

## 1. Introduction

When we globally look at the market of mobile phone, it reached the peak in the year 2000 as for the quantity of release; 400,000k units/year. Then the pace sifted to minus growth. In the meantime, the sign of recovery appeared, and now, it is entering upon a new phase of growth, which is expected to steadily continue while expanding the market. Specifically, the market size is estimated to expand a year-on-year 8.4 %. The demand breaks down into replacement by 330 million units and new subscription by 107.6 million units, according to sales forecasting.

As for the driving force for the expansion, there are three factors as follows:

1. Boom of color LCD and mobile camera phone
2. Increasing demand for replacement in line with the trend mentioned above
3. Active demand for new model mobile phones in China and other Asian countries

Mobile camera phones started to arrive on the market around the year of 2000. In those days, they were only for a limited market space. In spring of 2002, a domestic leading manufacturer of mobile camera phone achieved a significant growth and others started to go along. Accordingly, 80% of mobile phones (new model) in the domestic market are equipped with camera.

In 2003, this trend is spreading across overseas market. In western countries where the diffusion rate of mobile phone is already high, color displays are getting popular thanks to the appearance of mobile camera phone (Displays of monochromatic type were the majority before.), which will accelerate the trend of replacement. Additional and new functions also hold the key to the popularity in the market. Such functions are of moving images, music down load, GPS navigation, digital broadcasting, PC function and so on. Along with the functionalizing tendency, more compact and thinner devices are essential and, more specifically, thinner glass materials are crucial. Meanwhile, the quantitative growth in China as well as India and Russia will substantially be force of traction, since the diffusion rate is still very low in these countries despite their booming economy. (The diffusion rate in China: approx. 15%, in other Asian countries : approx. 10%)

Here I would like to give explanations of each device and glass materials to be used for the devices.

## 2.CCD/C-MOS Image Sensor Module

### (1) Basic imaging process

The basic imaging process for filming objects is as follows: Fig. 1 shows an airplane which is taking off. The image of the airplane fades away over time in the 3-D space of ups & bottoms, both sides and distance. The cameraman takes the image setting it at the center of the finder. It is necessary to focus the camera, adjust the aperture and the size of the filming object by zooming and controlling the color. These processes are carried out automatically in general.

As shown in Fig.2, the film is running intermittently while picking up the images so as to take each of them as a still picture one by one. The optical image of the object is formed on the photosensitive side of the film by the imaging lens, and then it is exposed on the film side through releasing the shutter. The next frame of the film comes up for another shutter releasing. Filming is a sequence of these processes. A frame of the film is shifted to another and the images are projected on the screen one by one to reproduce a sequential mages (moving image).



Fig 1 An airplane which is taking off



Fig 2 Movie system

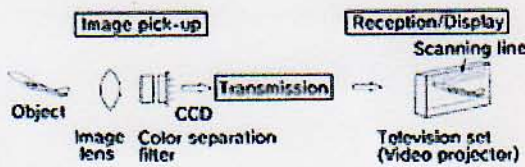


Fig. 3 television system

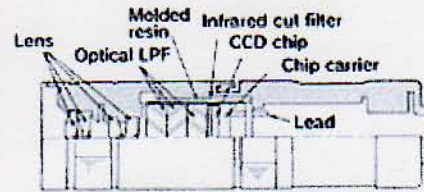


Fig. 5 Head part of micro camera

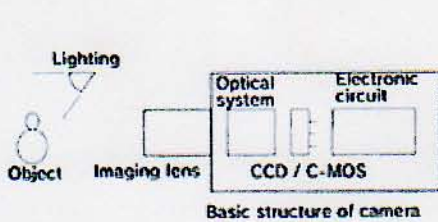


Fig. 4 Basic process of image pick-up

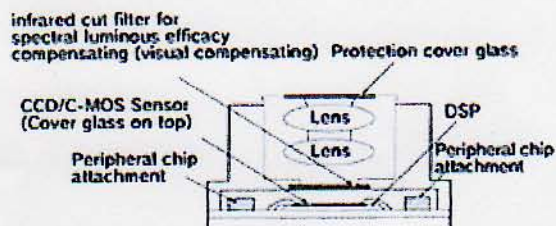


Fig. 6 CCD/C-MOS Image Sensor mobile phone

As for the image projection on a display screen, the process is as shown in Fig. 3. The optical image is picked up by imaging device such as CCD/C-MOS converting into electrical signals by 1/60s. An imaging lens forms the object image. The signal is recorded or directly transmitted to reproduce on the receiving display.

The basic process, taking the illuminated object image, is carried out by CCD/C-MOS camera as shown in Fig. 4. This camera is composed of imaging lens, optical system, CCD/C-MOS imaging device and electronic circuit. The optical system carries out optical processing to facilitate the conversion of the optical image taken by the imaging lens into electric signal. C-MOS camera technology is integration of all these elements.

## **(2) Micro camera**

Commercialization of micro cameras in 1987 completely changed the concept of conventional camera and created a sensation. The head part of micro camera is shown in Fig. 5. All essential functions for imaging such as imaging lens, optical LPF (low-pass filter), infrared cut filter, compact CCD, high density surface mounting printed circuit board are comprised in a cylindrical case.

This type of camera needs only fingertip manipulation to take pictures. This convenience has realized various special use such as anchorpersons' filming with micro camera while depicting the scene or taking real scenes of athletes in action attaching the camera to closer position of the play.

This technology evolved with miniaturization to come into practical application to mobile camera phones.

## **(3) Module of mobile phone**

The module of mobile phone, which is shown in Fig.6, has made the size of micro cameras much miniaturized and thinner. CCD-C-MOS image sensor, infrared cut filter for spectral luminous efficacy compensating, plastic lens and protection cover are cited as key devices involving glass. The vital necessity for the first and second items is ultra thinning of their glass materials.

### 3. CCD/C-MOS Image Sensor

#### (1) CCD (Charge Coupled Device)

CCD imaging devices in practical application are explained as follows. (Fig. 7 shows the case of 4 pixels of vertical direction X 4 pixels of horizontal direction, 16 pixels in total. This unit composes the alignment of pixels.)

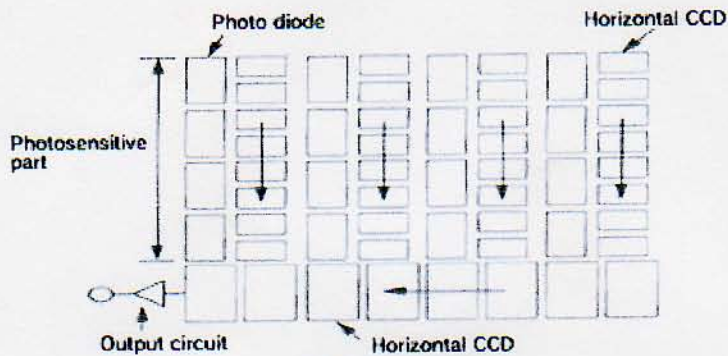


Fig. 7 IT-CCD

This figure also explains the configuration of IT-CCD (Interline Transfer CCD). The rectangle longer than is wide indicates photo diode and the long sideways rectangle indicates electrode of vertical CCD.

In between the columns of photo diode, vertical CCDs are arrayed respectively. Horizontal CCDs are provided adjacent to the last line of vertical CCDs. When an optical image of the object is formed on the surface by imaging lens, each photo diode executes photoelectric transfer, accumulating electrical charge according to the intensity of light and passage of time. In this way, an electrical charge image is created. This is the same process as a latent image is created by chemical reaction after exposure of film. This electrical image is output as one-dimensional electric signal through scanning. Each signal is transmitted vertically and horizontally one after another in CCD and the signals are output out of one signal output terminal. The CCD transmission part executes this process.

First, the signal charge accumulated in photo diode with 16 pixels is transmitted to a part of vertical CCD all at once by field shift pulse. Next, four vertical CCD columns start to transmit the charge vertical direction in parallel. The signal charge transmitted vertically is fed into horizontal CCD one after another. Every time the signal of 4 pixels by one line is fed into, the horizontal CCD transmits the signal in horizontal direction to output it through the output circuit provided on the extreme left. In this way a signal by one line is output out of the output terminal.

As described above, signal charge is read out rightward from the photodiode at the lower left sequentially in IT-CCD Imaging Device. The read-out signal of one line goes up to the above line, and moves in turn. Eventually the all pixels for one screen are read out. Though various modifications are tried depending on the application, the basic system of CCD imaging process is as mentioned above as a whole.

#### (2) C-MOS (Complementary MetalOxide Semiconductor) Imaging Device

The basics of C-MOS imaging device will be explained below.

As shown in Fig.8, pixels of photosensitive part are formed by combination of photo diode and MOS transistor switch. Each pixel is connected with horizontal and vertical shift resistors and switched by impressed pulse in turn.

Then signal charge of each pixel is output to the signal output part. When the light incidents, photo diode performs photoelectric transfer. And signal charge corresponding to the intensity of light is accumulated over time. (To this point, the process is the same as IT-CCD.) As for scanning, one of the pixels of vertical direction and a horizontal line are selected by vertical shift resistor first.

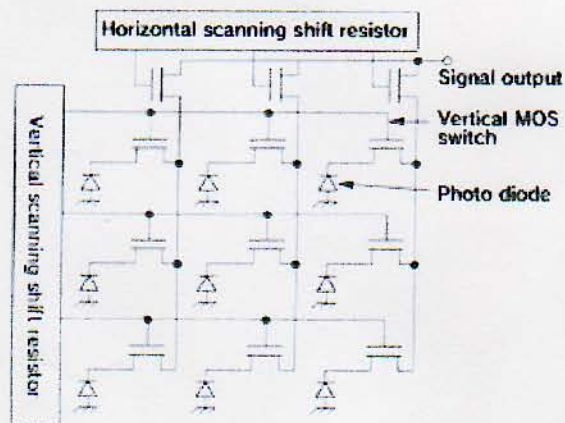
Then pulses are applied continuously in turn by horizontal shift resistor to switch each pixel from left to right in horizontal direction. Accordingly the accumulated signal charge is read

out to the signal output terminal. The termination of one line signal read-out leads to start of another horizontal scanning of next line through pulse application from the vertical shift resistor on this horizontal line.

In this way, horizontal / vertical scanning is performed in turn to read out the signals of whole pixels to the output part terminal. It is possible to provide 2 or 3 output signal lines to read out each signal independently. The advantage is that non-destructive read-out is possible.

In case of C-MOS device, the structure is simple compared to CCD and the driving power voltage is low, which helps electricity saving. Image read-out is fast. No need to install a dedicated production line. It can be manufactured on C-MOS memory production line, which enables cost-saving. Another advantage is the possibility of integration of other peripheral circuits into one chip. In addition, it is resistant to radiation such as alpha ray compared to CCD. Even when CCD was taking over the market of the imaging device for the most part, radiation-proof was the point of people's observation and persistent effort for R & D on radiation-proof has been made mainly in western countries.

C-MOS technology had once various weak points such as dispersion of transistor output from each pixel and susceptibility to noise generation in case of unnecessary current. For such problems, solutions have been found on and on. In the meantime, from 1999 to 2000, Optical Mouse hit the market. However, those days the line-up were anything but high end goods. After that, C-MOS function has been rapidly improved. Some domestic manufacturers started to set out C-MOS line in parallel with CCD. (There are several manufactures that are commercializing high-pixel-density products of C-MOS mainly.)



**Fig. 8 C-CCD Basic structure of C-MOS image device**

### (3) Required quality of CCD/C-MOS

The evolution of cameras built in mobile phone is going on rapidly, almost catching up with that of general digital cameras in their pixels. Pixel density of 11.0 thousand has increased to 310 thousand, and further new models with 1million pixels are appearing on the market.

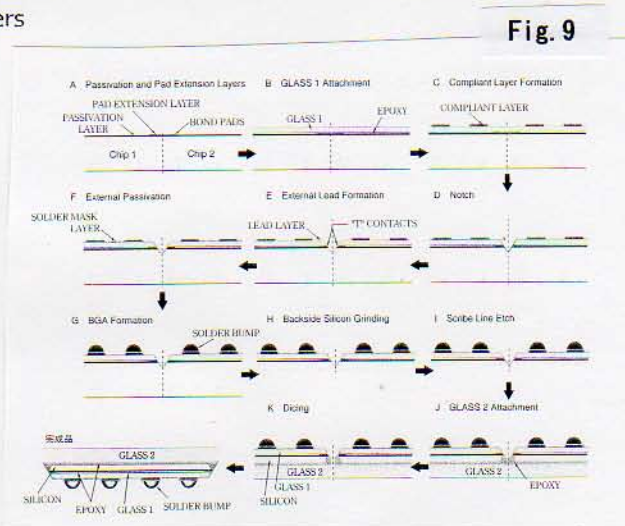
Now it is getting into the new generation of mega pixel of 2million. There is neither superiority nor inferiority between CCD and C-MOS any more in their structure. Item-oriented development strategy determines the superiority.

In 1980's, the pixel density of CCD was 200thousand (480 X 400H) in general and the size was as large as  $13\mu\text{m} \times 22\mu\text{m}$ . These says a pixel with  $5\mu\text{m} \times 5\mu\text{m}$  is quite common. The requirements in appearance also should be met on this level. Therefore, cleanliness is one of the critical elements. As a matter of course, image sensors employed in mobile phones are becoming thinner and more compact, for which cover glass should be finished in the size approx.  $7\text{mm}^2$  with  $t$  0.3mm. Furthermore the edges need chamfer.

#### (4) CSP (Chip Size Package)

Shellcase LTD. (HQ: Jerusalem, Israel. Established in 1993) has started globally to offer innovative package solution of wafer level chip for semiconductor device to be used digital products, which is enjoying an increasing demand, and for market of telecommunication infrastructure. This technology is epoch-making for CCD-C-MOS image sensor miniaturization. One of the production processes is shown in Fig.9.

- A. Passivation and Pad Extension Layers
- B. GLASS 1 Attachment
- C. Compliant Layer Formation
- D. Notch
- E. External Lead Formation
- F. External Passivation
- G. BGA Formation
- H. Backside Silicon Grinding
- I. Scribe Line Etch
- J. GLASS 2 Attachment
- K. Dicing



With regard to CPS technology, manufacturers in Taiwan started to introduce in 2001, and in Japan in 2002. This package has a 3-layered structure of glass, silicon and glass. The total thickness is approx. 0.7mm of ShellOP type and approx. 0.4mm of ShellBGA type. One of the factors that lead to great success of this structure is borosilicate thin film glass (described Table 1-3)(manufactured by down draw process), of which the expansion coefficient matches that of silicon.

Table1 Standard composition [ Unit : wt% ]

	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	BaO	B <sub>2</sub> O <sub>3</sub>	Na <sub>2</sub> O	K <sub>2</sub> O	ZnO
Borosilicate glass A	50.4	12.1	23.7	13.2	-	-	-
Borosilicate glass B	64.2	3.0	3.1	8.9	7.2	6.4	7.1

Table 2 Mechanical properties / Electricproperties / Chemical properties

	Borosilicate glass A	Borosilicate glass B	
Mechanical properties	Density 20°C(68°F) (g/cm <sup>3</sup> )	2.72	2.51
	Stress optical coefficient C (m <sup>2</sup> /N)	3.2×1.02×10 <sup>-12</sup>	3.44×1.02×10 <sup>-12</sup>
	Young's modulus E (kN/mm <sup>2</sup> )	66.0	72.9
	Torsion modulus G (kN/mm <sup>2</sup> )	26.7	30.1
	Poisson's ratio (μm)	0.235	0.208
	Knoop hardness (NK100)	555	590
Electrical properties	Dielectric constant (1MHz)ε <sub>r</sub>	6.2	6.7
	Dielectric loss (1MHz) tanδ	99×10 <sup>-4</sup>	61×10 <sup>-4</sup>
	Electric resistance at A.C.50Hz (Ωcm) ρ <sub>D</sub> (θ=250°C) ρ <sub>D</sub> (θ=350°C)	6.0×10 <sup>13</sup> 3.2×10 <sup>11</sup>	1.6×10 <sup>8</sup> 3.5×10 <sup>6</sup>

Chemical properties	Refractive index at 20°C $n_d$ ( $\lambda=588\text{nm}$ ) $n_d$ ( $\lambda=546\text{nm}$ )	1.5255 1.5275	1.5230 1.5255
	Abbe number (ve)	62.2	55.0

Table 3 Temperature properties

Viscosity $\log \eta$ (d Pas)	Temperature (°C)		Properties
	Borosilicate glass A	Borosilicate glass B	
14.5	627	529	Strain point
13.0	663	557	Annealing point
7.6	883	736	Softening point
Coefficient of mean linear thermal expansion $\alpha$ 20~300°C	$45 \times 10^{-7} \text{°C}$	$72 \times 10^{-7} \text{°C}$	

#### 4. Cut filter glass for visual compensation

Since spectral responsivity of imaging devices such as CCD/C-MOS is spreading from visible range to near-infrared spectrum, the near-infrared range should be cut by filter to make the spectral responsivity closer to human luminous efficacy. Otherwise the image would be reddish and good images cannot be reproduced. On the other hand, if the absorption of filter in the ultraviolet spectrum stretches to the visible range, the image would be darkened. This type of filter needs to have transmittance of wavelength 400-520nm as much as high keeping utmost cut in the range of 550-950nm.

As for absorption filter glass type, materials with CuO coloring base are used generally. This absorption filter is combined with phosphate as a whole. In addition, adding fluorine compound such as AlF<sub>3</sub> for up-graded moisture resistance has been popular.

However, adding fluorine compound caused difficulty in the material workability and washing process as well as deteriorated strength in case of thinner glass materials.

Glass materials produced by Matsunami Glass Ind., Co. Ltd. cleared these obstacles (Fig.10).

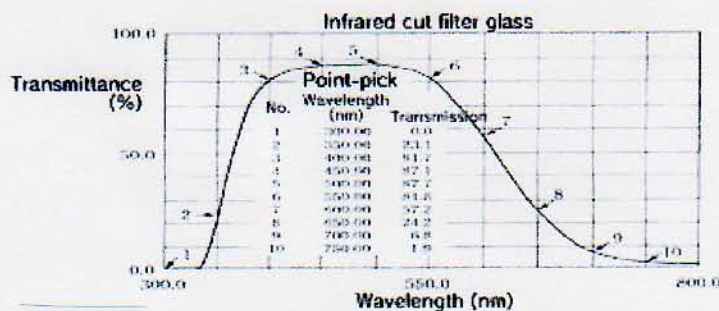


Fig. 10 Example of actual performance : BS7-t0.5

In case of reflection filter type, the coating goes up to 30 layers or more. Coating its self is expensive, but miniaturization realizes cost-down.

However, reflection filter type has a limitation for high-definition type due to its direction dependency. It is expected that absorption type filter will be employed for the items that require high quality screen image. In addition, materials for thin type products will be needed. Technical development in polishing process for mass production of ultra thin film glass should be established.

CCD has discrete alignment of pixels two-dimensionally. An optic image of the object is formed through imaging lens. Accordingly the optic image is formed continuously and sampling is carried out at the time of photoelectric transfer. When an optic image with frequency higher than pixel pitch comes in, aliasing happens. If the signal element of the object is interfused with the aliasing element, moir\_ happens to appear on the screen, which eventually deteriorates the image quality. This moir\_ comes in at the moment of photoelectric transfer. To eliminate it, there is an option to use a quartz plate as optical LPF (low pass filter). However, there are only a few cases of quartz plate used in mobile camera phone with 1million pixels so far. It is necessary to keep watching and evaluate the technology trend that at which level the resolution is required in the future.

### 5. Low temperature poly silicon LCD glass

LCD is used for a variety of products such as notebook PCs and monitors. Recently it is largely used for flat panel TV. Here the basics will be touched upon for reference and poly silicon LCD, which is used widely for mobile phone recently, will be described below.

#### (1) Principle of operation

LCD has in-between character of solid matter and liquid matter. Impressed voltage can change the direction of molecules that compose LCD. With the characteristics, optical switch is realized. Here is the explanation citing TN (Twisted Nematic) mode. (Fig. 11)

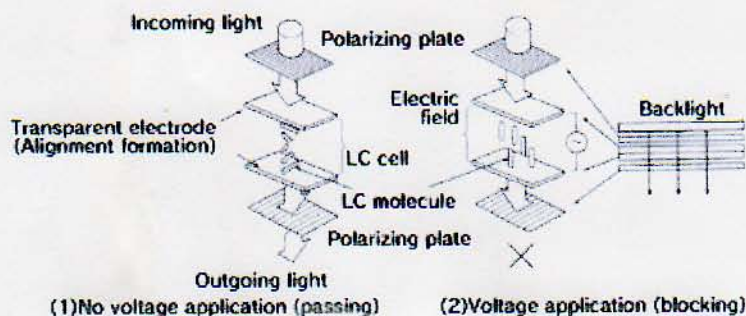


Fig. 11 TFT-LCD mechanism (TN display mode)

An LC cell is comprised of 2 glass substrates with infused LC in between them. The LC cell is sandwiched by 2 polarizing plates, both of which the direction of polarized light is straight. On the surfaces of the two glass substrates facing each other, transparent electrodes are formed in order to apply voltage to LC molecules. On top of them alignment films are formed to align the LC to certain direction. The alignment on the surfaces of facing glass substrates is crossing each other. Therefore, the LC is twisted. When voltage is not applied, the backlight of planate fluorescent material goes through the polarizing plate and becomes a flux of light to incident into the LC cell. After the incidence, it changes the direction by 90 degree to go through the other polarizing plate. When voltage is applied, LC molecules are aligned in the direction of electric field all together. Therefore the backlight cannot go through the LC and the polarization plate. This is the electrical mechanism of optical switch.

In addition, if divide one pixel into three and let through color filters of red (R), green (G), and blue (B) respectively, color display is possible. As for the method of voltage application, passive matrix, to apply voltage directly on LC, was employed at the beginning. In the meantime, for such items that image quality and speed of response are required, TFT (Thin Film Transistor) active matrix is becoming the mainline. TFT has been formed with amorphous silicon (a-Si) in general.



## (2) Low temperature poly silicon TFT-LCD

Poly silicon has a crystallographic structure of regularity and can transfer electrons faster 100 times or more. Therefore, optional circuits using p-Si TFT can be made. High temperature p-Si TFT-LCD using quartz substrate is growing rapidly for projector use. However, this quartz type high temperature p-Si that requires heat treatment at 900°C or higher is too expensive to use for mobile phones.

Under such circumstances, formation on alkali free glass substrates of low expansion coefficient is realized at a low temperature (600°C) like a-Si type opened the door to practical applications that require miniaturization and high-definition. This is the low temperature p-Si TFT-LCD. P-Si goes through a laser anneal process of excimer laser (wavelength: 308nm) irradiated where the temperature goes up 1000°C or higher. (No damage on glass because it happens in a flash.)

Certain heat treatment in advance is needed because the film would be peeled off out of the s-Si film (contains approx. 10% hydrogen), which is in the state prior to formation. In connection with this, anneal treatment technique of substrates taken glass contraction into account is also important know-how.

## (3) Technical and product development of low temperature p-Si TFT-LCD

The key word is high definition p-Si product development. The target is resolution that is expressed by pixel density. It is said that the image quality improves to be closer to that of printed image when the resolution exceeds 130ppi. The resolution of 100ppi is prevailing current a-Si type notebook PCs. It is quite sure that low temperature p-Si TFT-LCD that has larger display capacity exceeding 150ppi will be widely employed working together with increased pixel number of image sensor as mentioned above. Mobile camera phones will also make a leap forward with high-pixel-density type, which is hitting the market one after another. So far t 0.7 glass has been used for substrate glass and the thickness will definitely be thinner. Along with that, technical improvement of plate production, heat treatment and other relevant technology will steadily advance.

## 6. Conclusion

When having a check on various matters of mobile camera phones such as market trend, parts used in image sensor module and LCD panel, high-definition of the products has been accelerated and other key parts have been innovated accordingly.

In line with this trend, glass materials have an important place, while seeking thinner glass is the essential element to create quality function in thin-film glass. As for the shape of each material, though not mentioned this time, rounding processing with precise dimensional measurement of each material is the best to pack the materials in a case tightly. In term of the processing, it is getting to meet the need of the market sufficiently. Having a look at key parts of mobile camera phones from the global viewpoint, manufactures in Japan still have outstanding capacity and capability in technology. Hoping further advancement of the technology, I will spare no effort in contribution.

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