Fabricating color TFT LCD

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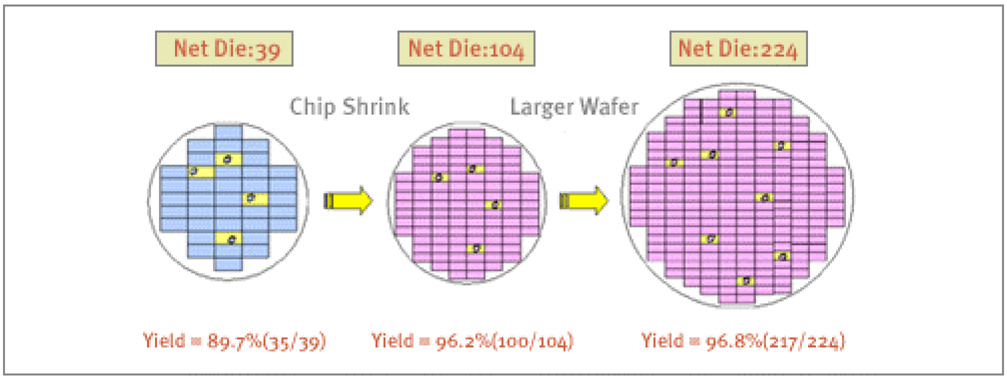
The pressure to reduce the manufacturing cost of TFT LCD displays is as constant and intense as it is in the semiconductor industry.

To increase productivity, IC makers continuously reduce the sizes of c-Si chips and transistors in order to increase the number of chips per wafer.

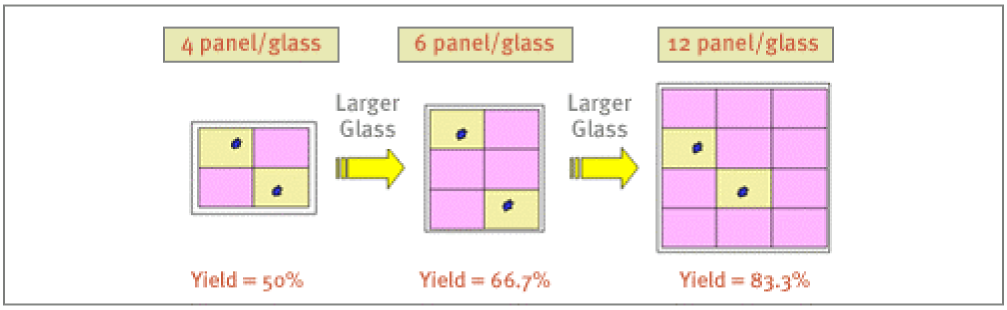
IC makers increase productivity by continuously reducing chip size and increasing wafer size to increase the number of chips per wafer.



But this strategy doesn't work for LCDs because the panel sizes users demand most get steadily larger, not smaller.

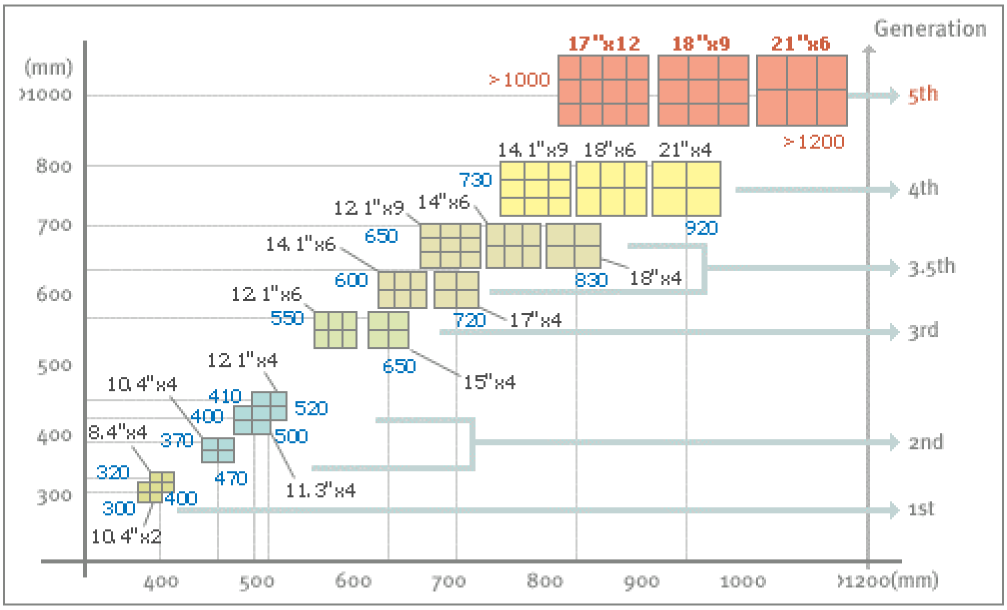
Still, by increasing the number of panels produced on a single substrate, the cost of TFT-array processes can be reduced.

The IC makers' size-reduction strategy doesn't work for direct-view LCDs, but LCD manufacturers can still reduce the cost of TFT-array processes by increasing the number of panels produced on a single substrate.



This process requires that the size of the glass substrate be steadily increased so that the number of LCD panels fabricated upon it can increase.

For more panels to be put on a glass substrate, the substrate size must be steadily increased - which requires the continual design and construction of new generations of process equipment.



New generations of process equipment must be continually designed and built to achieve these increases.
The fabrication processes this equipment must implement will be described below.
We can assume that the display being fabricated is a color TFT LCD that uses an inverse-staggered-type a-Si TFT as the active-matrix switching element.

Fabricating the TFT array

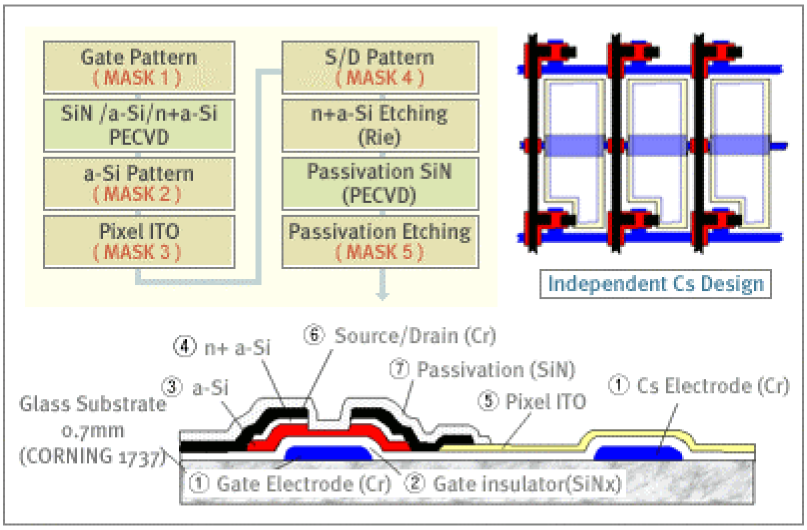
The manufacturing process used to fabricate an a-Si TFT array is very similar to those used to fabricate c-Si semiconductor devices.
The various steps, including cleaning, deposition of thin films, photolithography, and wet and dry etching of the thin films - are also very similar.
The difference between the a-Si TFT process and the c-Si semiconductor process is that a semiconductor layer is deposited onto a glass substrate in the a-Si TFT process, while Si wafers are used as the substrate in the c-Si semiconductor process.
Today, critical issues in the processing of TFT arrays include the development of a low-resistance gate-bus line, uniform and fine etching, and improved lithographic accuracy.
TFT-array technologies are aimed at achieving high precision, large aperture ratio, and low power consumption, in addition to large screen size.
AMLCD manufacturers are also competing to minimize the number of array processes by reducing the number of photo masks and simplifying the thin-film-formation and etching processes.

In the bottom-gate TFT-array fabrication process, the first layer consists of the gate electrodes and gate bus-lines, which can have one or two metal layers.
Some storage capacitors can be constructed by using a part of the gate electrode as an electrode of the storage capacitor - which is called the Cs-on-gate method - while other capacitors are constructed independent of a gate bus-line.
If the independent Cs lines are constructed simultaneously with the gate bus-lines

using the same metal layer, there is no difference in the fabrication process between the Cs-on-gate method and the independent Cs bus-line method.

The processing of an a-Si TFT array is complex.

The processing of an a-Si TFT array is complex. This flowchart outlines the processes for making an a-Si TFT array using a bottom-gate TFT structure and an independent storage capacitor.



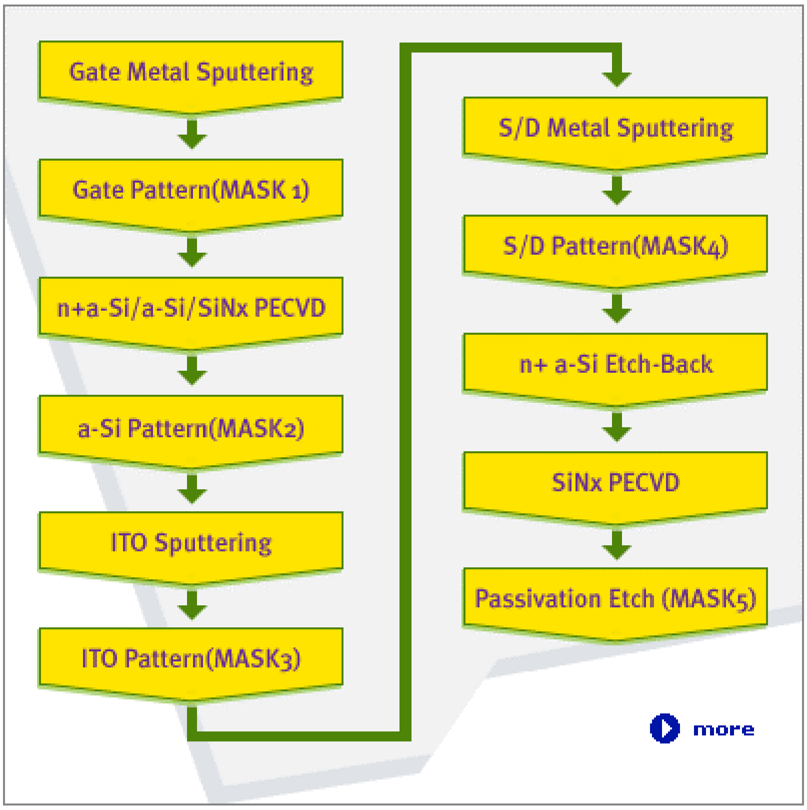
After constructing gate and storage-capacitor electrodes with 2000-3000A of a metal such as aluminum, chromium, tantalum, or tungsten, a triple layer of silicon nitride and amorphous silicon is deposited by using plasma-enhanced chemical-vapor deposition (PECVD).

In the etch-back type of TFT structure, the triple layer consists of 4000A of SiNx, 2000A of a-Si, and 500 A OF n+a-si, which is deposited over the gate electrode in a continuous process, i.e., a process without a vacuum break.

For the etch-stopper type of TFT structure, 4000A of SiNx, 500A OF a-Si, and 2000A of n+a-si) are deposited.

Let us look at the etch-back TFT fabrication process in more detail.

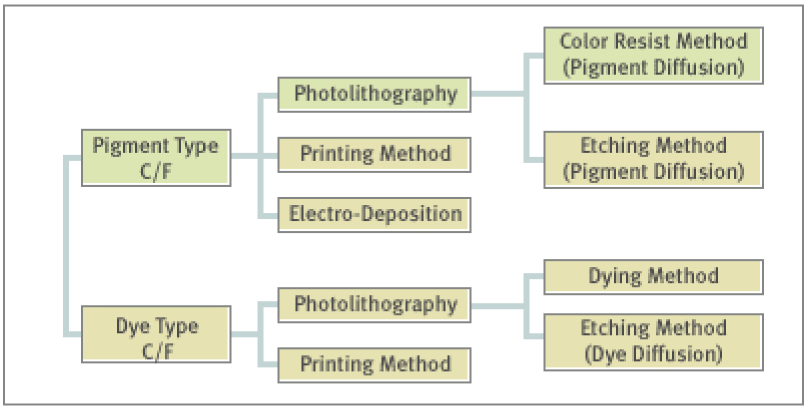
TFT Fabrication



After defining the a-Si area by using photolithography and plasma dry etching, an ITO layer is deposited with a thickness of about 500A via sputtering.
Then, the pixel electrodes are patterned. About 2000A of metal is sputter deposited, while data bus-lines and TFT electrodes are patterned by photolithography.
Then the ohmic contact layer (n+a-Si) at the channel region is etched by dry etching using the source and drain electrodes as an etch-protect mask.
Finally, a protective 2500A SiNx layer is deposited by PECVD and contact windows are opened.
The etch-stopper TFT structure requires one more process step - a chemical vapor deposition (CVD) - than does the etch-back TFT structure.
For etch-stopper TFT fabrication, an n+a-Si layer is deposited separately after the top insulator of triple-layer (SiNx/a-Si/SiNx) is patterned.
The a-Si area is patterned and the n+a-Si layer at the top of etch-stopper is removed. The source and drain electrodes are formed using about 2000A of metal; then, about 500A of ITO is sputter deposited, and pixel electrodes are patterned.
A SiNx protective layer is then deposited by PECVD and, finally, the contact windows are opened.

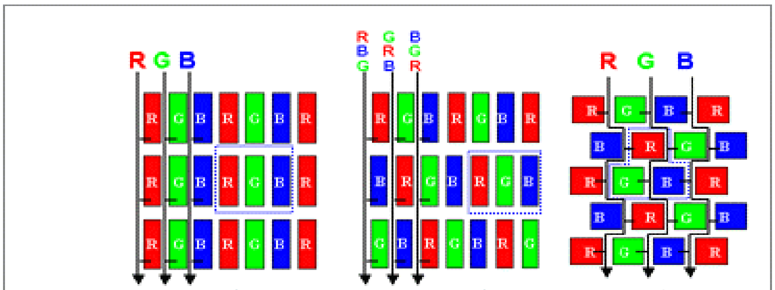
Fabricating Color Filters

Color filters (CFs) can be made with either dyes or pigments, utilizing coloring method such as dyeing, diffusion, electro-deposition, and printing.
Color filters (CFs) can be made with either dyes or pigments, and can be further divided by coloring method.



There are several fairly common color-element configurations.

There are many possible color-element configurations for LCDs. Stripe is the most popular, followed by mosaic and delta.



	Stripe	Mosaic	Delta
Array Design	Simple	Simple	Complex
C/F Fab.	Simple	Difficult	Difficult
Driving CKT	Simple	Complex	Simple
Color Mix	Poor/w.low res.	Good	Best

Among the many combinations of configuration and types of CF fabrication methods, the color-resist method with stripe-type RGB arrangement is currently the most popular in the CF industry.

Between the blocks of color in the CF is a black matrix (BM) made of an opaque metal, such as chromium, which shields the a-Si TFTs from stray light and prevents light leakage between pixels.

A double layer of Cr and CrOx is used to minimize reflection from the BM.

The sputter-deposited BM film is patterned using photolithography.

For reduced cost and reflectivity, black resin - made by diffusing C and Ti in photo resist - can be used as a BM material.

In the color-resist method, the primary color-filter patterns are formed by using a photolithography technique.

The color-resist is negative and made by diffusing pigment in a UV-curing resin, such as an acryl-epoxy resin, and by dissolving the resin in a solvent.

A red colored resist is spin-coated onto a glass substrate on which a BM has previously been formed.

The red pattern is then formed by exposing the red resist through a mask and developing it.

The process is repeated using the same mask with a shifted mask-align technique for green- and blue-colored resins.

A protective film is then applied, and 1500A of ITO for the TFT array's common electrode is sputter-deposited to finish the color filter.

Liquid-crystal Cell Process

The TFT-array and color-filter substrates are made into an LCD panel by assembling the two substrates together with a sealant, while the cell gap is maintained by spacers.

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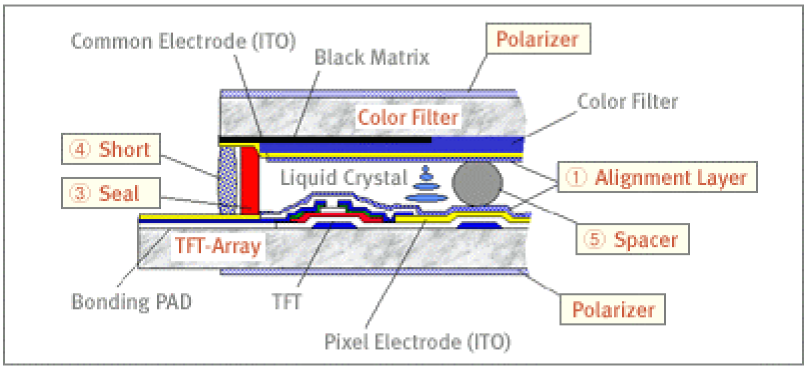


The assembly is begun by printing a polyimide alignment film on a cleaned TFT-array, and then rubbing the surface of the film with a piece of cloth wound on a roller, which orients the polyimide molecules in one direction.

Similarly, alignment film is applied to the color-filter substrate, and this substrate is also rubbed.

After the rubbing process, a sealant is applied to the periphery of the TFT-array substrate. To form electrical connections from the common electrodes on the color-filter substrate to the TFT array, the TFT-array substrate is coated with a conducting paste around the periphery.

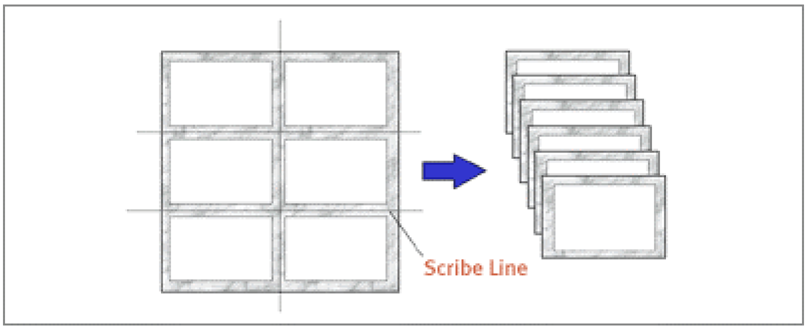
At the same time, spacers to control the cell gap are sprayed onto the color-filter substrate. (In some cases, spacers are sprayed on to the TFT-array substrate, and a sealant is applied to the color-filter substrate.)

The two substrates are then assembled after the sealant is pre-hardened.

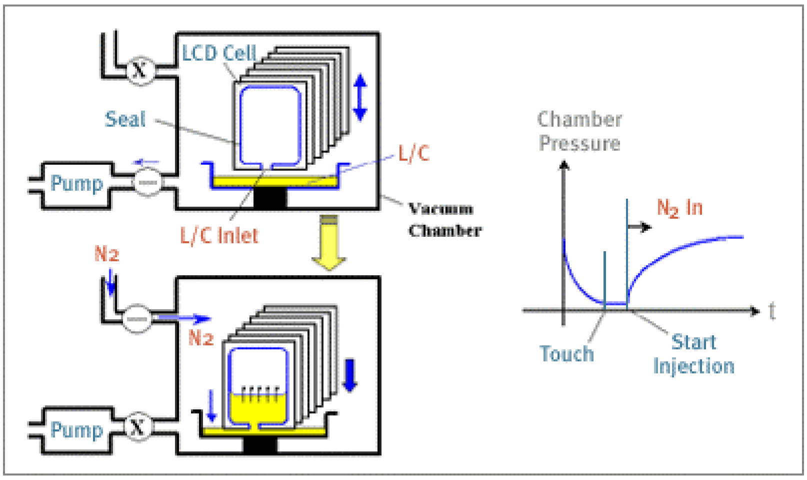
The sealant is then hardened completely with heat and pressure.

Then, the assembled substrates are scribed using a diamond wheel and separated into individual cells, and the empty cells are filled with liquid crystal material by vacuum injection.

Fully assembled LCD substrates are scribed using a diamond wheel and separated into individual cells.



The separated cells are filled with liquid-crystal material by vacuum injection.



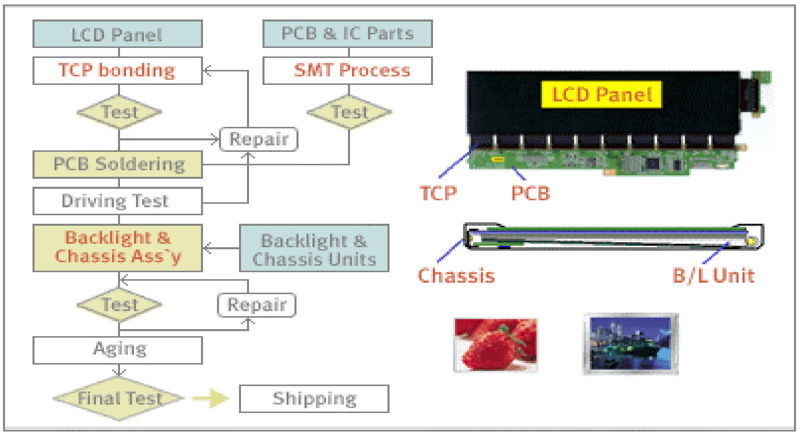
Finally, a sealing agent is used to seal the cell, and the polarizers are applied to both cell surfaces after a visual function test.

Assembling LCD Modules

Although critical for producing panels with the desired characteristics and price, the details of the manufacturing process for AMLCD panels are often of less immediate interest to the OEM purchasers of displays than are the details of the module assembly process.

This is so because it is the physical and electrical characteristics of the module that OEMs must deal with when integrating the display into products for end users.

The process flow for assembling a module using the tape-automated-bonding (TAB) method is conceptually straightforward, but it's not simple.

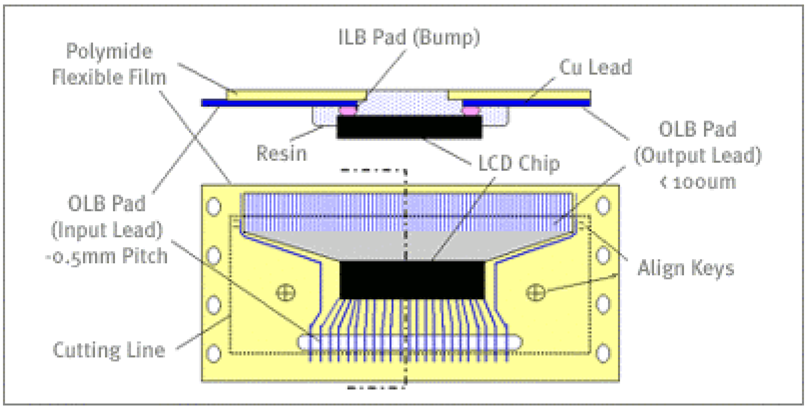


The process for assembling LCD modules(flow chart).

The first decision to make is whether you want to use TAB at all, or whether you would prefer the other basic way of applying the LDI chips needed to drive the TFT panel.

In the TAB method, the LDI chip is attached to a tape-carrier package (TCP), and the TCPs are then connected to the TFT-array substrate.

The structure of the tape-carrier package used in TAB.

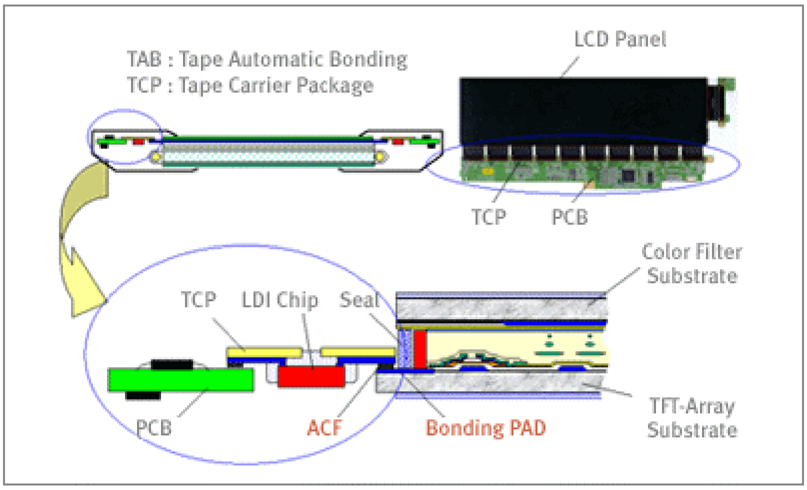


Anisotropic conducting film (ACF) is applied to the contact pads, where the stripe-shaped contact leads are formed as a group. The TCPs are then aligned and subjected to pressure-bonding.

The drive-circuit components, such as the timing controller, EMI filters, op amps, chip capacitors, and resistors, are mounted onto a multi-layered PCB using a surface-mount technology (SMT).

A soldering method is usually employed to connect the gate and control PCBs to the other end of the TCP leads, but in some cases ACF bonding can be used instead.

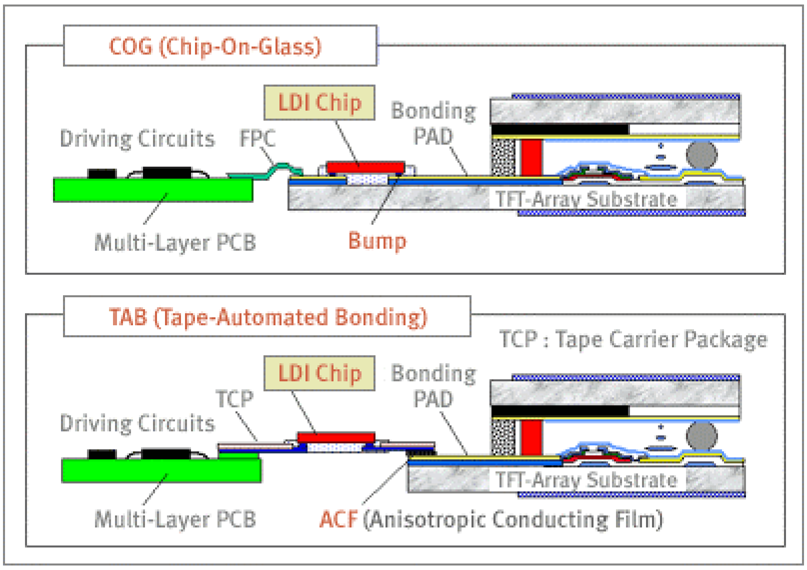
Mounting a TAB using a TCP and ACF.



Sometimes, to minimize bezel size, the drive-circuit unit is set to the back side of the LCD module by using bent TCPs.

Alternatively, one can use the chip-on-glass (COG) method, in which LDI chips are mounted directly on the TFT-array substrate.

Chip-on-glass vs. tape-automated bonding.



The choice of COG or TAB is determined by the peripheral area available and the limitations on bezel size for the display.

After testing the electrical functions, only the good LCD panels are subjected to the final assembly process, in which a backlight unit and a metal bezel are attached to compete the LCD module.