Featuring

# Sony “Exmor R” CMOS Image Sensors Achieve a Dramatic Increase in Performance

- Adoption of a back-illuminated structure
- Sensitivity characteristics approximately twice those of current image sensors achieved
- Improved vignetting
- Wafer thinning technology
- Unique Sony photodiode structure

Exmor R™

* “Exmor R” is a trademark of Sony Corporation. The “Exmor R” is a Sony’s CMOS image sensor with significantly enhanced imaging characteristics including sensitivity and low noise by changing fundamental structure of “Exmor” pixel adopted column-parallel A/D converter to back-illuminated type.

## Responding to Growing Market Needs

In the consumer digital cameras, the way digital still cameras are owned is changing from being shared by the whole family to being owned by the individual, and the number of consumer digital camera shipped worldwide will soon exceed 100 million units. Along with the increase in individual ownership, the ways cameras are being used is expanding beyond simply recording special events to capturing all sorts of scenes in their users’ daily lives. For example, there are now needs for taking pictures in situations where there may not be adequate light, such as photographs of children or pets at play, taking natural appearing photographs without flash, or taking clear photographs in dark locations without using a tripod. There are also increasing user needs for taking photographs of subjects that are moving rapidly. However the continuous high-speed imaging and S/N ratio of the miniature CCD image sensors used in current digital still cameras are not adequate to meet these needs. Given this background, Sony developed the “Exmor R” CMOS image sensor.

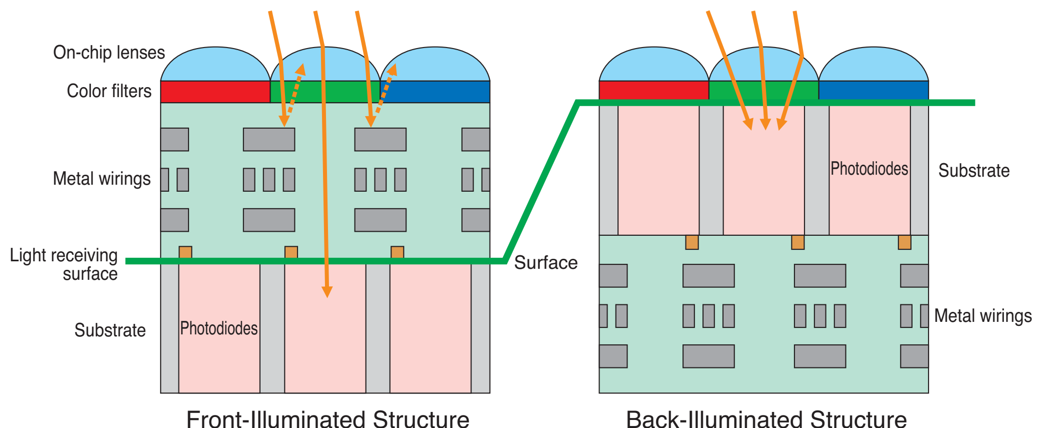
The “Exmor R” CMOS image sensor, in addition to supporting high-speed imaging due to the adoption of column-parallel A/D conversion, achieves sensitivity characteristics that are improved by approximately a factor of two from current front-illuminated image sensors by adopting a newly-developed back-illuminated structure. This structure significantly improves picture quality for photographing subjects that are moving or for taking pictures in dark locations.

## Sensitivity Characteristics Improved by Approximately a Factor of Two by the Back-Illuminated Structure

Since the incident light entering current CMOS image sensors passes through gaps in the metal wiring layer, the light is obstructed by that metal wiring layer and cannot be delivered efficiently to the photodiodes. In particular, since light that comes in at an angle is reflected back, problems such as the outer areas of the image being darker or the sensitivity not increasing as the aperture is opened wider occur. Also, when combined with a zoom lens, the sensitivity and color balance of the outer areas of the image may change with the zoom setting.

Sony has now developed a back-illuminated structure that differs from the current pixel structure (the front-illuminated structure) in that the metal wiring layer is placed below the photodetectors. In the back-illuminated structure,

**Figure 1** Cross-Sectional Structures



light is projected onto the rear surface of the silicon substrate (the back side) and as a result, the amount of light entering each unit pixel is increased since it is not affected by the metal wirings and other circuits. This also allows the change in sensitivity with the angle of incidence to be minimized. This structure increases the light collecting efficiency even under imaging conditions where high angles of incidence are common, and achieves sensitivity characteristics that are increased by approximately a factor of two over current image sensors. (See figures 1 and 2.)

## Wafer Thinning Technology

In the current CMOS image sensor structure, light receiving layers (photodiodes and transistors) that collect light are formed on the surface of a silicon substrate. While the silicon substrate itself is about 600 to 800 µm thick, in the Sony "Exmor R" CMOS image sensors, it was necessary to make of the silicon substrate, including the metal wiring layer, have a thickness of about 8 µm to allow light to be received through the back of the substrate. However, this thinning can cause wafer surface distortion and warping that cannot be seen by the naked eye as well as micrometer level positional discrepancies and height differences. If we were to see a 1 µm pixel as a person, then these height differences would be like a bump the height of a person on a skating rink that was expected to be smooth. This meant that it would not be possible to form the on-chip lenses and color filters over 1 µm pixels. To resolve this issue, Sony developed a new wafer thinning technology to assure that such distortion and warping does not occur.

## Unique Sony Photodiode Structure

In image sensors, it is easy for electrons that are unrelated to the incident light to be generated from the silicon surface, and even a single electron can become noise of a level that is visible to the naked eye. To avoid this problem, Sony developed a technology that prevents the generation of electrons that occurs at surface defects for this back-illuminated structure in which light is received on the back surface of the wafer.
Furthermore, since light is received on the back surface, it is necessary to transport all the photoelectrons that are generated at the back surface to the circuits on the front surface of the device. Sony also succeeded in developing a unique photodiode with a structure that makes this possible.

## Future Developments

Back-illuminated CMOS image sensors not only make high-sensitivity and low-noise imaging possible, but they also make it possible to use multi-layer metal wirings and arbitrary transistor structures. This means that we can expect even further improvements in speed and performance. Sony is committed to taking advantage of the superlative characteristics only available in back-illuminated CMOS image sensors and continuing our development efforts to create even easier to use and even higher picture quality image sensors.

**Figure 2** Image Comparison (100 lx, F4.0, 1/30 s accumulation)

Current CCD Image Sensor
(front-illuminated structure)
ICX675 (Type 1/2.3, 10M pixels, 1.65 µm)

"Exmor R" CMOS Image Sensor
(back-illuminated structure)
IMX050 (Type 1/2.3, 10M pixels, 1.65 µm)