Techno World

A Heartfelt 'THANKS' from Sony to All Our CCD Customers

Total CCD Production Tops 100 Million Pieces

The CCD: the electronic eye of the digital age. The market for CCDs, which grew quickly due to applications such as consumer camcorders and broadcast and commercial cameras, is now exhibiting even faster growth due to the recent popularity of the digital still camera. Now that more and more products are becoming digital and the use of networking is expanding, the market for visual communication products, such as PC cameras, PDAs, and portable video phones, is expected to make great strides. CCD image sensors are now part of our daily lives in a variety of forms, and they determine the picture quality provided by these cameras. Sony has overcome the difficulties of the early period of CCD development, and is now creating an expanding line of CCD products while striving for improved picture and device quality. Since starting CCD development in 1970, total Sony CCD production, including both area and linear sensors, has now exceeded 100 million pieces. In commemoration of that achievement, this issue presents the history of Sony CCDs over the almost 30 years from the start of CCD development to the achievement of the 100 million pieces.

Reporting the achievement of the production of over 100 million CCD devices at the grave of the late Sony President, Mr. Kazuo Iwama, who had energetically promoted the development of CCD products and technology.

■ **Photograph 1 Reporting Results at the Grave of the Late President, Mr. Kazuo Iwama**

Sony CCD Manufacturing Plant

1) Sony Kokubu Corp.

Sony Kokubu Corp. is Sony's largest semiconductor factory, and manufactures not only CCDs, but bipolar ICs, MOS LSIs, and LCDs as well. It was established in August 1973 at Kokubu city in Kagoshima Prefecture as Sony Kokubu Semiconductor Company. Sony Kokubu Corp. boasts the industry's largest capacity CCD production line as well as a CCD development center where new CCDs are designed.

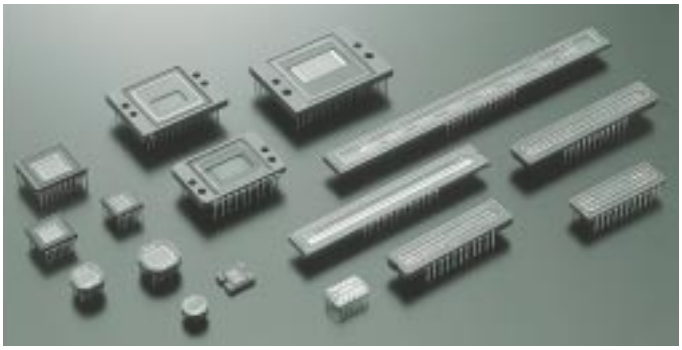
■ **Photograph 3 Sony Kokubu Corp.**

■ **Photograph 4 Manufacturing Line**

2) Sony Nagasaki Corp.

Sony Nagasaki Corp. was established in December 1987 at Isahaya city in Nagasaki Prefecture to design and manufacture MOS LSIs. It also produced CCDs from December 1988 until September 1993.

■ **Photograph 5 Sony Nagasaki Corp.**



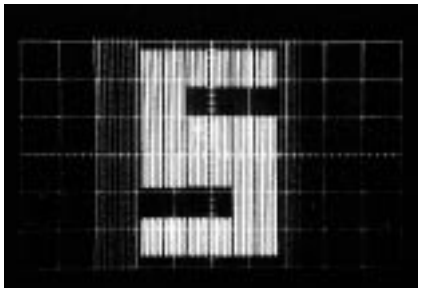
■ **Photograph 2 Area Sensors/Linear Sensors**

Looking Back on the Road to Exceeding 100 Million Pieces

Figure 1 shows the trends in total CCD production from the point Sony started producing CCDs to the present. In this section we look back on the journey from the 1970s, a period characterized by repeating trial and error cycles, to the present, where it is possible to radically increase the number of production. In particular, we look at the major issues of each period and how those issues changed over time.

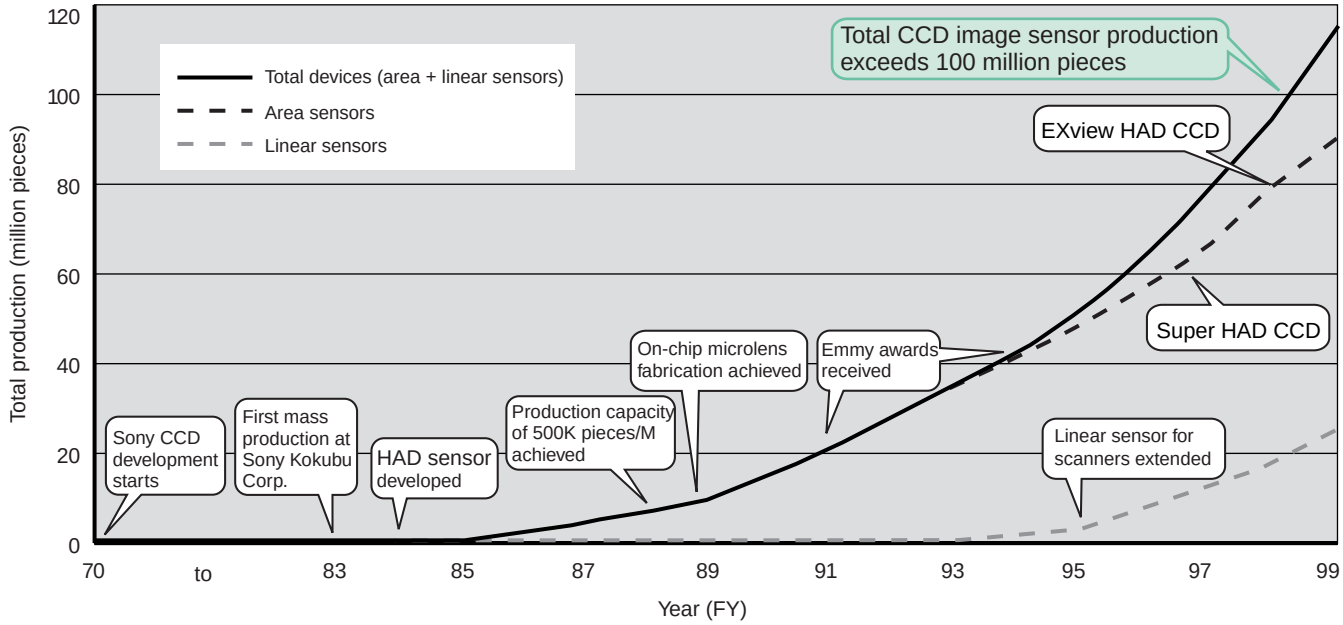
The 1970s (Pioneering Period)

The 1970s can surely be called a pioneering period. In December of 1970, the year that Bell Labs announced the first CCD, Sony started its CCD development efforts. The CCDs displayed at the Sony Corporation Research Center annual exhibition in 1972 included a 96-pixel linear sensor and an 8H × 8V (64 pixels) 3-phase FT CCD area sensor. These devices had a much harder time producing images than contemporary devices. Due to the enthusiasm of Sony's late president, Kazuo Iwama, for creating practical CCDs, all of Sony's CCD work, including the researchers and process development efforts, was concentrated at the Sony Corporation Research Center, thus starting Sony's CCD development project. This was the beginning of full-scale CCD development, and the start of the long road to practical CCDs. The first single-chip color camera prototype (with 142 pixels in the horizontal direction) was created in July 1976. While the picture quality of CCDs at that time suffered from vertical stripes, it goes without saying that this prototype was the first step towards achieving a practical single-chip color camera. Sony succeeded in developing a color camera using 3-chip of 110K-pixel IT-CCD in March 1978.



■ **Photograph 6 FT CCD Image with 8H × 8V (64 pixels) (1972)**

■ **Photograph 7 Sony Corporation Research Center in 1973**



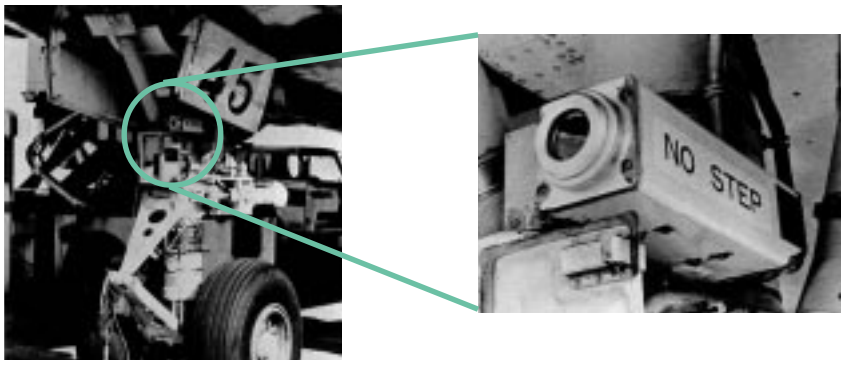
■ **Figure 1 CCD Production Total Trends**

The 1980s (Growth Period)

As the 1980s began, Sony announced to commercialize the world's first two-chip color camera. This product, the XC-1, was mounted in super jumbo Boeing 747s as All Nippon Airway's "Sky Vision" and created much interest. In 1983, Sony succeeded in mass producing a Type 2/3 IT CCD with 190K pixels, the ICX016, and in the next year, 1984, Sony released a Type 2/3 CCD with 250K pixels, the ICX018. At that time, Sony also began development of the HAD sensor, which can be said to define the basic structure of the contemporary CCD. Type 2/3 380K-pixel CCD, ICX022 released in 1987 implemented the world's first variable speed electronic shutter based on a vertical overflow drain structure. In 1988, Sony Kokubu Corp. and Sony Nagasaki Corp. achieved a combined monthly production capacity of 500K pieces, thus starting full-scale business deployment in the 19th year after the development of the CCD. Furthermore, Sony also developed the on-chip microlens, which, just like the HAD sensor, became the definitive basic structure in the contemporary CCD. The CCD-TR55 passport-size Handycam, which used this CD, became a hit product for Sony.

The 1990s (Development Period)

As the 1990s began, Sony's CCD business continued to expand and in May 1990, total Sony CCD production surpassed the 10 million pieces. Furthermore, not only Sony's business success, but Sony's CCD technology began to be recognized worldwide, and Sony CCD technology was awarded Emmy Awards in both 1991 and 1994. Sony's linear sensor business also made steady advances starting in 1993, and in 1995 Sony added 300, 400, and 600 DPI color linear sensors that adopted the single-sided readout method to the product line.
Applications for area sensors began to become increasingly diverse in 1995, and Sony developed progressive scan CCD that were optimal not only for video cameras but for digital still cameras as well. Sony continued to improve the basic characteristics, such as sensitivity and smear, of CCD sensors by developing the Super HAD CCD in 1997 and the EXview HAD CCD in 1998.

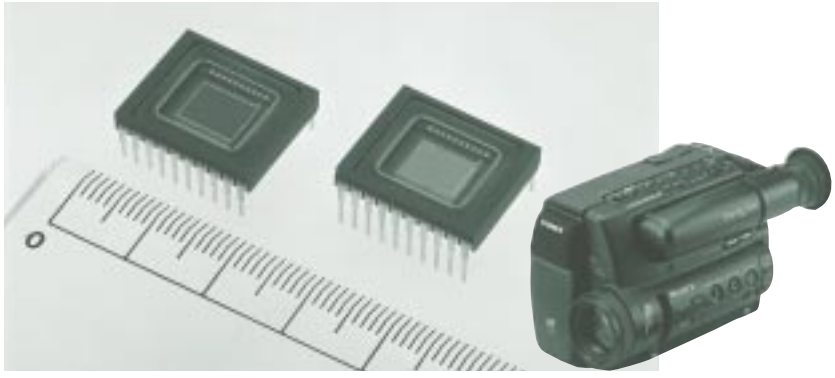


■ **Photograph 8 XC-1 (245H × 492V pixels) Adopted for Use in All Nippon Airways Super-Jumbo Jets (1980)**

1991
Sony's contributions to the broadcast industry by technological development since the start of CCD development recognized.

1994
Prize awarded for the technological development of the CCD on-chip microlens.

■ **Photograph 10**
Sony Receives Emmy Awards from the US National Academy of Television Arts and Sciences (1991 and 1994)



■ **Photograph 9 Type 1/2 250K-pixel CCD Used in the CCD-TR55 Handycam, which Became an Explosive Best Seller**

■ **Photograph 11 ISO 9001 Certificate**

In 1999, Sony achieved the 100 million pieces in total CCD production for about 30 years after the development of the CCD.

Trends in Technologies for Improving Basic CCD Characteristics

Recently, the unit pixel size in CCDs has fallen to less than one tenth of that in early CCDs. The size of the unit pixel will continue to decrease in the future due to miniaturization and increasing pixel counts. As shown in figure 2, despite the continuing reduction of the unit cell area, due to the development of many new technologies, the sensitivity per unit area has continued to increase.

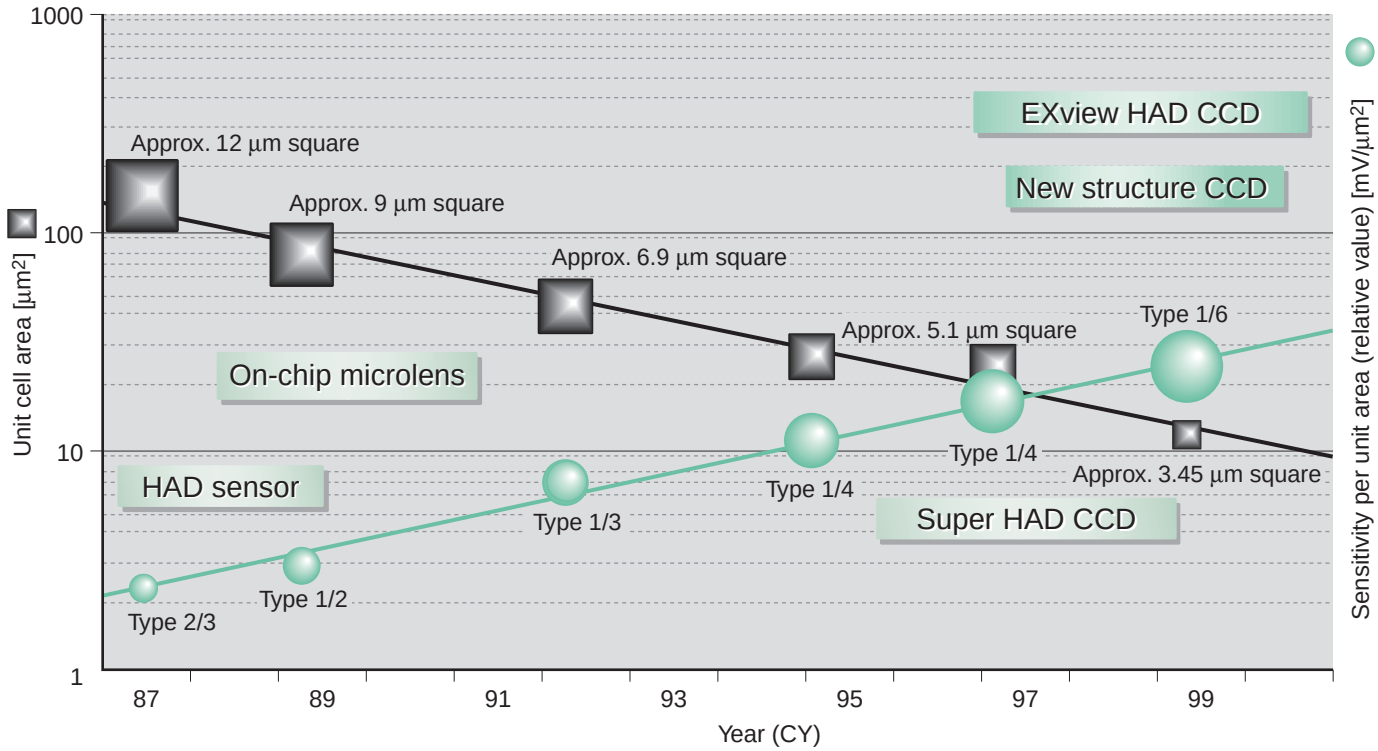
Sony has contributed to both miniaturization and improved picture quality in CCD cameras by maintaining or improving basic characteristics despite miniaturization. Here, we would like to present our technologies used to improve the basic characteristics of Sony CCD products.

HAD Sensor (1984)

The HAD (Hole-Accumulation Diode) sensor adds a hole-accumulation layer to the surface of the n-type substrate, P well, and n^+ diode sensor. This sensor structure is unique to Sony CCDs. By providing this hole-accumulation layer, these devices significantly reduce the dark current generated from the sensor surface. Also, by adopting the vertical overflow drain, which drains electrons to the n-type substrate, these devices increase the aperture ratio and achieve high sensitivity, and include a variable speed electronic shutter in an interline method for the first time in the world. This allows cameras that use this device to capture sharp images of objects that are moving quickly.

On-Chip Microlens (1989)

As the size of the CCD unit pixel becomes smaller, reduced sensitivity due to the smaller light sensitive area becomes a problem. Since smear increases if the aperture is made larger to increase the sensitivity, it is not possible to increase the aperture significantly. To solve this problem, Sony developed technology for creating on-chip microlenses for the photodiode associated with each pixel. This means



■ **Figure 2 Miniaturization and Sensitivity Improvement Trends in CCD Area Sensors**

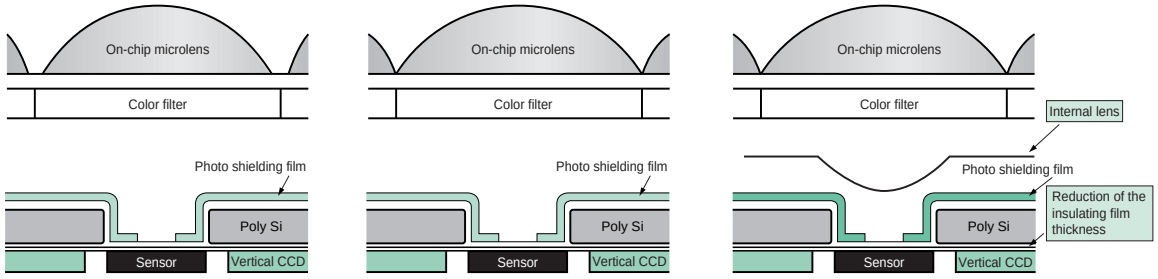
that the area that light enters is determined not by the aperture area of the sensor region but by the area of the on-chip microlenses. This results in an increase of the virtual aperture ratio, and a significant increase in sensitivity. Furthermore, these on-chip microlenses also increase the optical collection efficiency, and thus significantly reduce smear from previous levels.

Super HAD CCD™ (1997)

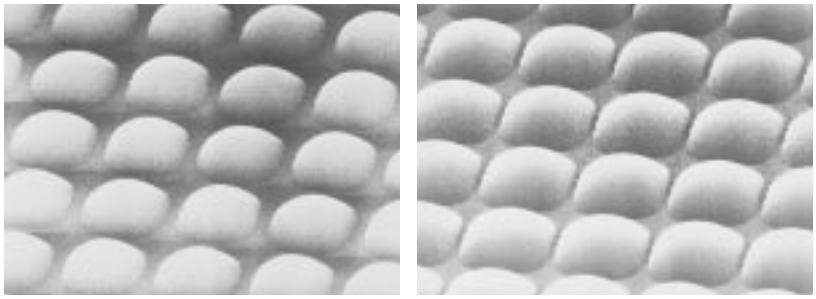
During the latter half of the 1990s, miniaturization of the unit pixel progressed even further, and it became difficult to achieve higher sensitivity using the earlier on-chip microlens technology. Increasing the gain at the output stage of the CCD device only lowers the signal-to-noise ratio and makes image defects more apparent. To solve this problem, Sony developed technology that optimizes the shape of the lens so that the light that is wasted by falling between the on-chip microlenses is minimized. This is the Super HAD CCD technology. Sony aimed at achieving high sensitivity by using this technology to increase the light utilization efficiency, and achieved cameras with high picture quality without reducing the signal-to-noise ratio. This has become a basic technology in the development of contemporary CCD devices.

New Structure CCD (1998)

When a wider f-stop is used, the component of the incident light that strikes the sensor at an angle increases. Since the on-chip microlenses cannot collect and bring this light to the sensor effectively, the sensitivity to parallel light rays is reduced. To solve this problem, Sony introduced a technology for forming internal lenses between the color filters and the photo shielding film. This technology increases the condensing efficiency by changing the optical path with internal lenses so that the slanted component of the incident light that passes through the on-chip microlenses can be collected in the sensor. Furthermore, Sony was able to suppress the smear component that enters the vertical CCD by introducing a technology for making the insulating film between the silicon substrate and the electrodes even thinner. This resulted in a major improvement in the smear characteristics.



■ **Figure 3 CCD Area Sensor Structure Models**



Conventional CCD **Super HAD CCD**

■ **Photograph 12 On-Chip Microlens Form Comparison**

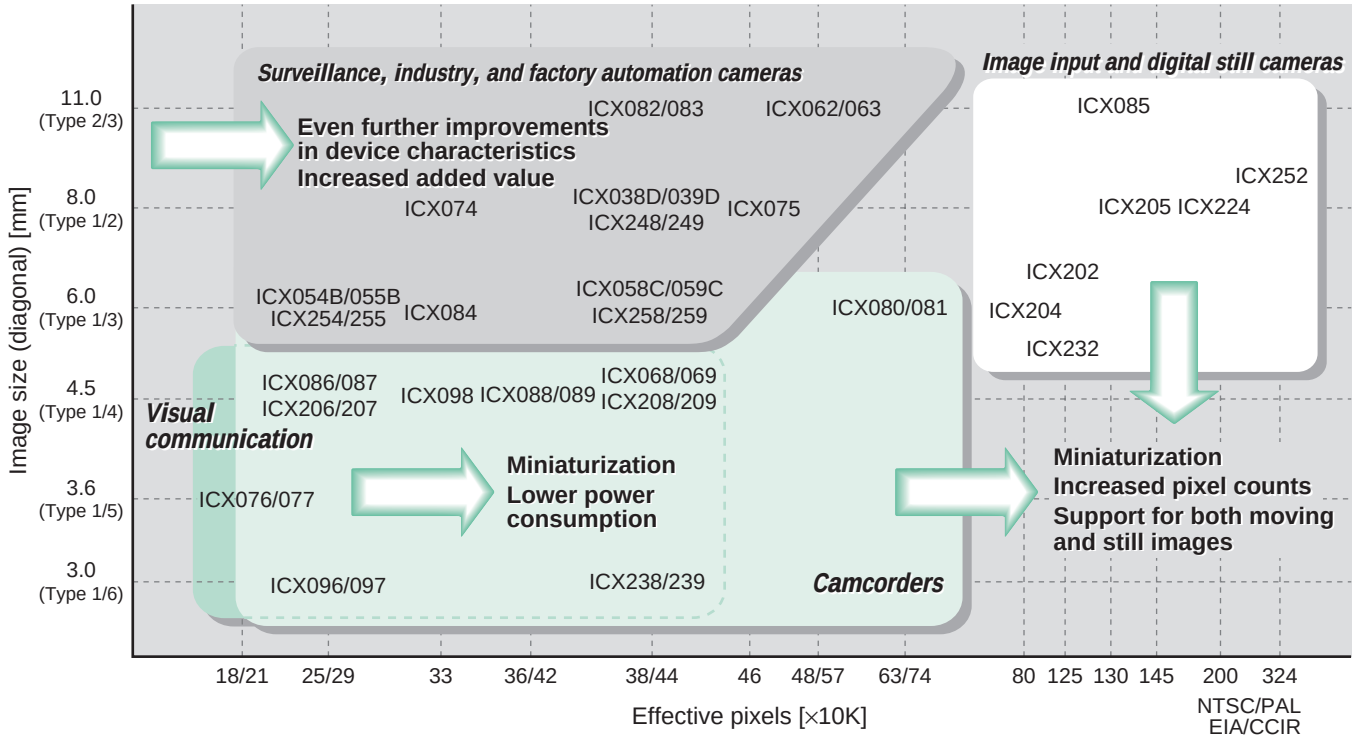
■ **Photograph 13 Smear Comparison**

EXview HAD CCD™ (1998)

With the conventional CCD structure, it was not possible to collect efficiently in the sensor the charge due to photo-conversion for light in the near infrared range, i.e. light with a wavelength longer than visible light, since that light is photo-converted deep in the semiconductor's silicon. The newly-developed EXview HAD CCD can handle charge due to near infrared light that was not acquired by conventional CCDs as video information and therefore achieves significantly improved sensitivity from the visible to the near infrared ranges. This EXview HAD CCD is capable of high-sensitivity imaging even in dark environments.
Furthermore, the fact that the component that was photo-converted deep in the silicon substrate and leaked as a smear component in vertical CCDs is now collected in the sensor results in a significant reduction of smear level in this device.

Moving into the 21st Century

While Sony's total CCD production exceeded 100 million pieces last year, this number of 100 million is merely one of many milestones. The applications that include CCD sensors will surely become increasingly diverse from the year 2000 and beyond. While it goes without saying that Sony will continue to work for increased miniaturization and higher pixel counts while at the same time maintaining the basic device characteristics, Sony is also committed to creating attractive high added value products that respond to our customers' needs. Furthermore, Sony will continue to strive to design products that are environmentally aware; that feature lower power consumption, reduced drive circuit part counts, and fewer pins.
Finally, we would like to point out that Sony's CCD System Division and Sony Kokubu Corp. have acquired ISO 9001 certification last year. The business division and the plant are now working together to assure stable product supply and to maintain and improve quality.
Keep your eyes on Sony CCDs, now and in the future.



■ **Figure 4 Sony CCD Area Sensor Product Line and Future Developments**