
Focal Point

The Newsletter from Southwest Precision Instruments

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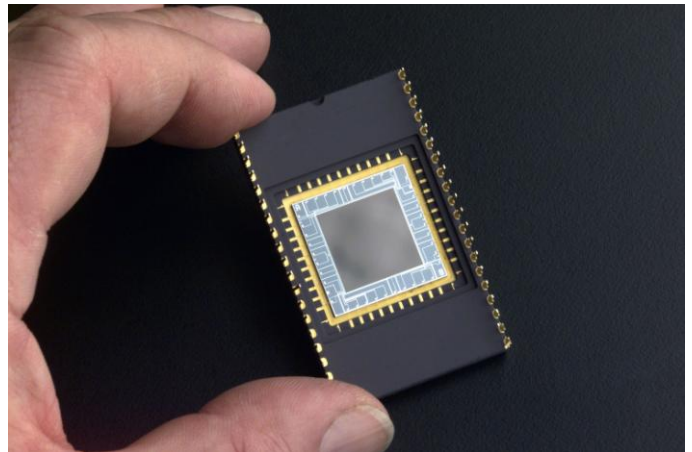
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Digital Imaging: CCD or CMOS Chip?



A packaged UV-visible light CCD imaging chip.

Congratulations to Leigh Ann Henricksen!

Dr. Leigh Ann Henricksen won our Virtual Open House door prize, a Garmin Nüvi® 205W GPS system!

Leigh Ann is an Assistant Research Scientist in the laboratory of Dr. Kate Dixon, University of Arizona Department of Molecular and Cellular Biology, where she is a part of the Dixon lab team studying DNA damage and repair mechanisms.

Leigh Ann received her Ph.D. in Biochemistry from the University of Iowa. She held a Postdoctoral Fellowship and a Research Assistant Professorship at the University of Rochester in upstate New York before coming to Tucson four years ago.

Congratulations, Leigh Ann! May you never be lost again!

Whether it's your "point-and-shoot" digital camera or the scientific imaging camera that's mounted on your research fluorescence microscope, the cameras have at least one thing in common: An imaging device that converts photons into digital bits of information.

The conversion of photons into bits is done by either a CCD (charge coupled device) or a CMOS (complementary metal oxide semiconductor) chip. Both chips are composed of pixels, or picture elements, and these pixels are the individual components which make up the final digital image.

CCDs are more sensitive, but CMOS chips are faster.

In a CCD chip, all of the pixels' charges are transferred off the chip as an analog signal. The signal is transferred off the chip through a limited number of output ports (there is usually only one "readout" port on the chip.)

The CCD's signal is converted to a digital signal "downstream" from the chip itself. On the positive side, there aren't large numbers of other electronic structures on the CCD, so all of the pixel area can be used to collect photons.

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This isn't the case with a CMOS chip. These devices usually have on-chip amplifiers, noise correction, and digitization circuits. The CMOS chip therefore gives direct digital output, but the extra circuitry occupies a lot of real estate on the chip. Many photons get absorbed or reflected because of the additional structures on the chip. CMOS chips are therefore usually less sensitive than CCDs because they tend to collect fewer photons per imaging area.

On the other hand, CMOS chips provide digital output directly off the chip, and there can be several output ports on the chip (instead of only one port on a CCD chip). These features make for a signal that is very quickly transferred off the chip.

Those advantages, along with lower energy consumption, make the CMOS chip an excellent choice for battery operated digital video cameras. Most consumer and "prosumer" digital video cameras capitalize on these advantages and use CMOS chips, as does the camera in your cell phone.

The energy savings in a CMOS chip is appreciable; comparatively speaking, a CMOS chip uses about 1/100 the energy of a CCD.

Manufacturing technology and software determine what's available to us.

CCD and CMOS chips were both invented in the late 1960s and early 1970s, but CCDs took the early lead in digital imaging. This was largely due to limitations of the manufacturing techniques of the time. Not too long ago a CCD chip with a million pixels (1,000 x 1,000) was about as good as it could get. Also, there was no possible way to pack the chip with all of the extra circuitry that's required by a CMOS chip.

In the 1990s UV and extreme UV lithography made it possible to produce pixels and circuits which were small enough to warrant a second look at CMOS chips. After all, CMOS fabrication is how memory and logic devices are normally manufactured. It was always hoped that a CMOS fabrication line could be relatively easily converted to produce digital imaging chips.

Easier said than done.

As in most cases, things are rarely as easy as expected, and making CMOS imaging chips is certainly no exception. Retooling a "wafer fab" line is not easily done, and getting acceptable CMOS chips out the other

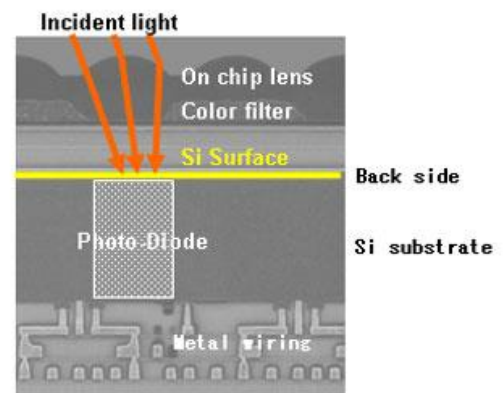
end turned out to be a lot more challenging (and expensive) than expected. In fact, the costs of manufacturing CMOS and CCD chips were quite similar for several years. This is changing as the chip manufacturers refine their processes and lithography techniques. CMOS chips are finally less expensive than their CCD cousins.

CCDs are still recommended for low-light situations, but things are changing rapidly.

A CCD, either cooled or non-cooled, is still probably the best choice if you must capture images under very low light level situations, such as weak fluorescence, but CMOS devices are much better than they were just a couple of years ago.

We recently sold a reasonably priced CMOS camera to a laboratory for brightfield imaging, and just for fun we tested the camera in the fluorescence mode with DAPI and FITC. Both probes admittedly had good, bright signals, but everyone was surprised at the performance of the CMOS camera. It did a very nice job of capturing fluorescence images.

The back-illuminated CMOS chip: Higher sensitivity, better signal-to-noise ratio.



A back-illuminated CMOS chip.

In recent developments, Omnivision Technologies and Sony are both working on new CMOS chips in which the layers of the chip are rearranged, bringing the photodiode structure (the light-sensitive area) closer to the surface. This effectively increases the sensitivity of the chip and improves the signal-to-noise ratio.

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In addition, the pixels on the chips are very small; Sony's chip has pixels measuring only $1.75 \mu\text{m}^2$.

Similar to back-illuminated (or "back-thinned") CCD chips, the new CMOS chips are designed to be back-illuminated, rather than using the usual front-illuminated configuration.

A normal CMOS chip is in some ways analogous to the retina; the light-sensitive photodiode area is deep in the chip, and light must pass through areas which contain electronic components in them. The retina is similarly "back to front." Light travels through a tangle of nerve cells and blood vessels before reaching the rods and cones.

The new configurations place the photodiode areas immediately under surface-mounted on-chip lenses and color filters, thereby maximizing the number of photons that are "trapped" within each pixel.

[Click here to read more](#) about Sony's technology and to view an animation which compares front-illuminated and back-illuminated CMOS imaging chips.

[Click here for an introduction](#) to Omnivision's new back-illuminated CMOS design.

Additional Reading and Viewing:

The Molecular Expressions Website (University of Florida) has several pages devoted to digital imaging as part of their Optical Microscopy Primer. [Start here](#).

A good "jump point" for more information on CMOS and CCD imaging chips is found at [How Stuff Works](#).

Manufacturing integrated circuits on a silicon substrate is no easy feat; it can involve 30-40 individual steps during the process. For an animation and an explanation of the CMOS process, go here: <http://www.youtube.com/watch?v=9rCyu8B0tYs>

Six most commonly misspelled U.S. Cities:

- | | |
|-------------------|--------------------|
| 1. Pittsburgh, PA | 4. Albuquerque, NM |
| 2. Tucson, AZ | 5. Culpeper, VA |
| 3. Cincinnati, OH | 6. Asheville, NC |

Special Newsletter Discounts!

If you missed the discount that was offered on our Website (it's gone now), here's a second chance:

We're offering a 15% discount on all microscope service and repairs. Just call or email us and mention that you saw this offer in *Focal Point*. That's all there is to it!

This is a limited-time offer, valid until September 1, 2009, for standard service and labor rates. Normal Zone Charges apply outside the Metro Tucson area.

The Bizarre, Weird, Informative and Useless Column

A long time ago, when your esteemed Editor was in grad school and taking a class in scientific writing, one of our favorite resources was a little journal called *The Journal of Irreproducible Results*, or *J.I.R.* We used *J.I.R.* mainly as a resource to see how badly mangled the English language became when scientific papers hit the presses.

The bad news: *J.I.R.* died several years ago. The good news: It's been replaced by the same bunch of irreverent scientists at Harvard that produced the original journal. The new resource is *The Annals of Improbable Research*, affectionately called *A.I.R.*

We'll hit some highlights from *A.I.R.* occasionally in this column. If you become addicted and can't get enough improbable results, you can go directly to the supplier at: improbable.com.

Some classics:

[How to Write a Scientific Paper](#)
[Kansas Is Flatter Than a Pancake](#)

A.I.R. awards the 2008 Ig Nobel Prize for Economics. [Here's the winning publication](#). Offered to you without comment.

And the Ig Nobel Prize for Medicine: [Expensive fake medicine is more effective than cheap fake medicine](#).