2 Feb 2017 | 14:00 GMT

Four IEEE Fellows Share Queen Elizabeth Prize for Digital Cameras

Inventors of the CCD, the pinned photodiode, and the CMOS imager honored with £1 million prize

By **Samuel K. Moore (/author/moore-samuel-k)**

Photo: Queen Elizabeth Prize for Engineering

Michael F. Tompsett taking a selfie with Eric R. Fossum [center] and Nobukazu Teranishi [right]

Four engineers and IEEE Fellows credited with major innovations in image sensors have won the £1 million Queen Elizabeth Prize for Engineering (http://qeprize.org/). Nobel Prize

(/semiconductors/optoelectronics/the-nobel-prize-and-its-discontents) winner George E. Smith (https://www.nobelprize.org/nobel_prizes/physics/laureates/2009/smith-facts.html) and Michael F. Tompsett (https://en.wikipedia.org/wiki/Michael_Francis_Tompsett) won for the charge coupled device (CCD) imager, sharing the prize with Nobukazu Teranishi who improved on the CCD by inventing the pinned photodiode and with Eric R. Fossum (http://engineering.dartmouth.edu/people/faculty/eric-fossum/) who invented the CMOS imager, the technology that succeeded the CCD in most applications and allowed for the proliferation of cameras in smartphones and other mobile devices.

In a **CCD**, each pixel is a potential well. Light falling on the pixel converts to charge by the photoelectric effect. The charge accumulates in the well and is then pushed from well to well until it reaches circuitry that measures the amount of charge and produces a digital representation of it.

The award must be particularly sweet for Tompsett, who missed out on the 2009 Nobel Prize for the CCD imager. At the time of the invention in 1969, Smith was Tompsett's boss at Bell Laboratories. Smith and the late Willard Boyle came up with the CCD while trying to invent a new kind of memory. Smith has said the invention's application in imaging was immediately obvious, but it was Tompsett who actually made it happen.

"If it were not for Mike's perseverance, Bell Labs would not have done any imaging work with the CCD," IEEE Fellow Eugene I. Gordon told *IEEE Spectrum* in 2009. Gordon worked for Boyle when the CCD was invented and was Smith's supervisor. (Eugene Gordon (/blog/semiconductors/devices/tech-talk/nobel-controversy-eugene-gordon-claims-he-gave-smith-the-idea-for-the-ccd) made his own claims on the invention of the CCD, which Boyle (/blog/semiconductors/devices/tech-talk/nobel-controversy-willard-boyle-denies-gordons-claims-proud-of-ccd-work) and Smith (/blog/semiconductors/devices/tech-talk/nobel-controversy-smith-dismisses-gordons-claims-heard-it-all-before) strongly denied.)

As *IEEE Spectrum* explained at the time:

> Tompsett, who ran Bell Labs' CCD group in the 1970s, is the sole inventor listed on U.S. Patent No. 4085456, "charge transfer imaging devices." The patent, filed in 1971, covers linear scanners and area imagers.
>
> Tompsett's key invention was a scheme called frame transfer. The invention solved a big problem with using a CCD as an imager: The CCD continued to sense light and gather charge even as each line of pixels was read out, smearing the image in the direction of the charge transfer. Tompsett's idea was to duplicate the entire CCD structure on a part of the chip that wasn't exposed to the image. He found a way to rapidly transfer the charge collected in the imaging CCD to the hidden CCD. The image was then read out from the hidden CCD, while the imaging side took another picture.

Tompsett took the first published CCD image, a picture of his wife, Dr. Margaret Tompsett that graced the cover of *Electronics* magazine.

The **pinned photodiode**—invented in by Teranishi at NEC in 1980 but not given its name until 1984—is a light-absorbing structure in the pixel that solved a number of problems with early CCDs and remains in the CMOS imagers that succeeded it. (Fossum coauthored an excellent review of the history of the pinned photodiode in the *IEEE Journal of the Electron Device Society* (http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=6742594) [PDF] in 2014. Teranishi's own review (http://ieeexplore.ieee.org/document/7118147/) was published in 2016 in *IEEE Transactions on Electron Devices*.)

The pixels of a **CMOS imager** are more complex than those of CCD imagers, because each contains its own amplifier. Tasked with coming up with miniaturized camera systems, Fossum invented the circuit, then called the CMOS active pixel sensor at NASA's Jet Propulsion Laboratory in 1992. As lithography improved and investment poured in, CMOS gradually took over from CCDs and allowed camera chips to fit in small gadgets with low power requirements. According to the prize announcement, 100 new CMOS imagers are made every second.

About the Tech Talk blog

IEEE Spectrum's general technology blog, featuring news, analysis, and opinions about engineering, consumer electronics, and technology and society, from the editorial staff and freelance contributors.

Subscribe to RSS Feed (/rss/blog/tech-talk/fulltext)