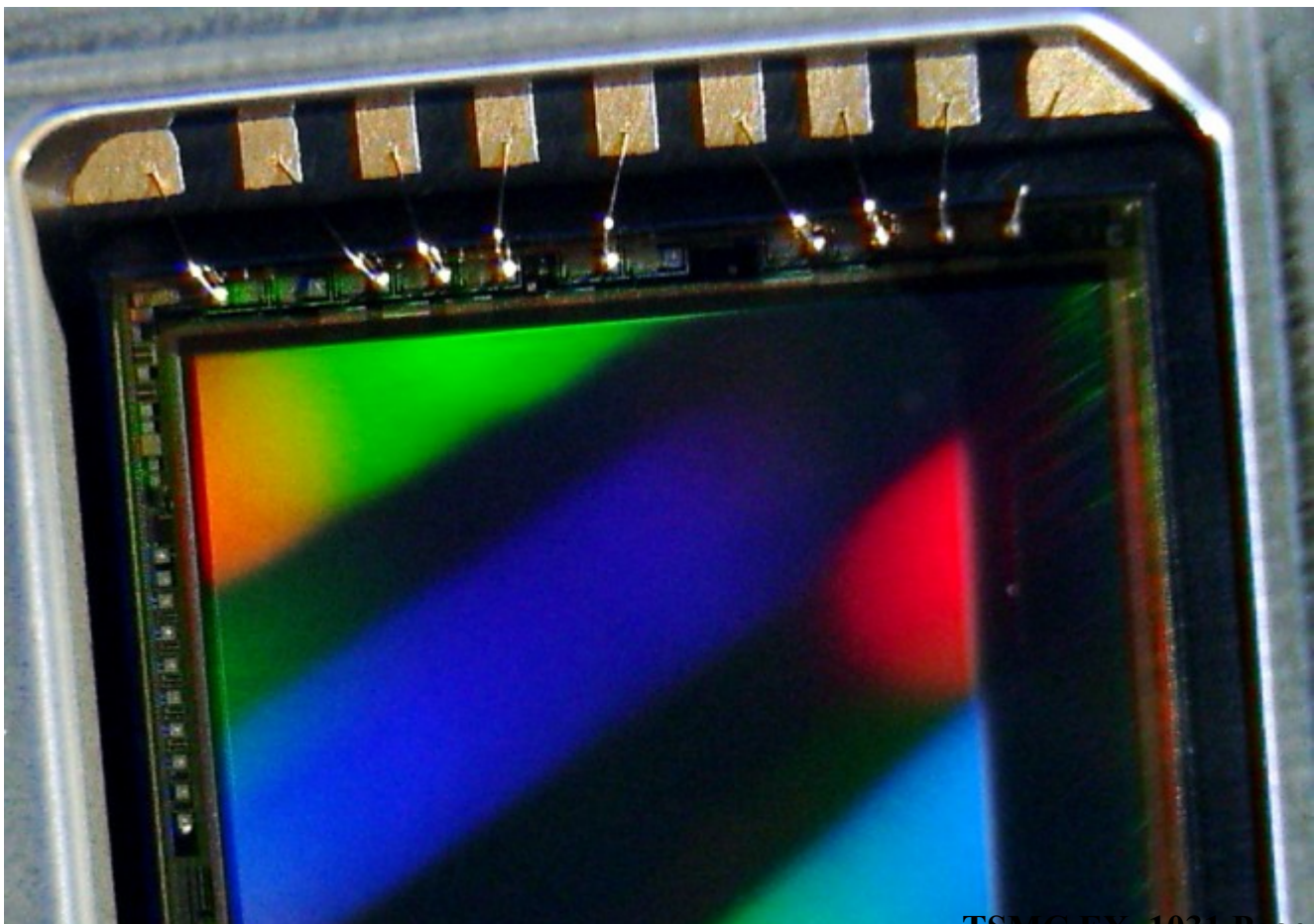
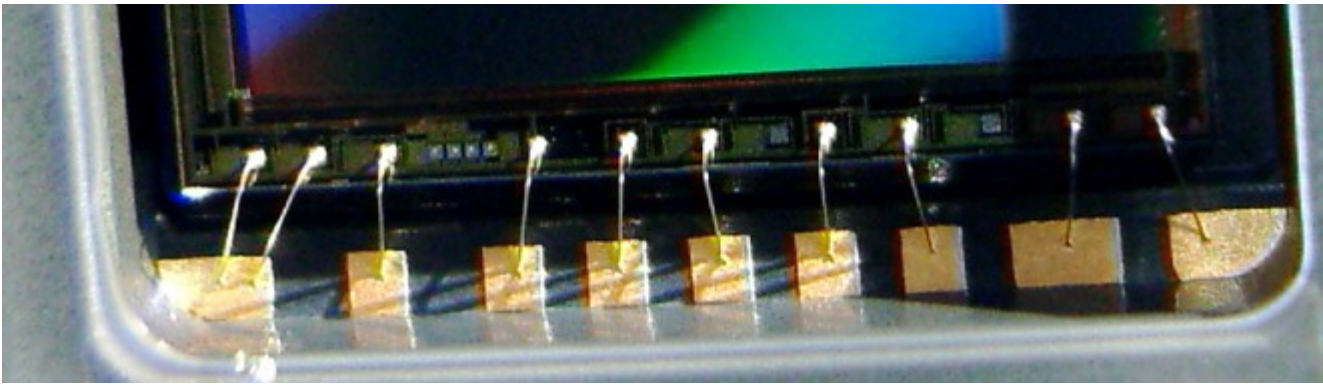


CHARLIE SORREL GEAR OCT 7, 2009 9:06 AM

Inside the Nobel Prize: How a CCD Works

This year's Nobel Prize for Physics has been awarded, with the inventors of the CCD getting recognition for the invention which enabled modern digital photography. It has taken a while: Whilst the invention took just one hour, the prize took 40 years to arrive. The true fathers of digital photography, Willard S. Boyle and George [...]





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The true fathers of digital photography, Willard S. Boyle and George E. Smith, invented the CCD, or Charge-Coupled Device, while working at Bell Laboratories, New Jersey. What will surprise you is that this invention was made way back in 1969, when everybody else was looking Moon-ward. The CCD was the first practical way to let a light-sensitive silicon chip store an image and then digitize it. In short, it is the basis of today's digital camera.

The CCD was based on “charge bubbles”, an idea inspired by another project going on in Bell Laboratories at the same time. The sensor is made up of pixels, each of which is a MOS (metal-oxide semiconductor) capacitor. As the light falls on each pixel, the photons become electrons due to the photoelectric effect (the same thing that permits solar power). The photoelectric effect happens when photons of light hit the silicon of the pixel and knock electrons out of place. On a CCD, these electrons are stored in a “bucket”: the pixel's capacitor.

At this stage, the “image” is still in analog form, with the charge, or amount of electron in the bucket, on each pixel directly corresponding to the amount of light that has hit it. The genius of Boyle and Smith's CCD was the reading of the information stored.

Essentially, the charge in each row is moved from one site to the next, a step at a time. This has been likened to a “bucket row” or human chain, passing buckets of water down a line. As these buckets of electrons reach the end of the line they are

dumped out and measured, and this analog measurement is then turned into a digital value. Thus, a digital grid is made which describes the image.

The image from a CCD is black and white, but by placing a red, green or blue colored filter over the top of each pixel, color information can be read directly from each pixel -- but only for one primary color per pixel. Subsequently, software can also extrapolate the color of adjacent pixels based on their brightness, so that each

pixel winds up with its own red, green and blue values. If you ever wondered just what a RAW file was, it is the “raw” color data from the chip before any of the post-processing extrapolation has been done. Cameras usually do all of this processing for you and spit out the result as a JPEG. With the RAW file you actually have all the original sensor data, which is much more information-rich.

As an interesting aside, early, primitive patterns for the color filters over the pixels soon gave way to the Bayer pattern still found in almost all sensors today, and developed by Kodak back in 1975.

Today, the CMOS (Complementary Metal Oxide Semiconductor) sensor is becoming more popular, as it reads information directly from each photo-site instead of row by row. It also uses less power, making it better suited to the multi-megapixel chips popular in modern cameras. CMOS sensors have also been around since the 60s, but their complex design, physically larger chips, higher noise and lower sensitivity meant that Boyle and Smith’s CCD triumphed, at least until recently.

But the most amazing thing about the invention is that Boyle and Smith came up with the design so quickly. With Bell Labs threatening to take the funds from their department and transfer the money to bubble memory research, Boyle had to come up with a competing semiconductor design. He got together with Smith and they came up with the idea and sketched it all out on a blackboard in just one hour. Instant photography indeed.

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