becomes highly efficient as a hole injection layer. Using this process, light-emitting devices with arbitrary patterns can be prepared.[[39]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-38)

Colour patterning can be accomplished by means of laser, such as radiation-induced sublimation transfer ([RIST](http://en.wikipedia.org/w/index.php?title=RIST&action=edit&redlink=1)).[[40]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-39)

Organic vapour jet printing (OVJP) uses an inert carrier gas, such as [argon](http://en.wikipedia.org/wiki/Argon) or [nitrogen](http://en.wikipedia.org/wiki/Nitrogen), to transport evaporated organic molecules (as in Organic Vapor Phase Deposition). The gas is expelled through a micron 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.

Conventional OLED displays are formed by vapor thermal evaporation (VTE) and are patterned by shadow-mask. A mechanical mask has openings allowing the vapor to pass only on the desired location.

## [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=8)] Backplane technologies

For a high resolution display like a TV, a [TFT](http://en.wikipedia.org/wiki/Thin-film_transistor) backplane is necessary to drive the pixels correctly. Currently, [LTPS](http://en.wikipedia.org/wiki/LTPS)-[TFT](http://en.wikipedia.org/wiki/Thin-film_transistor) ([low temperature poly silicon](http://en.wikipedia.org/wiki/Crystalline_silicon)) is used for commercial AMOLED displays. LTPS-TFT has variation of the performance in a display, so various compensation circuits have been reported.[[41]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-r1-40) Due to the size limitation of the [excimer laser](http://en.wikipedia.org/wiki/Excimer_laser) used for [LTPS](http://en.wikipedia.org/wiki/LTPS), the AMOLED size was limited. To cope with the hurdle related to the panel size, amorphous-silicon/microcrystalline-silicon backplanes have been reported with large display prototype demonstrations.[[42]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-41)

## [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=9)] Structure

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=10)] Bottom or top emission

Bottom emission uses a transparent or semi-transparent bottom electrode to get the light through a transparent substrate. Top emission[[43]](http://en.wikipedia.org/wiki/Organic_LED" \l "cite_note-42)[[41]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-r1-40) uses a transparent or semi-transparent top electrode emitting light directly. Top-emitting OLEDs are better suited for active-matrix applications as they can be more easily integrated with a non-transparent transistor backplane.

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=11)] Transparent OLED

Transparent organic light-emitting device (TOLED) use transparent or semi-transparent contacts on both sides of the device to create displays that can be made to be both top and bottom emitting (transparent). TOLEDs can greatly improve contrast, making it much easier to view displays in bright sunlight[*[citation needed](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed" \o "Wikipedia:Citation needed)*]. This technology can be used in [Head-up displays](http://en.wikipedia.org/wiki/Head-up_display), smart windows or [augmented reality](http://en.wikipedia.org/wiki/Augmented_reality) applications.

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=12)] Stacked OLED

Stacked OLED (SOLED) uses 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, and greatly reducing pixel gap. Currently, other display technologies have the RGB (and RGBW) pixels mapped next to each other decreasing potential resolution.

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=13)] Inverted OLED

In contrast to a conventional OLED, in which the anode is placed on the substrate, an Inverted OLED (IOLED) uses a bottom cathode that can be connected to the drain end of an n-channel TFT especially for the low cost [amorphous silicon](http://en.wikipedia.org/wiki/Amorphous_silicon) TFT backplane useful in the manufacturing of AMOLED displays.[[44]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-43)

## [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=14)] Advantages

The different manufacturing process of OLEDs lends itself to several advantages over flat-panel displays made with LCD technology.

Although the method is not currently commercially viable for mass production, OLEDs can be printed onto any suitable [substrate](http://en.wikipedia.org/wiki/Substrate_%28printing%29) using an inkjet printer or even screen printing technologies,[[45]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-44) they could theoretically have a lower cost than LCDs or [plasma displays](http://en.wikipedia.org/wiki/Plasma_display). However, it is the fabrication of the substrate that is the most complex and expensive process in the production of a TFT LCD, so any savings offered by printing the pixels is easily cancelled out by OLED's requirement to use a more costly P-Si (or LTPS) substrate - a fact that is born out by the significantly higher initial price of AMOLED displays than their TFT LCD competitors. A mitigating factor to this price differential going into the future is the cost of retooling existing lines to produce AMOLED displays over LCDs to take advantage of the economies of scale afforded by mass production.

Use of flexible substrates could open the door to new applications such as [roll-up displays](http://en.wikipedia.org/wiki/Rollable_display) and displays embedded in fabrics or clothing.

OLEDs can enable a greater artificial contrast ratio (both dynamic range and static, measured in purely dark conditions) and viewing angle compared to LCDs because OLED pixels directly emit light. OLED pixel colours appear correct and unshifted, even as the viewing angle approaches 90 degrees from [normal](http://en.wikipedia.org/wiki/Surface_normal). LCDs filter the light emitted from a [backlight](http://en.wikipedia.org/wiki/Backlight), allowing a small fraction of light through so they cannot show true black, while an inactive OLED element produces no light and consumes no power.

OLEDs can also have a faster response time than standard LCD screens. Whereas LCD displays are capable of a 1ms response time or less[[46]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-45) offering a frame rate of 1,000 Hz or higher, an OLED can theoretically have less than 0.01 ms response time enabling 100,000 Hz [refresh rates](http://en.wikipedia.org/wiki/Refresh_rate).

## [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=15)] Disadvantages

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=16)] Lifespan

The biggest technical problem for OLEDs is the limited lifetime of the organic materials.[[47]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-46) In particular, blue OLEDs historically have had a lifetime of around 14,000 hours to half original brightness (five years at 8 hours a day) when used for flat-panel displays, which is lower than the typical lifetime of LCD, LED or [PDP](http://en.wikipedia.org/wiki/Plasma_display) technology—each currently rated for about 60,000 hours to half brightness, depending on manufacturer and model. However, some manufacturers displays aim to increase the lifespan of OLED displays, pushing their expected life past that of LCD displays by improving light outcoupling, thus achieving the same brightness at a lower drive current.[[48]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-47)[[49]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-48)

In 2007, experimental OLEDs were created which can sustain 400 cd/m2 of [luminance](http://en.wikipedia.org/wiki/Luminance) for over 198,000 hours for green OLEDs and 62,000 hours for blue OLEDs.[[50]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-49)

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=17)] Color balance issues

Additionally, as the OLED material used to produce blue light degrades significantly more rapidly than the materials that produce other colors, blue light output will decrease relative to the other colors of light. This differential color output change will change the color balance of the display and is much more noticeable than a decrease in overall luminance.[[51]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-50) This can be partially avoided by adjusting colour balance but this may require advanced control circuits and interaction with the user, which is unacceptable for some uses.

In order to delay the problem, manufacturers bias the colour balance towards blue so that the display initially has an artificially blue tint, leading to complaints of artificial-looking, over-saturated colors.

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=18)] Water damage

Water can damage the organic materials of the displays. Therefore, improved sealing processes are important for practical manufacturing. Water damage may especially limit the longevity of more flexible displays.[[52]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-51)

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=19)] Outdoor performance

As an emissive display technology, OLEDs rely completely upon converting electricity to light, unlike most LCDs which are to some extent reflective; [e-ink](http://en.wikipedia.org/wiki/E-ink) leads the way in efficiency with ~ 33% ambient light reflectivity, enabling the display to be used without any internal light source.

OLEDs typically produce only around 200 [nits](http://en.wikipedia.org/wiki/Nit_%28unit%29) of light leading to poor readability in bright ambient light, such as outdoors. Displays with some degree of reflectiveness increase their brightness as ambient light increases, so overcoming unwanted surface reflections without using any additional power.

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=20)] Power consumption

While an OLED will consume around 40% of the power of an LCD displaying an image which is primarily black, for the majority of images, it will consume 60–80% of the power of an LCD - however it can use over three times as much power to display an image with a white background[[53]](http://en.wikipedia.org/wiki/Organic_LED" \l "cite_note-52) such as a document or website. This can lead to disappointing real-world battery life in mobile devices.

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=21)] Screen burn-in

Unlike displays with a common light source, the brightness of each OLED pixel fades depending on the content displayed. Combined with the short lifetime the organic dyes, this leads to [screen burn-in](http://en.wikipedia.org/wiki/Screen_burn-in), worse than was common in the days of [CRT](http://en.wikipedia.org/wiki/CRT)-based displays.[[54]](http://en.wikipedia.org/wiki/Organic_LED" \l "cite_note-53)

## [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=22)] Technology demos

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=23)] Samsung applications

In January 2005, Samsung announced the world's largest OLED TV at the time, at 21 inches (53 cm).[[55]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-54) This OLED featured the highest resolution at 2.3 million pixels ([WUXGA](http://en.wikipedia.org/wiki/WUXGA): widescreen ultra-extended graphics array) at the time. In addition, the company adopted AM-based technology for its low power consumption and high-resolution qualities.

In January 2008, Samsung showcased the world's largest and thinnest OLED TV at the time, at 31-inches and 4.3 mm.[[56]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-55)

In May 2008, Samsung unveiled an ultra-thin 12.1 inch laptop OLED display concept, with a 1,280×768 resolution with infinite contrast ratio.[[57]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-56) According to Woo Jong Lee, Vice President of the Mobile Display Marketing Team at Samsung SDI, the company expects OLED displays to be used in notebook PCs as soon as 2010.[[58]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-57)

In October 2008, Samsung showcased the world's thinnest OLED display, also the first to be 'flappable' and bendable.[[59]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-flapping-58) It measures just 0.05 mm (thinner than paper), yet a Samsung staff member said that it is "technically possible to make the panel thinner".[[59]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-flapping-58) To achieve this thickness, Samsung etched an OLED panel that uses a normal glass substrate. The drive circuit was formed by low-temperature polysilicon TFTs. Also, low-molecular organic EL materials were employed. The pixel count of the display is 480 × 272. The contrast ratio is 100,000:1, and the luminance is 200 cd/m². The colour reproduction range is 100% of the NTSC standard.

In October 2008, Samsung unveiled the world's largest OLED Television at 40-inch with a [Full HD](http://en.wikipedia.org/wiki/Full_HD) resolution of 1920×1080 pixel.[[60]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-59) In the FPD International, Samsung stated that its 40-inch OLED Panel is the largest size currently possible. The panel has a contrast ratio of 1,000,000:1, a colour gamut of 107% NTSC, and a luminance of 200 cd/m² (peak luminance of 600 cd/m²).

At the [Consumer Electronics Show (CES)](http://en.wikipedia.org/wiki/Consumer_Electronics_Show) in January 2010, Samsung demonstrated a laptop computer with a large, transparent OLED display[[61]](http://en.wikipedia.org/wiki/Organic_LED" \l "cite_note-laptoptransparent-60) and an animated OLED display in a photo ID card.[[62]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-photoid-61)

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=24)] Sony applications

In 2004, [Sony](http://en.wikipedia.org/wiki/Sony) released the [Sony CLIÉ PEG-VZ90](http://en.wikipedia.org/wiki/Sony_CLI%C3%89_PEG-VZ90), the first commercial device to feature an OLED screen.

In 2006, Sony introduced the MZ-RH1 Portable Minidisc Recorder, which has an OLED screen.[[63]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-62)

At the [Las Vegas](http://en.wikipedia.org/wiki/Las_Vegas_metropolitan_area) [CES 2007](http://en.wikipedia.org/wiki/Consumer_Electronics_Show), Sony showcased 11-inch (28 cm, resolution 960×540) and 27-inch (68.5 cm, full HD resolution at 1920×1080) OLED TV models.[[64]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-63) Both claimed 1,000,000:1 [contrast ratios](http://en.wikipedia.org/wiki/Contrast_ratio) and total thicknesses (including bezels) of 5 mm. In April 2007, Sony announced it would manufacture 1000 11-inch OLED TVs per month for market testing purposes.[[65]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-64) On October 1, 2007, Sony announced that the 11-inch model, now called the [XEL-1](http://en.wikipedia.org/wiki/Sony_XEL-1), would be released commercially;[[1]](http://en.wikipedia.org/wiki/Organic_LED" \l "cite_note-xel1-0) the XEL-1 was first released in Japan in December 2007.[[66]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-65)

In May 2007, Sony publicly unveiled a video of a 2.5-inch flexible OLED screen which is only 0.3 millimeters thick.[[67]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-66)

At the [CES 2008](http://en.wikipedia.org/wiki/Consumer_Electronics_Show), [Sony](http://en.wikipedia.org/wiki/Sony) showcased the [Walkman](http://en.wikipedia.org/wiki/Walkman) X series with 3” OLED touchscreen.[[68]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-67)

In April 2008, at "Display 2008", Sony showed a 0.2 mm (0.0079 inch) thick 3.5 inch display with a resolution of 320×200 pixels and a 0.3 mm thick 11 inch display with 960×540 pixels resolution (one-tenth the thickness of the XEL-1).[[69]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-68)[[70]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-69)

In July 2008, a Japanese government body said it would fund a joint project of leading firms, which is to develop a key technology to produce large, energy-saving organic displays. The project involves one laboratory and 10 companies including Sony Corp. [NEDO](http://en.wikipedia.org/wiki/New_Energy_and_Industrial_Technology_Development_Organization) said the project was aimed at developing a core technology to mass-produce 40 inch or larger OLED displays in the late 2010s.[[71]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-70)

In October 2008, Sony has published results of research it carried out with the [Max Planck Institute](http://en.wikipedia.org/wiki/Max_Planck_Institute) over the possibility of mass-market bending displays, which could replace rigid LCDs and plasma screens. Eventually, bendable, transparent OLED screens could be stacked to produce 3D images with much greater contrast ratios and [viewing angles](http://en.wikipedia.org/wiki/Viewing_angle) than existing products.[[72]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-71)

In April 2009, Sony demonstrated a 21" prototype at the Display Japan conference in Tokyo.[[73]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-72) This was followed up by a 24.5" 3D OLED demonstration from Sony, during CES 2010.[[74]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-engadget1-73)

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=25)] Other companies

The [Optimus Maximus keyboard](http://en.wikipedia.org/wiki/Optimus_Maximus_keyboard) developed by the [Art. Lebedev Studio](http://en.wikipedia.org/wiki/Art._Lebedev_Studio) and released early 2008 uses 113 48×48-pixel OLEDs (10.1×10.1 mm) for its keys.

OLEDs can be used in High-Resolution Holography ([Volumetric display](http://en.wikipedia.org/wiki/Volumetric_display)). Professor Orbit showed on May 12, 2007, EXPO Lisbon the potential application of these materials to reproduce three-dimensional video.[*[citation needed](http://en.wikipedia.org/wiki/Wikipedia:Citation_needed" \o "Wikipedia:Citation needed)*]

OLEDs could also be used as solid-state light sources. OLED efficiency and lifetime already exceed those of [incandescent light bulbs](http://en.wikipedia.org/wiki/Incandescent_light_bulb), and OLEDs are investigated worldwide as a source of general illumination; an example is the EU OLLA project.[[75]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-olla-74). On May 2009, [Philips](http://en.wikipedia.org/wiki/Philips) was the first company to comercialize on his website large area pixels OLEDs (60 cm2) for ambient lighting (Lumiblade OLED Pixels [[76]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-75) whose shape, size and color can be selected by customers).

On March 11, 2008 [GE Global Research](http://en.wikipedia.org/wiki/GE_Global_Research) demonstrated the first successful [roll-to-roll](http://en.wikipedia.org/wiki/Roll-to-roll_processing) manufactured OLED, marking a major milestone towards cost effective production of commercial OLED technology. The four year, $13 million research project was carried out by [GE Global Research](http://en.wikipedia.org/wiki/GE_Global_Research), Energy Conversion Devices, Inc and the [National Institute of Standards and Technology](http://en.wikipedia.org/wiki/National_Institute_of_Standards_and_Technology).[[77]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-businesswire-76)[[78]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-ge-77)

[Chi Mei Corporation](http://en.wikipedia.org/wiki/Chi_Mei_Corporation) of [Taiwan](http://en.wikipedia.org/wiki/Taiwan), demonstrated a 25" Low-Temperature [Polycrystalline silicon](http://en.wikipedia.org/wiki/Polycrystalline_silicon) Active Matrix OLED at the Society of Information Displays ([SID](http://www.sid.org)) conference in Los Angeles, CA, USA on May 20–22, 2008.

On June 5, 2009 [DuPont](http://en.wikipedia.org/wiki/DuPont) demonstrated a new material that can be printed, so called solution deposition. The breakthrough is the ability to produce economically scalable and durable OLED displays at the 2009 International Symposium, May 31-June 5, 2009, Henry B. Gonzalez Convention Center, San Antonio, TX, USA

The use of OLEDs is also being investigated for the treatment of cancer by [photodynamic therapy](http://en.wikipedia.org/wiki/Photodynamic_therapy).[[79]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-TV_cancer_treatment-78)

On 30 Aug 2009, South Korea's [LG](http://en.wikipedia.org/wiki/LG) Electronics said it would launch a 15-inch television set using AM-OLED displays for sale in November.[[80]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-79)[[81]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-80)

According to [Isuppli](http://en.wikipedia.org/wiki/Isuppli) Corp,[[82]](http://en.wikipedia.org/wiki/Organic_LED" \l "cite_note-81) upward momentum of OLED Shipments for primary cell phone displays is their expectation in coming years. They claimed that global shipments of OLED main cell phone displays would rise to 178 million units in 2015, up from 22.2 million in 2009. In other words, the shipments will rise eightfold by 2015. Therefore, it’s evident that the manufacture of OLED display and OLED equipment by [Samsung](http://en.wikipedia.org/wiki/Samsung), [DuPont](http://en.wikipedia.org/wiki/DuPont), [Anwell](http://en.wikipedia.org/wiki/Anwell_Technologies_Limited), [Chi Mei Corporation](http://en.wikipedia.org/wiki/Chi_Mei_Corporation), etc has expanded dramatically in recent years.

## [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=26)] Commercial uses

OLED technology is used in commercial applications such as small screens for mobile phones and portable [digital audio players](http://en.wikipedia.org/wiki/Digital_audio_player) (MP3 players), car radios, [digital cameras](http://en.wikipedia.org/wiki/Digital_camera), and high-resolution microdisplays for [head-mounted displays](http://en.wikipedia.org/wiki/Head-mounted_display). Such portable applications favor the high light output of OLEDs for readability in sunlight, and their low power drain. Portable displays are also used intermittently, so the lower lifespan of OLEDs is less important here. Prototypes have been made of flexible and rollable displays which use OLEDs' unique characteristics. OLEDs have been used in most [Motorola](http://en.wikipedia.org/wiki/Motorola) and [Samsung](http://en.wikipedia.org/wiki/Samsung) colour cell phones, as well as some [LG](http://en.wikipedia.org/wiki/LG) and [Sony Ericsson](http://en.wikipedia.org/wiki/Sony_Ericsson) phones, notably the Z610i, and some models of the [Walkman](http://en.wikipedia.org/wiki/Walkman).[[83]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-cellphone-82) It is also found in the Creative Zen V/V Plus series of MP3 players and [iriver](http://en.wikipedia.org/wiki/Iriver) U10/[clix](http://en.wikipedia.org/wiki/Iriver_clix" \o ). [Nokia](http://en.wikipedia.org/wiki/Nokia) has also introduced recently some OLED products, including the 7900 Prism,the Nokia 8800 Arte, and the [Nokia N85](http://en.wikipedia.org/wiki/Nokia_N85) and the [Nokia N86 8MP](http://en.wikipedia.org/wiki/Nokia_N86_8MP), both of which feature an AMOLED display.

**Timeline**

October 1, 2007. [Sony](http://en.wikipedia.org/wiki/Sony) become the first company to announce an OLED television for commercial sale. The [XEL-1](http://en.wikipedia.org/wiki/Sony_XEL-1) 11" OLED Digital Television sells for $2,499.99 in the United States and Canada.

December 2007 - July 2008. OLED applications include signs and lighting.[[84]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-83)[[85]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-84)

January 2009. Handheld computer manufacturer [OQO](http://en.wikipedia.org/wiki/OQO) introduce the smallest [Windows Vista](http://en.wikipedia.org/wiki/Windows_Vista) computer with an OLED display.[[86]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-85)

March 2009. [Samsung](http://en.wikipedia.org/wiki/Samsung) Electronics launch a 2.8" [AMOLED](http://en.wikipedia.org/wiki/AMOLED) capacitive touchscreen phone called the S8300 UltraTOUCH.

April 2009. Samsung bring the first phone using an AMOLED display to the United States, the [Impression](http://en.wikipedia.org/wiki/Samsung_impression) on [AT&T](http://en.wikipedia.org/wiki/AT%26T). The Impression has a 3.2" [WQVGA](http://en.wikipedia.org/wiki/Wide_QVGA) AMOLED.

May 2009. [Philips](http://en.wikipedia.org/wiki/Philips) Lighting commercialize the first OLED lights, opening a webshop where OLED lighting samples under the brand name 'Lumiblade' can be ordered online.[[87]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-86)

May 2009. Samsung Electronics launch a 3.7" nHD AMOLED capacitive touchscreen phone called the i8910 Omnia HD.

June 2009. Samsung Electronics launch a 3.1" WVGA AMOLED resistive touchscreen phone called the S8000 Jet.

July 2009. Samsung Electronics launch a 3.7" WVGA AMOLED 3G full-touchscreen phone called the Omnia II i8000 with Samsung's own touchwiz ui version 2.0.

August 2009. [Sprint Nextel](http://en.wikipedia.org/wiki/Sprint_Nextel) sell phones from Samsung Electronics featuring advanced AMOLED display technology. Company executives claim its technology provides longer battery life and enhanced video and photo images. [[88]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-87)

September 2009. [Microsoft](http://en.wikipedia.org/wiki/Microsoft) launch a 3.3" [Sixteenth HD1080](http://en.wikipedia.org/wiki/Sixteenth_HD1080) [OLED](http://en.wikipedia.org/wiki/OLED) capacitive multi-touch portable media player called the [Zune HD](http://en.wikipedia.org/wiki/Zune_HD).

January 5, 2010. [Google](http://en.wikipedia.org/wiki/Google) launch a 3.7" [AMOLED](http://en.wikipedia.org/wiki/AMOLED) smartphone called the [Nexus One](http://en.wikipedia.org/wiki/Nexus_One)

January 2010. Samsung Electronics launch a 14" prototype notebook featuring up to 40% transparency when turned off.

January 2010. Sony display a 24.5" prototype OLED 3D television during the Consumer Electronics Show.[[74]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-engadget1-73)

## [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=27)] Patents

Use of OLEDs may be subject to [patents](http://en.wikipedia.org/wiki/Patent) held by [Eastman Kodak](http://en.wikipedia.org/wiki/Eastman_Kodak), [DuPont](http://en.wikipedia.org/wiki/DuPont), [General Electric](http://en.wikipedia.org/wiki/General_Electric), [Royal Philips Electronics](http://en.wikipedia.org/wiki/Philips), numerous universities and others.[[89]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-88)[[90]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-89)

## [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=28)] Manufacturers

Current manufacturers of OLED panels include [Anwell Technologies Limited](http://en.wikipedia.org/wiki/Anwell_Technologies_Limited),[[91]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-90) [Chi Mei Corporation](http://en.wikipedia.org/wiki/Chi_Mei_Corporation),[[92]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-91) [DuPont](http://en.wikipedia.org/wiki/DuPont),[[93]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-92) [GE Global Research](http://en.wikipedia.org/wiki/GE_Global_Research),[[94]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-93) [LG](http://en.wikipedia.org/wiki/LG),[[95]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-94) [Samsung](http://en.wikipedia.org/wiki/Samsung),[[96]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-95) and [Sony](http://en.wikipedia.org/wiki/Sony).[[97]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-96)

### [[edit](http://en.wikipedia.org/w/index.php?title=Organic_LED&action=edit&section=29)] Samsung SDI

[Samsung](http://en.wikipedia.org/wiki/Samsung) SDI, a subsidiary of [Samsung Group](http://en.wikipedia.org/wiki/Samsung_Group), [South Korea](http://en.wikipedia.org/wiki/South_Korea)'s largest [conglomerate](http://en.wikipedia.org/wiki/Conglomerate_%28company%29), is the world's largest OLED manufacturer, producing nearly 50% of the OLED displays made in the world.[[98]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-97) In October 2008, it unveiled the world's largest OLED TV at 40-inch with a [Full HD](http://en.wikipedia.org/wiki/Full_HD) resolution of 1920x1080 pixel. It was the first company in the industry to develop and manufacture [AMOLED](http://en.wikipedia.org/wiki/AMOLED) displays[[99]](http://en.wikipedia.org/wiki/Organic_LED" \l "cite_note-findarticles.com-98) and has the world's largest market share in both Passive Matrix OLEDs (PMOLED) and Active Matrix OLEDs (AMOLED).[[100]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-99) The company is leading the world OLED industry, generating $100.2 million out of the total $475 million revenues in the global OLED market in 2006.[[99]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-findarticles.com-98)

Currently, it holds more than 600 American patents and more than 2800 international patents, making it the largest owner of AMOLED technology patents.[[99]](http://en.wikipedia.org/wiki/Organic_LED#cite_note-findarticles.com-98)

As of April 2009, Samsung has released one phone using the AMOLED display in the United States, the Impression for AT&T.