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Study of Photoconductive Indium Antimonide

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STUDY OF PHOTOCONDUCTIVE INDIUM ANTIMONIDE
1982 January 1 to 1982 June 30

The University of Arizona
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The intent of this study was to investigate the suitability of currently available indium antimonide for use as an intrinsic photoconductor. Early work, reviewed by Kruse (1969), showed that indium antimonide could be used successfully as a photoconductive detector under high background conditions. If material of sufficiently high purity is available, the photoconductive mode offers some potential advantages over the more common photovoltaic detectors. First, the photoconductive detectors are likely to be more rugged electrically than photodiodes, which rely on the properties of a very thin depletion layer. In particular, InSb photodiodes are subject to destruction from electrostatic discharge. Second, there are applications in astronomy where relatively high speed response is useful. With the usual transimpedance amplifier, the useful high frequency response is set by the detector capacitance, feedback resistor, and amplifier noise. Since the junction capacitance of a photovoltaic indium antimonide detector can be 20 pF or greater, the frequency response can be limited to below 10 Hz under very low background conditions (Rieke et al. 1981). Since a photoconductor does not have a thin depletion layer, devices can be made that have much less than 1 pF capacitance.

For this study, several slices of electronic grade n-type single crystal indium antimonide were obtained from Cominco American. The material has a resistivity of 9.5 to 11. E-2 ohm-cm, a Hall mobility of 6.4 to 7.0 E5 cm-2 v-1 s-1, and a net carrier concentration of 9.0 to 9.3 E13 cm-3 at a temperature of

77 K. The slices were cut in the (111) plane to an initial thickness of 0.5 mm.

A requirement for photoconductive detectors is good quality ohmic contacts. Generally, a highly doped layer between the bulk semiconductor and the metalization will provide such a contact. For n-type indium antimonide, Sn has been successfully used as a donor-type dopant (Sze and Wei 1961). For most of the studies under this grant, Sn and Au contacts were vacuum evaporated on samples of the material. These samples were subsequently annealed at 250 C for 1 hour in a nitrogen atmosphere. Leads were usually indium soldered in place, although conductive epoxy was also used.

The initial tests were to measure the resistance of 0.5 mm thick samples as a function of temperature. No significant variations were observed between room temperature and 4.2K. It is now believed that the bulk resistance of these thick samples was significantly lower, and that the measured resistance was dominated by contact resistance.

In order to increase the contribution from the bulk resistance, tests were run on chemically thinned samples. A number of different etches were investigated with the best results coming from a 3% solution by weight of iodine in methanol. The 0.5 mm thick samples were mounted on sapphire substrates with Armstrong A-12 epoxy. Initial thinning was done with a CP-4a etch to about a 100 um thickness, with the final etching to less than 50 um thickness done with the iodine etch.

For a typical sample, the resistance varied from 840 Ohms at room temperature, to 40 kOhms at 77K, to 7 MOhms at 4.2K. Additional runs at temperatures to 2 K showed no significant improvement in the resistance. The relatively low dark resistance of the material at the liquid helium temperatures indicates the presence of impurity levels of very shallow energies. These free carriers are likely to prevent the successful operation of photoconductive detectors made from this material at low backgrounds.

Tests of the photoconductive response of the material were done in one of our standard test dewars (Young and Low 1979) with the bandpass limited to 1.7 to 3.0 um. As expected, the test detectors showed only very poor photoconductivity at the test background levels.

Although the available material may be usable for high background application where the photon generated carrier density is much greater than the impurity carrier density, it is unsuitable as an intrinsic photoconductor for the low background conditions of interest. Significant improvements in material purity are needed before useful devices are possible.

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