Sony's Stacked CMOS Image Sensor Solves All Existing Problems in One Stroke

In conventional CMOS image sensors, the pixels (sensors) and circuits (logic) are formed on the same silicon substrate. Like oil and water, this coexistence of two conflicting elements makes it difficult to optimize their characteristics and also imposes other constraints. The "stacked CMOS image sensor\(^1\)\(^*\)\(^4\), a new generation of the back-illuminated CMOS image sensor, developed by Sony solves these problems in one stroke. Stacking the pixel section and the circuit section enables compact size, high image quality, faster speeds and flexible integration of versatile functions. Through this technology, Sony has created functions that will enable differentiation of final products to provide new ways of enjoying images.

\(^{*1}\): See press release at: http://www.sony.net/SonyInfo/News/Press/201201/12-099E/

Create a new world of imaging with Sony’s New Technology and Structure

- ▶ Figure 1 Demands by Customers that Use Image Sensors in Final Products

- ▶ Figure 2 Sony’s Objectives as an Image Sensor Supplier

Expectations of Pixels and Circuits

The expectations that customers have of a final product containing an image sensor can be categorized into expectations regarding pixels and those regarding circuits. (See figure 1.)

When it comes to pixels, customers are looking for improvements in basic performance such as pixel size, speed, sensitivity and high pixel numbers. For example, smaller pixel sizes make it difficult to obtain greater sensitivity. However, Sony thinks that image sensors should capture images at 1 lx (moonlight) and has once again raised their basic performance goals accordingly. It is often said that customers demand a new approach from image sensors that will allow differentiation of the design of the final product, for example, fun and ease of use. Some think that Sony as a leader in digital imaging technology should make better use of its intellectual property (IP).
Sony has set a goal to develop a “Super Reality” sensor that surpasses human vision to achieve high speeds and high picture quality. The increasing popularity of smartphones means a greater diversification of camera usage. Sony would like to specify a new evolution axis of higher performance in addition to this evolution axis.

Sony meets the customers’ expectation for greater differentiation in final products with the stacked CMOS image sensor that has the superb mechanism to provide new ways of enjoying images.

Sony’s Objectives as a Supplier

A number of hurdles remains to be cleared to satisfy these expectations and demands. (See figure 2.)

Firstly, the pixel and circuit manufacturing processes are as irreconcilable as oil and water. For example, to improve the light gathering efficiency of the pixels optical waveguides have been introduced. The dry etching process required to do this causes damage to the silicon crystals and the pixel section makes it necessary to follow it up with an annealing process (heat treatment) to recover from this damage. From the point of view of the circuit section, heat treatment is highly undesirable since it changes transistor parameters. As described above, pursuing pixel section characteristics when forming pixels and circuits on the same silicon wafer means that you add a constraint to the circuit section.

Completely unnecessary from the point of view of the circuit section, it is a process that the pixel section needs. On-chip color filters, microlenses and other components are formed both on the pixel section and also the circuit section, after which everything is removed. These kind of inefficiencies exist because the same silicon substrate is used for forming both pixels and circuits.

There are also constraints in process line generation. Sony currently uses the 65 nm process rule in IC manufacturing. Since the same silicon substrate is used for both the pixel section and the circuit section, the few μm to take in light. As it is difficult to transport a substrate this thin, a supporting substrate is usually added to the side opposite the light receiving surface (back side). Since a difference in the coefficient of thermal expansion between the different layers could cause them to separate, the supporting substrate, like the chip, is also a silicon substrate.

The supporting substrate also being a silicon substrate makes it a natural first step to use it as a circuit layer. (See figure 3.)

As placing the pixels and circuits on the same silicon substrate is a precarious approach at best, it is a natural second step to completely separate the two.

Two Concepts that Changes Configuration Considerably

In a back-illuminated CMOS image sensor, both pixels and circuits are formed on the silicon substrate, which is reduced to a few μm to take in light. As it is difficult to transport a substrate this thin, a supporting substrate is usually added to the side opposite the light receiving surface (back side). Since a difference in the coefficient of thermal expansion between the different layers could cause them to separate, the supporting substrate, like the chip, is also a silicon substrate.

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Future Image Sensor Evolution Axes

Provide new comfortable ways of enjoying images

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before delivering the product. The new CMOS sensor makes it easier to add new functionality to increase the shooting fun of the end user.

**Advantages to Final Product Manufacturers**

The stacked structure makes it possible to place large circuits on small chips, which further simplifies differentiation. Also, the technology enables use of cutting-edge processes with chips having formed circuits to speed up signal processing speeds and reduce power consumption. It also facilitates design and improves design flexibility.

**Advantages to Sony**

The new technology enables us to quickly provide digital imaging IP, a Sony strength, to increase productivity of the external foundry cooperative manufacturers and to quickly respond to customization requests.

In the following, Sony will describe the size of circuits – and their process rules – that can be placed on the stacked circuit section of typically sized image sensors. Digital still cameras mainly use Type 1/2.3 CMOS image sensors. If the 45 nm process rule can be used for the circuit section, it will become possible to implement signal processing circuits that equal the DSPs used in high-end digital still cameras. And even the 65 nm rule will make possible signal processing for middle class digital still cameras.

Type 1/3.2 image sensor processed according to the 65 nm rule could be incorporated in a surveillance camera. And if the 45 nm rule were used, it would enable integration of a signal processing circuit large enough for middle class digital still cameras.

Secondly, how can the surface area be reduced by completely separating the pixel section from the circuit section? Sony’s Type 1/4 CMOS image sensors can then be reduced by 30% and SoC CMOS image sensors for mobile phones with camera signal processing capability can be reduced by 40%. Although CMOS sensors are generally thought to be larger than CCD image sensors, stacked CMOS image sensors do not need any registers and can therefore be 20% smaller. The configuration of the sensor makes it ideal for use in medical cameras and other industrial applications.
Sony Proposal: Two New Functions to Eliminate Common Shooting Errors

Stacked CMOS image sensors can be used for work role-sharing with customer’s DSP, store digital imaging IP in the circuit section or enable flexible integration of customer developed functions. First we will introduce two new functions and what they mean in the evolution of the camera.

1. Sony’s unique “RGBW Coding” function enabling clear shooting in dark rooms or at night

The built-in “RGBW Coding” function which adds W (White) pixels to the conventional range of RGB (Red-Green-Blue) pixels has realized higher sensitivity, enabling high-quality shooting with low noise even in dark indoor or night settings.

While the addition of W (White) pixels improves sensitivity, it has the problem of degrading image quality. However, Sony’s own device technology and signal processing realizes superior sensitivity without hurting image quality.

2. “HDR (High Dynamic Range) Movie” function which enables brilliant colors to be captured even in bright settings

Typically, when shooting with differing light levels, such as an indoor setting against a bright outdoor background, there can easily be blocked up shadows for dark areas or blown out highlights for bright areas. Such phenomena are a result of the combination of low-light and bright-light which have different optimal exposure conditions in the same shot.

This function reduces this by setting two different exposure conditions within a single screen shooting and conducts the appropriate signal processing for the captured image information under each optimal exposure condition. This process generates an image with a broad dynamic range and enables shooting of both the background and subject matter with brilliant colors even in a bright environment.

When a stacked CMOS image sensor supporting these two functions are integrated into a smartphone or other device, there is no need to change the signal processing of the device.

- Type 1/3.06 stacked CMOS image sensor with approx. 13.0M effective pixels
  Sample shipments planned for June, 2012
- Type 1/4 stacked CMOS image sensor with approx. 8.0M effective pixels
  Sample shipments planned for August, 2012

![Conventional RGB method](image1.png) ![Newly developed “RGBW Coding” method](image2.png)

![Normal movie](image3.png) ![HDR movie](image4.png)