

This Week's Citation Classic

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Boyle W S & Smith G E. Charge coupled semiconductor devices.
Bell Syst. Tech. J. 49:587-93, 1970. [Bell Laboratories, Murray Hill, NJ]

This was the original publication describing a new invention called the charge coupled device (CCD). It is essentially a monolithic semiconductor shift register in which the shifted information is in the form of a charge packet stored on a capacitor. [The *SCI*[®] indicates that this paper has been cited in over 255 publications since 1970.]

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"Somewhat interesting circumstances surrounded the birth of charge coupled devices (CCD). In 1969, the device area of Bell Laboratories was strongly oriented toward innovation and exploratory development of new devices such as the IMPATT diode, semiconductor lasers, nonlinear optics, solid-state lasers, holography, magnetic bubbles, and the silicon diode array camera tube. The magnetic bubble work was particularly interesting in that it represented a new way of manipulating information by moving a magnetic domain from place to place in a solid material. Semiconductor circuits were wedded to concepts of discrete electrical devices wired together such that voltages and currents represented the relevant information. The vice-president of the electronics technology area, the late Jack Morton,

was a strong proponent of magnetic bubbles and yet felt that there should be some analogous scheme that one could devise using semiconductor technology; hence, the encouragement of management was there. Another bit of encouragement for those of us in semiconductors was the perceived threat that our funding would be in jeopardy if we did not come up with something that could compete with bubbles.

"The silicon diode array camera also played a role in the conception of the CCD. One of us (GES) was involved in the project to develop these devices which consisted of a large array of diodes fabricated in a single slice of silicon. Light falling on one of these diodes charged it, and its charge state was read off with a scanning electron beam. This provided the concept of a large single functional device in which information was stored in the form of charge. What remained was to ask the question, 'Why not try to move this charge (information) around in the semiconductor?' and then devise a way of doing it.

"The actual invention took place during an afternoon discussion between us lasting only about one hour. The basic structure was devised and preliminary ideas concerning applications developed. After thinking about and discussing it with colleagues for a few weeks, we decided to fabricate the structure. This was successfully done in about one week and resulted in this paper on the concept and an accompanying one¹ on the experimental verification. Since the inception of the CCD, about 2,000 papers have been written which directly concern the device and this accounts for the numerous times it has been cited.

"For this work, we received the 1973 Stuart Ballantine Medal from the Franklin Institute and the 1974 Morris Liebman Award from the IEEE."

1. **Amelio G F, Tompsett M F & Smith G E.** Experimental verification of the charge coupled device concept.
Bell Syst. Tech. J. 49:593-600, 1970. [The *SCI* indicates that this paper has been cited in over 65 publications since 1970.]