B－2－5 Solid-State Color Image Sensor using Hydrogenated Amorphous Silicon

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In conventional solid-state imagers such as MOS and CCD, their photo-diodes and charge transfer circuits are integrated on the same plane of a silicon surface, so that their effective photo sensitive areas are reduced to as little as 30% or so. This makes their sensitivity less than those of pickup tubes. Moreover, charges overflown from highly illuminated photo-diodes cause blooming of strongly lit images. To solve these problems, we have developed a new type of solid-state image sensor [1]. This sensor used a photoconductive thin film of Se-As-Te chalcogenide deposited on a solid-state scanner. In this structure, almost all of the sensor surface can be used as the photosensitive area, and blooming can be easily suppressed without the need for an n-p-n vertical structure or overflow drain. Although the performance of this device was confirmed, there were some problems to be overcome before this material could be applied to color video cameras. First, it needed a supply voltage as high as +50 V to induce a photo current in the thin film. Second, the film could not survive the on-wafer color filter process after film deposition, in which the chip was exposed to a temperature of 200°C. We examined other material and found that hydrogenated amorphous silicon (a-Si:H) satisfied our needs. This paper reports the first successful fabrication of a sensor using a-Si:H as the photoconductive thin film.

The cross sectional view of a sensor unit cell is shown in Fig. 1. The cell size is 23 μm(H) x 13.5 μm(V). The Al electrode corresponding to this cell is 20.5 μm (H) x 11 μm(V). Thus, an effective aperture of 73% has been achieved. There are also some improvements in the layout of the scanner circuit. The Al electrodes and Al readout lines are arranged properly to prevent light leakage into the scanner circuit. To make the surface of the scanner circuit smoother, through-holes of the first and second isolation layer were offset and a glass-flow process was introduced in the through-hole fabrication. Except for these points, the MOS scanning circuits were fabricated by the conventional LSI process (3 μm n-MOS technology). The a-Si layer of 5 μm was deposited on the scanner circuit by RF sputtering. Nitrogen was doped during deposition to improve electron mobility and lower the supply voltage of the film. ITO (Indium-Tin-Oxide) was then sputtered to form the transparent electrode on top of the a-Si film. Half-transparent electrode of Au has also been used. We made a single chip color image sensor by putting an RGB color filter array on the chip.

The spectral response is shown in Fig. 2. The supply voltage at which the photo current saturates are about -11 V for ITO and -9 V for Au. These values are much lower than 50 V for Se-As-Te chalcogenide thin film. At saturation, the quantum efficiency of the device using ITO is nearly equal to 1 throughout the visual spectral region. We made a-Si film of various thickness and confirmed that this saturation depends only on the electric field in the thin film. In the device fabrication, 5 μm-thick a-Si was used to cover the unevenness of 1.0 to 2.0 μm on the surface of Si scanning circuit. A saturation voltage of -7 V has been obtained for 3 μm-thick a-Si cell with ITO electrode, deposited on a flat surface of glass. A highlight image reproduced by this device is shown in Fig. 3. The highlight exposure of the halogen lamp is 250 times as intense as the saturation exposure, and yet blooming suppression is well achieved. The back scene illumination is 200 lx (F2). In this device, blooming can be automaticaly suppressed,since the voltage across the thin film drops to zero on highlight illumination, thus preventing charge separation or current flow. Although the lag of this device with Au electrode was 3% at third field, better lag characteristics are expected from the cell measurements. Little burning was observed in this device.

In summary, we have successfully fabricated a single-chip color image sensor using a-Si :H thin film as a photoconductor. This device features high sensitivity, little blooming, low lag and little burning.

Reference

1) T. Tsukada et al.,Tech. Digest of IEDM, 6-1 (Dec. 1979).

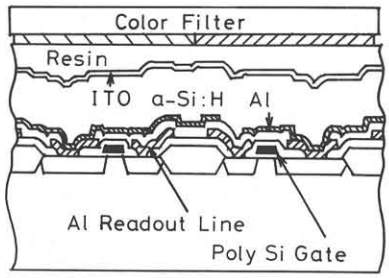

Fig. 1 Schematic cross section of a sensor unit cell.

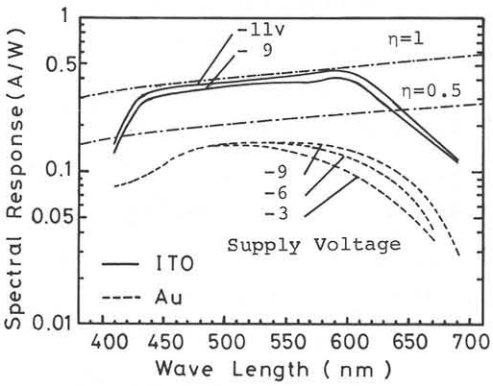

Fig. 2 Spectral response of a solid-state image sensor using a-Si:H.

Fig. 3 Highlight image reproduced by a single-chip color image sensor.