TECHNOLOGY OF CCD-IMAGERS WITH TRANSPARENT CONDUCTIVE ITO ELECTRODES.

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One of the alternatives to increase the quantumefficiency of solid-state imagers in general and to increase the response to blue light of CCD-imagers in particular is the use of Indium-Tin-Oxide (ITO) transparent conductive electrodes. However several problems arise when implementing ITO in the conventional CCD-process. This paper will point out some of these difficulties and will show how to overcome them. A reliable CCD-process with ITO sensor electrodes will be described.

A two step deposition technique is used : reactive sputtering in a 100% oxygen atmosphere with a RF-diode system results in a transparent high-resistivity ITO-film. An appropriate anneal is then needed to increase the conductivity of this layer. From a comparative study of different inert atmospheres and temperatures, a 30 min. treatment at 485°C is forming gas (90% N_2 + 10% H_2) gives the best results. For a film of 400 nm thickness, a sheet-resistance of 6 $\Omega/\square$ is obtained, combined with a light transmission of 97% (reflections excluded) over the whole visible range.
The workfunction difference between the ITO-film and a p-type silicon substrate ($N_A = 6 \times 10^{14}$ cm^{-3}) has been measured to be 0.63 V. Examination of the absorption coëfficient in the UV spectrum results in a forbidden energy gap of 3.9 eV for the ITO semiconductor.

One of the main problems in the ITO-technology is the need for a reliable ohmic contact. Different contacting materials are studied : Al, Poly-Si, Pd-Al, Ti-Al. In the paper attention will be paid to the contact resistivity (non linear for Al and Poly-Si), the reliability of the contacts (Pd-Al non reliable, Ti-Al reliable) and the technology (lift-off for the double layer Pd-Al and Ti-Al).

Etching of ITO is done by conventional photolithography and with commercially available etchants. Linewidths, down to 4μm, can be achieved with a great reproducibility.

Poor step-coverage and sputter damage are two problems which can be introduced by the nature of the deposition method. It will be shown that with a proper lay-out of the imager the step-coverage problem can easily be solved. A N_2-anneal at 800°C is found to reduce sufficiently the sputter damage. In the near future magnetron sputtering will be used to eliminate this difficulty.

The implementation of the ITO-film in the CCD process has to come after all high temperature steps, because these would make the ITO-film opaque. This means that after the glass reflow step a new gate oxide has to be grown in the sensor areas just before the ITO-deposition. The interface properties of this oxide layer strongly depend on the ITO-fabrication method.

A CCD line array with 256 pixels and transparent conductive electrodes has been fabricated. Figure 1 shows the quantum-efficiency of the imager versus wavelength of the incident light. As a reference, the quantum-yield of a similar CCD with a poly-Si photo-gate is also given.
The electrical and optical characteristics of these devices will be discussed in more detail.

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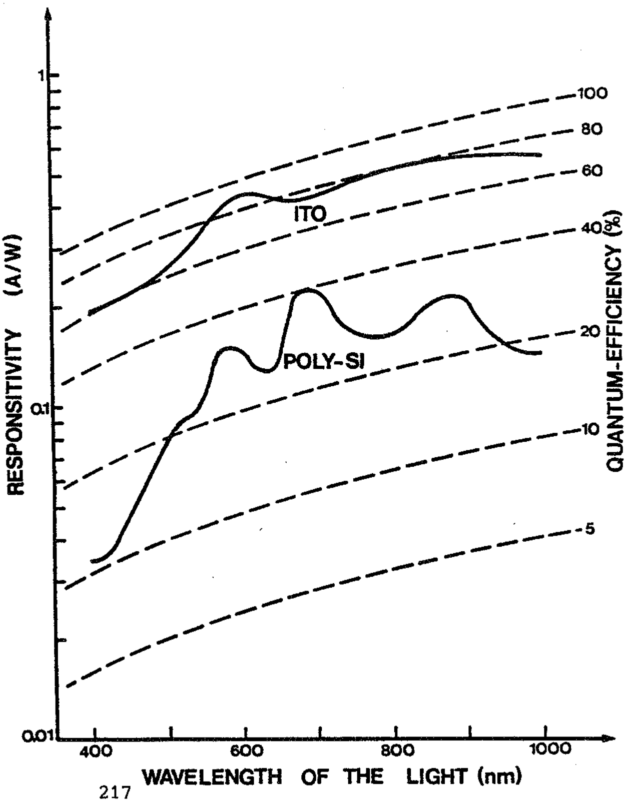

Figure 1. The quantum-efficiency and responsitivity versus wavelength of the incident light.
Comparison is made between a CCD with an ITO photo-gate and a CCD with a poly-Si photo-gate.