Samsung's 4th Generation TFT- LCD Production Line Concept

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Abstract

With the explosive growth of Note-PC and Desktop monitor market, TFT LCD market confronted a entire supply shortage during 1999. Forecasting a more booming stage for the next several years, many TFT-LCD panel manufacturers continue to expand the capacity of their existing plants and also make an additional investment in building new plants. The new investment is concentrated on the 4th generation TFT LCD line in order to improve investment efficiency.

The set up of the Samsung's Gen 3.5 line progressed with satisfactorily performance using 600x720mm glass size . We have continuously reviewed several issues regarding the glass size for our next Gen. 4 line, which leads to adopt 730x920mm. Due to the continuous enlargement of a substrate size and following difficulty in transferring cassettes, the next line is expected to be the last line that employs "cassette transfer". The layout of the next line will shift from conventional "concentration-type" to "separation-type" configuration for the purpose of reducing transfer distance as well as transfer time. The details will be discussed in this paper.

Introduction

TFT-LCD market has come through a deep depression in 1998 because of the oversupply caused by over investment in 1996. With the advent of a new Desktop monitor market for TFT-LCD, however, the market experienced an unprecedented boom in 1999. Many market research institutions forecast that this boom will last for the next several years because the market of Note-PC monitors are steadily increasing and the TFT-LCD share in desktop monitors market grows with high rate. Furthermore, the market is anticipating an opening of LCD-TV market which will accelerates the shortage in supply.

Taiwanese companies joined in the market with TFT-LCD lines of 3rd or 3.5th generation in 1999. Major panel makers including the existing Korean and Japanese companies as well as new Taiwanese companies are making an investment in new plants. And these plants aim to use 4th generation size substrates, bigger than 650x830 mm^2.

The greater the risk in new investment, the bigger the glass and the more the investment money. Therefore, the selection of adequate glass size is much more important than ever and will play a role in succeed of the investment.

Samsung also planned to make a new investment in a 4th generation line and reviewed several issues regarding the adequate glass size in detail. The issues such as panels size trend in market, availability and capacity, glass usage efficiency, and investment efficiency were reviewed and discussed in the following text. Additionally, we also paid attention to the fact that the layout concept needs modifying with the enlargement of glass size and more difficulty in transferring glasses and cassettes. Therefore, the issues on the layout of the 4th generation TFT LCD line will be discussed and several examples will be suggested to reduce the productivity losses that may come out of transfer loss.

1. Market Trend and Forecast

The application of TFT LCD is expanding from Note-PC and Desktop-PC monitors to LCD TV, mobile phone, and game machine displays, etc. Therefore, the market for TFT LCD grows further and further simultaneously with the growth of existing demand for Note-PC and Desktop-PC monitors.

Figure 1 shows the forecast of Note-PC monitor market trend from year 1999 to 2005 by several market research institutions. The market volume will increase from 21.2 million in 2000 to 33.7 million in 2003 and 44.8 million in 2005. That is, the market will make a steady annual growth of 16%.

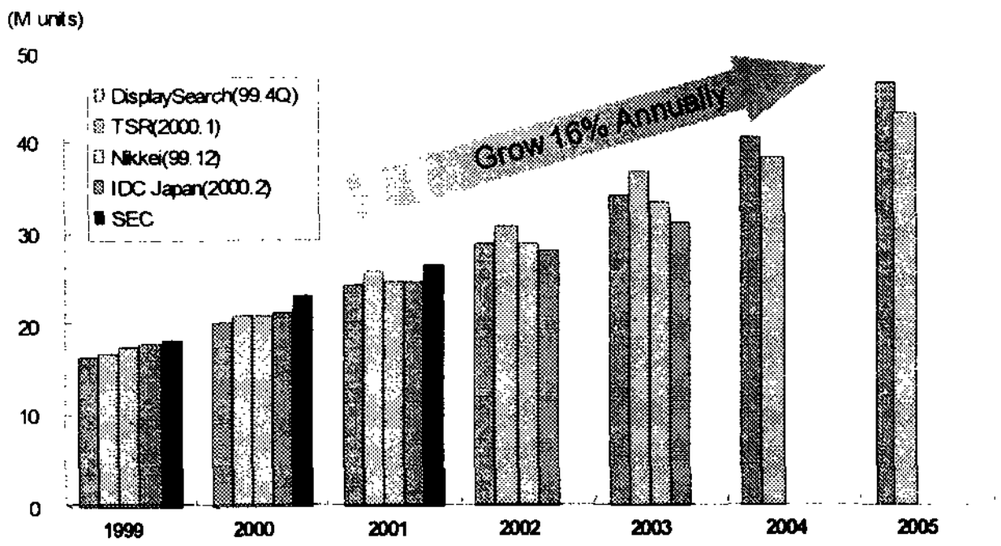

Figure 1 Forecast of Note-PC monitor market

As shown in Figure 2, desktop monitor market will become another big one for TFT LCD panels. The market volume will increase from 6.5 million in 2000 to 18.9 million in 2003 and 30.5 million in 2005. That is, this market is expected to make an explosive annual growth as high as 38% and the volume will reach about 70% of Note-PC monitor's in 2005.

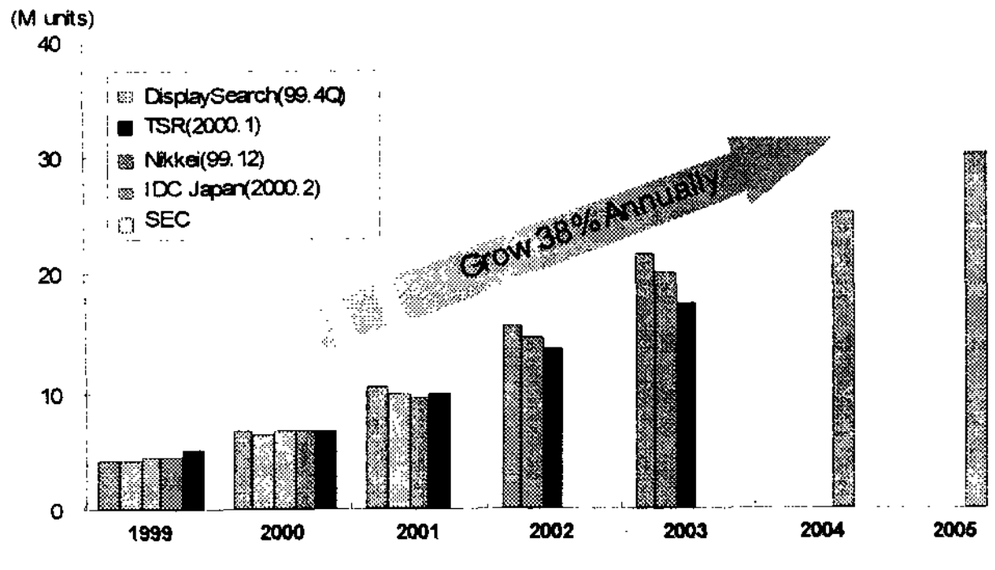

Figure 2 Forecast of Desktop-PC monitor market

The emerging market for TFT-LCD is LCD-TV. Although the volume will be as low as 0.2 million in 1999, it will rise up to 2.5

million in 2003 and 6.8 million in 2005, which corresponds to an annual growth of 102%.

Figure 3 shows a TFT-LCD crystal cycle that represents the relationship between market trend and price change. As can be seen from the upper left, the price should go down when the panels are oversupplied in market. In order to make a profit despite the low price, the panel makers will shift to new products such as larger-sized and high-resolution panels to make a new demand. Production of larger-sized and high-resolution panels will expand market and make a shortage market. To make up for shortage, panels makers will expand their existing plants and make new plants. This will cause oversupply and the price will go down again. The market turns around this cycle. This is a brief summary of a TFT-LCD crystal cycle.

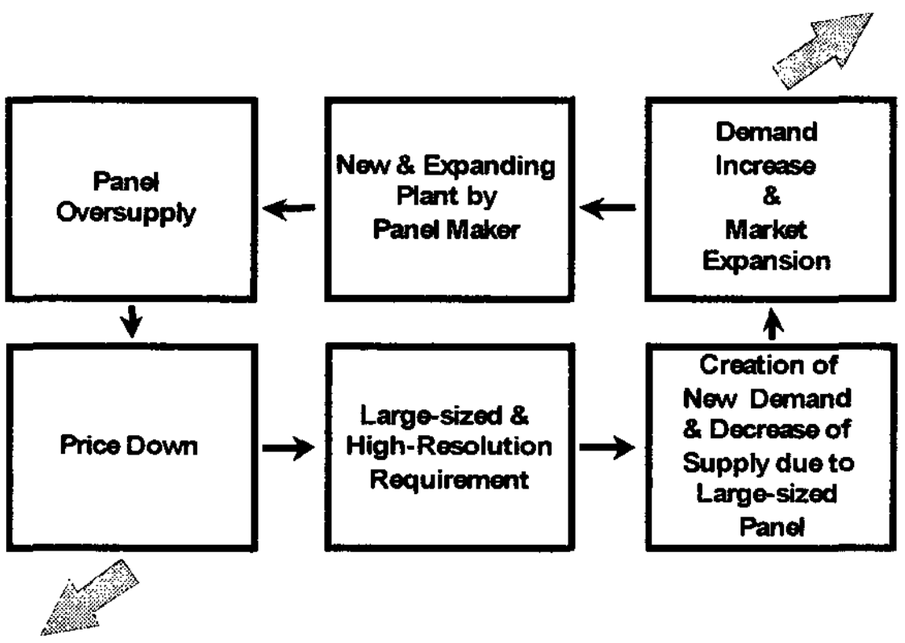

Figure 3 TFT- LCD crystal cycle

In view of TFT-LCD crystal cycle, the past and present market trend can be analyzed and future market forecast is possible. Figure 4 shows the real crystal cycle and price trend. In 1995, the price of 10.4-inch panels fell down with the oversupply. This shifted market from 10.4-inch to 12.1-inch panels in 1996 and limited supply due to the enlargement of panel size induced a new and large investment in 1997. Another oversupply of 12.1-inch panels caused panel price to go down again in 1998 and panel makers started to produce bigger panels such as 13.3-inch, 14.1-inch and 15.0-inch panels and stopped to make a new investment until the early 1999. The opening of Desktop-PC monitor market in early 1999 in addition to supply shortage raised the panel price in a great extent, so that new Taiwanese companies decided to make a new investment along with the additional investment by the existing panel makers in 1999.

The price goes down slowly from the end of 1999 due to the over investments and the market will again suffer from oversupply in a near future. But the market is expecting a new opening of LCD-TV market, which will require larger panels and diminish oversupply. Besides, the expansion of larger panel market for desktop monitors is expected from the past experience and trend. Then, this will cause again the shortage despite the huge investment made by most panel makers in 3 countries (Korea, Japan and Taiwan) in 1999 and 2000. Consequently, the oversupply that will happen in 2001 will be shorter than ever and the shortage will come again in 2002.

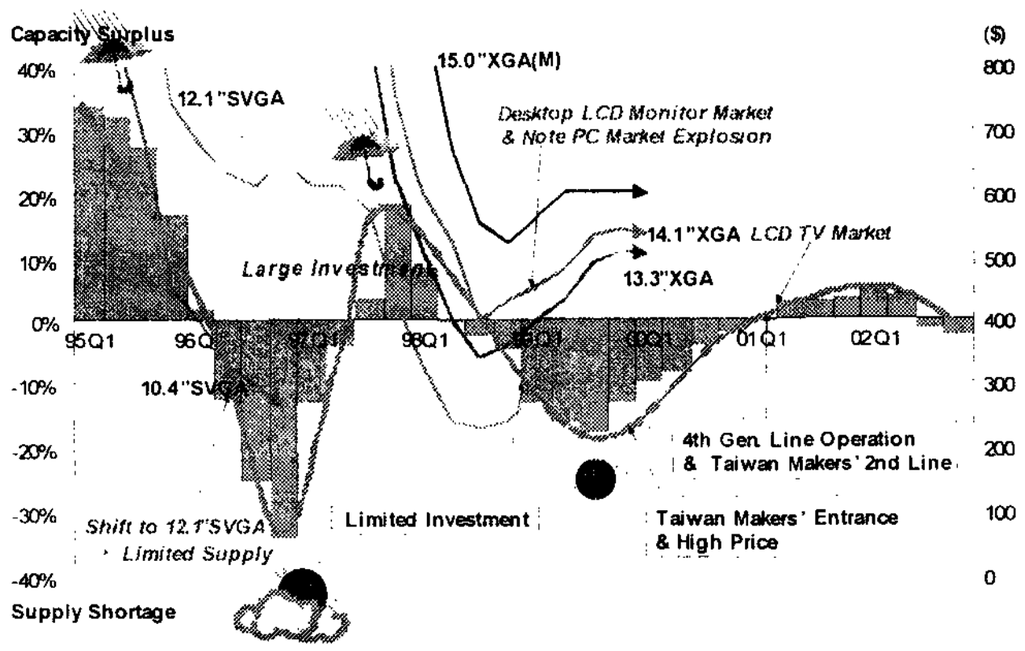

Figure 4 Crystal cycle and price trend.

2. Glass Size Consideration

2.1 Panel Size Trend

The panel size tends to be larger as the market grows. Simultaneously, the resolution of panels tends to and should be higher in order to prevent pixel size from enlarging. This is because enlargement of pixel size might cause degradation of display quality. On the contrary, in fact, the pixel size becomes smaller as the panel size becomes larger to improve display quality. Figure 5 shows the change of pixel size according to the diagonal size of TFT-LCD panels.

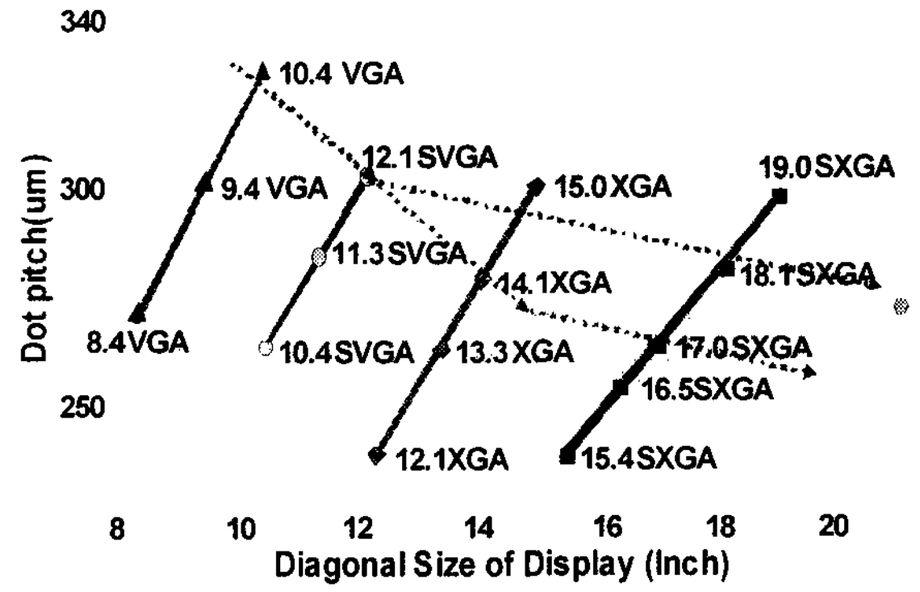

Figure 5 Trend of pixel size change with TFT-LCD panels

In case of Note-PC monitors, the major products shifted from 10.4-inch VGA to 12.1-inch SVGA and up to 13.3-inch XGA, 14.1-inch XGA and 15.0-inch XGA. In 1999, the main products were 13.3-inch and 14,1-inch panels, and 15.0-inch panels were also shared partial market. But from 2000 to 2005, 14.1-inch XGA panels are expected to be most popular products. Product differentiation such as higher resolution (SXGA, UXGA) and bigger-sized (16.5-inch) panels will open a new market. Among the examples are there 15.0-inch SXGA and 16.5-inch SXGA+.

15.0-inch XGA panels were main products for Desktop-PC monitors in 1999 and this trend will last until 2003. The demand for higher resolution is also increasing for Desktop-PC monitors with the popularity of Internet, multi-content, and multi-tasking. In 1999, a little amount of 15.0-inch SXGA panels also took part in this market.

On the other hand, 17.0-inch SXGA CRT monitors shared most of desktop monitor market. The point that cannot be ignored is that 17.0-inch and 18.1-inch SXGA panels are penetrating into this market. That is, LCD panels might expand its share in desktop monitor market with 15.0-inch XGA panels as consumer products and also with 17.0-inch and 18.1-inch SXGA panels as high-end products. In a near future, larger panels such as 17.0 or 18.1 will become major Desktop-PC monitors. However, no one can be sure which size(17.0 or 18.1) will occupy most LCD monitor market. The issues concerning this topic will be discussed more in the following section in view of availability and capacity of each panel.

2.2 Availability and Capacity of 17.0-inch and 18.1-inch Panels

Due to the smaller substrate size, TFT-LCD lines using glasses under 550x650 are inadequate and inefficient for products larger than 15.0-inch panels. Therefore, 17.0-inch and 18.1-inch panels are available only in lines using glasses over 600x720. Table 1 shows the substrate size and mass production capacity of available makers using glasses over 600x720. The makers are classified into two groups. One is for production of 17.0-inch panels, and the other for 18.1-inch panels. The capacity is assumed for that in 4th quarter, 2000.

Table 1 Capacity of 17.0-inch and 18.1-inch panels

Maker	Glass Size	Input Glass (Ksheet /M)	17" Capa (K/M)	Maker	Glass Size	Input Glass (Ksheet /M)	18" Capa (K/M)
TAIWAN A	600 x 720	30	120	JAPAN A	650 x 830	30	120
TAIWAN B	620 x 750	30	120				
TAIWAN C	610 x 720	30	120	JAPAN B	680 x 880	30	120
Samsung	600 x 720	70	280				
	730 x 920	30	180	KOREA B	680 x 880	30	120
Total		180	820	Total		90	360

To produce 4up 17-inch panels on a glass, a substrate size over 600x720 is necessary and up to 6 panels can be obtained for 730x920. However, to produce 4 18.1-inch panels on a glass, a substrate size larger than 650x830 is inevitable, so that the number of available panel makers are only 3, excluding Samsung (730x920). Therefore, total capacity sum of 17.0-inch panels is three times larger than that of 18.1-inch panels. As a result, it can be said that 17.0-inch panels are more available in market. And it can also be inferred that 17.0-inch panels will be more cost-effective, so that there is much more probability that 17.0-inch panels will become a major product in LCD desktop monitor market.

Table 2 Comparison of Glass usage efficiency

Device	680 x 880	730 x 920
13.3 XGA	88.0%	78.4%
14.1 XGA	65.0%	86.9%
15.0 XGA	75.7%	68.4%
17.0 SXGA	64.7%	87.7%
18.1 SXGA	73.2%	65.3%
21.3 UXGA	49.5%	89.3%

2.3 Glass Usage Efficiency

Table 2 shows glass usage efficiency according to the glass size. Glass usage efficiency strongly depends on panel size. In case of 13.3, 15.0 and 18.1-inch panels, 680x880 is more efficient. But 730x920 has higher efficiency for 14.1, 17.0 and 21.3-inch panels. Therefore, higher efficiency can be obtained for optimized panel size. It is advantageous and important to adopt adequate glass size after accurate market forecast.

2.4 Investment Efficiency

Investment efficiency becomes more important with the glass size increase and the investment cost-up. Investment efficiency rest on productivity and the latter is (a product of a number of panels on a glass, equipment uptime and yield) divided by (a product of TACT, equipment cost and footprints). Among these factors, uptime and yield depends on the capability of each manufacturer, so these factors are fixed The rest factors such as TACT, a number of panels on a glass, equipment cost and footprints are dominant ones that decide productivity. Table 3 compares each investment efficiency in terms of relative productivity ratio according to glass sizes, 600x720, 680x880 and 730x920. Four kinds of different Panel sizes, 14.1, 15.0, 17.0 and 21.3, are selected for comparison. 680x880 has a slight advantage over 730x920 only for 15.0, while 730x920 has a great advantage over 680x880 for 14.1, 17.0 and 21.3. Moreover, a relative productivity of 730x920 for 21.3-inch panels is about two times higher than that of 680x880, so that 730x920 is highly preferable for 21.3-inch panels. However, for all the panels except 21.3, 600x720 has an advantage over both 680x880 and 730x920. Therefore, in order to obtain relative productivity higher than 1.2 in the 4th generation line, TACT should be fixed at the similar value with that of 600x720, and the equipment cost as well as footprints should be less than 1.1.

Table 3 Comparison of Investment efficiency

Item	600 x720				680 x880				730 x920			
	14.1 NB PC	15.0 MONI	17.0 MONI	21.3 MONI	14.1 NB PC	15.0 MONI	17.0 MONI	21.3 MONI	14.1 NB PC	15.0 MONI	17.0 MONI	21.3 MONI
TACT	1.0	←	←	←	1.1	←	←	←	1.1	←	←	←
# of Panel	1.0 (6)	1.0 (4)	1.0 (4)	1.0 (2)	1.5 (6)	1.5 (6)	2.0 (4)	2.0 (2)	2.25 (9)	1.5 (6)	3.0 (6)	4.0 (4)
EQ Cost	1.0	←	←	←	1.3	←	←	←	1.3	←	←	←
Foot Print	1.0	←	←	←	1.3	←	←	←	1.35	←	←	←
EQ Uptime	1.0	←	←	←	1.0	←	←	←	1.0	←	←	←
Yield	1.0	←	←	←	1.0	←	←	←	1.0	←	←	←
Productivity Ratio	1.0	1.0	1.0	1.0	0.54	0.81	0.54	0.54	0.78	0.78	0.78	1.04

2.5 Samsung's Glass Size for 4th Generation

From the above research and analysis, Samsung forecasted that the major products for Note-PC and Desktop-PC monitors will be 14.1 and 17.0, respectively. The most adequate glass size for the next 4th generation line is found to be 730x920, so Samsung adopted 730x920.

3. Equipment Layout Conception

The substrate size increase will cause the increase of the manufacturing equipment size as well as cassette size. And it will also cause more glass bending, which results in the increase of cassette slot pitch and cassette height. As a result, more careful

handling of glasses and cassettes is required and it takes more time to transfer glasses and cassettes from one place to another. We cannot ignore the possibility that the transfer can become a neck step in a 4th generation TFT LCD line. In order to eliminate a time loss caused by transfer, a number of transfer should be minimized with the optimization of transfer method and route.

3.1 Macro Configuration

Figure 6 shows two configurations, concentration and separation. Cassette transfer was not a major factor deciding TACT (Turn Around Cycling Time) until the 4th generation TFT LCD line. Therefore, concentration-type configuration was adopted up to the 3rd generation line because it can flexibly cope with the partial equipment down under mass production and maximize the capacity and investment efficiency of each process by congregating same kinds of process equipments in the same area. But time loss can occur due to the long distance between consecutive process, which brings about TACT and productivity loss. This becomes more serious as the glass size increases.

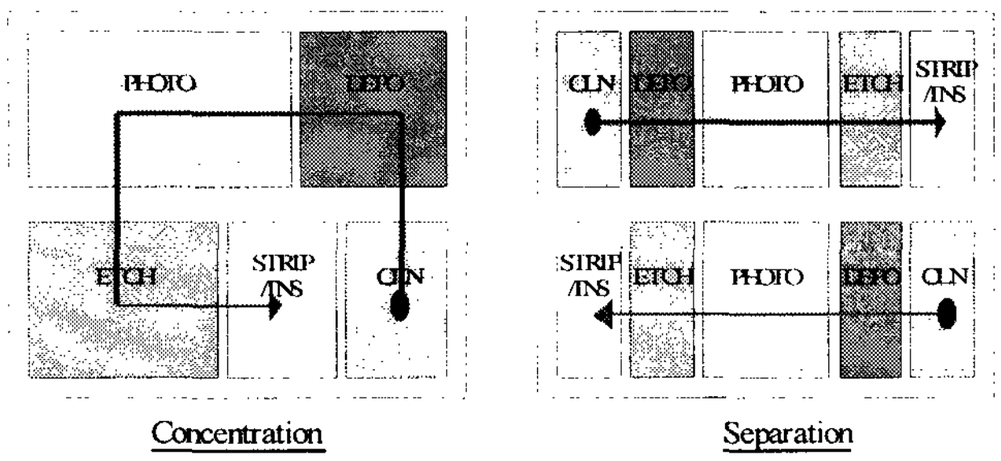

Figure 6 Comparison of concentration-type and separation-type configuration

The other type of configuration, "separation", can overcome this time loss caused by useless transfer. Cassette transfer distance is minimized because each process equipment is arranged sequentially according to the process sequence. When one layer process (cleaning, deposition, photo, etching, and stripping) is done, a cassette should move about two times longer distance in case of concentration-type than separation-type configuration, as shown in Figure 6. However, the advantages of concentration-type configuration equal to disadvantages of separation-type, so that the flexibility and the investment efficiency are lower for separation-type configuration.

Productivity and TACT were considered to be most important factors for our 4th generation line, so separation-type configuration was adopted in contrast with our previous lines.

3.2 Micro Configuration

In-Line configuration is one of those methods that can reduce a number of cassette transfer. As can be seen in Figure 7, 3 times of cassette transfer is required in case of confessional "independent" configuration while only one for "In-Line" configuration. The process shown here includes 3 steps which consists of 1st metal etching, PR stripping and 2nd metal etching

Other way to reduce a transfer number is Cluster-type configuration as shown in Figure 8. Multiple equipments for different process are assembled into a stocker and the cassette transfer is performed by common rack masters. With the help of cluster-type configuration, unnecessary transfer such as from equipments to a stocker, or vice versa, can be abbreviated. The process shown here includes 4-steps which consist of wet etching, PR stripping, inspection and dry etching.

TACT reduction of about 50% is expected to be obtained through the reduction of cassette transfer by more than 50% with the help of this micro configuration change, simultaneously with the help of the macro configuration change.

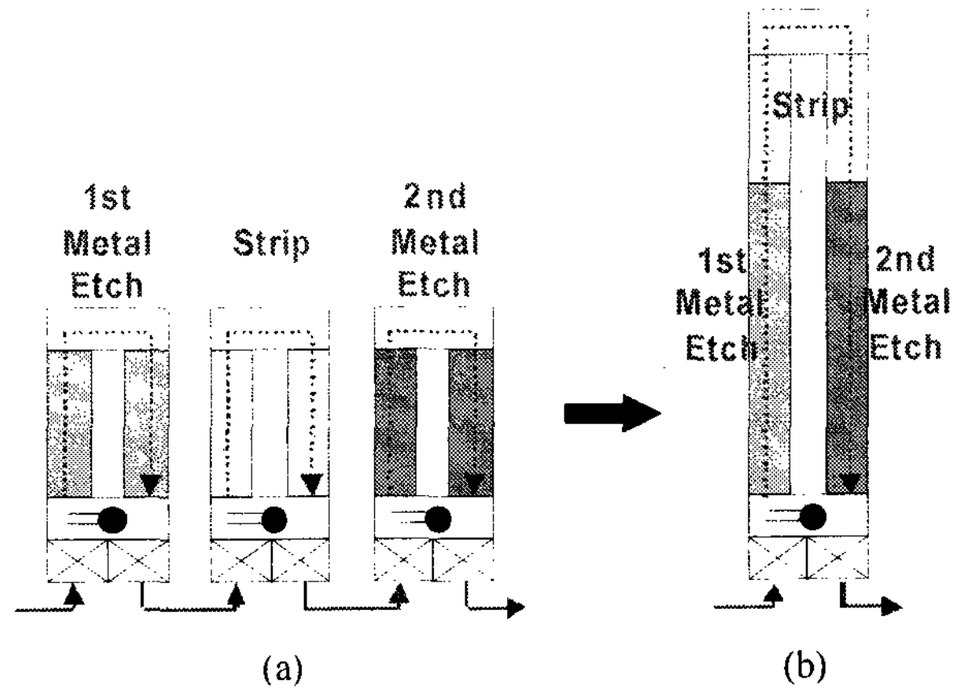

Figure 7 Reduction of transfer number of cassettes
(a) Independent configuration (b) In-Line configuration

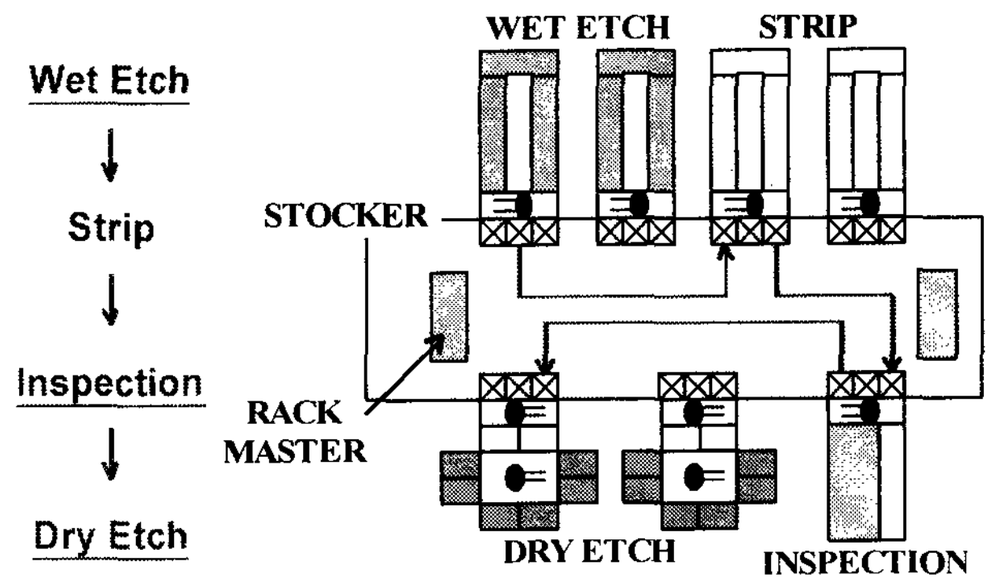

Figure 8 Cluster-Type configuration of multiple equipments.

Summary

The entire TFT LCD market will grow at high rate due to the steady increase of Note-PC monitor market and explosion of desktop monitor market.

After reviewing several issues regarding the optimized substrate size, Samsung adopted 730x920 as a glass size of the 4th generation TFT LCD line. Samsung aimed for 14.1-inch (15.0-inch) and 17.0-inch panels as major products for future Note-PC and Desktop-PC monitors, respectively.

Reduction of transfer loss is a key factor that will affect productivity in the 4th generation line. Samsung intended to obtain a TACT reduction of about 50% through reduction of cassette transfer by introducing "separation-type" configuration and partially applying "In-line type" and "Cluster type" configuration into multiple equipments.