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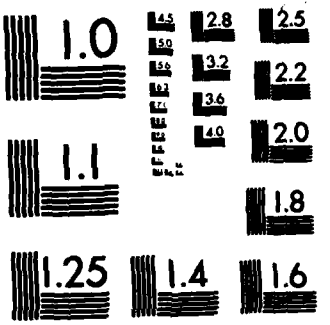

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FOREIGN TECHNOLOGY DIVISION

CCD CAMERA--A CAMERA THAT DOES NOT USE FILMS

by

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CCD CAMERA--A CAMERA THAT DOES NOT USE FILMS

Ho Ch'ien-min

A camera that does not use films sounds like something very interesting and unusual. This type of camera that has no need for photographic films is called "CCD camera" or "solid-state camera".

Since its invention, the camera not only has brought pleasure to many people but has, from the very beginning, been used in aerospace photography.

However, whether used on ground or in space, the tradition of using photographic films has been kept for a long time. The tedious and complicated process of developing and processing of films has always been a hindrance to a winder application of the photographic techniques. Is it possible to do without the films? Today, thanks to the rapid development in electronics and semi-conductor technology, a new type of camera has appeared. This type of camera does not use the traditional photographic film but instead employs a special micro-sized magnetic tape. The pictures taken are recorded on the magnetic tape that takes the place of the film. Therefore, people call this type of camera "magnetic recording camera".

The technique terms are "CCD camera" or "solid-state camera". The appearance of this type of portable camera foretells an important revolution in photography.

Simple in principle, exquisite in construction

CCD camera obtained its name from the fact that a CCD semi-conductor device is placed in the focal plane instead of the film. CCD stands for "charge coupled device".

The working process of the CCD camera can be briefly described as follows: the lens forms an image of the object on the focal plane

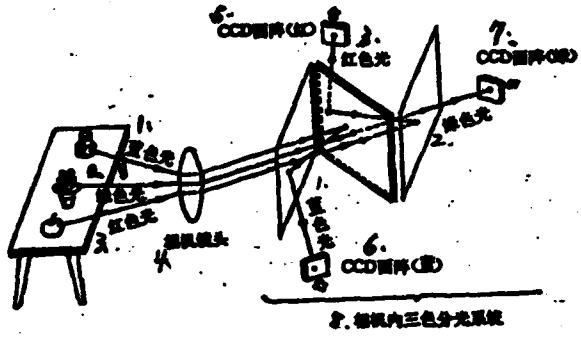

Figure 1. Principle of image formation by a CCD color camera
1--blue light; 2--green light; 3--red light; 4--camera lens; 5--CCD array (red); 6--CCD array (blue); 7--CCD array (green); 8--tri-color dispersion system

where the CCD element converts the optical signals into electrical signals. The signals are recorded on the magnetic tape after they are processed. This completes the process of "picture taking" (see Figure 1). When it is desired to view the "picture", the magnetic tape with the picture recorded on it is inserted into a special image-revealing equipment that is connected to an ordinary television set. The picture recorded on the magnetic tape can thus be viewed on the screen of the TV set. One can also copy the pictures onto a micro-tape that can be sorted away like a photo album.

We know that electrical charges are produced when light fails on a semi-conductor. We call these charges "light-generated signal charges". The quantity of light-generated charges is proportional to the intensity of light that falls on that region. Hence, when an image with a certain intensity distribution falls on the light-sensitive elements, each element produces electrical charges proportional in quantity to the intensity of light that falls on that element. Thus, there is a one-to-one correspondence between the intensity distribution of the image and the distribution of light-generated charges in the CCD units. However, it is not enough just to have converted the light signals into electrical charges. One also needs to be able to store the charges temporarily and then output them in an orderly manner according to a given time sequence so as to achieve the purpose

of image-recording. CCD devices meet both the requirement of storing the charges and of transporting the charges and have, therefore, become a new type of semi-conductor image-forming device in recent years.

Superior in performance, easy to use

Presently, there is already available a CCD camera designed for every day use (see Figure 2). Moreover, many different specialty CCD cameras have been made (Figure 3), including black-and-white, color, polychromatic, micro-light and infrared cameras that are widely used in various areas of remote sensing technology.

The essence of remote sensing lies in the word "remote". Only by rising high up can one see very far. This entails a disadvantage as it lengthens the time required to get hold of the picture. Time is a crucial factor in military reconnaissance photography. It would be best if one can see the pictures as they are being taken, as in

Figure 2. A CCD Camera used in every day life

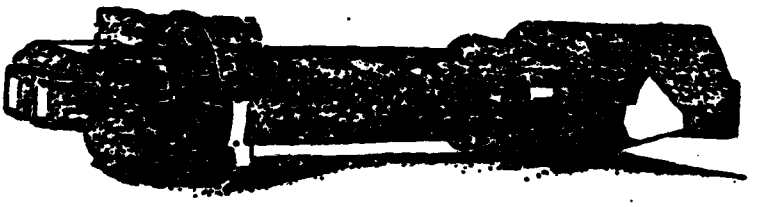

Figure 3. A large CCD camera used in aerospace photography

live TV broadcasts. The ordinary film-using camera is helpless in this respect. At present, the most widely used satellite for military reconnaissance is the photographing reconnaissance satellite because it is not limited by terrestrial boundaries but can come and go freely. However, with the reconnaissance satellite employing film-using cameras, one has to wait for it to complete the entire reconnaissance

mission before the film can be retrieved. This usually takes a few days to well over 10 days. After that, an even longer period of time is needed for the film to be processed before the pictures are obtained. The requirement of real-time reconnaissance is definitely not met here.

After the appearance of the video camera, real-time photography became a possibility. However, because of its large size, it is not feasible to mount an ordinary video camera in the satellite. On the other hand, a video camera made with CCD devices has a small volume, is light-weight and has very high reliability. The largest size it can get to be is that of an ordinary camera. A CCD camera with an array of 512x325 light-sensitive units is only about the size of a cigarette box, weighs only a few hundred grams, and uses only one watt of power. The pictures obtained are nevertheless as clear as those seen on TV screens. In contrast with the ordinary video camera, the CCD camera uses not several thousand volts of electricity, but only less than 20 volts, thus eliminating the need for high-voltage transformers, deflection coils and other bulky parts. By mounting a CCD camera in an airplane or a satellite, we can obtain real-time pictures taken by the camera. Hence, there are good prospects for the use of CCD cameras on airplanes and satellites. With the rapid development in semi-conductor integration, the resolving power can be greatly improved. One can expect to obtain for pictures taken with a CCD camera a resolution as good as that of pictures taken with film-using cameras. At that time, all the presently prevailing reconnaissance satellites that use film-using cameras will be replaced by satellites equipped with CCD cameras in remote sensing in space.

CCD devices not only can be used in black-and-white and color cameras, but also are used in making infrared and polychromatic cameras. The infrared pictures taken with a CCD infrared camera reflect the minute differences in temperature between the object and the background and among different parts of the object itself. As these temperature differences exist both during the day and in the dark of the night, the infrared camera can be used both day and night.

Furthermore, camouflages that look similar to the real object emit different infrared radiation than the real object. Objects that look similar in a visible light picture may look very different in an infrared picture. Therefore, the CCD camera has a definite ability to remove the effect of camouflages. The CCD infrared camera is superior to the ordinary infrared camera in that it does not require the use of a large number of amplifiers and a sophisticated optical scanning system. It is, therefore, especially suitable for use as the remote-sensing equipment in satellites or in the infrared forward-sensing equipment of airplanes. It can also be attached to a small unmanned remote controlled reconnoitering plane which is launched from the airplane at the appropriate location to reconnoiter a region several tens of kilometers wide. The pictures taken can be transmitted via radiowaves to appear on a screen in real-time operation, or they can be recorded on magnetic tapes and retrieved after the plane returns from its flight. The job of reconnoitering can also be done by means of long distance inclination photography from the airplane, the pictures taken being transmitted back real-time.

Polychromatic CCD cameras are constructed on the basis that semiconductor dopes with different impurities are sensitive to different spectral regions. In fact, color cameras belong in this category also except that they make use of separate CCD parts each sensitive to one of blue, green and red light only. A polychromatic CCD camera takes pictures separately in many more wavelength regions, as the situation demands. It can distinguish different objects not only by the difference in spectral characteristics of the electromagnetic waves emitted or reflected from them but also by the difference in intensity of these electromagnetic waves. Hence, polychromatic CCD cameras have the ability to discern minute differences. Many missions that cannot be accomplished using a black-and-white camera are poorly done with color cameras because of the adverse effect of height on color contrast. On the other hand, polychromatic CCD cameras can tell objects apart by their spectral distribution and can reveal details invisible to the naked eye. Moreover, it also has the ability to defeat the effect of camouflage, i.e., it can tell whether certain

Figure 4. An airplane equipped with a CCD camera doing inclination photography

plants are newly planted or have been there for a while. Hence, the polychromatic CCD camera has gained great popularity in military applications as well as in studies of the natural resources on Earth.

In summary, the birth of the CCD camera has revolutionized the technology of photography. With the continuous progress in science and technology, one can expect the CCD cameras to undergo many changes and modifications in the future.