Foreword

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Some of my most vivid memories revolve around research on LCD. I was involved in R&D to develop color LCDs beginning around 1973 and reflective color LCDs from around 1983.

In 1973, my colleagues and I decided we wanted to come up with a color LCD. We studied every system we could think of, including birefringence, optical rotation, and guest-host effects. Ultimately, we devised a full-color system for LCDs based on micro color filters within the cell, and put forth the idea in 1981. This system is now in widespread use, but when it was first announced, it was the object of a great deal of criticism. It was pointed out that, because it was a transmissive color system, we wouldn't be able to attain vivid, luminous colors like those from a CRT, and because the transmittance was extraordinarily low, we would be forced to use a backlight, and as a result, the LCD's low power consumption, one of its primary advantages, would be lost. However, we had spent the previous 10 years doing a theoretical analysis of every conceivable colorization method. Our studies indicated that, so long as the color spectrum was the same, there would hardly be any difference from light-emitting systems. This realization more than anything else convinced us that, in terms of performance of the LCDs of that time, there was no other approach to take. Before long, backlit color LCDs became commonplace, but the criticism I mentioned above continued to be an incentive for my colleagues and myself to try to come up with a reflective-type color LCD at some point in the future.

Because we were sure there wasn't any other way to make a color LCD beyond the micro color filter system described above, even in our subsequent research on reflective-type LCDs, we thought there was nothing else we could use. The average transmittance of color filters at that time was approximately 10%, and if you used a polarizer, the average transmittance dropped even further to around 3.5%. This is so dark, it's practically black! Accordingly, we first tried to calculate the theoretically optimum values. We limited the display colors to four: green, magenta, white and black, and using the guest-host effect, we confirmed that we could attain a reflectivity of approximately 30% provided one was willing to accept a 5:1 contrast ratio. The monochrome reflective-type LCDs of the time had a reflectivity of approximately 30%, and by comparison, we decided that this approach had sufficient practical value and launched into serious research.

However, our subsequent research efforts ran into a series of problems. Even though individual elements had properties that followed design values, when they were assembled into the liquid crystal cells, reflectivity failed to achieve even half of its theoretical value. We held a long series of discussions with students and conducted experiments late into the night for many days, and after about three months, we finally identified the problem. A large amount of the light reflected by the diffuse reflector situated in the interior of the liquid crystal cell was not coming through into the air from the glass surface of the liquid crystal cell. In other words, light scattered at high angles was being totally reflected by the undersurface of the glass, which had a refractive index of 1.5. We resolved this problem by drastically reducing the surface roughness of the diffuse reflector. The next problem was that the use of metal for the reflector caused a shiny metallic luster to appear, and no matter what we did, we couldn't achieve a white "paper-like" texture. Through further research, we discovered that by forming large numbers of micro-paraboloids on the surface, we could obtain uniform reflectivity within a specific range of viewing angles, regardless of the angle. As a result, we were able to make a reflector element that enabled us to obtain a texture similar to that of paper, and several times brighter than paper.

Around this time, we made a number of announcements about reflective-type LCDs, and we approached various LCD manufacturers proposing the idea of joint development of a prototype reflective color TFT LCD. However, many companies took the attitude that they didn't want to be involved with something that couldn't be expected to generate sales of several hundred million yen per month. Among these manufacturers, only Sharp and its Central Research Laboratories agreed to joint research and supported prototype development. Before long, Sharp researchers had developed a system for mass producing diffuse reflectors having a structure approaching the micro-paraboloids described above, and had also designed a system to make a TFT array structure work with reflective-type displays. The result was a several-fold improvement in reflectivity. A few years later, a prototype was completed, and a reflective color LCD with brightness as predicted was achieved. The fact that mass production was launched just three years ago is still fresh in my memory. It was nearly 15 years since the initial start of research, and 10 years since we began joint development.

Since then, reflective LCDs have become common in PDAs and mobile phones, and numerous manufacturers have begun to work on further development, but they have not been able to catch up with Sharp.

As the next reflective color LCD, my colleagues and I are currently working on a project to develop a large-format cordless monitor-type display with a contrast ratio of 100:1, reflectivity of greater than 80%, and the ability to handle full-motion video with bright, clear pictures.

However, it appears that recently the LCD industry has sunk to a point where they are incapable of pursuing any such dreams. It's not only LCDs, but the electronics industry as a whole is in the same situation. The pattern seems to be that, after much effort, the long years of R&D begin to bear fruit, and the market starts to grow exponentially. The scale of production then expands, more companies enter the market, and as they boost production further, the market becomes saturated, often in a fairly short period of time. Ultimately, price-slashing competition breaks out, and it becomes an all-out war to improve productivity and boost production still further.

The electronics industry has gotten itself into such a situation due to adopting the thesis of supplying products with high functionality and high performance at low cost. Not only Japan, but also all Asian nations will probably take the same path. Gradually, the electronics industry will have to find a way to break this spell. In order to move away from such a route and maintain a clear vision of the future and take on new challenges, we need to revamp our ways of thinking and the social systems needed to support healthy R&D and fair price competition based on long-term prospects.

Up to now, Japan has been the strongest country in the world in terms of "making things" such as developing new products, having high productivity, and developing and manufacturing the components and materials necessary for them. Even today, this essence remains fundamentally unchanged. But global trends have varied only slightly. By flexibly incorporating these trends, holding on to what's good about the uniquely Japanese system, and boldly eliminating what doesn't work anymore, we should once again be able to revitalize Japan's prowess.