Current Trends of Flat Panel Displays Viewed from Applications

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Abstract

With the rapid spread of broadband Internet and the improved infrastructure for wireless communication, we have substantially entered into the era of ubiquitous networks. FPDs are quickly gaining importance in this era, as they act as human-information interface and contribute to technological advances beneficial for our lives. The progress in LCD technology is lightning-fast, and LCD has become an integral constituent in every application field. It is expected that they will incorporate system functionality and evolve to System LCDs in future. This paper gives an overview of the trends of major FPDs. Focusing particularly on mobile applications, the current status and future outlook of mobile LCDs are described.

Introduction

This year marks the inauguration of terrestrial digital broadcasting. This technology will deliver high-quality video and audio, as well as enable the viewing public to participate in real-time interactive programming by means of two-way data broadcasts. In addition, using a mobile phone, TV pictures will be available whenever and wherever desired. Deployment of this infrastructure has been rapid as the era of ubiquitous (pervasive) networking dawns.

Against the backdrop of such trends, demand for flat panel displays that serve as "information gateways" linking people and information is expected to increase rapidly. Among these, LCDs have pulled far ahead of other flat panel displays in terms of thinner profiles, lighter weights and lower power consumption, and their use is spreading rapidly in all application areas, particularly for LCD TVs, where demand has surged from 3 million units in fiscal 2003 to 8 million units in fiscal 2005. They are also finding application in mobile phones, vehicle navigation systems, where they act as mobile information communication terminals, and even in wearable computers. They are becoming increasingly important as key devices that are contributing to the creation of a new era in human life.

This paper focuses on the current status of flat panel displays, and provides a brief introduction to their features and the technical issues that surround them. It also provides an overview of the current status and future prospects of LCDs in the mobile application area.

1. Current Status of Various Types of Flat Panel Displays

The CRT was invented at the end of the 19th century, but even today, after more than 100 years during which the electronics industry has undergone profound changes, it still has widespread market penetration as an integral technology in the display field. During this period, numerous novel flat panel displays (FPDs) have been proposed including vacuum florescent displays (VFDs), light-emitting diodes (LED), inorganic electroluminescent (EL) displays, liquid crystal displays (LCDs), and others. But only LCDs have shown exceptional growth, and since the LCD electronic calculator was first brought to market in 1972, their use has spread rapidly in all fields and applications, leading to a market that significantly exceeds the current ¥2-trillion CRT market (**Fig. 1**). However, technical innovations in FPDs are unfolding rapidly, and at this point, technology breakthroughs in display design and materials for the types of FPDs noted above, as well as in field emission displays (FEDs) and organic EL displays, are progressing. FPDs are on the verge of a new stage of widespread penetration oriented toward practical, real-world applications.

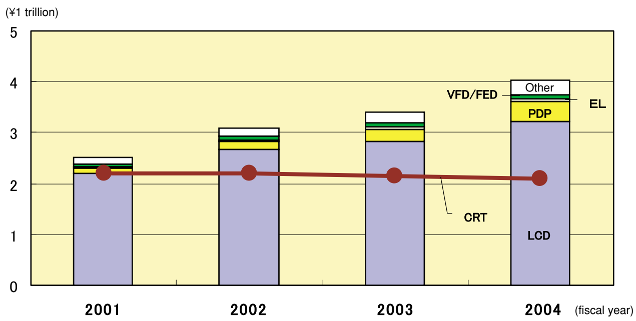

Fig. 1 Market size for flat panel displays (by value)[1)]

Below, I will describe the current status of these representative flat panel displays and the technical issues they face in the future.

1.1 Classifications of Flat Panel Displays

Flat panel displays can be divided into two broad classifications: self-illuminating and passively illuminated (non-luminous). Self-illuminating displays, typified by CRTs, have many attractive features, including fast response times (on the order of microseconds) and wide viewing angles from all directions, but are difficult to see in bright ambient light, and are not considered well-suited for use in mobile applications because of the challenges involved in reducing their power consumption. In contrast, passively illuminated displays utilize external light, so they are considered ideal for mobile applications because it is relatively easy to lower power consumption. However, they do have drawbacks that demand improvement, such as better response times and wider viewing angles.

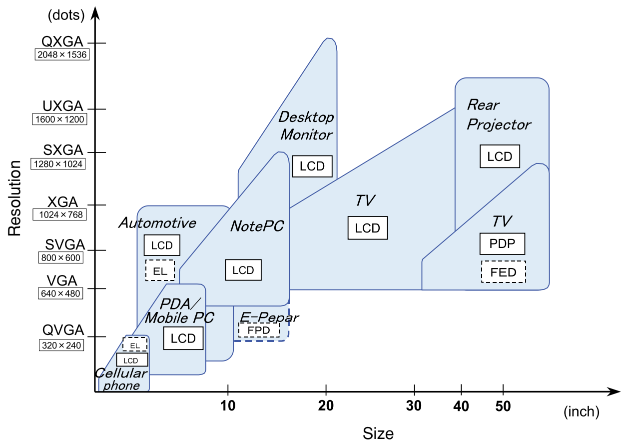

Fig. 2 Flat panel display application niches

Below, I discuss the major types of flat panel displays and provide an overview of their features and the current status of relevant technologies. **Fig. 2** shows the application niches occupied by the various types of flat panel displays.

1.2 LCDs (Liquid Crystal Displays)

Liquid crystal displays (LCDs) are passively illuminated displays that operate based on changes in the electro-optical characteristics of liquid crystal molecules encapsulated between two glass substrates. They can be classified under two groups, TFT LCDs and STN LCDs, according to differences in panel structure and drive systems. In particular, there are two types of TFT LCDs: TFT LCDs that use amorphous silicon are called a-Si TFT LCDs and ones that use low-temperature polysilicon are called LPS TFT LCDs. Technological progress in the field of TFT LCDs has been remarkable, and, as is well known, TFT LCDs with wide-ranging sizes from super-small sizes below 1 inch on the diagonal to large 40-inch sizes have been commercialized, and they have achieved widespread penetration in various fields.

Sharp, in conjunction with Semiconductor Energy Laboratory Co., Ltd., has developed continuous grain silicon (CG Silicon) technology that is further evolved from conventional LPS technology. This high level of technical competence is now the driving force in the industry, and has led to the commercial introduction in October of last year of high-resolution, high-definition System LCDs for mobile terminal devices that make full use of CG Silicon technology. Sharp continues to take up the challenge of uncovering new possibilities for LCDs, including 3D LCDs that render three-dimensional stereoscopic images without the need for special 3D glasses.

1.3 Plasma Display Panels

Plasma displays are self-illuminating displays in which a noble gas in a plasma state is used to react with phosphors to produce color light. A longstanding problem, image burn-in failure, has been resolved, and display technology with higher brightness and greater resolution has made rapid strides. This has accelerated commercialization of large-screen plasma display TVs ranging in size from 32 inches to 60 inches. According to a recent press release[2)], improvements in electrode design and infilling gasses have boosted prospects for practical use of plasma display TVs that cut power consumption to roughly half of current values; for example, a 50-inch model reduces power consumption from 385 W to 192 W.

1.4 Organic EL (Electroluminescent) Displays

Organic EL (electroluminescent) displays are self-illuminating and have a two-layer structure consisting of a light-generating layer and an electron hole transport layer. An electric-field effect within the layers is utilized for display. Improving the luminous efficiency of red and blue materials and lengthening service life have previously been regarded as major technical issues, but according to a recent news release[3)], full-scale mass-production of active-matrix type organic EL displays is planned for launch within this year. This represents a major breakthrough on these technical issues.

1.5 Electrophoretic Displays

Microcapsule electrophoretic displays[4)] developed by U.S. venture companies are typical of this type of display. These are passively illuminated displays in which negatively and positively charged black and white microparticles, respectively, are dispersed inside transparent capsules several microns in diameter, and are migrated by applying an external electric field, thereby creating the image. These displays are expected to be available on the market in 2003 as "sheet computers." Multicolor types are also currently under development.

1.6 Field Emission Displays

Field emission displays are self-illuminating displays in which electrons ejected from an electron gun strike phosphors, causing them to emit light. In the past, service life and reliability problems, such as deterioration of the electron guns due to minute quantities of gas generated during operation, have emerged. However, low-voltage FEDs that use carbon nanotubes in the electron gun[5)] and SEDs that use a surface-conducting electron gun[6)] have recently been developed, and product development has been stepped up with an eye to the large-screen, thin-profile TV market.

2. Current Situation and Future Prospects for Mobile LCDs

The preceding paragraphs outlined the current status of the major types of flat panel displays and their associated technical issues, and clarified that, of these flat panel displays, only LCDs can be used over a wide range of consumer applications, from mobile handsets to large-screen TVs.

In the paragraphs that follow, the current status and future prospects of LCDs for each application, especially in the mobile market, are broadly overviewed.

2.1 Infrastructure and Product Trends

In light of the development and upgrading of the wireless communications infrastructure, and particularly with the rapid diffusion of the Internet, ubiquitous (pervasive) networking that enables anyone to access necessary information by connecting to a network from anywhere, anytime, has at long last become a reality (**Fig. 3**).

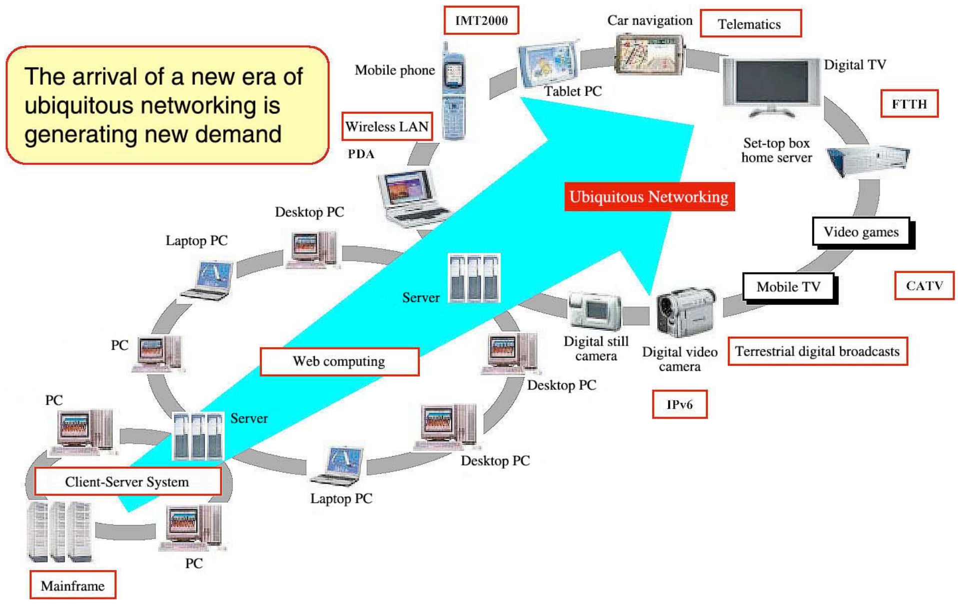

Fig. 3 Ubiquitous networking and mobile devices[7)]

Mobile phones, which are typical mobile devices, are moving from 2nd generation digital models to 3rd generation models incorporating special features such as e-mail with movie clips, high-speed data communications, and global positioning systems (GPS). Applications for these advanced phones are expanding rapidly and they are evolving toward multimedia-ready and multi-functional information terminals.

PDAs, up to now, have been used as stand-alone devices for personal schedule and address book management (PIM), but today, they are evolving into new personal information terminals that enable users to obtain diverse network content. Also for business use, reflecting the increasing need as network terminals, PDAs continue to spur new demand and spawn new markets as network devices.

Demand for in-vehicle displays, particularly for car navigation systems, is expected to significantly rise in the future, supported by the development and upgrading of Intelligent Transport Systems (ITS) [**1]. With the rapid development of networking, in-vehicle displays are becoming essential "mobile information terminals" for drivers and passengers: the Automatic Electronic Toll Collection (ETC) and the next-generation Telematics System, which has a wide range of telecommunication functions that originate or end inside automobiles through global networks.

**1 : Intelligent Transport Systems are new traffic management systems that link people, roadways, and vehicles via wireless networks with the goal of resolving problems related to road traffic such as accidents and congestion.

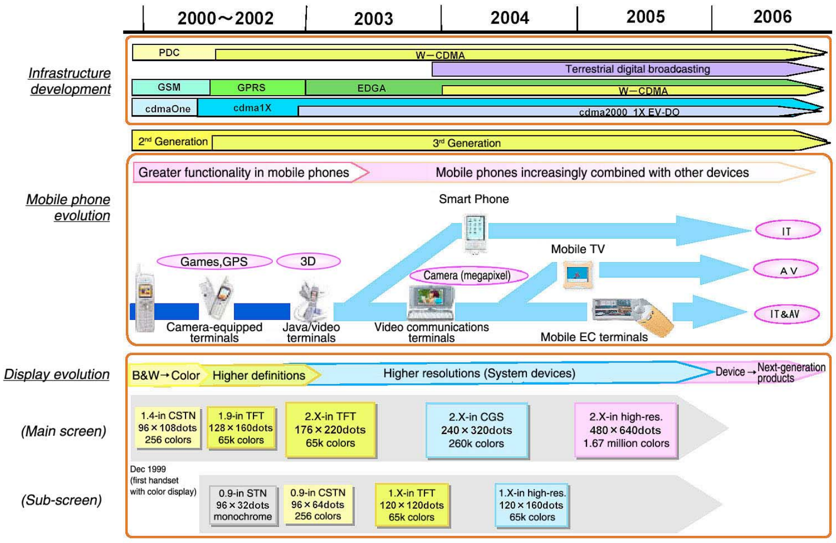

Fig. 4 Evolution of LCDs for mobile phones

2.2 Trends in LCDs by Primary Application

This section provides an overview of recent trends in LCDs from the standpoint of major applications, including mobile phones, PDAs, in-vehicle displays, and personal audio/video products.

2.2.1 Trends in LCDs for Mobile Phones

Estimates place the world aggregate demand for mobile phones at approximately 400 million units for fiscal 2002, 425 million units for fiscal 2003, and 460 million for fiscal 2004, with an average projected annual growth rate of around 7%. Under these circumstances, the CCD camera function has led to explosive diffusion of color devices and the estimated growth rate of mobile phones equipped with color LCDs is a remarkable +113% in fiscal 2003 compared to the previous year. It is estimated that in fiscal 2004, approximately 70% of mobile phones worldwide will be equipped with color screens. As 3rd generation mobile phone services become available, there have been growing demands for LCDs with higher resolution (QVGA in the 2-inch class), thinner profile, and lower power consumption features. Furthermore, looking ahead to the start of terrestrial digital broadcasting from the end of this year, there has been increasing demand for LCD modules with faster response rates that will enable users to enjoy crisp and clear TV images.

Sharp has anticipated such needs, and has started to deliver samples of 2.2-inch QVGA (320 x RGB x 240 dots), high-definition System LCDs that have double the brightness and quadruple the resolution of Sharp's conventional LCDs, thanks to CG Silicon technology. Because of their high ratings among users, we are planning to introduce them on a commercial basis from this spring. In addition, we are making a concerted effort to develop and commercialize high-value-added LCDs supported by our unique "one-of-a-kind" technologies. Examples include 3D LCDs and Twin LCDs that integrate a main LCD and a sub-LCD into a single package that utilizes an energy-efficient, high-brightness, thin-profile dual-surface illuminating backlight system based on our proprietary optical design technology. We are also working to develop and introduce ULC: [**2] technology that achieves ultra-low power consumption. (**Fig. 4**).

**2 : ULC = "Ultra Low Consumption"; technology to achieve ultra-low power consumption by radically revamping the drive system.

2.2.2 Trends in LCDs for PDAs

PDAs (personal digital assistants) have broken free from their traditional category of stand-alone compact information processing terminals and are evolving into network IT devices integrated with audio/video capabilities. The next step is to open up new application areas, such as PDA phones equipped with wireless communications functions. For the display system embedded in these devices, demand for full-color TFT LCDs has been increasing. An estimated 40% of all models sold in fiscal 2002 had full-color TFT LCDs while the estimate for fiscal 2003 is 60%. Thus, in the future, demand for full-color PDAs will likely increase. Most TFT LCDs will likely be in the 3-to-4-inch range and screen resolutions will increasingly shift from the current QVGA to higher resolutions such as VGA (480 x RGB x 640 dots) for increased compatibility with personal computers.

In anticipation of these trends, in December of last year Sharp developed the System LCD with multi-resolution functions、[**3] based on CG Silicon technology and put this LCD in our Zaurus, a PDA that proved extremely popular. In the future, we will proceed with further development of 3.7- to 4-inch-class, super-high-resolution VGA-compatible System LCDs with high PC compatibility with the aim of making these the de facto standard. We will also work to further enhance system integration capabilities and will broaden our product line with a multi-functional System LCD that offers thinner profiles, lighter weights and lower power consumption appropriate for a new category of PDAs.

**3 : Multi-resolution capability enables switching instantly between QVGA and VGA resolutions on the same panel.

2.2.3 Trends in LCDs for In-Vehicle Use

The typical display used in automobiles is that for car navigation systems. Riding the momentum gained from the deployment and improvement of Telematics services, demand for car navigation systems is brisk, not only in the Japanese domestic market, but also in Europe and North America. Demand growth for fiscal 2003 is estimated to be 16% over the previous year. Strong growth in demand is also anticipated in fiscal 2004 and beyond.

Automobiles are now starting to be equipped with information processing functions that turn them into "mobile information terminals," and the installation of LCDs that serve as gateways for this information continues to advance in every area in the vehicle, including navigation displays, rear-seat displays, and displays for rear-view camera systems that provide the driver with a view behind the vehicle. These displays require high-level performance and reliability: fast response even at low temperatures, wide viewing angles, and high visibility. They also demand higher resolutions, so we may see a move from QVGA and VGA to 7- to 9-inch W-VGA (800 x RGB x 480 dots) capable of displaying large amounts of information in a wide-screen format, and even to higher resolution W-XGA (1280 x RGB x 768 dots) that supports multiple displays.

Sharp is taking advantage of its proprietary liquid crystal material and novel optics technologies to develop and commercialize mobile Advanced Super View LCDs that achieve low-temperature high-speed response, high contrast, and wide viewing angles in all directions to meet the specifications demanded. In cooperation with major manufacturers both in Japan and abroad, active design-in with these advanced displays is pushing ahead. In the future, we will focus our efforts on developing and commercially introducing System LCDs that make full use of Advanced Super View LCD technologies built around CG Silicon technology, and will aggressively work to open up new markets for cluster displays (**Fig. 5**).

2.2.4 Trends in LCDs for Personal AV Devices

Personal AV devices include digital still cameras, video cameras, and portable DVD players. The digital still camera market continues its healthy growth at 24% year-on-year, going from 27.5 million units in fiscal

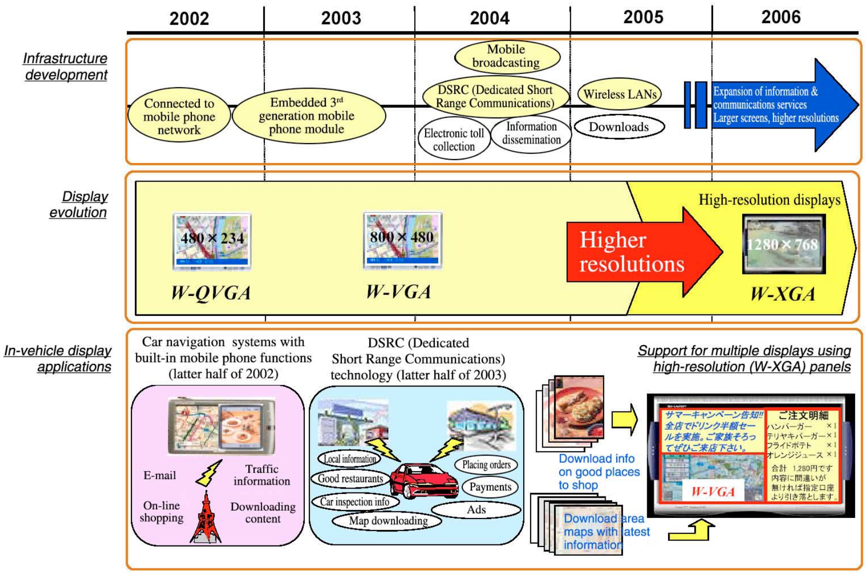

Fig. 5 Evolution of LCDs for in-vehicle applications

2002 to 34 million units in fiscal 2003. The displays embedded in these products are predominantly compact, high-definition panels 1.5- to 1.8-inches in size. In contrast, demand levels in the video camera market are expected to remain nearly flat in the future at around 10 million units annually, but product manufacturers are working to bring to market DVD-format video cameras equipped with LCDs in the 3.5-inch class, which will hopefully spur new demand. In addition, demand for portable DVD players is skyrocketing in the U.S. market. The predominant displays embedded in these products are 4- to 9-inch LCDs.

With new broadcast infrastructures such as terrestrial digital broadcasting and mobile satellite broadcasting coming on-line by the end of this year and into 2004, and with a new generation of personal AV devices based on new concepts expected to appear at the same time, the market for personal AV equipment is anticipated to expand significantly in the future.

Sharp has been closely monitoring these trends, and has introduced high-resolution System LCDs that take advantage of CG Silicon technology to provide high-definition images that project a realistic sense of presence. These displays have already been adopted by and have received high marks from major manufacturers, who are looking forward to future developments from Sharp. In view of this outlook, we will be working aggressively to make System LCDs emerge as the future de facto standard for the ideal display for personal AV devices.

3. Development of High-Value-Added System LCDs

Sharp began manufacturing System LCDs in October 2002, using CG Silicon technology as already described, and is currently deploying them primarily in products requiring small and medium screen sizes, such as digital still cameras, PDAs, and mobile phones.

The use of CG Silicon technology to form circuitry directly on the glass substrate is what lies beneath the outstanding features of System LCDs—high resolution, low power consumption, narrow frame, and multi-resolution display capability (**Fig. 6**)—and we have been receiving high praise from users. In October of last year, we also announced a groundbreaking achievement of using CG Silicon technology to form a CPU

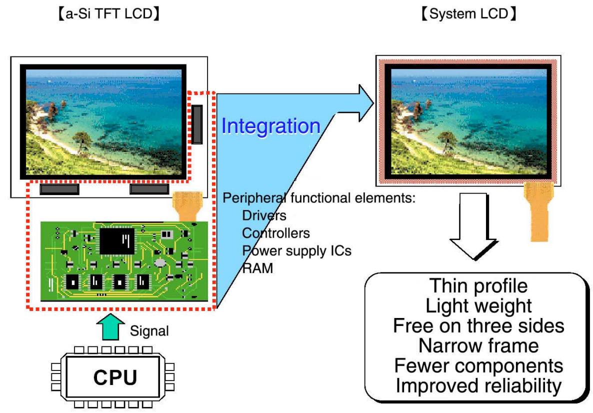

Fig. 6 Integrating peripheral functional elements

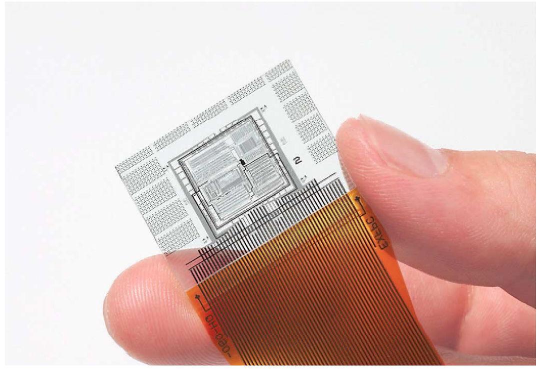

Fig. 7 CG silicon CPU formed on glass substrate (This panel is provided by Semiconductor Energy Laboratory Co., Ltd.)

directly on the glass substrate. This high level of performance was demonstrated to the entire world and the diverse range of new possibilities opened up by CG Silicon technology caused a major sensation (**Fig. 7**). As shown in **Fig. 8**, Sharp intends to take up the challenge of reaching even higher goals in the future, and we will be making an all-out effort to develop new high-added-value System LCDs that combine enhanced functionality with advanced display features.

In addition to broaden the product range based on the CG silicon technology and evolve the LCD device for the next generation products, we intend to redesign the estimating methodology of each LCD from the conventional cost-per-inch approach for Amorphous Silicon TFT LCD to another approach based on the cost-per-function point so that the cost of the system LCD is determined based on the functions integrated into the display (**Fig. 9**).

Conclusion

In this paper, I have outlined the current status of various flat panel displays and the future prospects for mobile LCDs. As we enter the era of full-fledged ubiquitous (pervasive) networking, ever higher levels of performance are being demanded for LCDs embedded in mobile devices and equipment. Sharp is engaged in

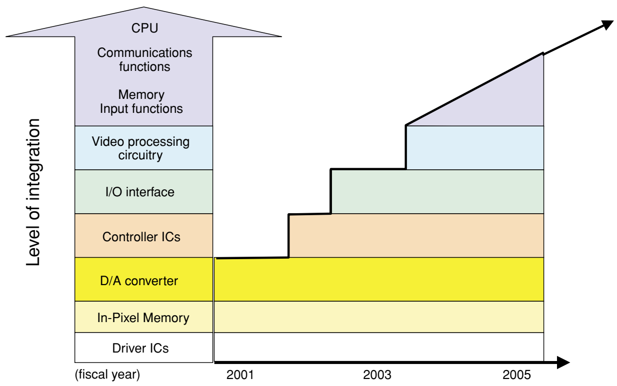

Fig. 8 Evolution of CG Silicon technology

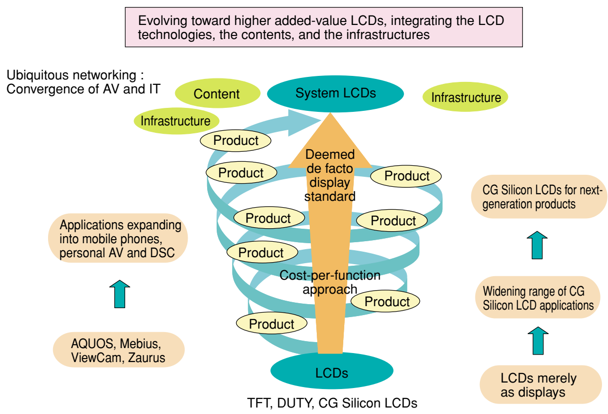

Fig. 9 Spiral evolution of products and LCDs

an all-out effort to make LCDs based on CG Silicon technology key devices for this ubiquitous networking era. We sincerely hope that we can make a significant contribution to society by facilitating the creation of new mobile devices.

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