Blooming Suppression in Charge Coupled Area Imaging Devices

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An intense spot of light projected onto the photo-sensitive surface of an imaging device can cause this device to saturate locally. Excess carriers generated by the light source can diffuse into the neighboring area which may also be driven into saturation. In the display the light source will then appear as a white area that can be considerably larger than its image in the true geometrical proportions. This effect, known as blooming, is present in most TV camera tubes, and demands special care by the operator to avoid bright objects in the scene being imaged. For the *Picturephone*® camera, which often has to operate in less than ideal conditions, the design of a camera with limited blooming is thus more than desirable.

The camera tube presently used in the *Picturephone* station set has a silicon diode array target scanned by an electron beam. Blooming is produced by the diffusion of carriers in the bulk silicon, leading to a circular spreading of the saturated area. In solid-state imaging devices, blooming can take on even more objectionable forms. The complicated potential distribution at the silicon surface can cause excess carriers to move along a preferred axis, generating quite irregular blooming patterns in the display.

In a recently demonstrated 128 × 106-element charge coupled array[1] the excess charge spills preferentially in the vertical direction. In this n-channel frame transfer[2] device the isolation between adjacent CCD channels is achieved by a p-type channel stopping diffusion which keeps the potential at the Si-SiO_2 interface close to zero. Due to the negative flatband voltage of this particular MIS-system, the potential underneath a grounded transfer electrode, separating two adjacent potential wells in the vertical direction, is a few volts positive, and this barrier is thus distinctly lower than the one produced by the channel stopping diffusion. No negative voltage can be applied to the transfer electrodes because they are connected to diffused crossunders or to protection diodes. In this device, blooming appears in a very objectionable form. Bright light spots bloom out into a vertical line that quickly extends the length of the picture and then, with increasing light intensity, starts to widen.

The basic idea behind blooming protection consists in providing an overflow drain for excess carriers. This drain can consist of a reverse biased diffused junction of the same polarity as the output diode. In area imaging devices with frame transfer organization these overflow channels can be placed between the vertical transfer channels and interconnected and accessed at the top of the device (see Fig. 1).

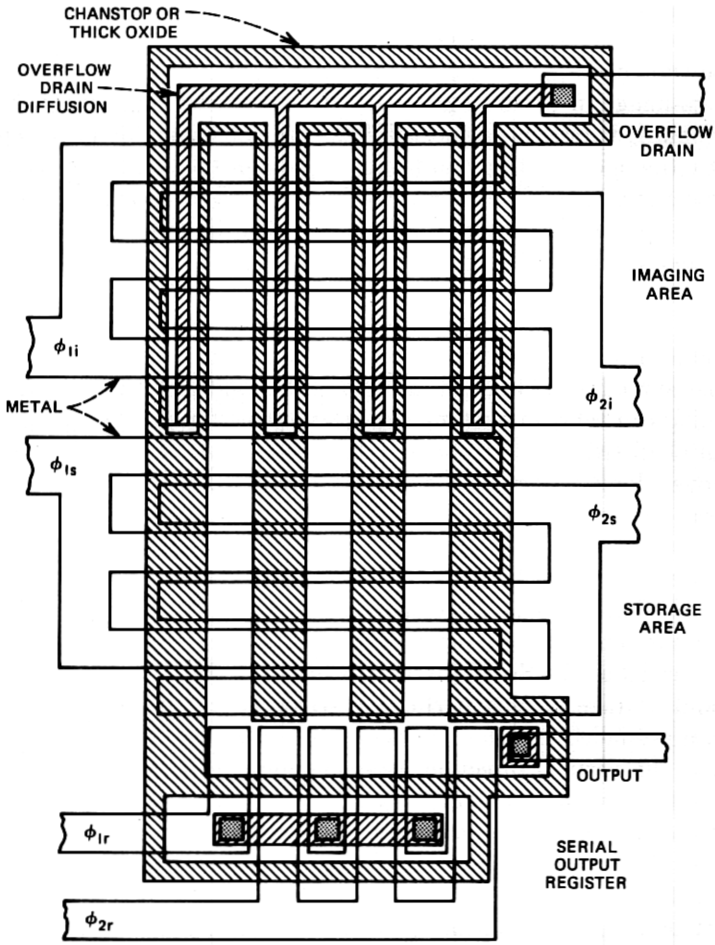

Fig. 1—Geometrical arrangement of the overflow channels in a charge transfer imaging device of frame transfer organization.

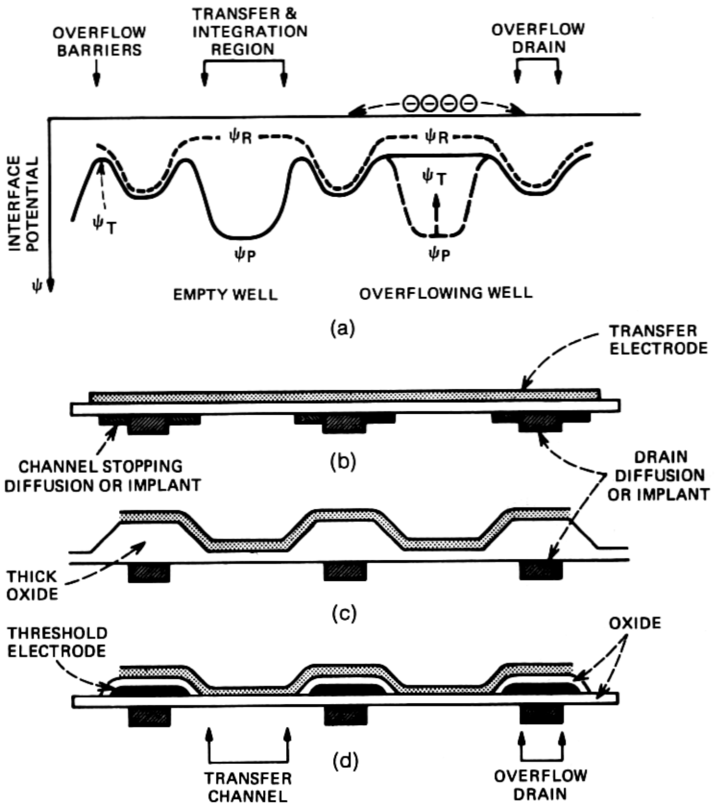

Fig. 2—Cross section through imaging area of a frame transfer image sensor. (a) Desired potential profile at Si-SiO_2 interface, underneath isolating electrodes (- - -) and underneath integrating electrodes (——). (b, c, d) Realization using a channel stopping diffusion or implant (b), using a thick-thin oxide structure (c), or a special threshold electrode (d).

Excess carriers can reach the overflow drain by passing over a potential barrier (Fig. 2a). This overflow threshold is established either by a light channel stopping diffusion or implant (Fig. 2b), by a thick oxide region (Fig. 2c), or by a special threshold electrode (Fig. 2d).

The centers of charge collection are the deep potential wells underneath the electrodes biased at V_P, generating an initial interface potential ψ_P (Fig. 2a). The resolution elements are isolated in the vertical direction by electrodes kept at V_R, producing interface potential ψ_R. This potential barrier has to be higher than the overflow threshold ψ_T. The potential well is filled when its interface potential has reached ψ_T and additional carriers will then escape laterally into the overflow drain. Ideally, an overflowing cell should thus not affect its neighbors.

The overflow drain will directly collect a certain percentage of all generated carriers, thereby reducing the light sensitivity of the device. To a certain extent, the sensitivity can even be modulated by changing the potential in the overflow channel.[3] On the other hand, the horizontal resolution might be somewhat improved since the overflow drain reduces the overlap of the sensitivity functions of adjacent resolution elements.

It is not anticipated that the introduction of a large area of p-n junction will lead to a problem with increased dark current. Excess current generated in the junction area should not influence the operation of the device but be swept away through the overflow drain.

A preliminary experiment performed on the described 128 × 106-element area CCD showed that the migration of excess carriers can be controlled. One of the protection diodes in the imaging section has been burnt out so that one of the sets of electrodes can be biased negatively. This drives the Si-SiO_2 interface underneath into accumulation and generates a potential barrier equal in height to the barrier produced by the channel stopping diffusion. As expected, when a negative potential of a few volts was applied to the unprotected electrode set, blooming in the display changed from a vertical line into a circle of about 200 μm radius, corresponding to the diffusion length of the minority carriers.

The described protection scheme could also be applied to an electron-beam-scanned target if in biasing the overflow drain special care is taken not to increase the target-to-ground capacitance, which reduces the signal-to-noise ratio. In a charge transfer device the substrate is normally grounded and the additional capacitance is of no concern.

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