

## **2.0 Industry Market Profile**

### **2.1 Computer Monitors: Volume and Technology Trends**

Virtually a one-to-one ratio exists between the number of computers and the number of displays in the marketplace. Because the world market for computers has grown so rapidly, a corresponding increase in displays can also be expected. Sales of personal computers (PCs) are expected to continue to grow beyond the year 2000. Many PCs will be desktop systems. ADI Corporation estimated worldwide demand for PCs at 66 million units in 1996, growing to 86.63 million in 1998, and over 100 million in 2000.<sup>4</sup> Desktop applications make up most of these sales.

The United States has been a major market for computers. The U.S. Bureau of the Census estimates that in 1993, 43.2 percent of the U.S. working population used a computer at work, compared with 34.8 percent in 1989 and 23.2 percent in 1984. Also in 1993, 22,605,000 households owned a home computer, up from 13,683,000 in 1989, and 6,980,000 in 1984.<sup>5</sup>

#### **2.1.1 CRTs**

The computer monitor has been one of the two largest applications for CRTs; the other has been television. According to a report published by Fuji Chimera Research, the 1995 worldwide market for monitor CRTs was 57.8 million units, 28 million of which (48.5 percent) were consumed in North America.<sup>6</sup> According to the same source, 1996 worldwide CRT monitor demand increased to 67.1 million units.<sup>7</sup> Stanford Resources reports that the CRT monitor market reached 84.2 million units in 1997 (25.6 million in the United States), and anticipates a worldwide growth to more than 100 million units in 2002, reaching 113.5 million in 2003.<sup>8</sup>

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<sup>4</sup> *Nikkei Microdevices' Flat Panel Display 1997 Yearbook*, Nikkei Business Publications, Inc., p. 98.

<sup>5</sup> "Computer Use in the United States: October 1993," U.S. Bureau of the Census, Current Population Reports, Special Series P-23.

<sup>6</sup> *The Future of Liquid Crystal and Related Display Materials*, Fuji Chimera Research, 1997, p.12.

<sup>7</sup> *Ibid.*

<sup>8</sup> Stanford Resources, Inc., web site.

In order to keep pace with more demanding computer applications, CRTs have been continually improved: larger screen sizes, higher resolution (for Windows, Macintosh OS, and Web-page font challenges), and higher luminance (for videos). This improvement is likely to continue, as the market moves away from sales of smaller (14-inch and 15-inch) monitors, toward 19-inch and 21-inch monitors. Features that were once accompanied by a high price tag are becoming more standard. Reduced dot pitch; color matching; flatter, lighter weight, touch-sensitive screens; and digital cameras are some of the new offerings at lower prices. This is due, in part, to an increased number of CRT suppliers in the marketplace and improvements in technologies, such as aperture grille, Invar shadow mask, and the flatter Trinitron CRT.

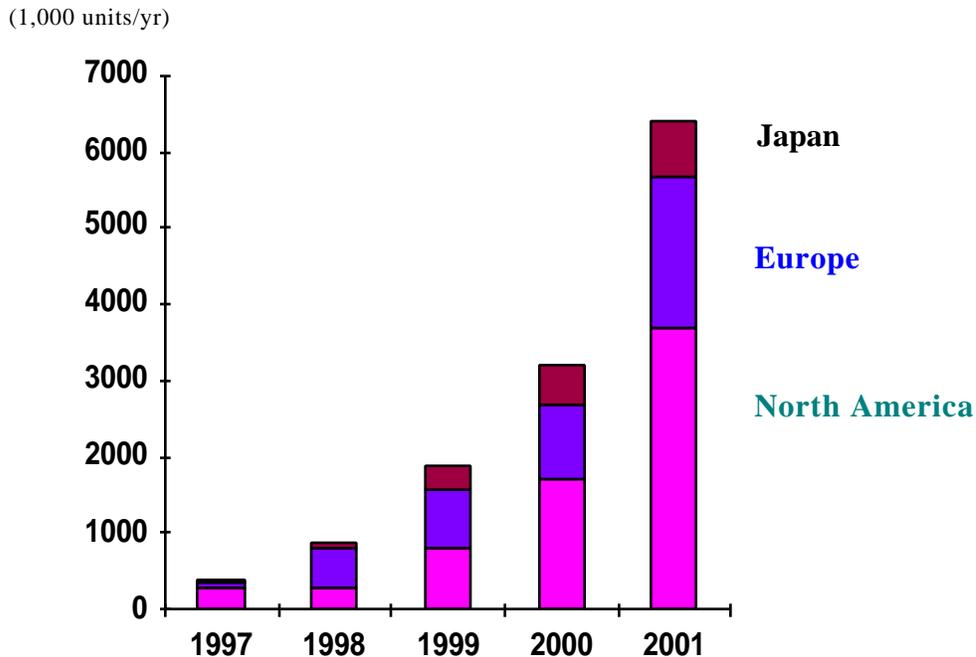
The marketplace is seeing other changes in CRTs, such as shorter necks that reduce the depth by at least three inches on a 17-inch monitor. DisplaySearch reports that while a wider deflection yoke angle enables this development, it causes problems with focusing, which may require more circuitry to resolve. A number of companies have recently released new monitors, many in the 17-inch and 19-inch range.

### **2.1.2 LCDs**

Although market analysts predict growth in the CRT monitor market through the first few years of the 21<sup>st</sup> century, it is widely anticipated that after that point, LCDs will begin to erode the CRT stronghold. Although the portable computer is currently the major application for LCDs, industry analysts expect this technology to increasingly penetrate the desktop monitor market, particularly in the 15-inch to 20-inch range. Industry experts anticipate that by 2000, LCDs will have captured 5.4 percent of the monitor market. The United States is a primary market for LCD monitors, and will grow into an even stronger market by the end of the century. NEC estimates that the United States will receive over half of the forecasted 6.4 million LCD monitors shipped in 2001 (see Figure 2-1). DisplaySearch also forecasts that the United States will constitute 30 percent of the worldwide LCD monitor market in 2001, with total LCD monitor sales of 7.7 million units. DisplaySearch predicts a worldwide LCD monitor market of \$4.2 billion by 2000.<sup>9</sup>

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<sup>9</sup> *DisplaySearch Monitor*, April 1997.



**Figure 2-1: LCD Monitor Forecast<sup>10</sup>**

LCD monitors are primarily active-matrix LCD (AMLCD), most of which are thin-film transistor (TFT) structures. Super-twisted nematic (STN), a passive-matrix LCD (PMLCD) technology, competes in some areas with AMLCD. Although some monitors are based on an STN structure, STN-LCDs are primarily found in electronic organizers and measurement devices. While STN-LCDs offer a cost advantage over TFT-LCDs, prices for the latter technology have been dropping. DisplaySearch reports that the TFT market will grow from \$4.87 billion in 1996 to \$13.7 billion in 2000, whereas the STN market is expected to drop slightly from \$4.3 billion to \$4.2 billion during the same time period.<sup>11</sup>

At Computex Taipei '97, a leading computer exhibition, over 20 companies displayed more than 100 models of LCD monitors.<sup>12</sup> A number of companies promoted both AMLCD and PMLCD monitors. More recently, DisplaySearch reported that over 180 LCD monitors are marketed by 50-some companies, 81 percent of which use thin-film TFT-LCD technology,

<sup>10</sup> *Nikkei Microdevices' Flat Panel Display 1998 Yearbook*, Nikkei Business Publications, Inc., p. 80.

<sup>11</sup> *DisplaySearch Monitor*, April 1997.

<sup>12</sup> *Information Display*, Official Publication of the Society for Information Display, October 1997, p. 37.

and 19 percent of which use STN technology.<sup>13</sup> According to DisplaySearch, TFT-LCD monitor shipments will grow from 1.1 million in 1998 to 13.1 million in 2002.<sup>14</sup> Between 1998 and 2001, the 15-inch display is expected to make up the greatest share of these monitors.<sup>15</sup>

Currently, the greatest obstacle facing LCDs in the desktop monitor market is not competition from other LCD technologies, but a high price tag relative to that of CRTs. TFT-LCD monitors currently cost several times that of a CRT monitor, with a 15-inch unit costing \$1200. There are indications that the price of TFT-LCDs will continue to decrease, prices have already dropped to \$900. Most of the LCD monitor sales have been to the medical and financial community, but expectations are that the customer base will spread when a 3:1 cost ratio with CRTs is reached, and even more so as prices continue to decline. Surveys indicate that given a 1.5:1 cost ratio of FPDs to CRTs, 30 percent of consumers would opt for the FPD. DisplaySearch reports that low prices by Korean LCD suppliers will likely bring prices of 15- and 18-inch LCD monitors down to a 2X price ratio with 17" and 19" CRTs by the end of 1998.

## **2.2 Manufacturing Locations and Suppliers**

### **2.2.1 CRTs**

The majority of CRT display fabrication takes place outside of the United States. In 1997, Asia (excluding Japan) produced 54 percent of all color TVs and 79 percent of all CRT monitors.<sup>16</sup> DisplaySearch reports that Japan supplies between 10 and 15 percent of CRTs produced worldwide, primarily 17-inch and larger. The greatest concentration of CRT manufacturers is in Taiwan, where 33.6 percent of total world production took place in 1996.<sup>17</sup> South Korea and China are also becoming major sites for CRT monitor production. Most color CRT monitors and small TV CRTs (less than 19 inches) are produced outside the United States. Due to the cost of transporting heavier displays, some TV CRTs, 19 inches and larger, are produced in the United States. It is possible that a

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<sup>13</sup> Presentation by DisplaySearch at the USDC Business Conference: *Enabling New Display Markets*, Display Works, January 20, 1998, San Jose, CA.

<sup>14</sup> DisplaySearch FPD Equipment and Materials Analysis and Forecast, Austin, Texas, June 1998.

<sup>15</sup> Ibid.

<sup>16</sup> *The Future of Liquid Crystal and Related Display Materials*, Fuji Chimera Research, 1997, p. 12.

<sup>17</sup> *Stanford Resources, Inc.*, web site.

similar situation will arise with larger CRTs monitors.<sup>18</sup> See Table 2-1 for regional production figures for CRT monitors.

|                    | 1994   | 1995   | 1996   | 1997   | 1998   | 2000   |
|--------------------|--------|--------|--------|--------|--------|--------|
| Europe             | 3,500  | 3,850  | 4,300  | 4,800  | 5,300  | 6,000  |
| North America      | 800    | 1,000  | 1,200  | 1,500  | 1,800  | 2,400  |
| Asia               | 41,000 | 45,650 | 53,000 | 60,000 | 65,000 | 75,000 |
| Japan              | 5,300  | 6,080  | 7,100  | 8,000  | 9,000  | 10,000 |
| So-Central America | 800    | 1,200  | 1,500  | 1,900  | 2,500  | 3,200  |
| Total              | 51,400 | 57,780 | 67,100 | 76,200 | 83,600 | 96,600 |

**Table 2-1: Color CRT Monitors Production by Region (,000 units)<sup>19</sup>**

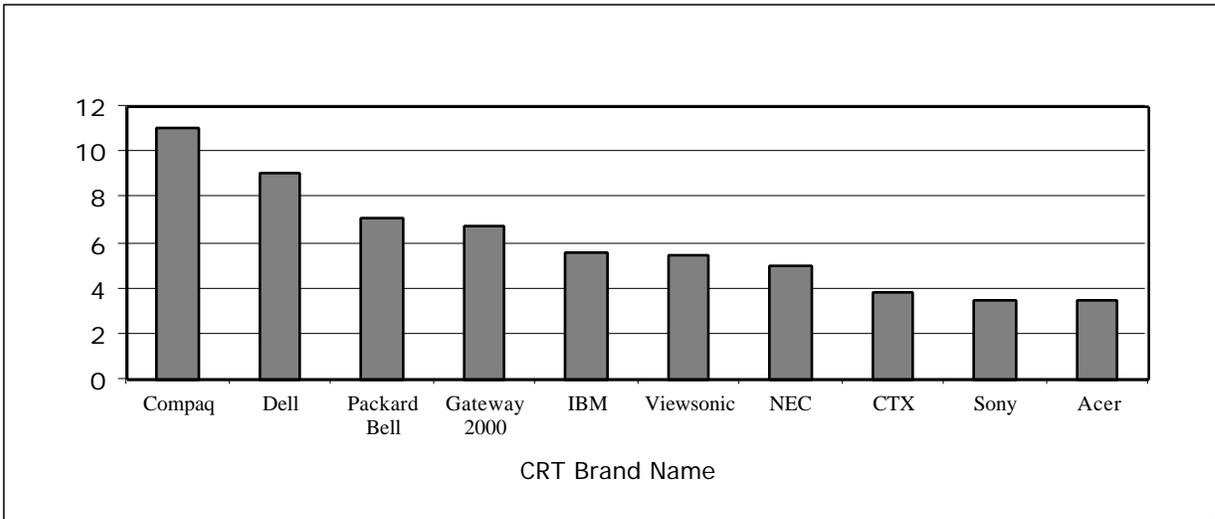
As is the case with most commodity goods, CRT monitors are distributed by the manufacturer via different routes. They may be sold under the manufacturer's name through retail channels, or to original equipment manufacturers (OEMs) or other system retailers, such as Dell Computers. Major manufacturers and retailers include Acer, Apple, Compaq, CTX, Dell, Digital, Eizo, Hitachi, Hewlett Packard, IBM, Iiyama, LG, MAG, Mitsubishi, NEC, Nokia, Panasonic, Samsung, Sharp, Siemens Nixdorf, Sony, Toshiba, and Viewsonic.

Figure 2-2 shows the 1997 market share in the United States per CRT monitor brand name. In this table, some manufacturers (such as Sony) will be under-represented, as the monitors they manufacture for other companies may carry the brand name of the other company (e.g., Sony monitors manufactured for Dell). Figure 2-3 provides data on the 1996 industry market share for main color CRT monitor-tube manufacturers.

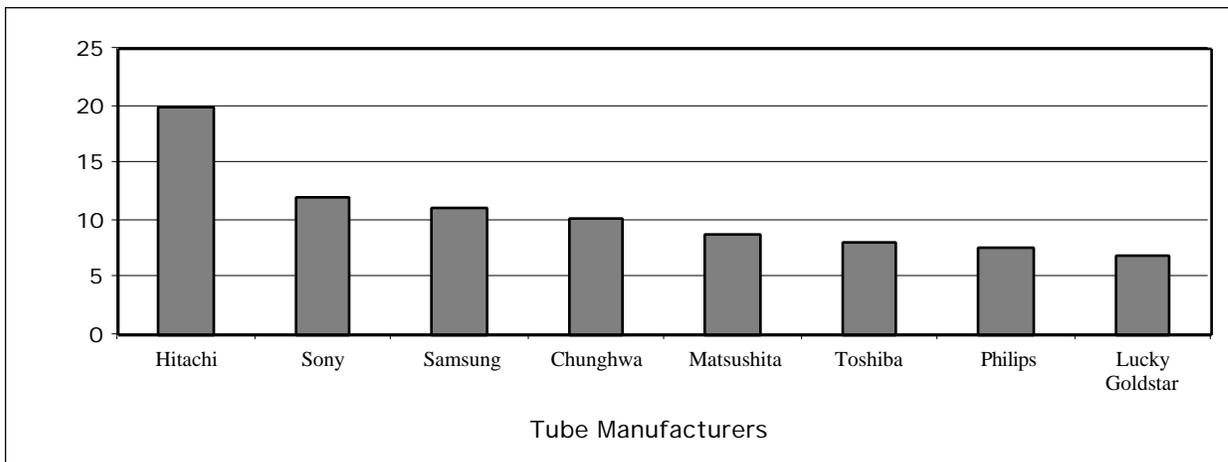
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<sup>18</sup> Reported at the Glass Roundtable meeting, February 6, 1997, University of Texas at Austin.

<sup>19</sup> *The Future of Liquid Crystal and Related Display Materials*, Fuji Chimera Research, 1997.



**Figure 2-2: CRT U.S. Market Share (Percent) by Brand Name<sup>20</sup>**



**Figure 2-3: Worldwide Market Share (Percent) of Color CRT Tube Manufacturers<sup>21</sup>**

<sup>20</sup> Source: Stanford Resources, 1997 data.

<sup>21</sup> Source: Stanford Resources, 1996 data.

### 2.2.2 CRT materials and subassemblies

The majority of CRTs (TVs and monitors) and CRT-related components and materials are manufactured outside of the United States. The major materials, components and subassemblies are as follows:

- Faceplate
- Funnel
- Neck
- Phosphors
- Frit
- Aquadag
- Lacquer coating
- Shadow mask assembly
- Electron gun assembly
- Deflection yoke
- Deflection amps
- Centering magnets
- Printed wiring boards (PWBs)
- Anti-static/anti-glare coating

For a more extensive listing, see the CRT process flow and bill of materials in Appendices A and B, respectively .

There are approximately 100 CRT manufacturers worldwide.<sup>22</sup> In the United States, there are five CRT glass manufacturing plants, producing approximately 600K tons of product annually: Thomson, Techneglas (two sites), and Corning (three sites, with one being a joint venture with Sony). Glass is imported from Asahi, NEC, Samsung, Schott, and Philips.

Sony is the only manufacturer of color monitor tubes in the United States, although they, along with Hitachi, Matsushita, Philips, Thomson, Toshiba, and Zenith, do produce TV-tubes in the United States. Aydin, Compaq, Display Tech, Digital Equipment Corporation, IBM, Modicon, NCR, and Unysis assemble computer displays domestically.

Techneglas, in addition to being a major North American manufacturer of panel and funnel glass, is a large producer of frit, planar dopants, and glass resins. Phosphors are supplied internally from vertically integrated manufacturing facilities and by foreign manufacturers (primarily in Japan).

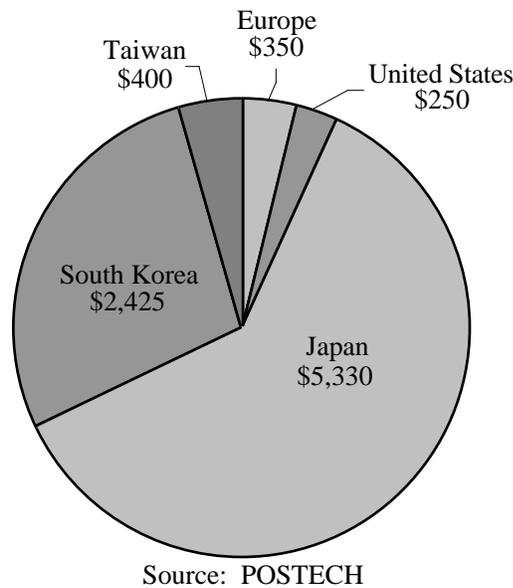
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<sup>22</sup> *Electronic Engineering Times*, December 1, 1997, num. 983, p. 27.

The remainder of the components and subassemblies are produced primarily in Asia. Although shadow masks for TVs are produced in United States, no United States manufacturer has established a high-volume, high-resolution shadow mask facility for monitors. Nippon Printing and Dai Nippon Screening are primary producers in Asia. Electron guns are made from precision metals parts, a significant portion being manufactured by Premium Allied Tube. Insulator glass used in the gun assembly is supplied by Corning Asahi Video and Technoglas. Deflection yokes and amps are produced primarily in the United States, Canada, and Taiwan, and there are a couple of domestic producers of centering magnets.

### 2.2.3 LCDs

The number of LCD suppliers is significantly lower than the number of CRT suppliers, primarily due to the high capital cost of manufacturing FPDs. As shown in Figure 2-4, Japan leads in AMLCD investment, followed by South Korea. More recent data from DisplaySearch shows that LCD capital investment by Japanese and Korean companies will decrease significantly in 1998 to \$676 million, down from \$3.85 billion the previous year.



**Figure 2-4: Capital Investment in AMLCD Production 1994-1996 (\$millions)**

In 1995, Japan manufactured 94.7 percent of all LCDs, followed by Korea at 3.5 percent and Taiwan at 1.7 percent; 0.1 percent were produced outside of these regions. By 2005, Japan is forecasted to lead LCD production, with 75 percent. Korea is expected to increase its share to 12.9 percent, and Taiwan to 11.9 percent; 0.2 percent will be produced elsewhere.

Korean and Taiwanese LCD manufacturers have been able to enter this market partially due to strategic relationships with Japanese companies. Samsung Electronics has established technical cooperation with Fujitsu for TFT-LCDs. LG (Lucky Goldstar) Electronics jointly developed technology with Alps Electric. CPT is in technical cooperation with Mitsubishi for TFT-LCDs. Chunghwa Picture Tubes has a partnership with Toshiba for STN-LCDs and is searching for a partner in TFT development. In addition, IBM and Acer are working together on TFTs, as are Toshiba and Walsin Linwa.

#### **2.2.4 LCD materials and subassemblies**

The LCD manufacturing process, particularly for TFT-LCD, is more complex in terms of types of materials and process steps than is the CRT process. The following list has been abbreviated to provide only the major materials, components, and subassemblies. For a more complete listing, refer to Appendices C and D for the TFT-LCD process flow and bill of materials, respectively.

- Front glass panel
- Color filter materials
- Indium tin oxide
- Back glass panel
- Liquid crystal materials
- Transistor metals
- Alignment material
- Etchants
- Photoresists
- Developing solution
- Sealer
- Spacers
- Polarizing material
- Driver ICs
- Backlight units
- PWB

Almost all of the materials, components, and subassemblies for LCD monitors are made in Asia. The exceptions are backlights and some driver integrated circuit (IC) devices, which are produced in North America or Europe.