German Flat Panel Display Forum

German Technology: Flat Panel Displays

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Dear Reader,

Rolf R. Kuhnke
Managing Partner,
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Flat panel displays made in Germany? "Hardly possible", is what the layman would think. "Just doesn't work", is the opinion of some who have already gone into the matter. To have a vision is hard work and, in the end, one has to convince others with facts to succeed.

In the capital goods industry, we share visions. As the largest European trade association, our commitment is to establish conditions for promoting entrepreneurship and letting markets develop. Entrepreneurs have visions and a feeling for markets.

We welcome the German Flat Panel Display Forum (DFF) as a new VDMA working group in which 56 companies are currently working together in a strongly growing area. These undertakings master all steps along the process chain for producing flat panel displays and they know future market requirements.

It is not a question of placing on the market me-too products against established competition from Japan, Korea and Taiwan. They have know-how and cost-saving potentials available that make it impossible for us to compete with them with an eye to traditional technologies and products. But the world is moving – faster and faster it seems – and markets change.

The companie having invested € 50 billion in UMTS licenses will want to offer mobile phone users the functionalities of this new technology. Something which the displays in the mobile phones and organisers available today cannot offer. Display size, contrast and color are insufficient.

To date, a mere 12 automobile manufacturers have remained on the market and not before long, maybe 5 will survive. Consumers will increasingly choose their products according to their presentation. In addition to the externals, the interior plays the most important role here. Freely programmable instruments, perhaps even in free form spaces will be just as important a factor as various monitors for internet access, DVD players and security features.

Monitors currently used for navigation purposes are only a very first step in the development. Displays are required which, in an extreme case, allow the driver of a convertible to read all the data easily even on a bright sunny day.

In the future, bank cards will have to provide their users with information, for example on account balances. But only to the account holder, that is. Within the size restrictions imposed by the card, we need to accommodate energy supply, the integrated display and the security functions. Unthinkable today – but who knows, tomorrow may tell us better.

The market calls for these applications and many others, especially in Germany and Europe. Germany has made great contributions in this respect, and it will certainly not reduce its efforts. To keep abreast of the developments, it is necessary to round off the process chain and start to produce special displays, i. e. end products, locally. This is the objective of the members of the German Flat Panel Display Forum.

In the VDMA there is a tradition of members with strong expertise in production technology. In the Factory Automation Forum I coordinate, we are dedicated to creating the factory of the future: The Next Economy will be an intelligent and meaningful convergence of the Old and the New Economy. Intelligence moves into the machines which need to be internet-compatible and networked. With our knowledge and our tools we are certainly in a position to start production of flat panel displays in Germany on a globally competitive scale.

This is why VDMA and DFF fit together so well. Let's make visions work.

Yours faithfully,

Editorial

Prof. Dr.
Wolfgang Ehrfeld
DFF Chairman

Flat panel displays are about to assume a permanent role in our daily lives. At first only used as simple, alphanumeric devices for wrist watches or calculators, they are nowadays utilized in a broad variety of modern products. Especially in devices for mobile communication they have unique advantages: Lightweight and compact construction as well as low energy consumption are basic prerequisites for the use of displays in portable devices.

Flat panel displays have evolved to a key component of technical systems. Without this convenient interface between man and the digital world, today's intense information flow would be unnavigable. Laptops, notebooks or cellular phones would have been unrealizable without them!

But this is only the dawn of a brighter future: Imagine electronic books, intelligent credit cards showing the current balance of your account, the all-in-one dashboard instrument in the car, high-power PCs of the size of a wristwatch or movie-screen wallpaper – flat panel displays will make these visions become reality. Therefore, it is not surprising that the flat panel display market is one of the most promising and fastest growing ones. In 2000, the annual turnover worldwide has already reached US$ 20 bn. and researchers predict growth rates exceeding 20 % p. a. for the next five years.

The flat panel display industry is dominated by companies located in the Far East. In addition to Japan, which still holds a market share of about 60 %, many other East Asian countries have developed broad production capability. Firms in South Korea are leading the race among these countries, Taiwanese companies are catching up fast. On the other hand, Europe and the U. S. contribute only 3 % to the world production of flat panel displays, despite the fact that they have the biggest markets for end products employing flat panel displays.

However, many basic developments and inventions in flat panel display technology have been carried out in Europe, especially in Germany, in established as well as in emerging fields. Important suppliers of basic materials and equipment, machinery, automation tools and plant manufacturers for flat panel display production are located here. Moreover, leading know-how in research and development has been built up in Germany. We are proud to introduce you to their remarkable capabilities with the present compilation "German Technology: Flat Panel Displays".

There are lots of possibilities for companies and researchers to get involved with flat panel displays – from the industrial user to the manufacturer himself. With the German Flat Panel Display Forum (DFF) we have created a leading voice for this broad, growing industrial sector in Germany. Apart from that, we believe that a strong extension of the German flat panel display production is feasible and necessary. Find out more about DFF's goals and tasks in the following pages!

We have added an introduction to flat panel display technologies and schematically describe a production process to give you an idea in which part of the supply chain or production stage an advertiser has his core competencies.

Use "German Technology: Flat Panel Displays" as your proficient navigator through Germany's flat panel display branch. Meet the German players in this promising field of the economy. We want to help you to find the right partner for your business needs.

Herzlich Willkommen!

The German Flat Panel Display Forum (DFF)

Founded in February 2000 as a cooperation between the German Engineering Federation (VDMA) and the Institute of Microtechnology Mainz (IMM), the "**D**eutsches **F**lachdisplay-**F**orum (DFF)" launched an effective communication platform promoting information exchange between European companies and the international display community and has meanwhile grown into the official lobby for the flat panel display branch in Germany. This includes the supply industry, manufacturers, display end users as well as research institutes.

Currently 57 international members have joined DFF, 47 of them being companies involved in display production, material and equipment manufacturing, plant manufacturing, handling, system integration, user industry and research and development. As part of the VDMA, DFF has a well-established background to make the interests of the branch heard – in public as well as on the political scene. DFF is financed solely by membership fees. DFF's goal is the creation of stimulating conditions to build up competitive production capacities of flat panel displays in Germany.

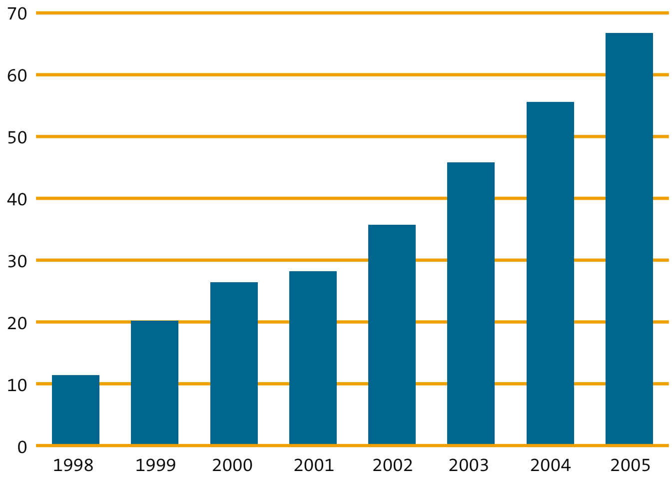


Fig. 1: Enormous economic opportunities: the flat panel display world market will grow in excess of 20 % per year. (Source: Display Search, 2000)

Why would somebody want to invest in display production in Germany? Even though flat panel displays represent a key technology of today's information society and their production is one of the fastest growing branches of economy worldwide (Fig. 1), Europe only plays a minor role in manufacturing.

Germany – big opportunities in the heartland of Europe

Europe with its high-tech industry is one of the largest markets for information displays worldwide – and Germany is located in Europe's heartland: Think of the automotive, engineering, and electronics industries, the "supporting pillars" of the German economy. They have an enormous demand for innovative flat panel displays. Therefore, future growth rates are predicted to even exceed those of the other regions of the world.

The roots of DFF

In December 1998 Prof. Dr. Wolfgang Ehrfeld in his function as then managing director of the Institute of Microtechnology Mainz (IMM), started an initiative gathering 24 suppliers, end-product manufacturers, potential producers, associations and institutes of the German display community. This initiative elaborated a strategy for the set-up of globally competitive flat panel display production capacities in Germany, which attracted great attention in industry and politics. This activity became the seed of the "**D**eutsches **F**lachdisplay-**F**orum (DFF)" which was founded in February 2000 as a cooperation of the German Engineering Federation (VDMA) and IMM.

The Institute of Microtechnology Mainz (IMM) is a leading institute in the field of applied R&D of Microsystems Technology. IMM develops innovative products and techniques in close collaboration with other research institutions as well as with industry worldwide.

The German Engineering Federation (VDMA) is the largest European trade association with 3000 predominantly medium-sized enterprises, representing 38 branches. Its Productronics Association provides sector-specific expertise to more than 100 member companies, many of them being market partners to the flat panel display producers. VDMA is an active player within the mechanical engineering committees of the European Union, the Association's counterparts on the European level.

Many basic inventions in flat panel display technology have been made in Europe. The first display with twisted nematic liquid crystals (TN-LCD) was developed in Switzerland. Further decisive achievements of European research groups are the synthesis of cyanobiphenyls, which make up a whole class of liquid crystals, the development of the amorphous silicon thin film transistor technology (α-Si TFT), the development of the super twisted nematic LCD (STN-LCD), just to name a few. Leading R & D know-how in flat panel display technology has a long tradition in Europe.

Furthermore, many leading material suppliers as well as producers of processing and automation equipment are based in Germany. The very high degree of automation in modern flat panel display production make wages play a minor role in the overall costs: Highly skilled engineers and well-educated, trained personnel are vital to run production effectively and dependably. Staff and machinery you can rely on make Germany a very attractive location for this innovative, technology-oriented industry.

Display manufacturing requires huge investments and imposes risks – especially when new technologies are involved. However, since flat panel displays represent a key technology to leading industry branches in Germany and Europe, Germany's federal and state governments as well as the European Commission are ready to add funding to an investment in flat panel display production as a way to promote structural development in this sector. With this background, the funding programs are not restricted to Germany or member states of the European Union.

A close cooperation between manufacturers of high quality displays and end-product producers will lead to mutual advantages: Simplified logistics, with the excellent infrastructure in Europe, and the possibility of joint developments will result in lower costs and faster access to the domestic market. The strong position of the German automotive, engineering, and telecommunication industries provides a powerful access to the world market. A production line operated by an international consortium offers the opportunity to unite the strengths of Orient and Occident – of Asian and European companies.

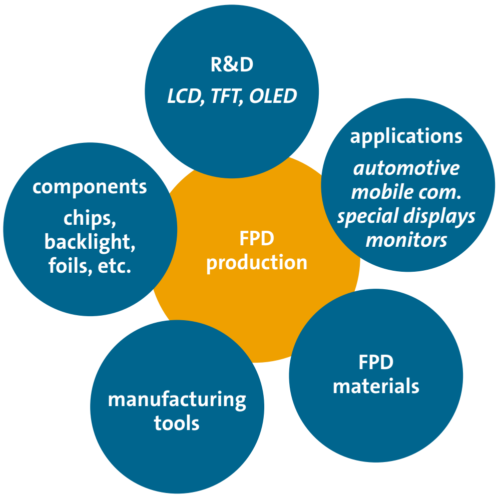


Fig. 2: The situation in Germany. Flat panel display production would link all players in the field. (Illustration courtesy of IMM)

Germany offers unique opportunities for an investment into flat panel display production. Take them!

DFF – what we can do for you and what we aim for

Since DFF is not the production consortium – how can it support an establishment of competitive flat panel display production facilities in Germany?

DFF has worked to establish international cooperations right from the beginning. It is clearly seen that national activities can only be successful if international strategies are pursued.

Therefore DFF has launched a communication platform promoting information exchange between European companies and the international display community, between researchers, producers and users. Starting from Germany, the network will be further extended and collaborate with other display activities in Europe. In particular, contacts with international display associations like SID, USDC or EDIRAK and other display networks like FLATNET have already been established.

These are the services we offer our members:

- DFF provides its members with up-to-date information about leading-edge technologies and market developments.
- DFF links supply industries, flat panel display producers, end-product manufacturers and research centers in order to speak with "one voice" to public and politics (Fig. 2).

- Long-term strategies, essential to penetrate the exploding billion-dollar market, are developed in expert teams.
- Cooperations with supply industries, flat panel display producers, end-product manufacturers and research centers in Europe, the US and the Far East are fostered by DFF.

DFF members are encouraged to participate in the DFF working groups “Technology, Plant Manufacturing, Metrology (TAM)” and “Strategy, Market, Products (SMP)”. In TAM, a comprehensive overview of technological and production capabilities of the German/European industry has been compiled. Furthermore, the possibilities of strategic company partnerships, domestic and international, are being identified. SMP members are currently developing a roadmap entitled “Flat Panel Displays for Germany/Europe” in terms of products and worldwide trends in market and technology focusing on domestic developments and needs.

Domestic production should target the local markets. Therefore, an entrance into today’s mass markets – notebooks, computers, television – will only be pursued on a long-term basis. Two technologies are currently considered to be especially attractive to serve the domestic market:

- The OLED-technology has a high potential to boost the market of portable applications due to its superior optical properties.
- TFT-LCD provides a mature technology to address existing markets with innovative products.

It is a niche compared to the overall flat panel display market we address – but a very promising one in which the big European export industries are present. This forces the developments to be strictly oriented by market and cost aspects. Market pull instead of technology push – DFF ensures this by involving all players, equipment manufacturers, materials suppliers, device manufacturers, research institutes, and end-product manufacturers in setting up the strategies.

Flat Panel Display Technologies

Revising the range of products where flat panel displays are employed, it comes at no surprise that there are a number of technologies to realize them. We want to give you an overview to flat panel display technologies and their specific advantages in this chapter.

One can roughly divide into emissive displays, which act as a light source themselves, and non-emissive displays which need an external light source to function. Figure 3 shows currently existing flat panel display technologies using this classification. The particular technologies and abbreviations are explained below.

Liquid Crystal Displays (LCD)

The functionality of Liquid Crystal Displays (LCDs) is based on the controllable rotation of the polarization plane of incident light using a thin liquid crystal layer. LCDs are non-emissive – the liquid crystals work like “light valves”. Light sources are either backlights like Cold Cathode Fluorescent Lamps (transmissive mode) or incident light reflected by a mirror foil behind the display (reflective mode).

Liquid crystals were discovered already in 1888, but it took about 80 years before the materials and electronics were advanced enough to practically use them. In 1971 the twisted nematic (Schadt-Helfrich) effect was invented. Implemented into early displays, this very quickly changed the watch and calculator industries. Even though there are thousands of types of liquid crystal molecules, they fundamentally all fit into three broad categories: nematic (“thread-like”), cholesteric (“cholesterol-like”, a gradually twisting nematic), and smectic (“soap-like”).

The twisted nematic liquid crystals operate by causing a rotation of polarization in the light by about 90 degrees when the cell is activated (Fig. 4). When the cell is inactive, the light passes through without modification. The use of polarizing films on either side of the display allows the unbiased state to be set to either black or white according to their orientation (90 degrees relative polarization gives a black off-state behavior).

Early displays mostly used the TN mode, but as the displays kept growing, the industry found ways to improve the contrast ratio by using a so-called super-twisted nematic mode (STN). In this mode the LC molecule twists light 270 degrees. The response characteristic of the material is steeper resulting in a better black and white appearance (versus TN materials which exhibit more of a gray-scale behavior due to their flat response characteristic) of the display. However, additional effort had to be taken to reduce color effects of the STN-LCD due to birefringence.

Different developments in LCD technology (cf. e. g. MLA, DSTN, FSTN, CSTN) improved the display performance significantly and even made the other two LC phases, smectic and cholesteric LCs, usable for display application. Common disadvantages of LCDs like narrow viewing angles, temperature and shock sensitivity are steadily being reduced.

The LCD technology is an established, mature technology for a broad application range. Almost 90 % of the flat panel display market today is covered by LCDs.

Passive Matrix driving scheme

Early displays which had only a few elements were built with segments or pixels connected

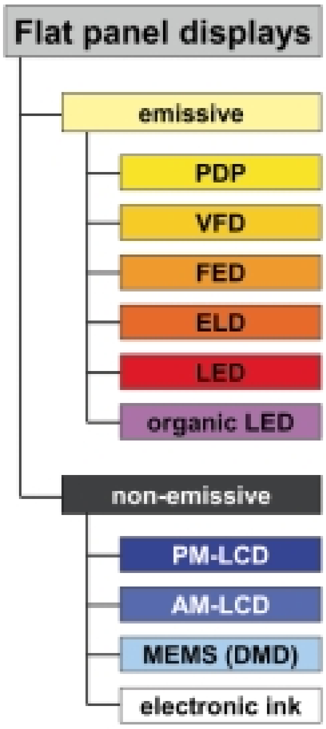


Fig. 3: Spectrum of flat panel display technologies.

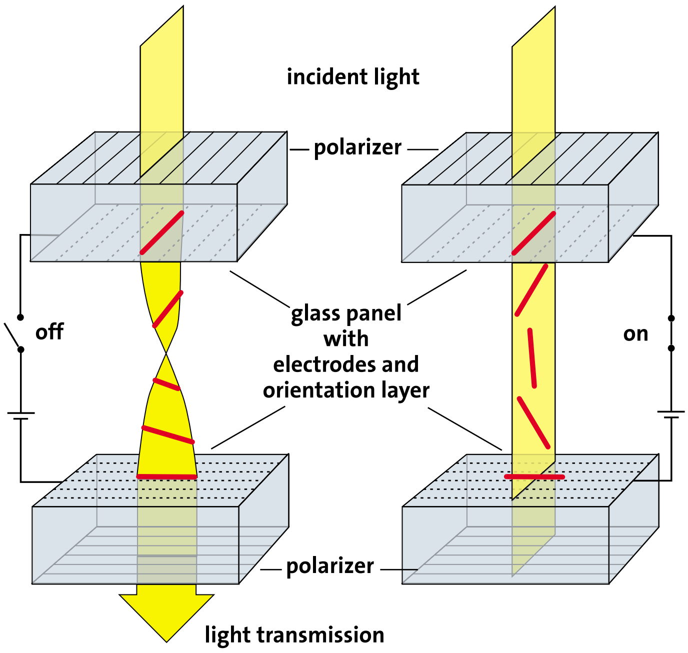


Fig. 4: LCD “light valve” technology (example shows TN cell). Dimensions not to scale. (Illustration courtesy of IMM)

Fig. 5: Ruggedized LCD module. (Picture courtesy of Siemens I-SFT)

together electrically in a multiplexed manner (Pixels are the crossing points of "data columns" and "scan rows" in dot matrix displays). This allowed for a reduction in the number of driver chips and connecting wires, while giving reasonable performance for small displays. A big advantage of these passive matrix (PM) displays is their low-cost producibility which facilitates a broad range of applications. Most segment 8, alphanumeric and small graphic displays are using this multiplexing scheme. However, with increasing number of row lines to be multiplexed, the contrast of the displays decreases because the driving voltage is present less time at a single pixel. Without a storage element the driving voltage drops very fast.

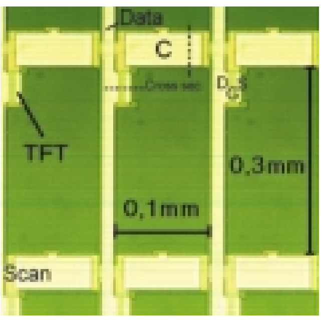


Fig. 6: Top view on three pixels of an AM display. The thin film transistors (TFT) are used to drive each pixel separately. (Picture courtesy of University of Stuttgart, LfB)

Active Matrix driving scheme

With the larger number of lines multiplexed together, the liquid crystal material is not driven often enough, and starts to relax back into its natural state. Furthermore, passive driven displays have a rather long response time (>100 ms), resulting in a "smearing effect" when images change quickly. The solution to this is to change from passive to active matrix driving – one that addresses each pixel separately. The commonly used method today employs a thin film transistor (TFT) for each pixel. Silicon transistors directly integrated into each pixel (Fig. 6) amplify the driving signals, whereas the voltage is stabilized by capacitors between the drive pulses. The AM driving scheme allows the display material to be constantly driven, with the transistor circuit providing a short-term memory for the image-state of the display.

Actually a display is characterized by a light modulation or -generation technique *and* a driving scheme. AM or PM driving is therefore also used in the other display technologies introduced here.

Silicon types used for active matrix displays

The most common type of active matrix display in use today is one fabricated from hydrogenated amorphous silicon (α-Si:H) deposited on a glass substrate. It is used in most high-performance notebook computers, monitors, and even in handheld video games for children.

However, the size of crystalline grains in amorphous Si is rather small, which results in rather low electron mobility and therefore big transistors and large pixels. The demand for higher resolutions and therefore smaller pixel sizes especially for small high-density camcorder and projection applications has driven efforts to manufacture TFTs with polycrystalline silicon (p-Si) by tempering of α-Si glass substrates to increase Si grain sizes.

There has been a considerable development in the field of microdisplays (Fig. 7) which have to utilize even smaller transistors with a single-crystal silicon substrate. They integrate display material directly over the top of the silicon. The technology was enabled by a combination of events in the integrated circuit industry:

- significant reduction of cost for processed silicon wafers,
- greatly increased number of circuits that can be put on an individual die,

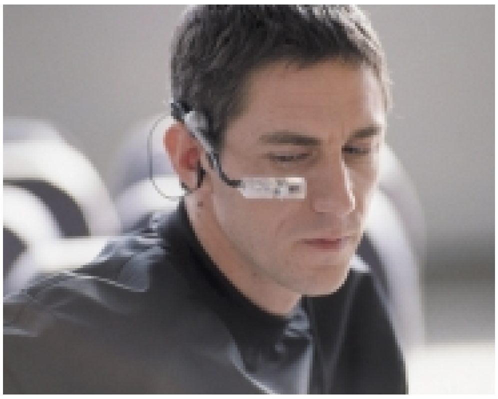


Fig. 7: Microdisplay employing silicon substrate.
(Picture courtesy of IBM Germany)

- improvement in yield of these large die, and
- inclusion of chemical-mechanical-polishing (CMP) as a standard IC process.

These events enabled a number of companies to create these small format displays. If liquid crystals are employed this type of display is called Liquid Crystal on Silicon (LCoS) display. Targets for them are head-mounted virtual-reality displays and projection applications.

Plasma Display Panels (PDP)

One technology that has been very successful for large-format displays is the Plasma Display Panel (PDP). This technology has the benefits of a Cathode Ray Tube (CRT), but can be built in a much thinner structure. Plasma Displays are typically filled with a gas such as neon, and driven in a row-column passive-matrix manner. They require high voltages to ignite the plasma, and careful current limiting to prevent display heating. Since the actuation mechanism ionizes gas at each pixel, PDPs create radio frequency emissions, which must be carefully controlled. In spite of all of these technical issues, the technology is gaining acceptance and looks to be the winner for the very large-format display market (40 inches to 60 inches).

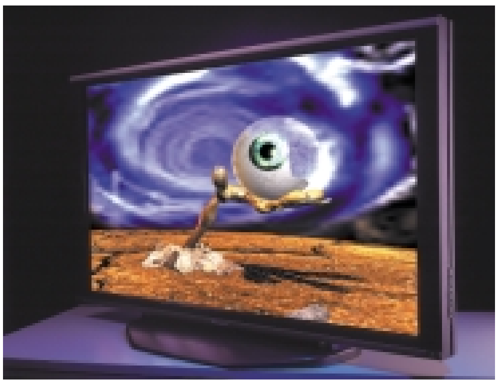


Fig 8: Common application for PDPs: HDTV.
(Picture courtesy of 4D-Vision)

PDP technology is important for large area viewing, but due to the size limitation of the plasma channels, small high-resolution displays cannot be realized so PDPs will not be significant for portable and handheld devices in the future.

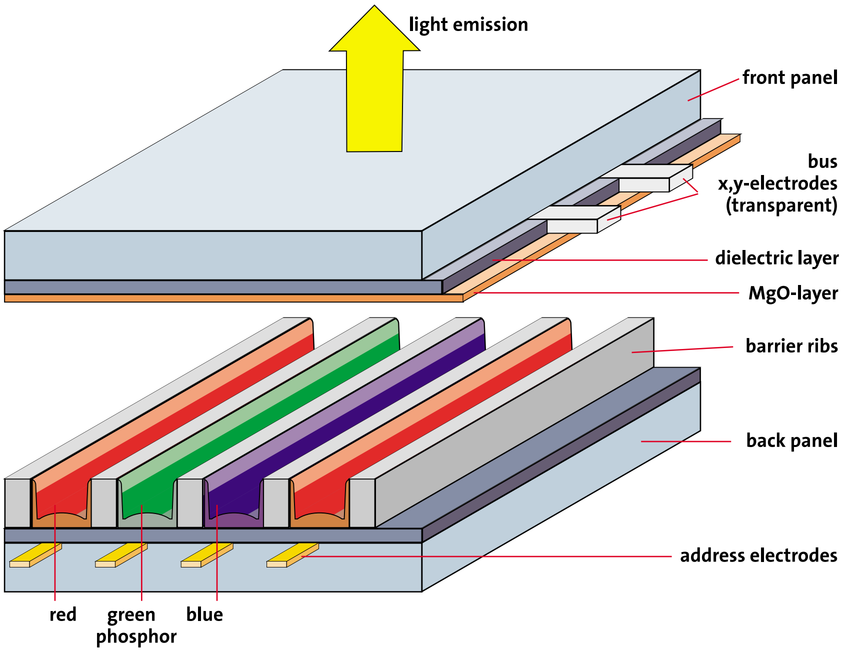


Fig. 9: Schematic cross section of a Plasma Display Panel (PDP). Dimensions not to scale.
(Picture courtesy of IMM)

Vacuum Fluorescence Displays (VFD)

VFDs are an established technology still widely used as LiC displays in audio- / video devices or household appliances. The VFD technology uses the fluorescence of phosphors under electron bombardment similar as in cathode ray tubes (CRT). However, the device structure is quite different from CRTs and resembles the

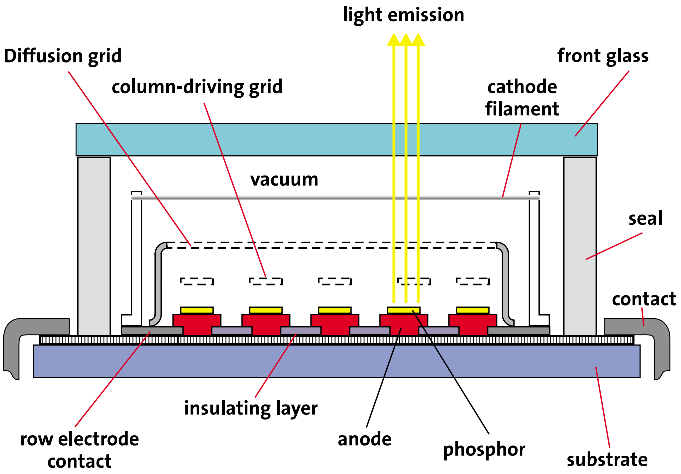


Fig. 10: Schematic cross-section of a Vacuum Fluorescence Display (VFD). Dimensions not to scale. (Picture courtesy of IMM)

classical triode: Electrons evaporate from the metal cathode, a filament with around 10 µm thickness. They are accelerated by a grid voltage around 50 V. VFDs can be easily identified by the honeycomb structure of that grid which is fabricated by etching a very thin steel foil. As soon as the electrons penetrate the anode at around 100 V light is being emitted. VFDs are robust, reliable with a high contrast ratio and long life span. One disadvantage is their large spatial dimensions compared to the active display area.

Electroluminescence Displays (ELD)

ELDs have a very simple device structure and can entirely be built employing solid state thin film technologies. Between two electrically conducting slabs (e. g. glass with structured ITO stripes in matrix configuration) with applied insulating layers a thin electroluminescent layer is deposited. Doped zinc sulfate ZnS, or strontium sulfate SrS with a rather broad emission spectrum ("white") are used as EL compounds. Conventional color filters generate RGB colors. With the EL layer being only about 100 µm thick, fully transparent displays, like for OLEDs, can be achieved. Typical driving voltages are chosen around 200 V AC at up to 10 kHz which necessitates rather expensive driver ICs. With an AM driving scheme (AMEL) employing a transistor matrix on a silicon substrate, high-resolution microdisplays have been demonstrated.

Light Emitting Diodes (LED)

(Inorganic) Light Emitting Diodes (LED) are widely used as large-area screens or displays for tickers. These LED displays are commonly monochrome or multicolor and are composed of commercially obtainable LEDs. Meanwhile high-efficiency blue LEDs are available, making full-color large-area LED displays possible. LEDs exhibit high luminescence, high efficiency and long life span which makes them particularly attractive for outdoor use. However, LEDs are rather spacious. Therefore medium-sized displays for monitors or PDAs are not feasible with this technique. Monolithic integration of LEDs on a single chip, however, can be used for virtual (monochrome) displays.

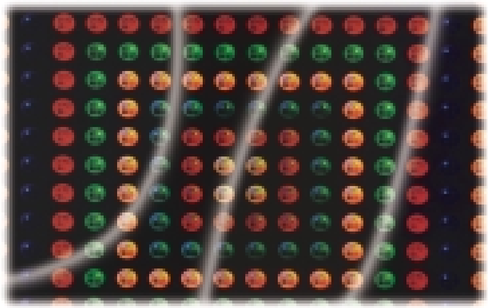


Fig. 11: Closeup of a full-color LED display. (Picture courtesy of Osram Opto Semiconductors)

MEMS (DMD)

Another microdisplay-oriented technology is based on Micro-Electro-Mechanical Systems (MEMS). In these types of displays, silicon and other materials are machined using standard semiconductor processes to make miniature mechanical structures. In the case of a Digital Micromirror Device (DMD), the structure is a mirror supported by a hinge, which can be actuated by placing a charge on plates connected to an underlying memory cell. The size of each mirror is about the width of a human hair. This device has gained acceptance widely in portable business projectors and home theater projectors.

Field Emission Displays (FED)

In an effort to create a thin CRT display, several companies have been developing Field Emission Displays (FEDs). FEDs resemble thin CRTs, but without the heating element in the cathode; in addition, they are organized in a one cathode per pixel passive matrix organization. Like the Plasma Displays Panels, FEDs typically require a high voltage to operate, anywhere between 200 V and 6 kV. These displays can be very thin, but thus far the production costs of manufacturing facilities have kept them out of mainstream commercial products.

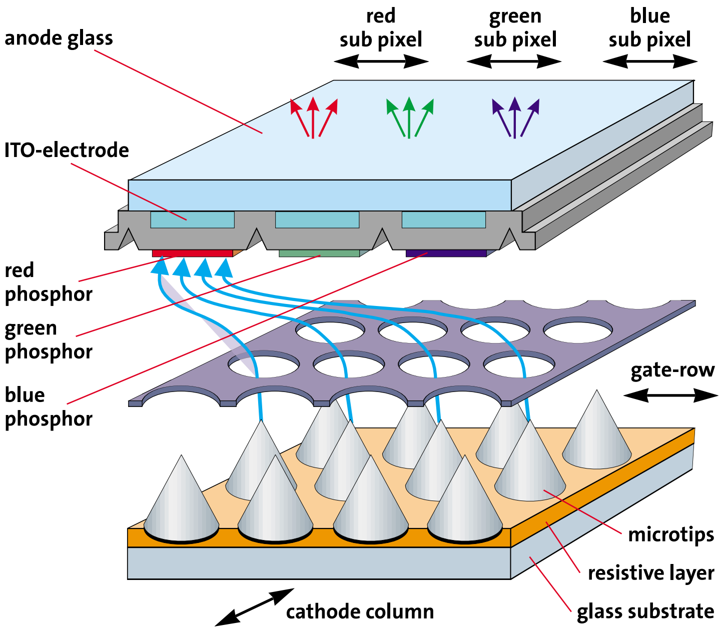


Fig. 12: Schematic cross-section of a Field Emission Display (shown here: microtip-FED). Dimensions not to scale. The stack of organic layers is about 150 mm thick. (Picture courtesy of IMM)

Organic Light Emitting Diodes (OLED)

One of the most exciting technologies to come along in the past 25 years is Organic Light Emitting Diodes (OLEDs). This field was first applied by Kodak and significantly enhanced by Cambridge Display Technology (CDT) in the UK. Kodak introduced the technology also called Sublimed Molecular Films (SMF) with monomer-based materials whereas the CDT-based technology referred to as Light Emitting Polymers (LEP) employs polymers.

In OLED displays, electrical current passes through one or more layers of plastic, which recreates the behavior of an inorganic Light Emitting Diode (LED) wherein light is emitted from a junction of two dissimilar materials. That means that all that is basically needed for an OLED device is in a stack of solid films on a substrate. However, the organic material is very susceptible to water vapor and oxygen, which makes thorough encapsulation indispensable.

Fig. 14: One of the first products where OLED display will be commercially available. (Picture courtesy of Covion)

OLEDs are self-emissive and show excellent optical properties as well as low power consumption. They have high potential to be mass-produced on flexible substrates which enables processing in a roll-to-roll manner. Moreover, the possibility to simply print the organic material makes fabrication very inexpensive.

A wide range of applications from simple monochrome large-area lighting to full color, video-capable graphic displays can be covered by OLED technology. Commercialization started in 1999 with the introduction of a multicolor OLED display in a car stereo.

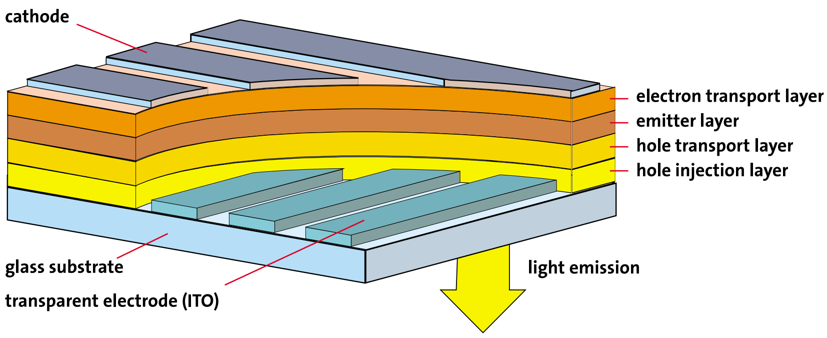


Fig. 13: Schematic cross-section of a passively driven Organic Light Emitting Diode (PM-OLED). Dimensions not to scale. The stack of organic layers is about 150 nm thick. (Picture courtesy of IMM)

Fig 15: An application of electronic ink: the electronic newspaper. (Picture courtesy of IBM Germany)

E-Ink and Gyricon

E-Ink, a spin-off of MIT in the US, has created a technology called Electronic Ink which is a bistable, printable ink-like material that can be changed by the application of an electronic field across the material. E-Ink is composed of microencapsulated clear spheres, each about 100 µm in diameter and containing a dark-colored liquid dye material along with thousands of microscopic particles of white-colored titanium dioxide.

When a field is applied across the material the titanium dioxide particles migrate towards one electrode or another according to the state of the charge. This allows the pixel to be written to either an “on-state” or a “dark-state.” Since the fluid contains thousands of sub-pixels, the definition of light and dark can be on a finer grain than that of the encapsulating spheres. Since this material is bistable, it holds its information for months at a time. Because an electrical field controls the mechanism, there is very little energy used to change the contents of a display.

Xerox is also working on a version of the technology called Gyricon. The principle of operation is similar, but instead of thousands of white particles, they use one element per sphere.

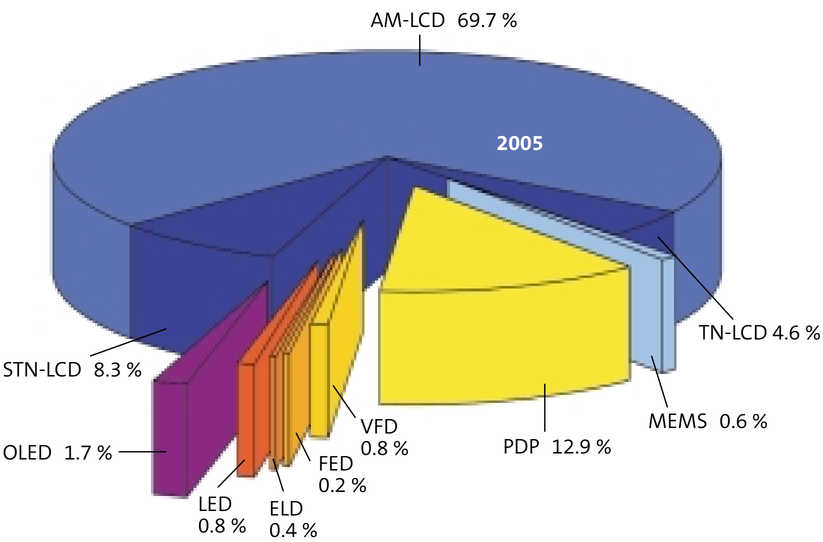


Fig. 16: Forecast of market shares of flat panel display technologies in 2005. (Source: Stanford Resources, 2000)

This technology holds promise for information that seldom needs to change. Applications of it range from advertising screens to electronically printable T-shirts and soup can labels containing extra information such as expiration dates and supermarket advertising.

Comparison of the Technologies

Even though numerous promising concepts to build flat panel displays exist, LCDs dominate the flat panel display market. Their market share of around 90 % today will only slightly decrease within the next few years. However, there is no such thing as a universal display!

The different maturity of flat panel technologies and their production processes aggravate a quantitative comparison of efficiency. Independent from their development stage, every technology has specific advantages for a certain range of applications.

The column “advantages” in table 1 denotes characteristics that can help to make a decision for the employment of a specific technology. “Difficulties” indicate inherent problems of the technology or problems which will persist for the foreseeable future. Problems which are satisfactorily solved already, e. g. the viewing angle of LCDs, have not been mentioned here.

Technology	Advantages	Difficulties	Typical applications
PM-LCD	mature cheap flexible substrates possible	switching speed contrast graphics non-emissive effectiveness temperature range	broad range of small displays like in cellular phones, automotive applications
AM-LCD	mature many technical options minimum pixel size: – 15 µm (reflective displays) – 50 µm (transmissive displays) flexible substrates possible video-capable	non-emissive effectiveness low yield for production of large displays huge capital investments necessary temperature range	computer monitors, laptops, full color car navigation
Plasma displays PDP	emissive technology simple construction video-capable robust large size	complicated driving scheme weight power consumption contrast minimum pixel size 300 µm expensive	HDTV, information systems on fairs
VFD	emissive mature brightness temperature range	high voltage necessary color range graphics power consumption installation depth	low information content displays in audio- or video devices, household appliances
ELD	emissive simple construction robust thin, lightweight minimum pixel size only few µm transparent flexible substrates possible easy production	high AC voltage necessary limited color range brightness effectiveness larger size displays hard to realize expensive	LCD backlight (frequently used in PDAs), Passenger information system in German high speed train ICE
LED	emissive mature brightness lifetime robust easy production	graphics expensive pixel size	outdoor applications like large size video screens, tickers
DMD	brightness contrast compact color reproduction	expensive non-emissive production	projection TV, presentation equipment
FED	emissive, large viewing angle temperature range video-capable minimum pixel size few 10 µm effectiveness	high voltage necessary vacuum color range lifetime low production yield	possible applications: ruggedized displays, automotive, aviation
OLED	emissive brightness video capable thin, lightweight minimum pixel size few µm flexible substrates possible	lifetime ↔ colors extensive encapsulation current driven	potential broad range from large area lighting, backlight to full-color video displays, microdisplays; market launch with car audio, cellular phone
E-ink / Gyricon	power consumption (bistable) contrast cheap flexible, thin, lightweight large size	two color only switching speed non-emissive	possible applications: electronic newspaper, electronic price tags, large scale advertisement

Table 1: Display technologies: advantages, inherent problems and typical applications. [Ehrfeld], supplemented.

The Production Process

There are numerous publications describing flat panel display device architectures and performance, but manufacturing processes and yield issues naturally remain as company secrets in this intensely competitive market. An in-depth report on the latter is beyond the scope of this paper. However, we want to give you a brief, schematic overview of the materials, equipment and processes involved in flat panel display production, so that an assignment of the company profiles in the second part of this publication to the process chain is possible.

Although there is quite a number of different display technologies employing different device architectures and driving schemes one can find overall similarities: Simply speaking, most displays basically consist of three parts:

- a backplane, where transparent electrodes (called anode, mostly consisting of Indium Tin Oxide (ITO)) are patterned onto a transparent substrate (glass or plastics),
- a light modulating (in the case of LCD this is the liquid crystal cell with polarizers and color filters) or light emitting element (VFD, ELD, PDP, FED, OLED), characteristic for the display technology used, and
- a counter electrode (cathode), mostly a simple metallic structure either patterned directly onto the emissive layer (in the case of OLED) or on an additional substrate containing color filters, polarizers (e. g. in LCDs).

This results in three basic steps for display manufacture,

- the fabrication of the backplane, employing deposition and patterning techniques similar to the ones used in the semiconductor industry for the production of integrated circuits (IC),
- the fabrication of the essential display part between the electrodes, where a large variety of chemical and physical procedures and treatments, strongly dependent on the display technology used, are necessary, and finally
- the assembly of a display module which is then ready to be integrated into an application. Wire bonding, packaging and final testing is required here.

We want to describe these steps briefly naming the basic processes and materials involved. Nevertheless, for simplicity we have to focus on one sample technology, to be more precise a display technology plus a driving scheme (active or passive).

From the technological point of view, the flat panel display market is dominated by Liquid Crystal Displays (LCD), which make up nearly 90 % of flat panel displays produced. The production techniques for LCDs show a high standard of maturity and are well established. The most promising new display technologies, on the other hand, are displays based on **organic light emitting diodes (OLED)**. OLEDs are self-emissive and show excellent optical properties as well as low power consumption. They have high potential to be mass-produced on flexible substrates which enable a wide range of new applications. Most other flat panel display technologies, like LCD, PDP and FED, have three-dimensional structures that have to be kept either in a vacuum state or have to be filled with gas or liquid crystals. In contrast, all that is needed for an OLED device is in principle a stack of solid films on a substrate. Although OLED is still an emerging technology requiring a considerable amount of time and effort to further develop the technology itself as well as the implementation into methods of production, we have chosen it as sample technology for this paper.

Fig. 17: AM backplane. (Picture courtesy of Merck)

Fig. 18: Display Fabrication has to be carried out in clean room environment. (Picture courtesy of Optrex Europe)

Flat panel displays are used in a wide spectrum of products ranging from simple alpha-numeric low-information content displays to large area, high-resolution, color video-displays. These high-information content displays are **actively driven (AM),** most of them employing the so-called Thin Film Transistor technology (TFT) where every pixel is addressed by an individual transistor. This results in a better contrast and a higher switching speed – important criteria for high quality displays. We want to focus on this driving scheme, since more and more applications will demand larger, high-resolution, full color displays. However, in contrast to the LCD technology, at least two transistors instead of one have to be produced for each pixel for AM-OLED displays.

AM-OLED display fabrication step I: The AM backplane

Since display manufacture deals with the creation of structures of the size of a few microns on large panels of the size of almost up to a square meter, a high degree of precision in manufacturing technology as well as cleanliness is required. Most of the manufacturing steps have to be carried out in cleanroom environment. Clean room requirements are as follows: The lithography areas with wet etch are commonly Class 10. Much of the area for sputter and CVD loading is Class 100, with the rest being Class 1000–5000.

Extensive automation of production steps themselves and handling as well further reduces pollution. AM backplane manufacturing technology has quite some similarities to integrated circuit (IC) processes in the semiconductor industry. Instead of silicon wafers rectangular glass substrates are used for volume production of flat panel displays. The extremely competitive environment at least notebook and computer monitor manufacturers face today, makes manufacturing cost and therefore production yield a key issue. As a result, like in the semiconductor industry, substrate sizes have to increase to get better yield for large panels. Today, generation 4 lines with substrate sizes 680 x 880 mm^2 are being built.

	Glass substrate size [mm^2]
Generation 2	400 x 500
Generation 3	550 x 670
Generation 3.5	600 x 720
Generation 4	680 x 880
Generation 5	950 x 1150 (proposed)

Table 2: Substrate size standards in flat panel display manufacturing. Generation 4 fabs are currently being built.

Of course, the substrate size considerably affects capital expenditure for the production line itself. OLEDs, however, do not target the above mentioned markets first, so smaller substrate sizes down to 400 x 400 mm^2 can be sufficient. Moreover, with the use of flexible plastic substrates, reel-to-reel OLED-display processing becomes possible, with a high potential to decrease manufacturing costs substantially.

Category	Cleaning Method	Feature
Wet Cleaning		
Physical cleaning	Brush Scrubbing	Removes stubborn particles, not suitable for smaller particles, effect is proportional to brushing pressure
	Jet Spray	Suitable on patterned, hydrophilic, and soft surfaces, requires caution regarding static charge: ineffective without high water pressure
	Ultrasonic Cavitation	Accelerating effect of chemical washing is conspicuous, has difficulty eliminating particles, requires caution regarding cleaning unevenness due to generation of standing waves
	Megasonic (1 MHz)	Can eliminate submicron particles when used with chemical cleaning fluid, strong recti-linear propagation of sound waves, requires caution around jig structure
Chemical Cleaning	Organic Solvent	Suitable for eliminating multiple contamination of organic substances; solvent is chosen depending on contaminant; difficult with high level of cleaning
	Neutral Detergent	Suitable for contamination from particles and organic substances, no damage to material being cleaned; difficulty is that interface activator adsorption layer remains
	Chemical Cleaning Fluid	Depending on the orientation constituent, it acts in etching, oxide decomposition, hydro-philic surfaces, and ionization, suitable for all contaminants; needs chemical management
	Pure Water	Eliminates chemicals after chemical processing; cleaning capability depends on water pu-rity, insufficient for particles and organic substances
Dry Cleaning	Ultraviolet Ozone	Eliminates organic contaminants at the adsorption film level; improves coverage prior to resist application
	Plasma Oxide	Applies to eliminating organic substances such as photoresist; not suitable for particles and non-organic contaminants, low throughput
	Non-oxide	Eliminates slight organic and inorganic contaminants; allows for highly clean surface, equipment is expensive; low throughput; limited application
	Laser	Localized selective cleaning; not suitable for full surface cleaning

Table 3: Cleaning processes used in TFT production. [Thompson]

In a first step, the substrates have to be cleaned. Cleaning processes are one of the key factors in achieving higher yield. Around 80 % of the defects come from particles on the substrate, which are almost impossible to completely eliminate. Cleaning prior to deposition and resist coating is very important in TFT manufacture.

The thin film transistors (TFTs) themselves consist of stacked layers of doped either amorphous (α-Si) or polycrystalline (p-Si) silicon and insulating SiO_2 layers which are subsequently deposited and patterned onto the substrate. At the present time, only the plasma enhanced chemical vapor deposition (PECVD) method is used for forming the precursor α-Si film in production lines. CVD equipment is already available for motherglass substrates as large as generation 4.

The low process temperature (<400°C) of α-Si has led to its initial dominance in large-area AM-LCD technology. Substantial experience and infrastructure in large-area α-Si manufacturing for solar cells has been made during the oil crisis of the 1970s. α-Si allows overall pixel sizes of approx. 100 x 100 µm.

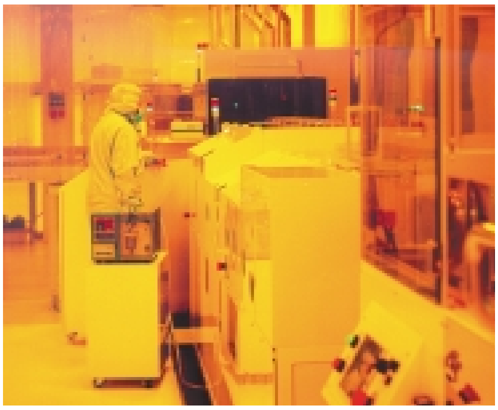


Fig. 19: Photolithography in the cleanroom.
(Picture courtesy of Optrex Europe)

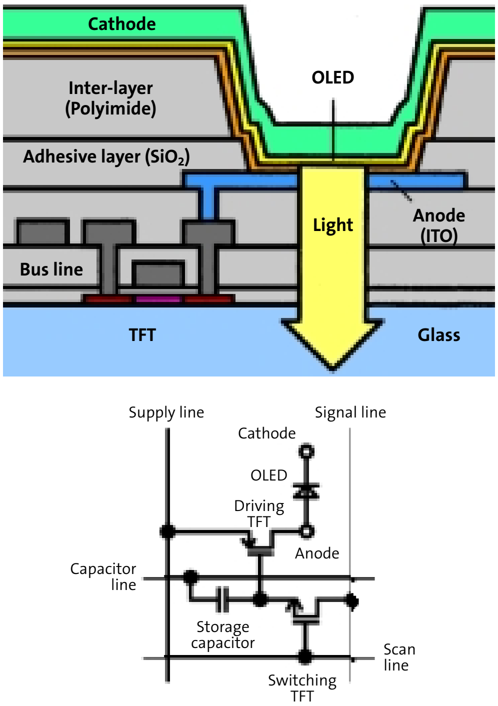


Fig. 20: Cross section and circuit diagram of an AM-OLED device [Kimura]. At least two TFTs for each pixel have to be used because OLEDs are current-driven.

The demand for higher resolutions and therefore smaller pixel sizes, especially for small high-density camcorder and projection applications, has driven efforts to manufacture TFTs with polycrystalline silicon (p-Si). Since grain sizes are bigger and electron mobility increases, transistors can be made smaller resulting in pixel sizes an order of magnitude lower than in α-Si. However, the standard method of tempering α-Si requires temperatures as high as 900°C (High temperature polysilicon, HTPS) i. e. beyond the melting point of glass and therefore needs expensive quartz substrates. The panel size with this method is limited to approx. 8 inches. Another way to produce p-Si layers is to anneal α-Si locally with UV radiation from an excimer laser (ELA). This method requires process temperatures below 400°C, so that ordinary glass substrates can be used (Low temperature p-Si, LTPS). Another advantage using this technique is the possibility of processing built-in p-Si drivers directly onto the motherglass, which further reduces cost and enhances reliability.

Subsequent photolithography, etching and doping process steps common to IC fabrication form the TFT array. Considering three RGB subpixels and the fact that for AM-OLED two transistors are needed for every pixel (Fig. 20) one has to form approx. 2 x 4 million transistors for an SXGA resolution (1280 x 1024) display. Approx. 20 photolithography steps are needed to form the TFT substrate. If the yield for every step is 95 %, the overall yield for an error-free TFT panel is only 32 % which makes it already very expensive. TFT testing is very important. A very elegant method is the contactless test with an electron beam.

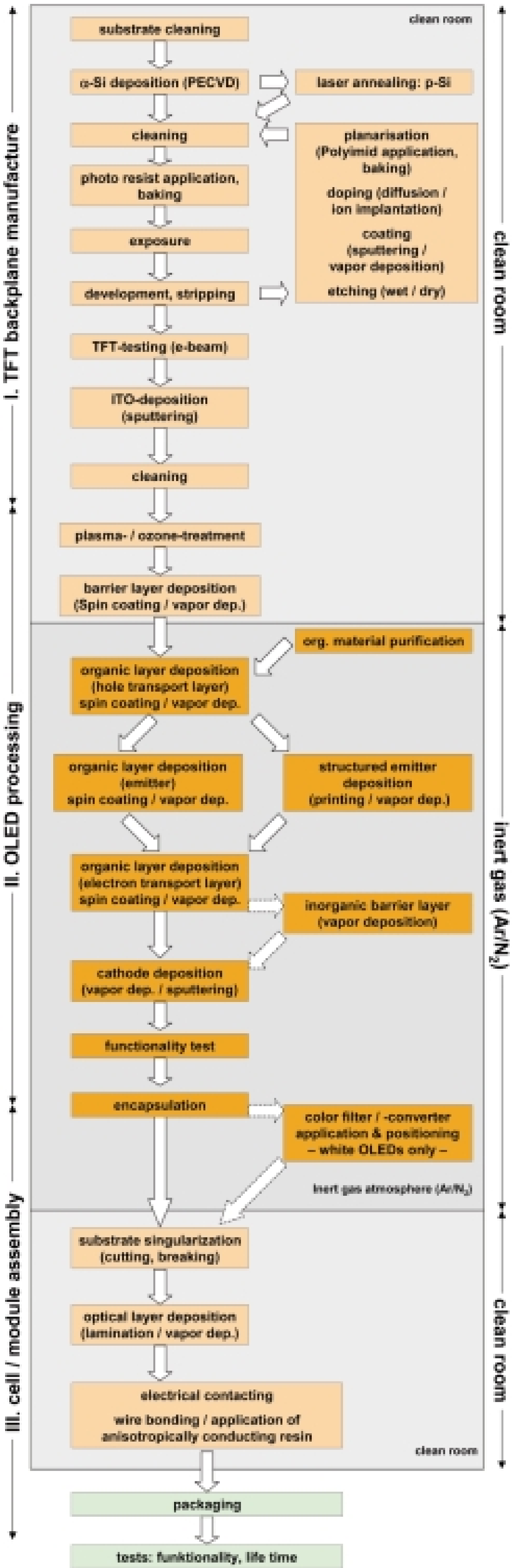
Afterwards, the transparent anode (mostly made of Indium Tin Oxide (ITO) which has a considerably low sheet resistance) is sputtered onto the substrate connecting the TFTs to the “outside world”. For the following deposition of the OLED materials an extremely flat ITO layer is of vital importance.

Another cleaning step followed by an optional plasma or ozone treatment and subsequent depostition of a buffer layer by spin coating or thermal evaporation makes the backplane ready for OLED processing.

AM-OLED display fabrication step II: The organic layers

OLED materials can be classified basically into two groups with pronounced differences in processing: The small molecule type material first applied by Kodak consists of low molecular

Fig. 21: The basic materials for OLED displays: Small molecule and polymer OLEDs. (Picture courtesy of Covion)



compounds like dye systems and metal-chelate-complexes. The small molecule layers are fabricated using vacuum sublimation (Sublimed Molecular Films, SMF). On the other hand, the materials introduced by Cambridge Display Technologies (CDT) are polymers (Light Emitting Polymers, LEP). These are soluble and can therefore be processed by spin coating or even simple printing techniques. Whereas the vapor deposition exhibits advantages especially for multilayer structures, cost-effective coating of large areas is viable with the soluble polymers. On the other hand, the deposition of multilayer structures is more difficult in the latter case since mutual mixing of the solutions must be avoided. Despite the structural differences of both OLED types the overall working principle is the same.

In contrast to LCD panels which are driven by controlling a voltage, OLEDs are diodes and therefore have to be driven by controlling a current. This necessitates one additional TFT for current switching. Distinct differences of OLED processes in comparison to other display technologies also arise through the high sensitivity of the organic substances: OLED rapidly degrade and are finally destroyed when exposed to water vapor or oxygen. Therefore, the entire OLED processing step has to be carried out in inert gas atmosphere (Ar, N_2). Moreover, a thorough encapsulation of the organic layers is crucial to performance and lifetime of the display.

Another problem arises as ordinary exposure techniques cannot be used for patterning because extremely thin films of organic material are involved. Since fine patterning of RGB pixels is required to obtain full-color displays, partial deposition using a metal mask has been used for patterning the small molecule. For the polymers type printing techniques (like ink-jet printing) can be employed. Considerable progress has already been achieved in this field. The overall thickness of the stack of organic layers is approximately 150 nm.

Another way to introduce full color in OLED displays is to use white organic emitter material together with color filters or -converters like in LCDs. A structured emitter is not necessary for this type of OLED-display (as well as for monochrome devices, of course). However, through absorption of the filters, efficiency drops down. Furthermore, the color filters are quite expensive and have to be properly aligned to the underlying TFT backplane which increases the panel costs significantly.

AM-OLED display fabrication step III: Module assembly

Actually, if compared to LCD fabrication, module assembly for an OLED display starts with the application of the metal cathode. A thin calcium layer with an aluminium film on top, to protect the Ca and to enhance conductivity, acts as cathode. No post cathode deposition patterning is required as the pixels are defined at the anode level which in turn is connected to the drive electronics.

It is more common, however, to regard the encapsulation of the device as first step for OLED-module assembly.

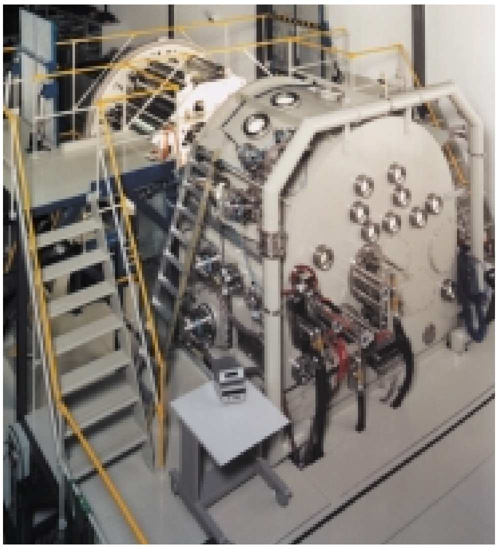


Fig. 22: Potential low-cost OLED fabrication with reel-to-reel process. (Picture courtesy of Fraunhofer Institut FEP)

Today, thin glass panels glued on top of the device are used for encapsulation of the organic layers. Various types of resin together with getter materials – they absorb water and oxygen that diffuse into the device – are employed. Better methods, especially for OLEDs on flexible substrates are under development. After the delicate organic substances have been sufficiently encapsulated the device can be taken out of the inert gas environment and processing proceeds in the clean room.

The following steps are more or less similar to the ones used in LCD fabrication. The substrate is cut into single display panels either by scribing it with a simple hard-metal wheel and subsequent breaking or, more advanced but also more expensive, by laser cutting which results in very smooth edges. In order to reduce background reflections of the cathode, which actually acts as a mirror, and to enhance contrast, optical filters and polarizers are applied.

Electrical contacting of the ITO either directly or with prior metallization by applying an anisotropically conducting resin or by employing wire bonding techniques is the next step. Advanced methods directly connect the driver ICs to the ITO lines (Chip on Glass CoG) or even make the incorporation of the drivers into backplane production possible (cf. p-Si).

After this, the display is not susceptible to particles any more and can be taken out of the clean room. Packaging basically employs common mechanical and electrical techniques like wiring the display to a printed circuit board (PCB) with driver-ICs on it, attaching connectors and finally put the device into a housing. The display module is ready for shipping now after a thorough final inspection.

Profiles of DFF Members

Companies

Research Institutes

ACR Automation in Cleanroom GmbH

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Company Information
Year of foundation: 1989
Managing Director:
Dr.-Ing. Wolfgang Schmutz
Number of employees: 50
Revenue 1999: DEM 20 million

Just professional – With the challenges in the development and realization of new technologies like OLED the task of ACR is to support the customer base worldwide with field-proven and reliable automation and process solutions for the FPD-manufacturing, especially for customer specified processes.

Since 10 years ACR is working in the field of the semiconductor industry. Based on this experience and combined with a modern infra-structure like 3,000 m^2 office/manufacturing area including cleanroom facilities, ACR is ready to take care of your specific requirements.

ACR Product Range

ACR develops and manufactures automation components and systems as well as process modules and process equipment for production in cleanroom areas like Semiconductor, Microsystem-Technology, Photovoltaic and Flat Panel Display.

This includes the following product range:

- Semiconductor
  - SMIF-Components
  - Transport and Storage
- Photovoltaic
  - Handling and Transport including Carrier
  - Process and Metrology Equipment
  - Key Contractor for production lines
- FPD-Equipment
  - Handling and Transport including Carrier
  - Process Equipment
  - Key Contractor for production lines

FPD-Equipment

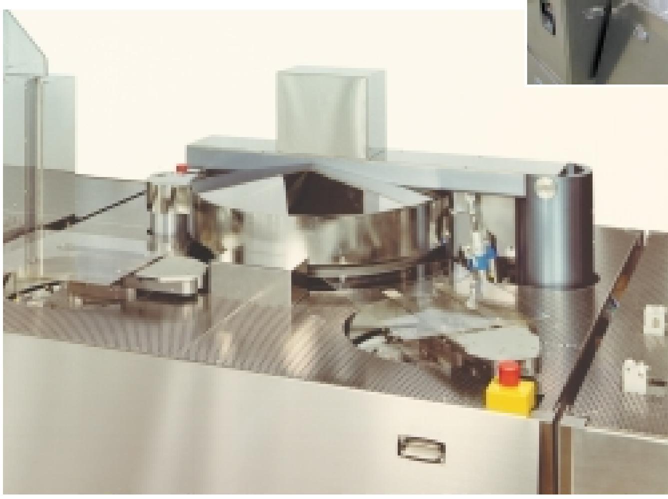
Based on the customer's requirement and specification ACR develops and builds-up various kinds of equipment starting from R&D-equipment for e. g. OLED (research of new manufacturing technologies) up to complete high-volume production lines (based on existing and field-proven manufacturing technologies) from the following modules:

- Process-Modules such as Cleaner, Coater, Developer, Etcher, UV-Cleaner etc. (all modules are available in single and multiple-process-configuration with different dispense and/or spray-systems)
- Handling- and Interface-Modules such as Sender-/Receiver-Module, Storage-Module, Hot-/Coolplate (single/stacked, various types of cassettes)

ACR is your partner for all steps starting from planning and designing up to installation, ramp-up and after-sales-service for your successful FPD-production.

Process-line with Sender-/Receiver-Module

Single-process configuration



High Precision Etching Technology

Buckbee Mears, as one of the world leaders in photo etching and one of the world leading producers of shadow masks for tube industry, is dedicated to maintaining the highest standards of quality. BMC offers complete production of etched parts (see picture 1), i. e. aperture masks, filter, lead frames, screens, grids, gaskets, etc. in different metals like stainless steels, Ni-alloys, Cu-alloys, Invar, low carbon steels.

Picture 1: Examples of etched parts

With our expertise in photoetching, we can offer minimum hole to hole dimensions (and down to 0.012 mm per 300 mm) maximum precision (hole, slot: down to 0.005 mm, depending on material thickness). At prices, that are more economical than low quantities of stamped parts.

Other finishing work can be added as necessary including shaping, plating and welding.

The production system for precision parts operates according to the BMC Industries Inc. patented inline process principle. We use extremely flat glass photo templates with stable dimensions (tolerances down to 0.001 mm) to make the etching process extremely precise. Drawings or CAD files provided by the customer can also be used as templates. We integrate our technical planning and construction skills into the design phase.

Process (see picture 2): Metal flushed from the system moves through the separate stages of production without manual intervention. In the next stage the metal is coated with a liquid photo resist. The part is then exposed with a negative and the image is developed. Next, the unprotected excess metal is chemically removed, so that only the finished components remain.

Photochemically produced products offer a number of distinct advantages over stamped metal components. The photochemical method not only makes it possible to use very thin metal sections (down to 0.025 mm), larger formats (up to 600 mm x 800 mm) and much more complex forms enables more functions in less space. This results in extremely flat and smooth parts without burrs. In contrast to stamping, etching technology makes it possible to create 3 dimensional structures.

New technological progress at Buckbee Mears allows the production of parts on endless reels with a part to part precision of 0.025 mm, including all the other advantages of etching technology.

BMC

BMC Buckbee-Mears Europe GmbH

A Unit of BMC Industries, Inc.

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Managing Director: Michael Sillmann

Founded (Germany): 1972

Staff (2000): approx. 450

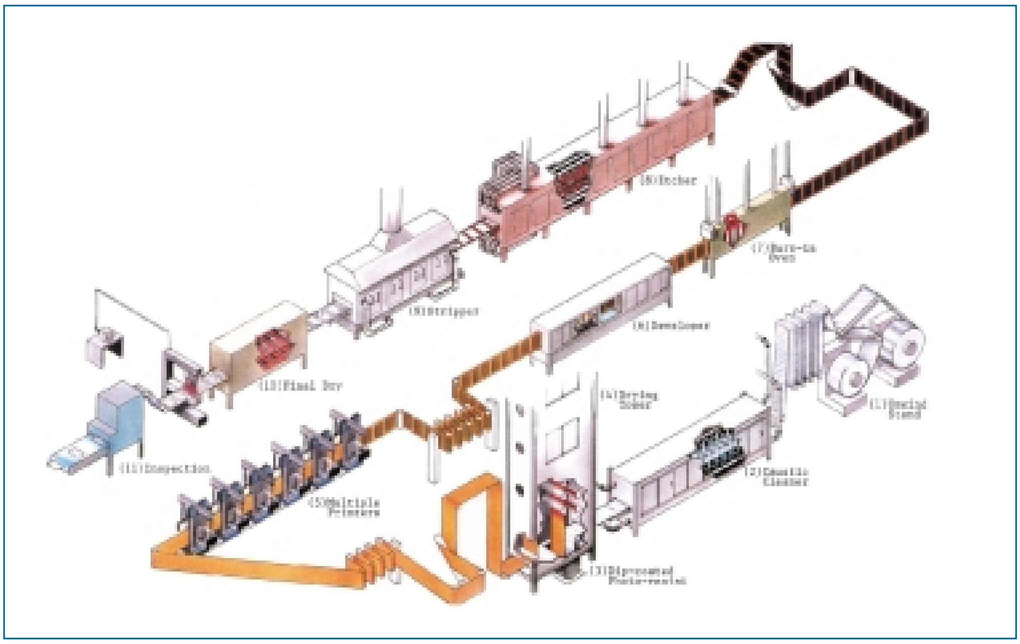
Sales in 2000: approx. € 100 million

Locations: Germany, USA, Hungary

Headquarters:

BMC Industries, Inc.
One Meridian Crossing, Suite 850
Minneapolis, MN 55423, USA

Picture 2: Inline Etching Line



Flexible OLED

Polymer materials

Different coloured OLED's on glass

Covion's manufacturing facility

Covion Organic Semiconductors GmbH

Industrial Park Höchst, G864
65926 Frankfurt/Main
Germany

Fax: **+49 (0) 69 · 30 54 75 70**
e-mail: **info@covion.com**
Internet: **www.covion.com**

Managing Director:
Dr. Hermann Schenk

COVION Organic Semiconductors GmbH, based in Frankfurt/Main, was formed on 1 April 1999 and is a joint venture between the specialty chemical company Avecia of the UK and Celanese Ventures – part of Celanese AG – based in Germany. Within the JV, COVION designs, manufactures, and markets high performance materials for the OLED flat panel display and optoelectronic markets.

The company is the first to offer both high performance small molecule and conjugated polymer OLED materials at commercial scale. Its prime focus is as a materials manufacturing partner to display industry innovators.

COVION was created to build on technology leadership in organic semiconductor materials, firstly capitalising on a series of R&D achievements in OLED's over the past decade. The company aims to translate materials innovation into high quality commercial production and supply for leading electronics OEMs.

The COVION business is built around highly qualified materials specialists. It also benefits from the extensive and secure manufacturing and business infrastructure of the Industrial Park Höchst, Frankfurt.

Marking an industry-leading step into full scale manufacture of high performance conjugated polymers, COVION commissioned a US $5m state of-the-art extension to its OLED materials manufacturing facility during 2000. The expanded plant can now produce a volume of 40,000 litres of polymer solution annually.

COVION's future research and development focus includes advanced organic semiconductor applications for electronic circuitry, image recognition, advanced lighting, lasers and optical data storage.

For further information, please visit our website at www.covion.com.

CODIXX Aktiengesellschaft

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Executive board members:
Thomas Ryll
Detlef Prinzler

Founded: 1998

Staff in 2001: 35
Production area: 1000 m^2

Locations:
Magdeburg, Barleben, Berlin (Germany)

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CODIXX in brief

The CODIXX AG is an innovative joint-stock company founded in 1998. The objective of the company is the development, production and marketing of components for information and communication technologies. The company produces large area customer designed displays based on LED. These displays find application in traffic guide systems, in production control systems, in the stock market information, as terminals in railway stations and airports and as advertisement boards.

References for instance can be given by Siemens, LAU and Bosch.

Further products are dichroic polarisers based on soda-lime flat glass suited for the production of coloured LCD with enhanced performance under user condition and for the production of shutters in the UV and VIS-Range for many and various application.

About it the company offers a platform to young inventors for the new display idea transfer in products.

Within this development strategy the CODIXX AG has the right to participate in other companies inside and outside Germany and also to found new companies.

Glass cleaning box

Large Area LED-Display

Competences:

Development and production of large area LED-Displays in monochrome and full colour version adapted to the customer's requests refer form, size and driving scheme. Preparation of LED-Displays for indoor and outdoor use.

Development and production of dichroic glass polarisers for the visible and ultraviolet spectral range based on a special technology patented by CODIXX.

Due to the material properties of the polarisers, LCD-Displays with an enlarged value in use can be prepared. LCDs with CODIXX colorPol® polarisers can be used in an enlarged temperature range (-30 to +130°C, other larger T-range is possible, too); they are resistant against UV-radiation and against chemical and mechanical stresses.

Development of customer designed LCD Displays based on CODIXX colorPol® polarisers.

LCD with enlarged T-range with colorPol® polariser

Benefit from our know-how

Modern machinery, comprehensive service and over 30 years of experience guarantee competence and reliability.

Research and development together with optimized planning are preconditions for the realization of our customers' desires.

The experiences gathered in national and international trade since 1968 back the successful export of machines and entire plants.

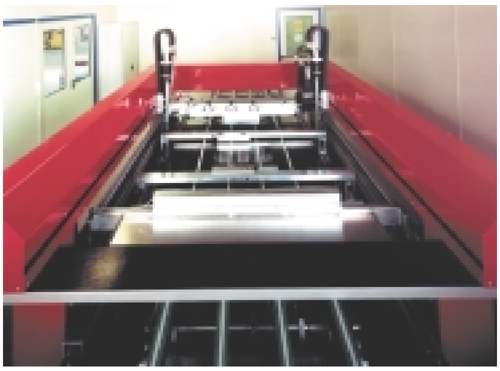
GEROLD supplies customers throughout the world with up to the minute machines e. g. for screen printing technology, material handling technology, rubber industry and turn-key solutions.

Our main customers are internationally renowned glass manufacturers and suppliers to the automobile industry.

Microstructures economically applied ... µm precise !

GEROLD screen printing technology for economically applied microstructures. The newly developed machine technology allows the reproducible application of microstructures with minimum structure widths of up to 50 µm.

This opens new perspectives in areas such as display manufacturing, solar applications as well as the production of functional components for automotive and architectural glazing.



Fully automatic precision screen printing machine

Screen printing technology

A technique offering numerous advantages for the exact and reproducible application of printed structures. These advantages are backed through realistic investment and production costs. Cost reduction due to more economical material use, protection of the environment thanks to reduced production waste as well as a continuous material flow are additional benefits screen printing technology offers.

Comprehensive know-how, the longstanding experience in the trade together with extraordinary R&D efforts enabled GEROLD to design a precision screen printing machine which opens new perspectives in several areas. This newly developed machine covers all the characteristics necessary for an excellent printing result.

The new PSD 1000 is a fully automatic screen printing machine with integrated positioning system, guaranteeing an alignment exactness of +/– 0.005 mm – even for large substrates.

Thanks to this new machine technology it is possible to align large formats reproducibly with µm-precision. The alignment is executed without a relative motion of the printing material to the printing table. Thus, also the exact alignment of thin products with sensitive surfaces e. g. thin glass or silicon-wafers is made possible.

Besides its numerous technical innovations, characteristics such as high flexibility and operator-friendliness, high productivity together with production line capability distinguish this new development from customary systems.

Maschinenbau GEROLD offers its customers advanced technologies and realizes sophisticated processing lines – the basis for your success.

Maschinenbau GEROLD

Maschinenbau GEROLD GmbH & Co. KG

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41334 Nettetal
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Internet: **www.gerold-mb.de**

Managing Director: Wolfgang Gerold

Founded: 1968

Staff in 2000: 33

Production area: 4000 m^2

Headquarters: Nettetal,
located ca. 45 min. from Dusseldorf

Contact for Service and Sales:
Johannes Deutges, Jürgen Weiss

Sales: worldwide

ISRA VISION SYSTEMS AG

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Company Information

Management:
Dipl.-Ing. Enis Ersü
Chief Executive Officer

Hans Jürgen Christ
Chief Sales Officer

Branches:
Germany:
Darmstadt, Karlsruhe, Salzgitter, Wolfsburg, Dresden

USA: Lansing/Mi

France: Paris, Lyon

Business Units:
Surface Vision (SV)
Surface- and texture inspection

Product areas:
- Surface inspection
- Paint inspection
- Print and texture inspection

Robot Vision (RV)
Robot Guidance

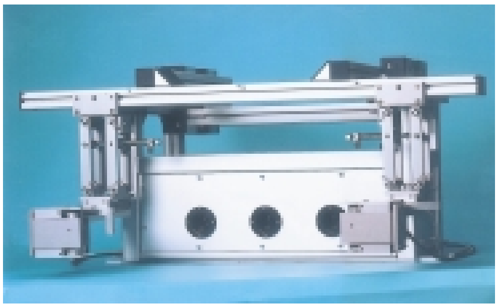
Product Divisions:
- 2D, 2 1/2 D
- 3D photogrammetry
- 3D stereo vision

Quality control with focus on surface inspection

Our in-line surface inspection systems are successfully used worldwide in different industrial sectors such as the glass, plastics, non-woven, printing or paper industry. One of the focus areas is the quality control for Flat Panel Display production. ISRA's optical inspection systems are in use in every production step of the process beginning at the drawing of glass up to the final quality control. Installations at various key manufacturers in Europe and Asia successfully confirm the benefit of many years of experience and technological competence.

Inspection of Draw Glass in production

To optimize the drawing process of glass, the relevant production information is needed very fast and just behind the raw material feed at high temperatures. Detection of defects in the glass, classification of these defects and feeding this information back to the process control is realized in an optimum way by our superior vision technology. A flexible and highly sophisticated lighting system and multiple high resolution line-scan cameras are combined with an advanced machine vision software. The result is a leading edge solution with outstanding defect detection performance.



Quality inspection of Draw Glass Sheets

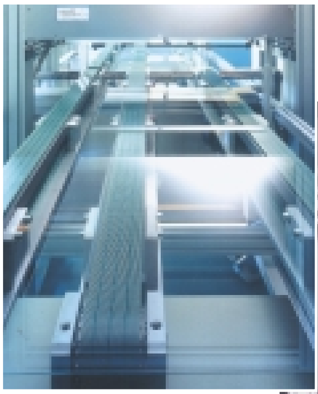
Efficient and effective high level glass production is guaranteed by inspecting the received glass sheets before further processing. Optical inspection here helps to recognize defect sheets before expensive processing starts, in order to reduce waste. ISRA's optical inspection systems are designed for edge- and corner defect detection and the classification of standard glass defects. The system utilizes high resolution line-scan cameras and direct lighting for in-line inspection.

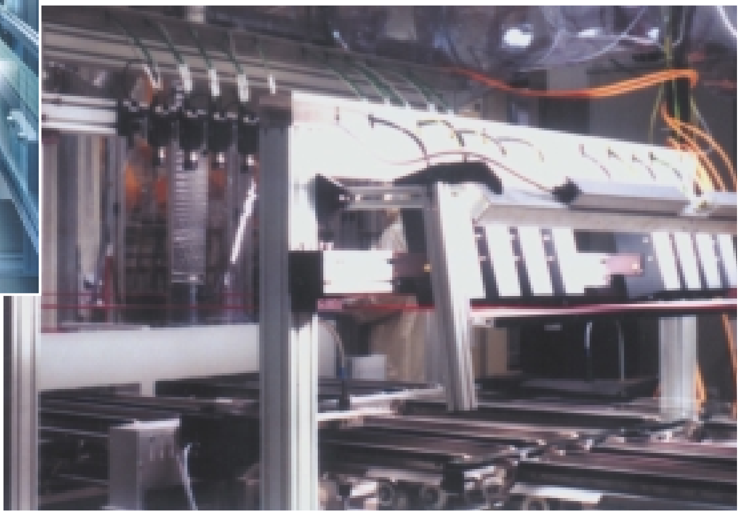
Inspection of ITO coating

Coating companies successfully use our surface inspection technology with the advanced two unit layout for highest defect sensitivity and reliable defect classification. Line-scan cameras and the combination of different lighting techniques are the building blocks of the two unit technology achieving resolutions of a few microns. The result is 100 % documented quality control. There is no further need for inspection at the end-user's site.

Inspection of Color Filters

This high end application covers a wide field of difficult image processing tasks: pattern recognition and verification within ranges of only some microns resolution and the complex layer inspection of ITO or Color Filter coating. Our advanced and innovative machine vision technology offers a very efficient solution with a complex system design using leading edge lighting and color line-scan techniques.





Final inspection of Flat Panel displays

After the final assembly of flat panel displays, various quality control tasks such as completeness and functional tests are necessary before the shipment. Pixelwise intensity checks, illumination distribution and intensity control as well as the optical inspection of characters, logos and signs are typical standard tasks for our machine vision systems.

High Tech Films for Emerging Markets

As a subsidiary of Lonza Group, LOFO High Tech Film is a highly innovative mid-sized company located in Southwest Germany near the Swiss border and is operating worldwide.

For several years now, LOFO High Tech Film has focused on the development and production of solvent cast films based on Cellulose Triacetate, Polycarbonates, and other high performance engineering plastics. Additionally, LOFO is the European leader in sales and distribution of specialty films for the print finishing industry.

Over the last few years, new products have been developed for emerging opto-electronic and electrical applications. Thanks to the company's proactive approach to conquering niche markets, these products now account for more than half of sales. Using the specific know-how of the solvent cast film process, soluble polymers are converted in clean-room production to films with outstanding physical properties.

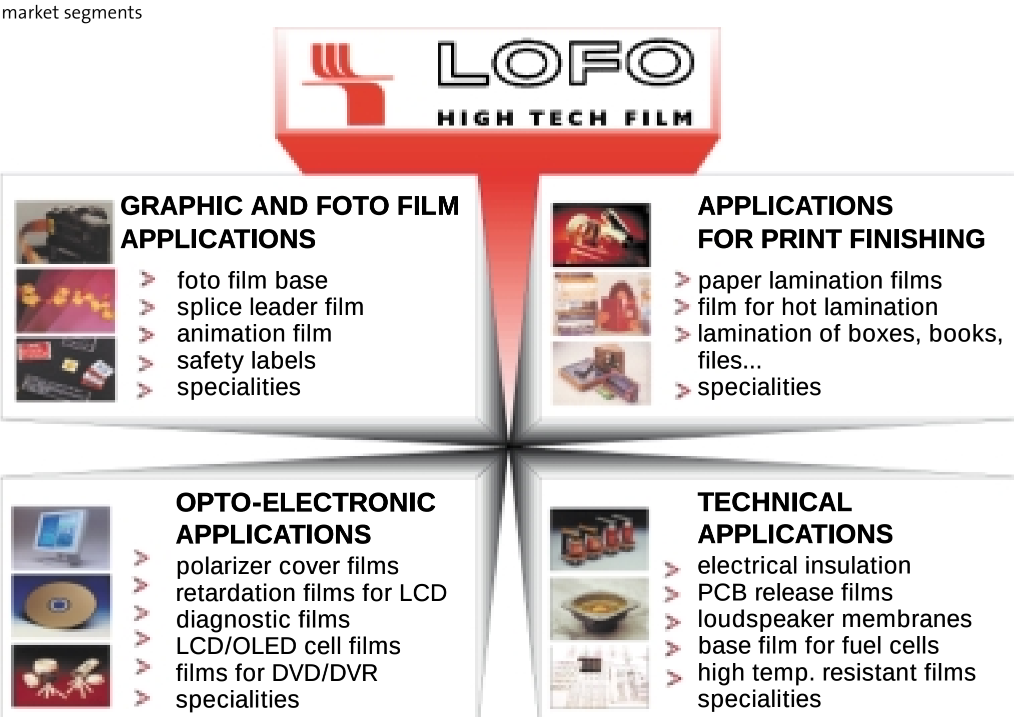
The main advantages of a variety of films used for optical applications such as LC displays are maximum transparency, low optical retardation, excellent thickness distribution, absence of gels and very low surface roughness.

A series of products provides matt structured surfaces. For instance, membranes used in loudspeakers are matt films with defined properties at higher temperatures.

Another advantage of the LOFO production process is the capability of adding a high concentration of electrically, optically and magnetically active substances, resulting in thin electrical conductive films or flexible magnetic films with outstanding properties.

Using unique proprietary technology, LOFO cooperates with clients in developing new films for new market segments, e. g. for fuel cell applications, new optical data storage systems, and high temperature resistant optical films for new display types.

The company's clients are divided over four different market segments



LOFO High Tech Film GmbH

Weidstrasse 2
79576 Weil am Rhein
Germany

Phone: +49 (0) 76 21·7 03-0
Fax: +49 (0) 76 21·7 03-2 55
e-mail: info@lofo-de
Internet: www.lofo.de

LOFO has at its disposal a production area of 42,000 m^2

The Company:
CEO: K.-H. Becker
Founded: 1928
Workforce: About 100
Area: 45,000 m^2
Location: Weil am Rhein, Germany
Sales in 2000: Appr. € 30 million

Main products:
Cast film for optical, technical and photographic applications, print finishing film

Contacts for Sales:
Dr. L. Borla
Phone: +49 (0) 76 21·70 31 00

R. Krause
Phone: +49 (0) 76 21·70 32 41

Contacts for Service:
Cast film
J. Nick
Phone: +49 (0) 76 21 · 70 31 69

Paper lamination
P. Röbbeling
Phone: +49 (0) 76 21 ·70 31 13

M+W Zander Holding AG

Lotterbergstrasse 30
70499 Stuttgart
Germany

Phone: +49 (0) 7 11 · 88 04-0
Fax: +49 (0) 7 11 · 88 04-13 09
E-Mail: info@mw-zander.com
Internet: www.mw-zander.com

Company Profile
M+W Zander, a subsidiary of the Jenoptik Group, consists of the two business fields Facility Engineering and Facility Management. More than 3,600 employees in around 40 locations worldwide contributed in 1999 to sales of about 2 billion DM.

The company was formed in 1998, the result of a merger between the two long-standing businesses Meissner + Wurst and Zander under the umbrella of the Jenoptik Group.

Managing Directors:
Juergen Giessmann, Helmut Laub, Siegfried Wagner, Reimund Blessing

Mission

Our business mission is to be the worldwide market leader of integrated solutions utilizing high value added products and services that provide our customers with a competitive advantage in their market environment.

Branches

Stuttgart (Headquarters – Germany), Dallas (U.S.A.), Singapore, Hsinchu (Taiwan R.O.C.), Seoul (South Korea)

Key Clients (abstract)

ADT Acer Display Technology Inc., AMD Advanced Micro Devices, CSM Chartered Semiconductor Manufacturing, Infineon, Philips, ST Microelectronics, TI Texas Instruments, TSMC Taiwan Semiconductor Manufacturing Company, UMC United Microelectronics Company

M+W Zander's successful track of records reflects the acknowledgement of our customers worldwide as a professional and reliable partner for advanced industrial design, construction and facility management projects.

M+W Zander provides a wide range of services for high-tech buildings and production facilities for clients in the microelectronics, flat panel and pharmaceutical industries, featuring consulting, design and construction, as well as upgrades and operation of such facilities.

With more than 30 years of experience in cleanroom technology, M+W Zander is recognized worldwide as market leader in the fast-track design and build of turnkey wafer fabs.

At its Stuttgart headquarters and R & D center, the internationally operating company designs and manufactures advanced cleanroom components assuring contamination free environment.

Special building and HVAC solutions are realized also for other industries such as the automotive, food, chemical and power plant stations, as well as for theaters, congress centers and first-class hotels. M+W Zander ranks amongst Europe's leading providers of facility management services.

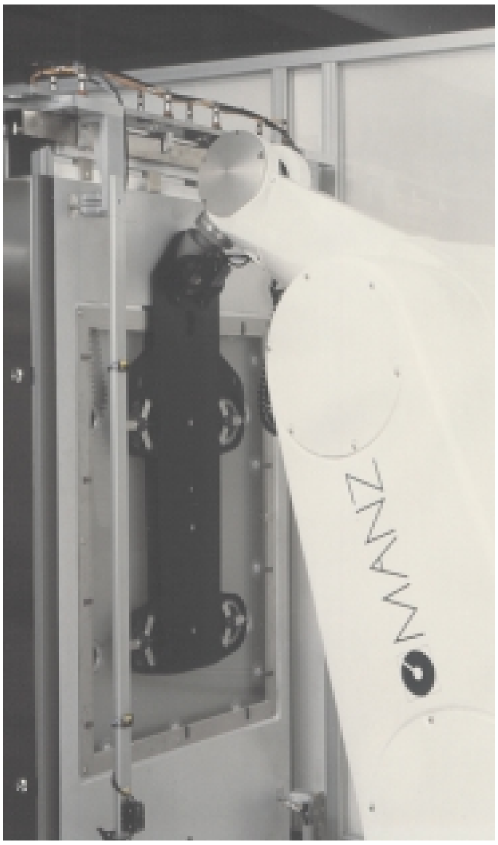
Manz Automation sees its role as that of a "System supplier for robotics and image processing" in the field of electronic production, small component assembly technology as well as the handling of small components and sensitive products.

Focal areas of the company's competence in the field of electronic production include odd component placement on printed circuit boards, flexible assembly of electrical and electro-mechanical devices as well as fully automatic final inspection and packaging.

Another key area of the company's expertise is in automated systems for sensitive products such as ceramic substrates, sensor systems, silicon solar cells, or substrates for flat panel displays. These systems are mainly used under cleanroom conditions.

Especially in the field of Flat Panel Display handling, Manz gained a lot of experience in recent years. Already in 1994, Manz installed its first fully automatic substrate handling system for an inline sputtering machine. After successful installations in Japan, Manz expanded its business activities also to the USA, Korea and Taiwan.

Today, Manz is in a position to offer fully automated handling systems for flat panel displays of all generations. Even oversized substrates can be handled safely and reliably with the Manz Robotic Systems.



6-axes Robot for substrate handling

Automation system for New Aristo sputtering machine

Main areas for the Manz systems are the loading and unloading of inline sputtering systems, but a wide variety of other different handling applications in the FPD manufacturing can also be performed by the Manz Robot Systems. Systems for the automation of inspecting, packaging and sorting of substrates are under development.

Various models of automation systems for different process needs and different substrate transportation methods are available. The supply of the substrates could be performed either by conveyor or by means of cassettes.

The Manz systems could be equipped with single or multi-cassette stages. In the maximum configuration, the Robot will be able to access four cassettes simultaneously.

The cassette stations provide interfaces for MGV's and AGV's. For fully automated production plants, the Manz Automation systems could also use SECS communication with Host computers.

For the handling of the substrates articulated cleanroom Robots with 6 axes are used in most cases. These Robots guarantee a very high precision, high dexterity, and extremely high reliability. As a result, a high production yield with almost no glass breakage can be achieved.

Manz Automation has a powerful engineering background with more than 14 years of experience in Robotics and cleanroom automation. Hundreds of installations and a worldwide customer base are testimony to the quality and reliability of the Manz Automation Systems.

Manz Automatisierungstechnik GmbH

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email: Info@manz-automation.com
Internet: www.manz-automation.com

Contact: Dieter Manz

President & CEO:
Dieter Manz

Sales and Service Offices:
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Manz Automation, Inc.
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North Kingstown, RI 02852
Phone: +1 · 4 01 · 2 95 21 50
Fax: +1 · 4 01· 2 95 21 90
Contact: Wolfgang Jeutter

Asia:
A Sales and Service Office in Taiwan will be opened soon
Contact: Dr. Steffen Gürtler

MERCK

Merck KGaA

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64293 Darmstadt
Germany

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Fax: +49 (0) 61 51 · 72 2000
Internet: www.merck.de

Prof. Dr. Bernhard Scheuble,
Chairman of the Executive Board

MERCK ORGANIZATION

- **Pharmaceuticals**
  Ethicals
  Generics
  Consumer Health Care
- **Specialty Chemicals**
  Liquid Crystals
  Electronic Chemicals
  Pigments/Technical Industries
  Cosmetics, Health, Nutrition
- **Laboratory Products**
  Laboratory Reagents
  Scientific Laboratory Products
- **Laboratory Distribution**
  Merck Eurolab
  VWR Scientific Products

Dr. Juergen Gehlhaus,
Vice President,
General Manager of the LC Division

That´s Merck

Merck is a globally operating group of companies for high-quality pharmaceutical and chemical products. With specialized know-how we focus on the sectors of Pharmaceuticals business, Specialty Chemicals as well as Laboratory Products and Laboratory Distribution. In 48 countries our activities are successfully conducted by 196 companies of the Merck Group – from research and development, production through to marketing and sales, with comprehensive offerings of products and services.

Ethicals used in the treatment of cardiovascular and metabolic diseases, generic drugs, products for self-medication, liquid crystals for displays, electronic chemicals for chip manufacture, pigments, cosmetic and pharmaceutical active ingredients, reagents and laboratory products – with these nine core businesses Merck generated sales in 2000 of EUR 6.74 billion.

In all of our activities we strive to bring benefits to people and to utilize natural resources responsibly. This will enable us to sustainably secure our economic success and our jobs, enhance our share-holder value, and fulfill highest requirements for our customers in the long term.

In this context, we see the keys to success in application-oriented research and development as well as close customer orientation in the markets. The primary guarantors of our success are the around 33,000 people working for the Merck Group worldwide, with their high level of commitment and competence, who are dedicated to the benefit of our customers and who influence, change and drive our company. We systematically exploit appropriate opportunities presented by continuous change in our long-term change process.

Liquid Crystals Division

Merck develops customer-specific liquid crystal mixtures for display manufacturers. LCDs are used in notebooks, PDAs and in navigation systems and as flat screens for PCs and TV sets. Liquid Crystals are also used in an ever-growing number of small-sized devices for consumer applications such as video and still cameras, electronic games and mobile phones and also for projection systems.

The liquid crystal mixtures are offered for all major technologies such as Twisted Nematic and Supertwisted Nematic LCDs, Active Matrix (TFT) LCDs, Vertically Aligned Nematic, Inplane Switching and Dichroic Displays, Bistable Cholesteric (SSCT) LCDs and all kinds of Micro-displays.

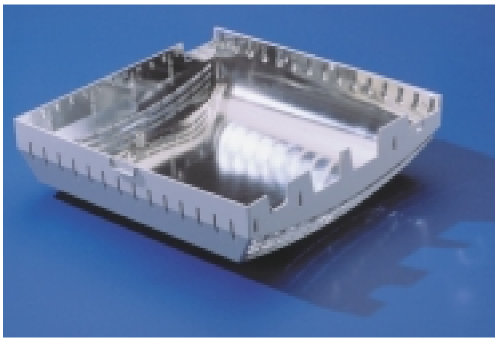
The LC Division also produces ITO (Indium Tin Oxide) coated glass substrates for flat panel displays in its manufacturing facility at Merck Display Technologies Ltd. (MDT) in Taiwan, and develops polarizers and optical films for the LCD industry.

Contact:

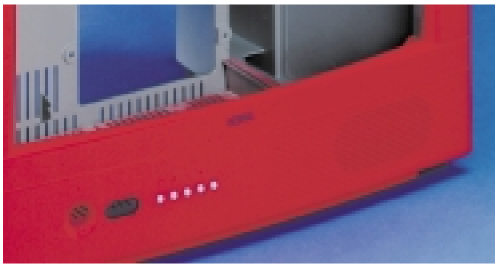
Merck KGaA
Liquid Crystals Division
Phone: +49 (0) 61 51 · 72 73 60
Fax: +49 (0) 61 51 · 72 31 32

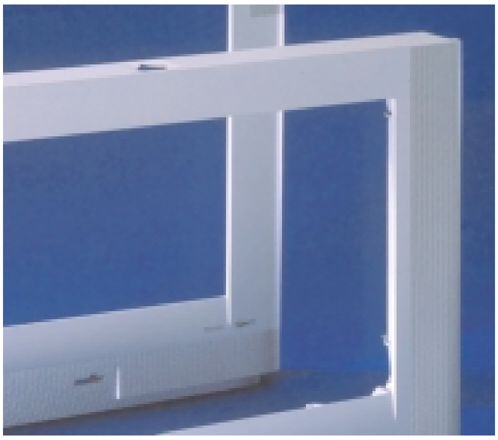
For a successful product it takes more then brilliant displays and powerful electronics: It takes appealing design, perfect housings, smoothly and precisely working functional elements.

Based on ideas from designers and engineers, ninka creates plastic injection moulded housing parts that meet the highest demands. Based on your plans and needs, and with your co-operation, we draw up the requirement profiles and specifications, develop concepts for solutions, design and realise products which turn out to be exactly what you had in mind. We transform ideas into innovative and long-lasting products. Quality conscious expertise, integral solutions and comprehensive service are the foundation of our work.

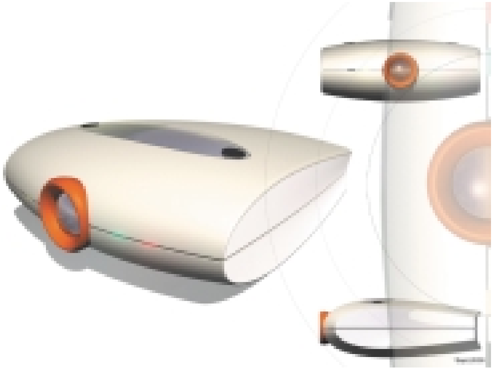


Our in-house workshop produces prototypes and samples so that we, together with you, can test the visual and functional properties of the products as realistically as possible. From less than one gram to more than 10 kilograms: Over 55 injection moulding machines shape ideas into products.





Whether suede painted or high-gloss, whether hot-stamped, multi-colour-printed or foil-laminated – the possibilities of finishing seem endless. Simple pre-assemblies as well as complex final assemblies – various joining and assembly processes are applied manually or on fully-automatic assembly lines.



Of course, we also provide logistics services on request. On the procurement end, for instance, we offer to purchase components or sub-assemblies that are integrated into the product during final assembly – this saves you work, time and space in material and product planning, stock management etc., and you can concentrate on essential matters.

The mission of our qualified workforce is to achieve maximum quality and customer satisfaction in all areas of work – we offer individual concepts for perfect solutions.

ninka® Ideen gestalten die Zukunft.

NINKAPLAST GMBH

Plastic Injection Moulding Painting, Assembly...

P. O. Box 35 06
Benzstrasse 6
32079 Bad Salzuflen
Germany

Phone: **+49 (0) 52 22 · 9 49-0**
Fax: **+49 (0) 52 22 · 2 11 69**
e-mail: **info@de.ninka.com**
Internet: **www.ninka.com**

Founded: 1928
Staff in 2000: 475
Turnover in 2000: € 56 million

Optrex Europe GmbH

Seligenstädter Strasse 40
64832 Babenhausen
Germany

Phone: **+49 (0) 60 73 · 7 21-0**
Fax: **+49 (0) 60 73 · 7 21-2 30**
e-mail: **info@optrex.de**
Internet: **www.optrex.de**

Managing Director:
Kazutoshi Sawada
Martin Tibken

Founded: 1991

Staff in 2000: 950

Sales in 2000: approx. 100 million Euro

Production sites:
Germany, Czech Republic

Headquarter: Babenhausen, Germany

Contact for Service and Sales:
Annkatrin Strubel:
Phone: +49 (0) 60 73 · 7 21-2 49

Optrex Europe GmbH (OEG), located in Babenhausen near Frankfurt, Germany, was established in 1991 as a joint venture between Optrex Corporation, Japan, and the former LCD-section of VDO (now Mannesmann VDO AG). Optrex Corp. holds a share of 75 % in OEG.

OEG operates in the following two fields of LCD-business:

European development, production and sales of LCD panels and modules

The products are developed and produced in Babenhausen. Assembly is done in the Czech Republic. Approximately 90 % of the European products are related to the automotive market and cover a woldwide market share of about 50 %. Devices for telecommunication are gaining increasing market share. Proprietary high reliability technologies were developed by OEG and are under continuous improvement. All products produced at Babenhausen are designed according to customer specifications. About 300 employees are working at Babenhausen, approx. 650 in the Czech Republic.

Trading with LCD-products from Far East production sites of Optrex Corp.

Development takes place at Tokyo, production at different locations in Japan and China. The major share of products is for the telecommunication market. Optrex produces both standard parts and custom specific parts. A wide range of products are available, from monochrome alphanumeric Displays to full colour graphic modules.

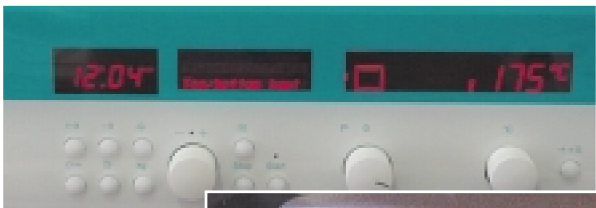
The turnover of OEG increased from 18 million Euro in 1991 to more than 100 million Euro since 1998. The total turnover in the Optrex Group was about 800 million Euro in 2000. Approximately 2,200 people are presently employed.

Due to a strong market growth, OEG recently installed an entire new (third) line. This makes OEG one of the world's most modern LCD production facilities. Capacity was increased and latest technologies were invested in to secure the production place in Germany and to increase quality to the customer. The capacity of panel production increased from about 25 million to about 45 million cm^2 per month.

OEG's LCD-products from the Babenhausen factory are based on TN, proprietary MTN, STN, FSTN and DSTN technologies as well as on different interconnection technologies including COG. Optrex produces Displays for nearly all applications.

In the most european cars you can find at minimum one Optrex LCD and Optrex LCDs can also be found in cell phones, white ware products, clocks or information boards.

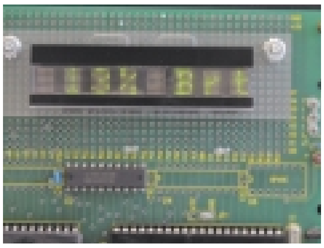
OEG is certified according to ISO 9001, VDA 6.1 and QS 9000.



German Flat Display Forum

The product portfolio of OSRAM Opto Semiconductors (OSRAM OS) encompasses display solutions, LEDs in all colours and a variety of packages, infrared detectors and emitters, high-power laser diodes, and modules for lighting and signal technology. Displays are a significant market for OSRAM, since, as a future-oriented technology, they open up vast growth opportunities.

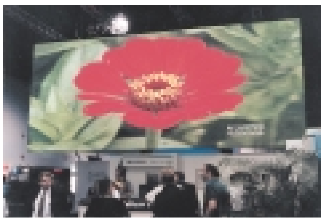
Intelligent Displays



Typically these consist of 5x7 LED chips per digit, with 4 to 8 digits in a row. Additionally, a driver IC is incorporated into the Intelligent Display, enabling external control, e. g. via ASCII. Intelligent Displays can be used anywhere simple alphanumeric information is to be displayed. Only individual characters can be shown, in contrast to full matrix displays like LCDs, where each pixel is separately addressable, allowing pictures to be displayed, as e. g. in mobile telephones.

The advantages of Intelligent Displays: they themselves emit light, have high contrast, and are quite bright. They have usable lifetimes of 100,000 hours, and are mechanically stable over a temperature range of –40° to +85°. In addition, they have a wide viewing angle, and consequently offer excellent readability. Main applications are: seat reservation systems on trains, digital set-top boxes, cellular telephones, and top-range Hifi systems, etc.

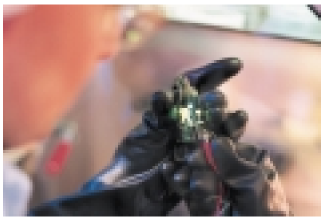
LED Displays



Indoor full colour LED Displays are mainly made with MULTI-LED from OSRAM OS. In the future there will be more displays with single-colour LED. A multi-coloured display can be made by placing several different colours close together (e. g. SmartLED, MiniTOPLED, TOPLED). Applications for LED Displays correlate with pixel pitch, i. e. the viewing distance, different arrangements may be needed to achieve optimal images. 10mm is a standard pitch, but 6–7 mm are also under test. The special feature of LED displays lies mainly in their function as eye catchers. They are very bright compared with other technologies.

Indoors (e. g. in sport halls and arenas) they can attain brightness from 320 to 4000 cd/m^2 (@ 10mm pixel pitch) depending on the LEDs used. By way of comparison, a TV screen attains 400cd/m^2. The size of LED displays is flexible in the sense the desired dimensions can be achieved by using individual modules (usually of the size of 16 x 16 or 16 x 32 pixels) as building blocks. Despite this, no “jailhouse effect“ results, e. g. horizontal or vertical bars. The impression of a uniform image persits. The main areas of application for these displays are in advertising (trade shows, shopping centres, billboards), entertainment (sports events, concerts), and information (airports, railway stations).

OLED Displays



OLED Displays radiate in ranges of wavelength determined by the organic materials utilised. In contrast to LCD displays, OLED displays emit light themselves. They have high contrast and exceptionally good legibility, even at a wide angle. Because of their very short response times, OLED displays are video-capable over their entire operating temperature range. It is possible to form dot matrix displays, segmented displays, and seperate icons. These characteristics open up OLED display use in mobile phones, automobiles and household appliances.

OSRAM Opto Semiconductors GmbH & Co. OHG (OSRAM OS), founded on 1 January 1999, is a joint venture between OSRAM GmbH and Infineon Technologies AG. OSRAM OS was established to continue the activities of Siemens in the optoelectronic semiconductors business. OSRAM GmbH holds a majority share of 51 % and is responsible for the executive management of the company.

Opto Semiconductors OSRAM

OSRAM Opto Semiconductors GmbH & Co. OHG

Wernerwerkstrasse 2
93049 Regensburg
Germany

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Fax: +49 (0) 9 41 · 2 02-12 24
e-mail: pr@osram-os.com
Internet: www.osram-os.com

Managing Director:
Dr. Ruediger Mueller

Founded:
1960 by Siemens Semiconductors, 1999 as Joint Venture of OSRAM GmbH and Infineon Technologies AG

Staff in 2000/01:
1 113 in Germany, 3 113 in Malaysia, 60 in USA

Production area:
10,000 m^2 in Germany, 23,000 m^2 in Malaysia

Headquarter:
Regensburg, Germany

Sales:
EUR 281 million in 99/00

Contact for Service and Sales:
for Intelligent Displays and OLED
Ms. I. Reisinger
Phone: +49 (0) 9 41 • 2 02-24 71

for Intelligent Displays and OLED in USA
Mr. K. Drexler
Phone: +1 · 4 08 · 7 25-35 27

for LED Displays
Ms. Swenja Heller
Phone: +49 (0) 9 41 • 2 02-12 42

Sales via distributors:
see www.infineon.com/business/index.htm

PolyDisplay ASA

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Norway

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Fax: +47 (0) 33 46 19 39
e-mail: hq@polydisplay.no
Internet: www.polydisplay.no

PolyDisplay ASA is a Norwegian company established in 1991. The company is owned by private, industrial and venture capitalists, the largest being Telenor Venture AS. The PolyDisplay Group counts some 65 employees today, and is growing fast.

Contacts are welcome at:
Phone: +47 (0) 33 48 27 00
Fax: +47 (0) 33 46 19 39
e-mail: hq@polydisplay.no
Internet: www.polydisplay.no

Operational subsidiaries:
Locus AS
Sandefjord, Norway
TechnoDisplay AS
Oslo, Norway
PolyDisplay AB
Stockholm, Sweden
ImageDisplay ltd.
London, UK
PolyDisplay Inc.
Michigan, USA
PolyDisplay SA
(SIDSA Sistemas)
Madrid, Spain

New generation of LCD displays emerging

In co-operation with SINTEF (Norwegian Center for Industrial and Technological Research) and the Norwegian Defence (Army Material Command), PolyDisplay is developing a new generation of display technology based on smectic liquid crystals (SmA) and new production process.

The technology is protected, demonstrated, documented and 100 % owned by PolyDisplay.

Picture without power

The EASL (Electrically Addressable Smectic A Liquid) is characterised by its ability to achieve several stable positions between two extremes: transparent and reflective, by applying electrical fields across the liquid crystals.

We call this quality multistable.

The multistability of EASL gives the display the ability to indefinitely maintain the structure of the molecules set, without any power.

The EASL DMD™ screen has complete optical memory

This memory phenomenon offers a number of advantages. In applications where continous updating of the image is not necessary – as in word processing, map- and navigation systems, still graphics and the web/internet. Power consumption is reduced dramatically and battery lifetime substantially extended.

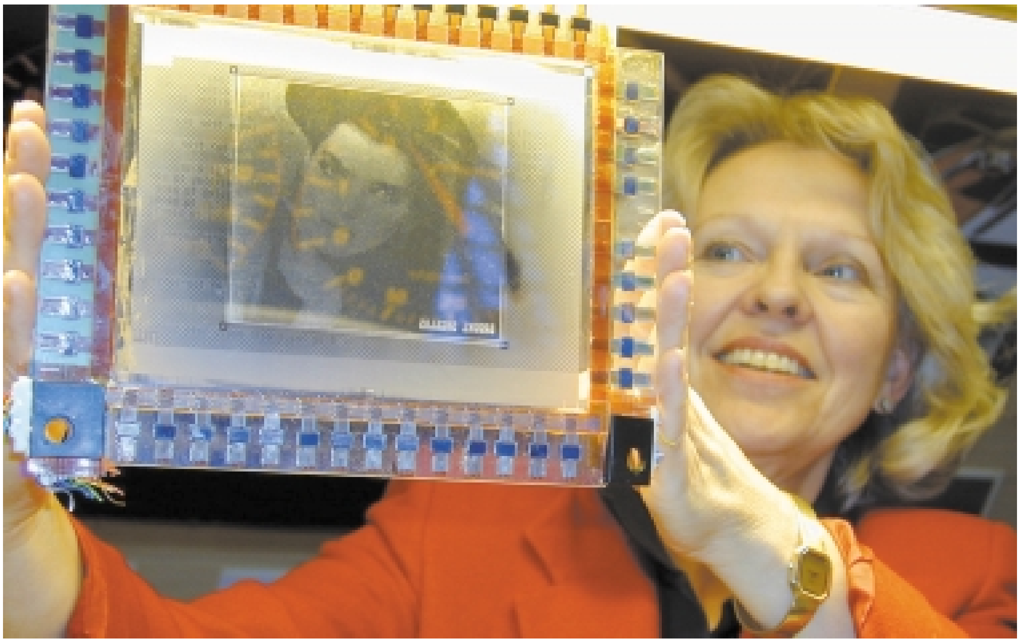
By this quality EASL DMD is radically different from current LCD technologies (monostable) where the picture is lost as soon as you turn off the power.

Traditional twisted light treatment has severe drawbacks

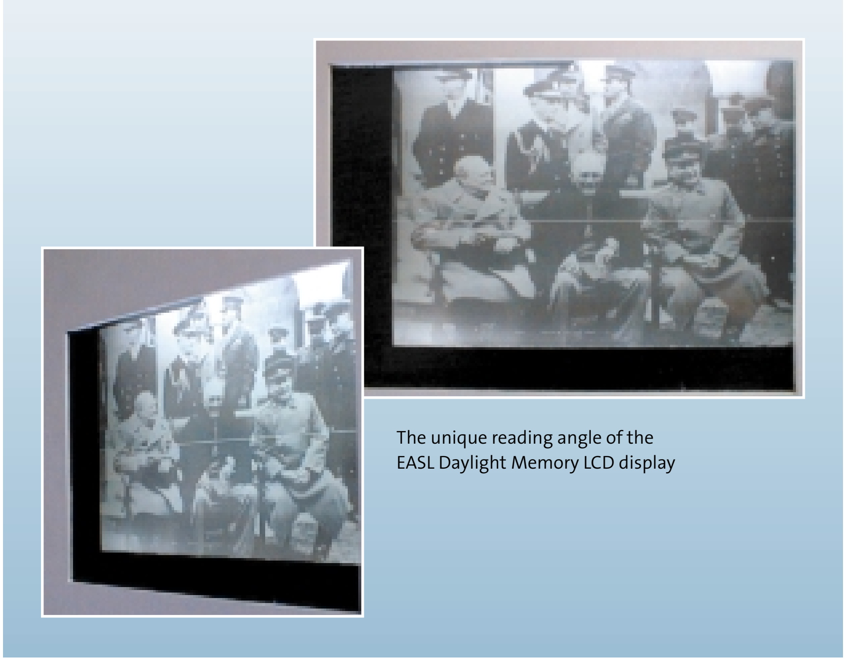
In addition to being heavy on power consumption, todays common displays (twisted nematic) utilize a technique of turning the light from 0 to 90 degrees (or more) through the display. The more twist, the more transparency.

This techique requires polarizing filters on both sides of the display to help our eyes see the image.

This process absorbs light and restricts the viewing angle severly. The demand for evenness in the cell gap, makes curved/flexible displays difficult.



The EASL Daylight Memory Display keeps the image on the display without power supply, and needs power only for updating



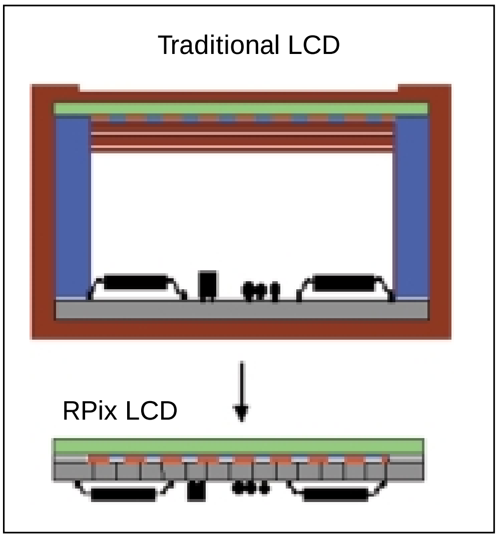
The unique reading angle of the EASL Daylight Memory LCD display

EASL DMD works like a blinder

In EASL no twisting of light is necessary. When the LC molecules are aligned, they become transmissive, and when scattered, they become reflective. In this way no polarizing filters are needed.

This quality gives EASL DMD much higher light efficiency (>90 %) and transmission, and better contrast and viewing angles.

Incoming light from external sources (e. g. sun-light) actually contributes to better images, as compared to current LCDs where "wash-out" is often a problem. EASL may be compared to "print-on-paper" – the more incoming light the better the readability. In addition, there is less need for eveness in the cell gap, making it better suited for curved displays.



RPix patent reduces production costs dramatically

Ultra slim display modules with new patented production method

By integrating the printed circuit as part of the LCD panel, several production steps and connector problems are eliminated. The process is applicable for twisted nematic as well as smectic technologies. Production cost and thickness of the modules are dramatically re-duced.

Strategic partners wanted

The Board of Directors is aiming towards the stock exchange – in Scandinavia first, then in Europe and the USA – leaving the dates open for perfect timing.

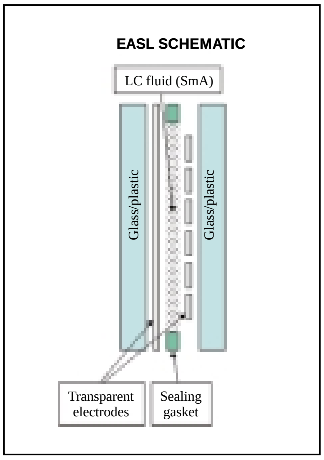
Before such a decision is made, strategic part-ners in specific countries and markets will be chosen for the commercialisation of the first applications and for the further development of the technology's potential.

In the short term, the technology has signifi-cant business potential in the industries of all kinds of electronic price tags, information boards – in-door and out-door, and displays in vehicle fleet management and information systems.

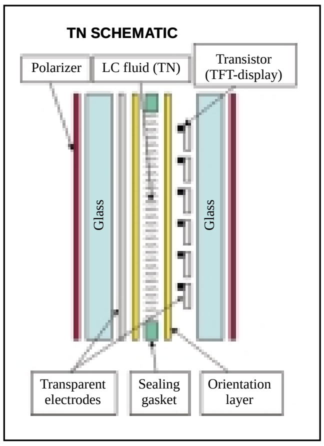
Paradigm shift

In the long term, the technology represents a paradigm shift on the arena of digital displays, as the SmA holds optical memory and has the potential of taking full advantage of modern processing and transmission equipment.

A partner that can add commercial and indus-trial force will benefit from PolyDisplay's core of knowledge, documentation and patents.



Traditional twisted nematic LCD display



The simplicity of the EASL LCD display

Liquid Crystal Technology for Tomorrow

Rolic Technologies Ltd.

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4123 Allschwil
Switzerland

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Fax: +41 (0) 6 14 87 · 22 99
Internet: www.rolic.com

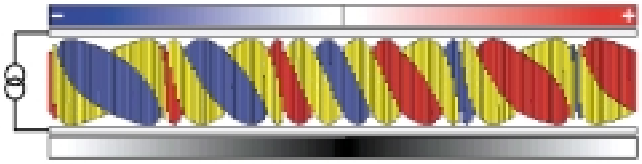
CEO: Dr. Martin Schadt
MD: Graham Johnson
Founded: 1994
Employees in 2000: 45
Location: Allschwil
Switzerland
(close to Basel airport)

Company Profile

Rolic is a research company that invents and develops sophisticated optical effects and effect-specific functional materials, incorporates these into today's and tomorrow's devices and thereby demonstrates fascinating possibilities and exciting new applications. We license our technology portfolio and help our partners in the manufacturing industries to create a wealth of new products.

Photo-alignment of Liquid Crystal Displays

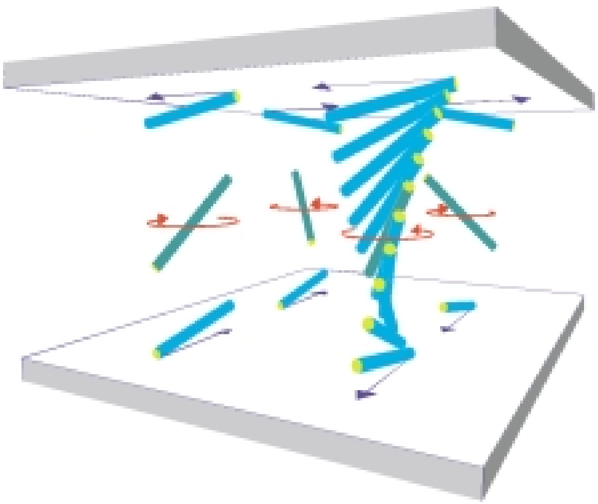
Key trends in LCD research at present include improved optical performance – specifically improvements to the viewing angle.



Rolic has invented and patented a new, optical LCD alignment technology. Rolic's **Linearly Photo-Polymerizable (LPP)-technology** aligns and tilts the liquid crystal molecules in an LCD using polarised light and allows for the creation of multi-domain pixels within the display.

This technology replaces mechanical alignment using brushed polymer films, which can result in poor yields due to non-uniformity of the brushed substrate, generation of dust particles and electrostatic charge.

By using LPP-photo-alignment, therefore, LCD manufacturers can increase yields, lower costs and improve optical performance, especially for large area LCDs and LCDs integrated on silicon substrates (LCoS) used increasingly in the industry.



Optical Wide View Films

The combination of the LPP technology with Liquid Crystal Polymer (LCP) thin-films – invented and patented by Rolic – enables a plethora of novel **optical LPP/LCP-thin-films.** These films can be specifically designed to substantially improve the viewing angle of LCD's used in notebooks, PC-monitors and car navigation systems and open-up numerous new display- and non-display related applications.

Deformed Helix Ferroelectric LCD's

Rolic's research into **deformed helix ferroelectric (DHF)** liquid crystals has led to a breakthrough technology which improves upon the performance of today's twisted nematic thin-film transistor (TN-TFT)-LCDs.

Rolic's patented DHF technology enables LCD's to be used in very fast responding colour TV-projectors, exhibiting fast response even at low temperatures.

Rolic's DHF displays generate angular independent images similar to prints, response times that are more than hundred times faster than current TFT-LCD's and the capability to display grey levels, and therefore full colour images.

Company Profile

As an engineering company, Schiller is focusing on the development and implementation of user specific turn key solutions for the manufacture of innovative, future-oriented products designed for cutting-edge technology markets.

The company's aim is to solidify and further expand its market position through engineering flexibility and superior technical expertise.

Since its foundation in 1978, Schiller's focus is to establish itself as a medium-sized company group with activities in the international global marketplace. The company, privately owned, today is as it was 20 years ago: with emphasis on full customer satisfaction. Customer satisfaction does not only apply to product quality, but also to general communication, and to cooperation in supporting and servicing the customer base upon completion of system installation. This is the motivation for Schiller management and employees alike to continue to striving for even more excellence.

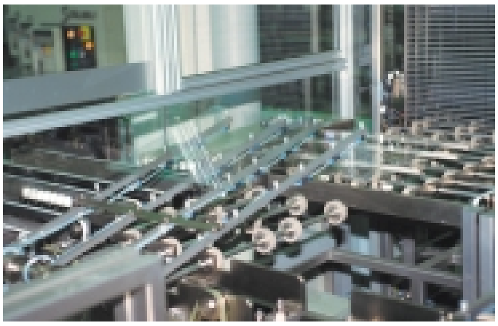
Teamwork plays a key role in the company's success; new and challenging tasks are eagerly accepted. Schiller customers reap the benefits, because they know that they can rely on highest product quality as well as service and support standards.

These qualities and expertises continue to strengthen Schiller's market position as an innovative company in a more and more interconnected and competitive world.

Benefit from SCHILLER experience – automation for flat panel display manufacturing

Flat Panels and LCD displays with their wide range of applications represent one of the biggest growth markets. Automation of the various production processes ensures highest product quality due to less people in clean room, elimination of operator induced errors, constant high manufacturing availability of the equipment; resulting in reduced dependence of qualified required human resources and as such in lower operating cost and higher productivity.

Schiller designs and manufactures customized turnkey solutions with design criteria for highest standards in product quality, superior performance and reliability, while relying on extensive experience gained since 1994 in implementing numerous automation projects in the field of glass substrate handling.



Automation systems

Individualized automation solutions in the manufacture of flat panel displays combined with Schiller's modular system design concept provide a solid market basis for the wide range of applications from "bare glass" manufacture, ITO – glass substrates, to TFT and color-filter glass production, all the way to finished displays.

The modular product concept also provides the basis for achieving maximum flexibility and offers the best possible compliance with regard to customer-specific requirements.

The inline cluster solutions, configured according to specific customer requirements, include automation and integration of various required production equipment (such as Cleaning/Washing Stations, Sputtering Equipment, Optical Inspection Systems) and featured implementation of accessory units (such as Airknife, Packaging Station, Plate-Labeling and Marking).

Schiller's product offering includes also off-line automation stations for robotic load/unload of cassettes and PP-boxes, interface to customer AGV or MGV transport systems, multi-purpose handling stations from and to stand-alone equipment used e. g. for automatic optical inspection-, film-deposition and -etching equipment, photolithographic equipment and more.

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Internet: **www.sschiller.de**

Managing Directors:
Sieghard Schiller, Stefan Schiller, Joachim Schiller, Guni Schiller

Established: 1978

Employees 01/01: 230

Sales 1999: DM 58 million

Subsidiaries:
- Schiller + Uhr Sondermaschinenbau GmbH & Co. D-07629 Reichenbach/Germany
- Schiller Automation Systems LLC, Fayetteville / Atlanta, GA – USA
- Taiwan / Asia, foundation spring 2001

Representations:
Western Europe, Canada
– for details see www.sschiller.de

Automation and Production Systems for the Manufacture of:
Data Storage, Semiconductor, Flat Panel Display, Microelectronics and Smart Cards

industrial siemens
flatpanel technology

Siemens I-SFT

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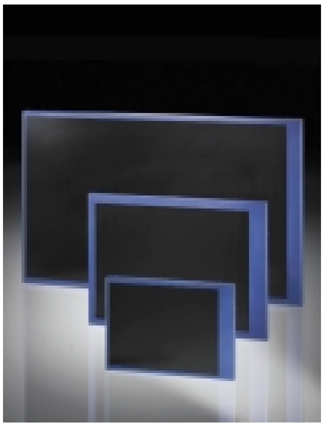


Brighter than daylight

was the headline as Siemens presented the world's first daylight readable flat-screen at the end of 1995. Thanks to continuous systematic development and optimization of the TFT technology, Siemens successfully generated ten times higher brightness values than standard.

Beside their high brightness, I-SFT displays are also known for their extreme ruggedness.

The applications for the I-SFT displays can be found in the transportation and traffic sector, for example railroad technology and special vehicles, in POI/POS systems, machine construction and mining, as well as aviation and the naval sector.

A current example for the use of the I-SFT is the new German high speed train ICE 3, where the displays are installed in the cockpit at the very forefront of the train.

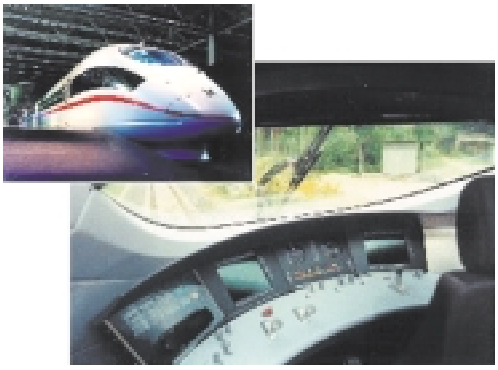
Thanks to its proven reliability and durability, I-SFT saves the user a great deal of maintenance costs.

Even Eurocopter is using I-SFT technology in its Allweather Rescue Helicopters. In these helicopters, the classic cockpit instruments are combined with displays, showing additional information required for the system's allweather capability.

The I-SFT product family:

- Sizes from 10.4“ to 15“
- Extended temperature range
- Full daylight readability
- Rugged construction

Today's I-SFT product family consists of industrial displays in different resolutions and sizes, some of which are capable of withstanding temperatures from -40° C to +95° C.



The latest development is a highly integrated I-SFT 10.4“ flat screen with XGA resolution and adjustable brightness in a range from 1 to 1,000 cd/m^2. The display features are compact design and high degree of efficiency resulting in low energy consumption.

In the years to come the product portfolio will fan out even more. The plan is to build I-SFT displays in sizes ranging from 7“ to large 24“. New ultra-high-bright displays will have brightnesses exceeding today's maximum of 1,000 cd/m^2.

I-SFT:
... all the way up to customized projects

Based on a large number of successfully completed projects, including, for example, system solutions for railroads in both Europe and Asia, Siemens I-SFT has at its disposal sound technical know-how and detailed market knowledge. This excellent basis and the necessary technical competence enables Siemens I-SFT to develop and manufacture displays to customer specifications.

I-SFT at its Wendelsheim location
– Competence Center for flat screens

By concentrating its I-SFT flat screen activities in Wendelsheim, Siemens is pursuing a lofty objective. The MikroForum in Wendelsheim is to be turned into the European Competence Center for flat displays, and is thus to lay the cornerstone for a German flat display production for future-oriented top-notch products.

Plasma-chamber

TePla AG develops and produces low pressure plasma systems for industrial and R + D applications. TePla is technological leader in the low pressure plasma technology sector. Our equipment is sold worldwide in close cooperation with our regional distributors. Subsidiaries have been found in Carrollton/Texas (USA) in 1999 and in Saint Quentin en Yvelines (near Paris/France) in June 2000. To expand the sector Industrial/Medical TePla acquired in September 2000 the US-enterprise MetroLine Industries in Corona/California (USA). Since June 1999 the TePla AG is listed on the German “Neuer Markt”.

Within the last few years we focused on industries involving semiconductor, printed circuit boards, high density interconnect technologies, surface technology as well as laboratory fields. Due to experience for years and consequent further development of the products TePla has acquired a leading position in plasma treatment for printed circuit board manufacturing and surface pre-treatment.

TePla manufactures high quality standard machines and custom systems in compliance with today’s strict requirements for safety, environmental protection and user-friendliness. Our product line ranges from small laboratory and pilot plant machines to industrial scale systems. In product development and problem solving we work closely with our customers to meet their current needs and to develop long term business relationships.

In the field of Semiconductor and Flat Panel Display TePla provides the following manufacturing and test equipment:

- Microwave plasma asher
- Dry plasma decoating systems
- High-density ECR plasma sources
- Systems for slipline detection in SI-Wafers
- Systems for thin film measurements
- Systems for mechanical inspection of cassettes

In 2000 TePla AG started the production of the Plasma System FPD40 to become a major player in the booming Flat Panel Display manufacturing market. This dual chamber system is an advanced Microwave Plasma Treatment equipment for Flat Panel Manufacturing and represents a superior solution for ITO-Conditioning and Resist Stripping. This most productive ITO-tool is designed for state-of-the art applications for 400x400 mm panel sizes and also can be used for other substrate sizes by easy exchange of retrofit kits. A central robot with a prealignment unit transfers the substrates precisely from 2 cassettes to the process chambers. The chambers are equipped with an uniform and efficient large area microwave plasma source for high rate ITO-treatment with the option of additional heating of the substrate. The FPD40 can also be used for resist stripping under control of a fully automated end point detection unit and is easily operated by a touch screen as the interface to an industrial PC with a sophisticated software solution for advanced process engineering.

TePla AG

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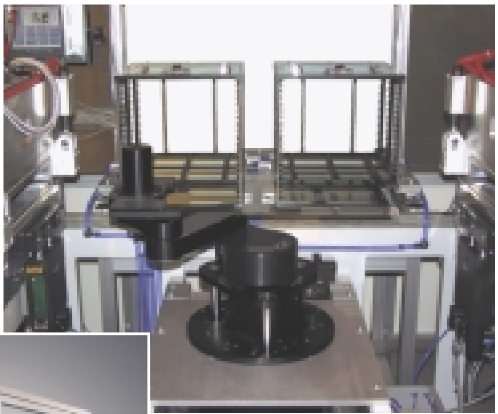

Interior view with robot and magazines

Plasma-system FPD 40

4D-Vision® GmbH

4D-Vision® GmbH

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e-mail: **info@4d-vision.de**
Internet: **www.4d-vision.de**

4D-Vision® Ltd. –
A better way to see the world

4D-Vision® Limited was established in August 1998 with the aim of developing, marketing and producing new techniques, products and applications for autostereoscopic imaging. So far, the company has been extremely successful, its research resulting in the registering of twenty-seven patents for an autostereoscopic technique for projecting visual images. 4D-Vision®'s techniques project images in 3D, which helps observers view large stretches of terrain or even gain a unique insight into the internal working of the human body. One technique in particular projects a variety of visual perspectives, thus presenting the observer – or observers – with information that they can analyse without having to use additional viewing apparatus. During the "Photokina" exhibition in Cologne on September 20th 2000, Armin Grasnick, CEO at 4D-Vision®, launched the first real 3D movie sequence using methods developed by the company. The success of the sequence was immediate, attracting the interest of 3D specialists around the world. It proved a major step towards the company's vision of becoming market leader in the area of spatial representation and establishing 3D-TV worldwide by 2010.

As regards to 4D-Vision®'s technique there are eight or more privileged points of perspective that come into play. Information in separate parts of a specific point of perspective becomes visible at a particular positioning of the eyes, while from a different position, other information from a different perspective becomes visible. This occurs due to the directions of expansion over the screen being dependent on the wavelength of the selected perspective, in line with the technique of 4D-Vision®. The combination of this partial information into the whole of the points of perspective is represented by the subpixels of a viewing apparatus. According to this technique the generation of the necessary points of perspective can be rationalised in this way; although the eight or so perspectives are necessary, this requires nowhere near as much as eight times the effort. Therefore it becomes possible to create the perspective where autostereoscopic depictions of images can show images in motion in real-time.

Armin Grasnick, general manager of 4D-Vision GmbH, with a 15"-3D-LCD (4D-15)

Besides enabling the company to achieve its objective of establishing 3D-TV worldwide, the power of 3D representation in line with the 4D-Vision® technique has opened up a practically limitless field in many areas of everyday life, e. g. advertising and marketing. With the installation of attractive "Points of Sales" or "Points of Interests" at exhibitions, fairs etc. and by using large-size 3D displays, a message aimed at potential consumers does come across much more effectively. This is due to the new 4D method transferring a greater amount of information through realistic representation.

Medical ultrasonic equipment by Toshiba Medical Systems Europe (TSME) connected with a 4D-15 (in the background on the wall): at the "Dreiländertreffen Ultraschall" (6th to 9th of September 2000 in Vienna)

50"-3D-Display (4D-50) at Pioneer's exhibition stall on the "Photokina" exhibition (20th to 25th of September 2000 in Cologne)

A scene from MDR-news (Thuringia) on 14th of November 2000 showing Thuringia's Minister President Dr. Bernhard Vogel awarding the founder's prize "Marktlücke"

Sample construction; a scene from the science magazine "nano" on 3sat on 10th of July 2000

Moreover, 4D-Vision®'s technique provides valuable support in the field of diagnostics for the evaluation and transferral of visual diagnostic techniques into 3D representations. Apart from the evaluation of visual data from a 3D ultrasound scanner, the pin-sharp pictures of a digital computer-tomographer can be reproduced as 3D images, which are far superior to the previous fiddly operations of 2D X-ray pictures. Subsequently, last year 4D-Vision® made an agreement with one of the worlds major suppliers of ultrasound equipment, Toshiba Medical Systems Europe (TMSE) B. V., to integrate its 3D-displays into TMSE ultrasound stations. While 3D pictures allow for tailor-made planning in the operating theatre for implants and operations, they also enable the users to make a more precise diagnosis since they see a 3D picture in front of them that is extremely true to reality. Of course, working without distracting additional viewing apparatus facilitates working conditions for medical staff, e. g. surgeons, especially during long operations. What is more though, other medical staff in the operating theatre, e. g. students and nurses, will also be able to follow the operation in 3D images. This technique is therefore also perfectly suited for study purposes or for long distance diagnoses.

Since 4D-Vision®'s technique delivers spatial representations of complex CAD-drawings on one screen it enables the user to watch realistic perceptions of topographic objects and renders life-like representations of natural or technical details in one picture. Thus another potential field of usage is the 3D representation of architectural and design models. Here 4D-Vision®'s technique offers users realistic 3D impressions, something that was not possible hitherto with the standard photographic images. Likewise, objects, interiors and buildings that have not yet been created or are still in the planning stages on a PC can be shown to the customer in a form that is true to reality.

4D-Vision® produces 3D-displays of various sizes which are based on flat panel displays. They provide a spatial impression for a plurality of observers. Each 4D-Vision® 3D-display is capable of reproducing true colour images (preferably 24-Bit).

If you wonder about the company's name, 4D-Vision®, here is the clue: 3D displays provide a temporally changing three-dimensional impression, hence it is scientifically correct to speak about four dimensions.

50"-3D-Display (4D-50) based on a plasma-display by Pioneer

FEP

Institut Elektronenstrahl- und Plasmatechnik

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Internet: www.fep.fhg.de

Director: Prof. Dr. Günter Bräuer

Founded: 1992

Staff in 2000: 98

Production area: 6500 m^2

Locations: Dresden, Stolpen-Helmsdorf (Germany)

Contact (Public Relation):
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Technologies of FEP

One of the major fields of FEP's activity includes high-productivity coating of large surfaces by sputtering. In the past, several projects related to display technology were accomplished. As a result FEP technology is used in industrial scale manufacturing processes by both European and Asian companies.

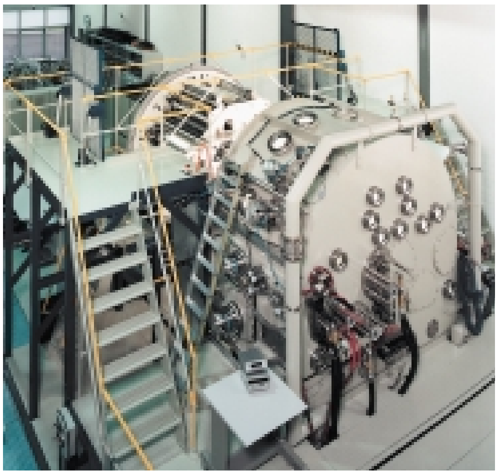
The projects covered the following fields of interest:

- Optical layer stacks (e. g. ARAS)
- Low resistivity transparent conductors for both glass and plastics
- Barrier layers against water vapor and oxygen
- High rate deposition of MgO

Apart from the traditional glass substrates, new display materials like polymer webs and plates can be coated.

FEP focuses its activities on process research and development and all the connected issues such as monitoring, quality control, reproducibility, up-scaling and productivity. Particular emphasis is placed on the complex development and testing of technologies and specific hardware under production conditions. FEP has the necessary equipment to test its technologies on an industrial scale. Two pilot plants are shown in the illustrations.

The FEP closely cooperates with other institutes of the Fraunhofer group and several other research institutes and companies in a great number of projects. Thus both the high technological level and the applicability of the results are ensured.



Pilot Sputter Roll Coater FOSA 600

Substrate: Bandware, Polymer webs

Deposition width: 600 mm

Separately pumped zones: 6

Web thickness: 12–200 µm

Web speed: 0.1–100 m/min

Sputter equipment:
Up to 6 Dual Magnetron Systems (DMS) or single magnetrons

In-line surface treatment:
Plasma etching (Web Treater)

In-line monitoring:
Reflectance, Transmission

ILA S 750

Substrate: Glass, Plastic, Metals

Substrate size:
up to 400 mm width x 600 mm height

Number of deposition zones:
4 (double side)

Sputter equipment:
4 Dual Magnetron Systems (DMS) and
4 Single Magnetrons

In-line surface treatment:
Sputter etching (r. f.), Heater

Special features:
Input/Output connected to cleanroom

The fields of activity of the glass coating department include the development and optimization of optical layer systems on flat substrates, as well as the advancement of the Pulse Magnetron Sputtering (PMS) technology for the reactive deposition of dielectric layer materials including the stabilization of the reactive processes mainly by means of a plasma control unit (PCU).

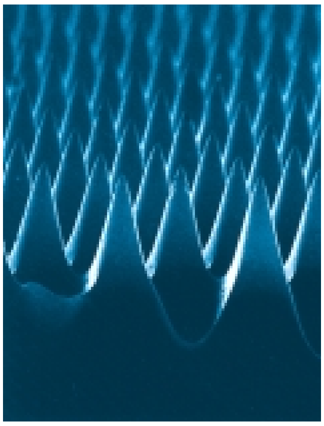
Service of FEP

- Applied fundamental research
- Feasibility studies
- Pre-production qualifications
- Pilot production
- Integrated Packages for production consisting of
  - Hardware (key components)
  - Technology transfer and know-how
  - Training
  - Operation and maintenance manuals
  - Retrofit of existing production coaters
  - Providing equipment suppliers with pretreatment and coating sources, key components and technology to diversify markets and increase sales
- After sales services and process consulting

Micro-Structured Surfaces for Display Optics

Micro-structured plastic components are already used in displays today to improve the luminance and homogeneity of the background lighting, or as anti-glare surfaces to eliminate reflections.

The Fraunhofer Institute for Solar Energy Systems ISE is developing new micro-structures for display applications. “Moth-eye structures” suppress reflections as effectively as high-quality interference film systems, but for considerably lower production costs. Light-scattering panes with customised scattering profiles, which usually differ in the horizontal and vertical directions, can be applied in projection displays and for background lighting.



Fraunhofer ISE has particular competence in the optical modelling, structure generation and characterisation of micro-structured surfaces.

Holographic exposure of photoresist is the technology we use to generate the structures. In this method, a laser beam is split, expanded and superposed. Interference patterns, with which the photoresist is exposed, occur in the superposition zone. The surface structure is formed during development of the photoresist, depending on the exposure used. Both periodic and irregular structures with dimensions from 100 nm to 100 µm are possible. At present, we create homogenous micro-structures over areas of up to 60 x 80 cm^2.

The original structure is reproduced in polymer sheets or films by micro-replication. We co-operate very closely with companies in Europe and USA which specialise in micro-replication. As a result, our developments can be quickly transferred to manufactured products.

Fraunhofer Institut Solare Energiesysteme

Fraunhofer Institute for Solar Energy Systems ISE

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Take a close look at our core competence

Are you looking for an innovative solution for flat panel display, semiconductor or microtechnology? Then take a look at the range of services we offer in the following fields of work:

Production:

Production environment, production scheduling, quality control, information management

Tools and equipment:

Layout and control, automation solutions, interfaces, cleanroom suitability studies

Processes:

Contamination avoidance, inspection and monitoring, cleaning, microstructuring, microassembly and adjustment, particle-measuring techniques

Products:

Specific manufacturing (e.g. design for cleanliness or microassembly), specific applications (e.g. modularization of microcomponents)

Take advantage of our knowledge, creativity and experience

With our competence, we are in a position to provide you with the best solutions and concepts for the production of flat panel displays:

- Manufacturing Execution Systems (MES), its specific requirements for LCD-manufacturing, evaluation concepts and interface specifications;
- Full-chain, single-display traceability and identification throughout the entire LCD manufacturing process, from TFT-process to module assembly;
- Strategies and simulation for full automation and transport system integration (e.g. AGV) into front-end and back-end manufacturing processes.

Fraunhofer Institut Produktionstechnik und Automatisierung

Fraunhofer Institute for Manufacturing Engineering and Automation IPA

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IMM – Progress Through Microtechnology

Since its foundation in 1990 the Institute of Microtechnology (IMM) is engaged in the field of applied R&D. **IMM develops innovative products and techniques** in close collaboration with other research institutions as well as with worldwide industry. Important fields of operation comprise microoptics, thin-film technology, x-ray lithography, microelectroforming, micromoulding, laser lithography, mechanical ultra-precision machining, and more. IMM has built up extensive know-how in many application areas of Micro System Technology.

Application areas are manifold and comprise optics, telecommunication, chemistry, biotechnology, microdrives, medicine, sensors, process control, surface finishing, measurement, and many more. The central idea of all developments is a **fast and cost effective adaption of laboratory results into industrial fabrication.** Hence IMM can offer an optimum technological support for the high-tech industry, which is highlighted by many industry projects, which have successfully been completed in the past.

Flat panel displays – excellent prospects for the future

The worldwide competition forces IMM to continuously take up new R&D fields of microtechnology. Currently, the multi-billion dollar market of flat panel displays offers excellent chances, particularly as the production technologies of flat panel displays and of micro systems possess many common features. IMM concluded to engage in this sunrise technology and **therefore initiated the German Flat Panel Display Forum (DFF).** The display activities of IMM also include several R&D projects.

Novel R&D service for flat panel displays

From its beginning IMM supported high-tech start-ups. This path is consistently continued by the foundation of a new company offering extensive R&D service for flat panel displays. The main areas of this new company – development of displays based on organic light emitting diodes (OLED) and testing and characterization of displays – aim at two particularly promising fields of the flat panel display technology.

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Founded: 1995

Equipment: various display technologies, optical and electrical testing, hard- and software

Location: Pforzheim, IC train station Pforzheim (10 minutes by taxi, bus line 5, Stop: FH), Airport Stuttgart (45 minutes by taxi), Autobahn A8

Display engineering and measurement

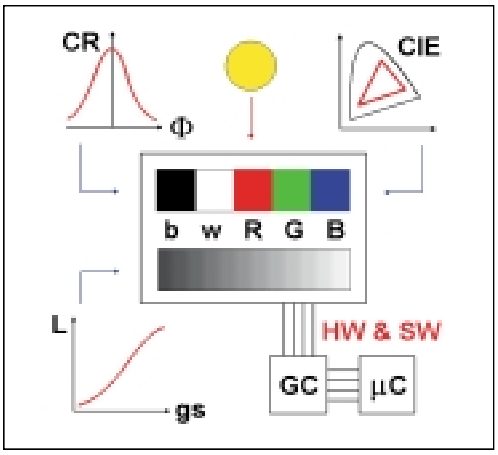
The Display Laboratory of the University of Applied Sciences Pforzheim is dedicated to research and development in the electronic display area:

- various display technologies
- hard- and software
- optical characterisation
- simulated ambient light
- electronics

All major display technologies (LCD, VFD, Plasma, LED, EL, CRT) are available with various types (foils, segment and character displays, passive and active matrix). Experience on electronic driving of displays by micro controllers and dedicated display ICs including hard- and software development can be provided, an analog & digital test generator including LVDS and TMDS can also be used for driving. With an open spaced 3D, fully computer controlled test bench, optical characteristics of displays are measurered, e. g. contrast and colour, gray-scale capability, switching time, ... – in dark room or with artificial ambient light.

Numerous projects with the industry (e. g. BOSCH, DaimlerChrysler, SIEMENS and also small companies) have been carried out. We can provide consulting and development also projects and thesis with students can be offered.

Due to the interdisciplinary orientation of the University of Applied Sciences Pforzheim a broad range of know-how can be offered in addition to the display tasks: industrial design, marketing, logistic, finance, production, mechanical engineering, ... – ideal for turnkey projects.



Glossary

Every technology has its own “language”, display technology is no exception. This is a compilation of acronyms, definitions and abbreviations commonly used by the display community.

α-Si:H / a-Si:H Amorphous Silicon (hydrogenated), the most common type of substrate for active matrix thin film transistor-based displays.

AM-[ ] Active Matrix driving scheme. Fabricated with an array of transistors to drive the display elements. The brackets [ ] denote the kind of display that is being driven, for instance, AM-LCD or AM-OLED. *Cf. PM-[ ]*

CCFL Cold Cathode Fluorescent Lamp. Gas discharge tube with small diameter used especially in LCD backlights.

CMOS Complementary Metal Oxide Semiconductor. Special device structure and composition used for integrated circuits in the electronics industry.

CMP Chemical Mechanical Polishing. This is a recently adopted process step in the integrated circuit industry wherein between major processing steps the wafer is polished with chemicals and mechanical grinding to make it extremely flat. This helps subsequent layers to be formed more accurately.

CNC Computerized Numerical Control. Machinery automation tool.

CoG Chip on Glass. Integrated circuit (driver-IC) directly mounted on ITO-coated display glass backplane in flip-chip arrangement.

CRT Cathode Ray Tube. This style of display is one of the most commonly used displays today. Electrons emitted from a hot cathode hit phosphors on a screen and emit light.

CSTN Color Super Twisted Nematic. STN-LCD equipped with RGB color filters.

CVD Chemical Vapor Deposition. Method for growing solids in which a gaseous precursor containing fragments of the desired solid is decomposed and deposited onto a desired surface. CVD is one of the most powerful synthetic methods in material science due to its remarkable flexibility. A variety of surfaces can be coated, and very thin layers can be applied if necessary.

DMD Digital Micromirror Device. Micromachined light modulator device in which tiny mirrors on a silicon substrate act as light valves. Alternatively called DLP – Digital Light Processing.

dpi Dots per inch (or pixels per inch). This is the common metric for resolution of printed media as well as displays.

DSTN Double Super Twisted Nematic. Two similar STN panels glued together to compensate the birefringence of the liquid crystal resulting in an enhanced contrast of the display.

The abbreviation is *also used for* Dual Scan Super Twisted Nematic. Display is split into two areas for separate line scanning.

ECB Electrically Controlled Birefringence. The voltage-dependent birefringence of liquid crystals is employed to create colors without color filters in a simple reflective PM-LCD. Used e. g. in cellular phones or in so-called “gameboys”.

EL Electroluminescence. Physical property of a material to emit light when biased with a voltage.

ELA Excimer Laser Annealing. *Cf. LTPS*

ELD Electroluminescent Display. Emissive-type display in which an anorganic solid state layer creates light by applying a (high AC) voltage.

FED Field Emission Display. CRT-like, emissive-type display employing microtips as a cold cathode to generate electrons.

FLC Ferroelectric Liquid Crystal. Type of LC with permanent dipole used for bistable displays.

FSTN Film compensated Super Twisted Nematic. Birefingence of liquid crystal is compensated by retarding foil.

HDTV High Definition Television. The new 16:9 wide-format display technology that is currently being introduced.Provides brilliant image due to its higher resolution compared to NTSC or PAL.

HIC High information content display like a full-graphics, pixelated display. *Cf. LIC*

HMD Head-Mounted Device.

HTPS High temperature polysilicon. High-temperature treatment (> 900°C) to transform amorphous silicon into polysilicon. Quartz substrates required. *Cf. LTPS*

IPS In-Plane Switching. Planar arrangement of corresponding electrodes in LCDs to enlarge viewing angle.

ITO Indium Tin Oxide. Electrically conducting transparent anorganic material widely employed in display technology to form the anode.

IC Integrated circuit.

LIC Low information content display like a simple alphanumeric or character display. *Cf. HIC*

LCD Liquid Crystal Display.

LCoS Liquid Crystal on Silicon. AM display built on a crystalline Si substrate which results in mallest pixel sizes and highest resolutions. LCoS is used for microdisplays e. g. in viewfinders.

LED Light Emitting Diode.

LEP Light Emitting Polymer. This term is used by some manufacturers to distinguish between polymer and small molecule OLEDs.
Cf. PLED/PolyLED, OLED, OEL

LTPS Low temperature polysilicon. Intense UV radiation generated by an excimer laser only heats the amorphous silicon layer on a substrate to form polycrystalline silicon without heating the substrate itself. *Cf. HTPS, ELA*

MEMS Micro-Electro-Mechanical Systems. This is a name given to miniature devices commonly fabricated with IC processes.

MLA Multi-Line Addressing. Advanced driving scheme used in PM-LCD to increase brightness. Multiple lines are addressed at the same time, in contrast to the standard PM driving scheme, where only one line is addressed.

NTSC National Television System Committee. The NTSC is responsible for setting television and video standards in the United States (in Europe and the rest of the world, the dominant television standards are PAL and SECAM). The NTSC standard for television defines a composite video signal with a refresh rate of 60 half-frames (interlaced) per second. Each frame contains 525 lines and can contain 16 million different colors.

OLED Organic Light Emitting Diode. The generic term for Organic LEDs, which can be made from a wide range of organic materials, either small molecule or polymeric (Kodak- or CDT-invented materials). *Cf. OEL, LEP, PLED and SMF*

OEL Organic Electroluminescent. This is a generic term for organic light emitting devices typically fabricated from sublimed molecular films. This term is often used in Japan to describe variants of technology that originated with Kodak. *Cf. OLED, SMF*

PAL Phase Alternate Line. The television broadcast standard throughout Europe (except in France, where SECAM is the standard).
This standard broadcasts video signals with a refresh rate of 50 half-frames (interlaced) and 625 lines of resolution per second. *Cf. SECAM, NTSC*

PALCD Plasma-Addressed Liquid Crystal Display. Alternative active driving method for LCDs utilizing the switching characteristics of a plasma ignited in channels below the LC cells. *Cf. TFT, AM*

PDA Personal Digital Assistant.

PDLC Polymer-Dispersed Liquid Crystals consist of micrometer-size liquid crystal droplets that are dispersed in a solid polymer which makes LCDs on flexible substrates feasible.

PDP Plasma Display Panel. This technology uses the radiation of ionized gas (plasma) to excite a phosphor which then emits light with CRT-like characteristics.

PECVD Plasma Enhanced Chemical Vapor Deposition. Gases are activated by a plasma discharge resulting in lower substrate temperatures required for deposition

PLED/PolyLED Polymer Light Emitting Diode. This term is used by some manufacturers to distinguish between polymer and small molecule OLEDs. *Cf. LEP, OLED, OEL*

PM-[ ] Passive Matrix driving scheme.
Cf. AM-[ ]

POI/POS Point of Information / Point of Sales.

p-Si Polycrystalline Silicon. Amorphous silicon can be heat treated to increase silicon grain sizes. p-Si has higher electron mobility than α-Si.

PVD Physical Vapor Deposition. Vacuum deposition process where a material is vaporized and condensed into a film at the substrate's surface. There are actually several different PVD processes, including thermal evaporation, electron beam gun, ion plating, sputtering, cathodic arc, and laser ablation.

R2R Reel-to-Reel / Roll-to-Roll. Continuos processing on a flexible substrate that can be rolled, in contrast to step-by-step processing of single substrate sheets.

RGB Red, Green and Blue. The usual pixel triads for emissive light reproduction of full-color images.

SECAM Sequential Couleur avec Mémoire (Sequential Color with Memory). The television broadcast standard in France, the Middle East, and most of Eastern Europe. SECAM broadcasts video signals with a refresh rate of 50 half-frames (interlaced) and 819 lines of resolution per second. *Cf. PAL, NTSC*

SMF Sublimed Molecular Films. Refers to the molecular approach to Organic Electroluminescence using monomers. (Although a lot of people refer to this as OEL or OLED, referring to it as SMF clarifies the distinction with polymer based alternatives.) *Cf. OLED, OEL, LEP, PLED*

Sputtering A physical vapor deposition process where high-energy ions are used to bombard a solid target, ejecting vapors of the target material which are then deposited in thin layers on a substrate.

STN Super Twisted Nematic. Liquid crystal configuration used in larger displays that require more lines to be multiplexed together.

TFD Thin Film Diode. Potentially cheaper alternative method to realize active matrix driving.

TFEL Thin Film Electroluminescent. This kind of display uses thin film EL layers as a light source for the display elements.

TFT Thin Film Transistor. A transistor formed from thin films of materials that are sequentially deposited on a substrate. The active layers of these devices are typically made with a multiple-crystal structure (either amorphous or poly-crystalline). Their performance is much lower than that of a single crystal transistor.

TN Twisted Nematic. Liquid crystal configuration that is commonly used in small displays without lots of rows of columns. It exhibits a reasonable gray-scale behavior.

UHV Ultra High Vacuum. Typically defined as pressures less than 10 torr of gas. Such vacuum conditions are necessary for deposition techniques like PVD (sputtering) and CVD.

VA Vertical Alignment. Liquid crystal molecules oriented almost perpendicular to the orientation layer, resulting in a better viewing angle for the LCD.

VFD Vacuum Fluorescent Display. CRT-like, emissive flat panel display technology resembling the classical triode arrangement.

VGA Video Graphics Adapter. VESA resolution standard introduced for early personal computer monitors. See below.

Common Resolution Standards

The columns denote the abbreviations for display resolution standards, the corresponding resolution in dots (pixels) per inch, and aspect ratio.

QVGA	320 x 240	4:3
VGA	640 x 480	4:3
SVGA	800 x 600	4:3
XGA	1024 x 768	4:3
SXGA	1280 x 1024	5:4
SXGA+	1400 x 1050	4:3
SXGAW	1600 x 1024	25:16
UXGA	1600 x 1280	4:3
HDTV	1920 x 1080	16:9
UXGAW	1900 x 1200	8:5
QXGA	2048 x 1536	4:3
QSXGA	2560 x 2048	5:4
QUXGA	3200 x 2400	4:3

Display Societies and Networks

DFF Deutsches Flachdisplay-Forum (German Flat Panel Display Forum). Arose from a joint activity of German industry, research institutes, and associations hosted by the Institute of Microtechnology Mainz (IMM) to push high-volume display production in Germany. Started as DFF in Feb. 2000 as a cooperation of the German Engineering Federation (VDMA) and IMM. Established official lobby of the flat panel display branch in Germany with 56 international, mostly industry members today.
www.displayforum.de/

DTA Display Technology Alliance (UK). Established in 1996 as a collaborative project between 14 companies and 6 universities supported by the UK Department of Trade and Industry. Main objective of the DTA is to develop flat panel display and related technologies that will be of benefit to the UK's displays' industry. 34 associate members joined DTA.
www.dta.ihost.com/

EDIRAK Electronic Display Industrial Research Association of Korea. Established in 1990. Regulatory support and supplementary funding contributed by the Korean government; the actual sponsors are the 34 member companies. Main goal is to jointly develop and standardize information display technologies through the distribution of government funds to companies for industrial research and development. Close collaboration with USDC since 1996.
www.edirak.or.kr/

EIAJ Electronic Industries Association of Japan. Founded in 1948 as a non-profit national trade organization to develop Japan's electronics industry and represent its views. Merged with JEITA in 2000. *Cf. JEITA*
www.jeita.or.jp/

FLATNET The project "New materials and technologies for flat panel displays" is a thematic network sponsored by the European Commission within the Fourth Framework Programme for coordinating industrially relevant RTD work on flat panel displays in the European Union. 22 project partners from industry and university research institutes. Several associated members.
www.flatnet.org/

FPDF Taiwan Flat Panel Display Forum. In March 2000 Taiwanese industry, government and academia formed this organization to strengthen the structure of the Taiwan flat panel display industry. Deals with production as well as educational issues. About 40 members from upstream, midstream and downstream elements of the display industry in Taiwan including leading companies and research bodies, and ITRI's Electronics Institute and Materials Institute.

GDN Global Display Network. USDC initiative to create a worldwide, corporately-focused electronic display organization that should increase and enhance executive-level networking, identify and resolve issues impeding industry growth, establish groundwork for industry cooperation, and cooperate with regional organizations. First exploratory committee meeting was held in Dec. 2000.
www.globaldisplaynetwork.com/

ITRI Industrial Technology Research Institute (Tw). Government-sponsored non-profit organization for applied research and technology transfer founded in 1973. Main goal is to accelerate industrial technology development and promote industrial growth in Taiwan. Display technology is one of the major research areas of ITRI. 6000 employees.
www.itri.org.tw/

JEITA Japan Electronics and Information Technology Industries Association. Established in November 2000, through the merger of the Japan Electronic Industry Development Association (JEIDA) and the Electronic Industries Association of Japan (EIAJ). At the time of its estab-lishment, JEITA's membership included 422 full members (including 10 associations) and 158 associate members (including nine associations), for a total of 580 members. JEITA areas include display devices.

www.jeita.or.jp/

KIDS Korean Information Display Society. Established in 1999. Research-oriented.

www.k-ids.or.kr/

PIDA Photonics Industry and Technology Development Association (TW). PIDA's goal is to work with private enterprises and government agencies to increase the competitiveness of Taiwan's optoelectronics industry, to assist government in drafting policies for optoelectronics industry, to provide consultation in technology and market trends, to assist technology transfer, and to help investment, to promote international cooperations, and to train optoelectronic field specialists.

www.pida.org.tw/

SEAJ Semiconductor Equipment Association of Japan. Founded in 1985. Promoted by the major Japanese semiconductor equipment manufacturers. Nationwide organization of semiconductor manufacturing, and LCD panel manufacturing equipment manufacturers, and related equipment manufacturers. Restarted as public service corporation, with authorization from the Ministry of International Trade and Industry (MITI) in 1995. Major goal is to promote development of the semiconductor manufacturing equipment industry and other related industries.

www.seaj.or.jp/

SEMI Semiconductor Equipment and Materials International. Global trade association representing the semiconductor and flat panel display equipment and materials industries. Founded in 1970 in the United States. Created a flat panel display division. 2400 corporate members (11 % Europe, 55 % North America, 21 % Japan, 5 % Korea, 3 % Singapore, 4 % Taiwan, 1 % ROW). Primary products and services are industry events, manufacturing standards, and technical as well as business information. Member companies are equipment suppliers, materials and services to the semiconductor and flat panel display industries.

www.semi.org/

SID Society for Information Display. International display organization founded in 1962 structured into regional chapters. The chapters interact both directly and through the central SID International Office, and chapter meetings often feature speakers with international reputation. SID's largest international gathering is the annual SID Symposium, Seminar, and Exposition. Personal membership. The 6000 members of SID are professionals in all of the technical and business disciplines that relate to display research, design, manufacturing, applications, marketing, and sales.

www.sid.org/

TTLA Taiwan TFT-LCD Association. In 2000 Taiwan's TFT-LCD monitor industry decided to set up this industry Association focussed on TFT-LCD. It will be a unified window for negotiating for resources, providing information to the Taiwanese government. TTLA's mission will focus on promoting standardization and Intellectual Property rights.

USDC United States Display Consortium. Industry-led public-private partnership, created in 1993 by industry and the U.S. Defense Advanced Research Projects Agency (DARPA) to advance the flat panel production capabilities of U.S. companies. Established forum for flat panel display manufacturers, developers, users, and equipment and materials suppliers with more than 100 corporate members and affiliates. Created the Global Display Network (GDN) to enhance international activities and foster multinational cooperation. Distribution of government funds to companies for industrial research and development. SEMI Flat Panel display division is an affiliate to USDC. Close collaboration with EDIRAK since 1996.

www.usdc.org/

VESA Video Electronics Standards Association (USA). Established in 1989 to promote and develop display and display interface standards designed for PC, workstation, and other computing environments. 160 international industry members.

www.vesa.org/

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