American Impatience Cedes Technolo

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marketplace. It installed the first, primitive screens in battery-operated pocket calculators, then in digital wristwatches, clocks and tiny television sets. Now, in much refined form, flat panels are omnipotent not only in those products but also in portable computers, video cameras, compact disk players and medical equipment.

"There was such keen competition in calculators that it forced improvements in ways that laboratory research never could," said Atsushi Asada, Sharp's senior executive vice president and its head of research. "We had to make the screens thinner and thinner, more and more compact. This was research by industrialization."

But only in recent years has the work begun to pay off. Liquid crystal's chief advantage is that it requires relatively little electric power, meaning that it can run on batteries. It has taken years, however, to improve sharpness and contrast — and, most recently, the ability to display thousands of brilliant colors. Now, the big challenges are to make the screens larger, to reduce their power requirements and to manufacture them without defects in enormous volume.

An Ulterior Motive

If the Japanese makers seemed single-minded in their dedication to the technology, they had an ulterior motive. Early on, they intuited that the technology could be parlayed into a huge lead into a new generation of small notebook computers. Those five- to seven-pound machines are Japan's first big hit in the computer business. And while some parts of those systems, including the microprocessors, are made by foreign companies, the panels are the single most expensive component. Not surprisingly in a country that has learned to hoard the highest value-added work for itself, the screens are virtually all produced in Japan.

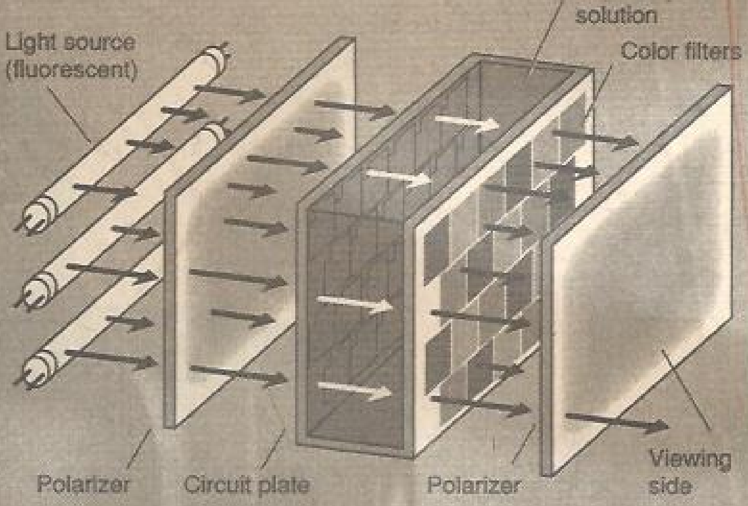
Sharp alone has made 20 million small liquid-crystal screens this year, and 600,000 large units, including its new color panels. And in the past year the field has exploded here: Matsushita, Hitachi, NEC and a host of lesser-known Japanese companies are in a race to build new plants, all spending at least $100 million a year, in some cases far more. Even a giant American player like the International Business Machines Corporation has been so daunted by the costs and risks of manufacturing large color panels that it created a rare joint venture with a Japanese competitor, Toshiba. The venture is planning to begin production of a color screen next spring.

American Entries Unlikely

"Except for some research, almost all of the advanced work is now here," Dr. Heilmeier, now the chief technical officer of Texas Instruments in Dallas, said in Japan. "And the cost of building facilities to produce them is so high that I doubt we are going to see any serious American entries."

How a Flat-Panel Display Works

The flat, lightweight video screen known as the flat-panel display could replace the bulky cathode-ray tube now used in computers and television sets. This diagram shows an active-matrix color liquid crystal display, the main flat-panel technology being pursued by the Japanese.



Light from a lamp shines from the back of the screen toward the front. When a particular spot in the solution of liquid crystal, an organic material, is subjected to an electric voltage, it blocks the light's passage, and a dark spot appears to the viewer. The polarizers in front of and behind the liquid crystal layer help block the light.

An active-matrix display uses individual electronic transistors to supply voltage to each dot on the screen. The transistors are embedded in the glass circuit plate next to the liquid crystal solution. The use of individual transistors for each picture element allows the liquid crystals to be turned on and off quickly enough for such screens to display television pictures, not merely stationary images. It also makes the picture sharper.

Sharp

Liquid crystal display technology is used in a palm-size television.

Source: MRS Technology

The New York Times

large Japanese company that only recently began pouring money and talent into liquid crystal.

Even those who bet correctly early on, like Sharp and Hitachi, say they still face enormous problems. Chief among them is the disappointing level of their "yields," the number of usable screens that emerge from the processes of manufacturing the giant chips that underlay active-matrix screens. While all companies guard their yield figures zealously, engineers say that for the most complex color screens, only 10 to 20 percent are good enough to sell.

Companies like Toshiba, Hitachi and Matsushita are becoming their own biggest customer for the technology, installing their fanciest screens in a series of luxury products.

The evidence is in towns like Ome, on the outskirts of Tokyo, where Toshiba is making its first laptop computers to use its newly developed, brilliant-color liquid-crystal screens. The computer costs nearly $13,000 in Japan; one of the company's top engineers estimates that $5,000 of that is the price of the

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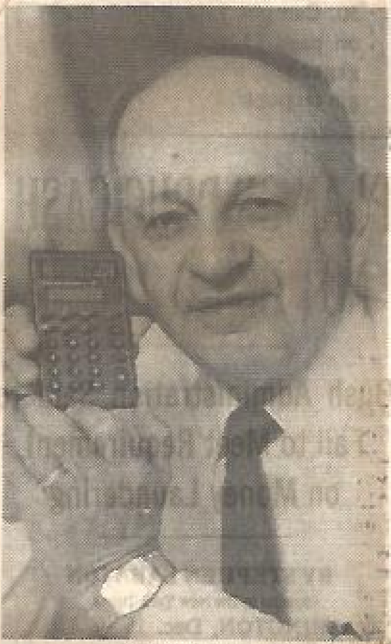

Sal DiMarco for The New York Times

George H. Heilmeier, the inventor two decades ago of a flat, lightweight video screen, on which the Japanese have built a multibillion-dollar business.

screen alone. But the company is betting that, just as it learned how to solve yield and cost problems with memory chips, it will solve them again.

Liquid crystal's existence has been known for more than 100 years. In nature, liquid crystal is produced by octopus and squid, and scientists have toyed with it for decades. But it was 1964 before Dr. Heilmeier and other researchers began to experiment with one of the material's stranger characteristics: By applying an electric current, liquid crystal could be transformed into a type of camera shutter, letting in light when its molecules are standing on end, blocking it when they are twisted horizontally.

That discovery permitted the first liquid crystal displays, with their giant, blocky displays of numbers. But the material was so strange — and posed enough of a challenge to existing technology — that Dr. Heilmeier recalls that his colleagues at RCA came up with a long list of reasons to ignore it.

The first screens, he said, were not silicon, referring to the common material for most microelectronic parts. "They were 'dirty' by semiconductor standards. They were liquids. They were said to be too difficult to make."

But he viewed those more as excuses than compelling logic, and it was those same features that seemed to intrigue the Japanese. "It is a suitable kind of technology for the Japanese mentality," said Shinichi Hirano, an I.B.M. Japan engineer who is overseeing major parts of the alliance with Toshiba. "It was a manufacturing puzzle. I'm not sure American management would wait a quarter of a century" to solve it.