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[54] **ELECTRO-OPTICAL DETECTOR ARRAY**

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[73] Assignee: **Cincinnati Electronics Corporation**, Mason, Ohio

[21] Appl. No.: **609,678**

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[51] **Int. Cl.**[5] **H01L 27/14**; H01L 31/00

[52] **U.S. Cl.** **257/441**; 257/443; 257/459; 257/460

[58] **Field of Search** .... 357/30 B, 30 H, 30 P, 357/32, 16, 45, 61; 250/208.1, 211 J

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,483,096	12/1969	Gri et al.	204/15
3,555,818	1/1971	Lambert et al.	148/186
3,577,175	5/1971	Gri et al.	317/237
3,808,435	4/1974	Bate et al.	250/332
4,053,919	10/1977	Andrews, II et al.	357/30 B
4,364,077	12/1982	Chiang	357/30 P
4,646,120	2/1987	Hacskaylo et al.	357/32 X
4,783,594	11/1988	Schulte et al.	250/370.08
4,956,687	9/1990	de Bruin et al.	357/30 H
4,975,567	12/1990	Bishop et al.	357/4

FOREIGN PATENT DOCUMENTS

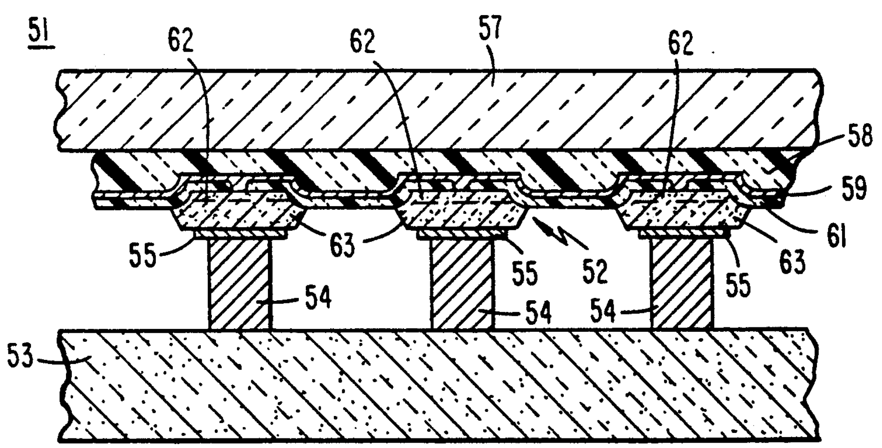
0116791	8/1984	European Pat. Off. .
0350351	1/1990	European Pat. Off. .
57-73984	5/1982	Japan .
58-164261	9/1983	Japan .
WO87/07083	11/1987	PCT Int'l Appl. .

Primary Examiner—Andrew J. James
Assistant Examiner—Sara W. Crane
Attorney, Agent, or Firm—Lowe, Price, LeBlanc & Becker

[57] **ABSTRACT**

Each diode of an indium antimonide electro-optical detector array on a dielectric backing transparent to optical energy to be detected includes a junction that less than about a half micron from the diode surface on which the energy is initially incident. The optical energy is incident on a P-type doped region prior to being incident on a bulk N-type doped region. Both P- and N-type doped regions of adjacent diodes are spaced from each other. Metal electrically connects the P-type doped regions together without interfering substantially with the incident optical energy. A multiplexer integrated circuit substrate extends parallel to the backing and includes an array of elements for selective readout of the electric property of the diodes. The elements and diodes have approximately the same topographical arrangement so that corresponding ones of the elements and diodes are aligned. An array of indium columns or bumps connects the corresponding aligned elements and diodes.

38 Claims, 3 Drawing Sheets



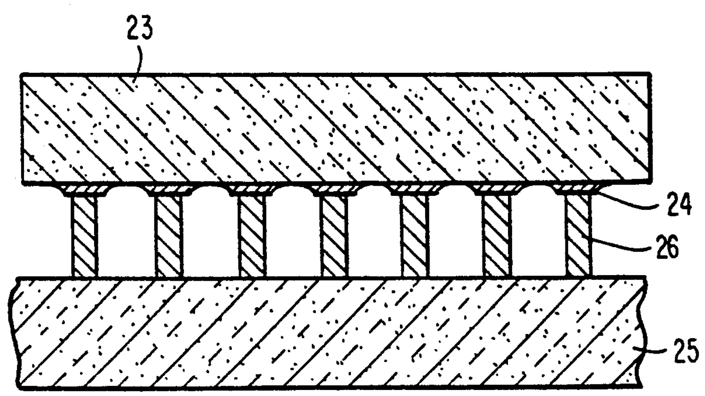


Fig. 1
(PRIOR ART)

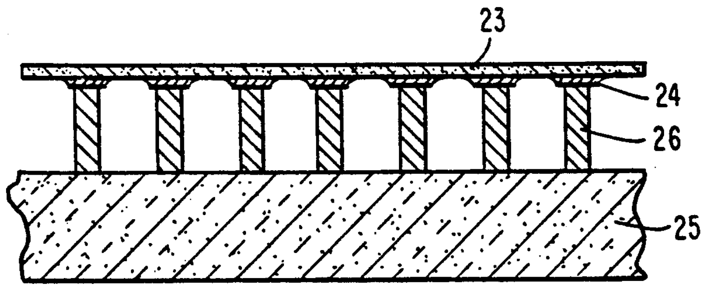


Fig. 2
(PRIOR ART)

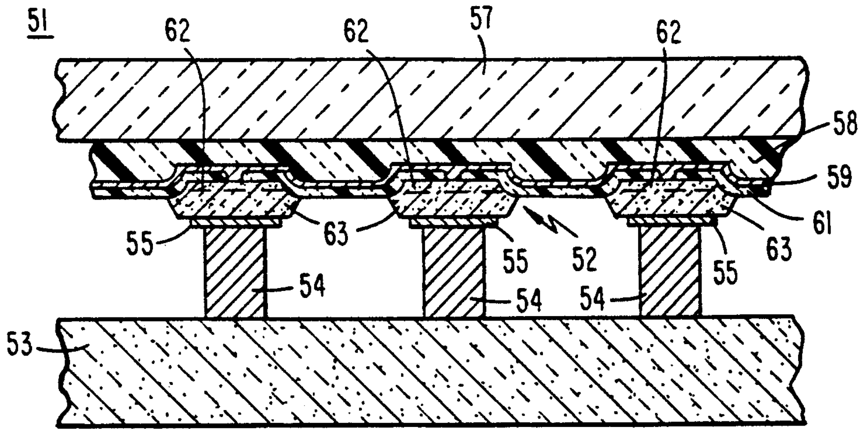


Fig. 3

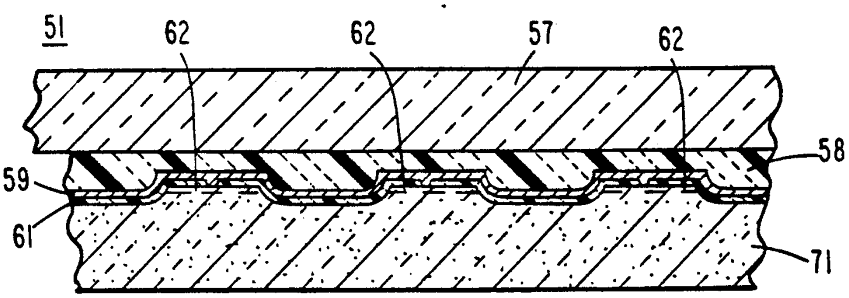


Fig. 4

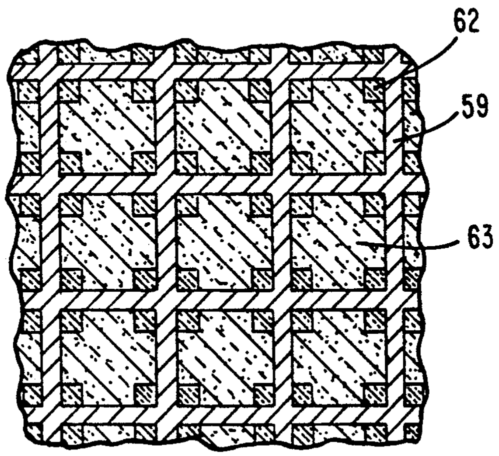


Fig. 5

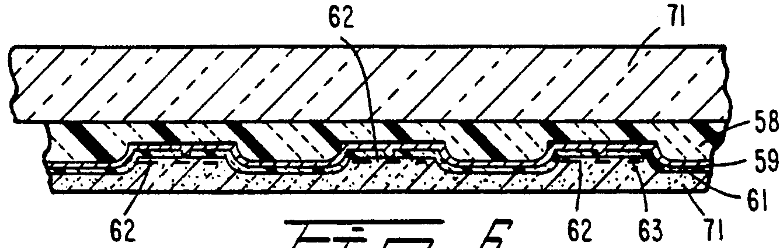


Fig. 6

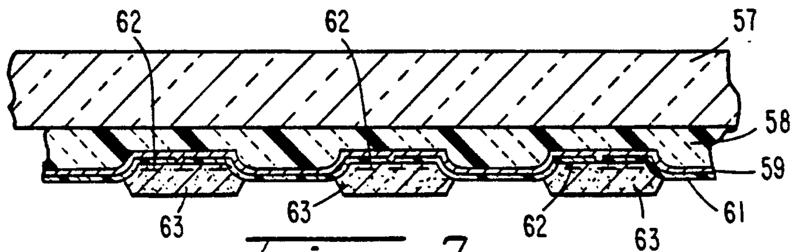


Fig. 7

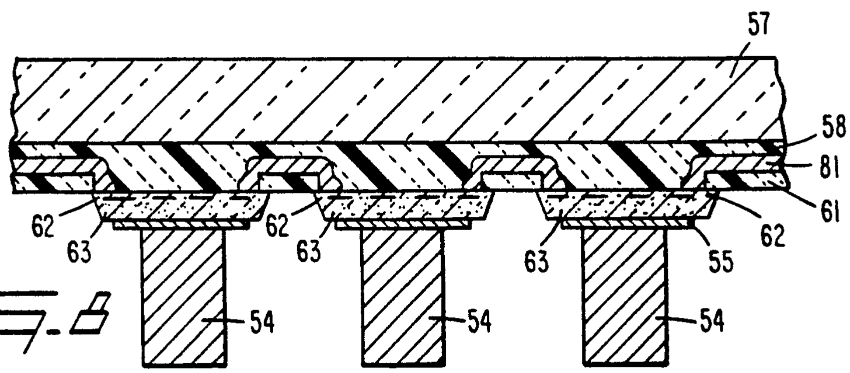


Fig. 8

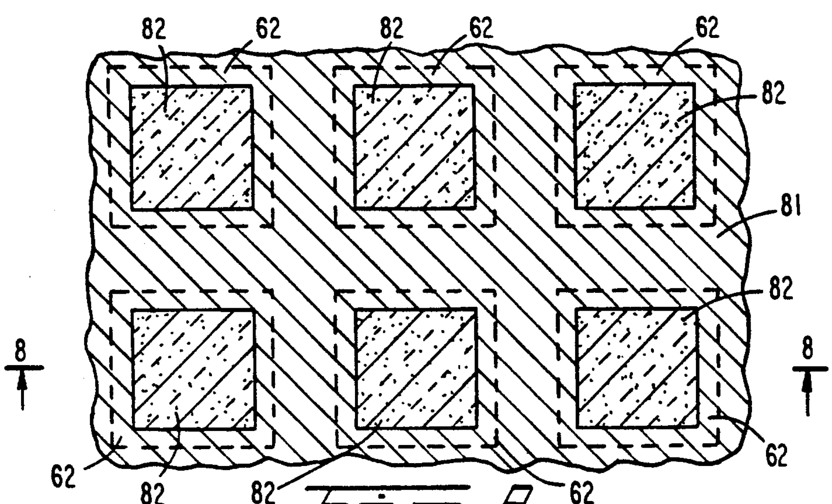


Fig. 9

ELECTRO-OPTICAL DETECTOR ARRAY

FIELD OF THE INVENTION

The present invention relates generally to electro-optical detector arrays and more particularly to an electro-optical detector array having front faces of semiconductor elements illuminated by the optical energy, and to a method of making same. The invention is also related to an electro-optical detector array including multiple semiconductor elements that are spaced from each other on a dielectric backing, and to a method of making same.

BACKGROUND ART

Semiconductor electro-optical detectors are either of the photovoltaic or photoresistive type. Different types of electro-optical detectors are employed for different wavelength regions from infrared through ultraviolet. For example, photovoltaic electro-optical detectors for the infrared wavelength range from approximately 8 to 12 microns and 1 to 5.6 microns are frequently made of mercury cadmium telluride (HgCdTe) and indium antimonide (InSb), respectively. The specific construction of indium antimonide electro-optical detectors is described, for example, in commonly assigned U.S. Pat. Nos. 3,483,096, 3,554,818 and 3,577,175. While the following description is made for InSb electro-optical detectors, the invention in many of its broadest aspects is not limited to this material.

Single element devices, as disclosed in the aforementioned patents, typically include a P-N junction wherein an N-doped bulk substrate carries a P-doped region that is exposed to an optical energy source being detected Usually, the P-N junction is no greater than about 4 microns from the surface of a P-type region on which the optical energy to be detected is incident. In other words, the P-type region exposed to the optical radiation to be detected has a thickness of no greater than about 4 microns For. certain InSb devices, the P-N junction is closer than 0.5 microns to the surface of the P-type region exposed to the radiation. The P-type region is desirably positioned so that the optical radiation is directly incident thereon to enable photogenerated charge carriers formed in the P-type region to diffuse, somewhat uninterrupted, to the junction. Even in this configuration, a significant amount of optical energy penetrates through the P-type region into the P-N junction where some additional charge carriers are generated and on into the N-type region where still more charge carriers are generated. As long as this absorption in the n-type material does not occur too far away from the junction, the resulting charge carriers also diffuse back to the junction. In addition, this arrangement enables optical energy that is not absorbed in the P-type region to reach the P-N junction directly. Thereby, efficiency in converting optical energy to electric energy is relatively high if the P-doped region of an indium antimonide detector is arranged such that the optical energy is incident on the P-type region.

While these characteristics have long been known, to our knowledge, they have not been achieved when relatively large InSb electro-optical semiconductor detector arrays have been manufactured. In the large InSb array prior art of which we are aware, it has been the practice to illuminate the relatively thick N-type doped bulk substrate semiconductor material, i.e., the "back" face of the array has been illuminated. The thickness of the illuminated N-type doped bulk substrate is typically 10 microns which increases the probability that photogenerated charge carriers will interact with crystal defects or other charge carriers in the N-type bulk substrate. This is particularly true of the shortest wavelength energy to which the optical detector is exposed because the shortest wavelength energy is absorbed closest to the back face, and the resulting photogenerated charge carriers must travel the greatest distance to the P-N junction. In addition, very little, if any, of the optical energy in the 1–4 micron region can propagate unimpeded to the P-N junction through the bulk material.

The construction and manufacturing method of a typical prior art indium antimonide, photovoltaic detector array are illustrated in FIGS. **1** and **2**. In this and other prior art arrangements, the optical energy to be detected is first incident on the relatively thick (about 10–20 microns) N-type bulk substrate. Hence, the distance between the P-N junction and the surface on which the optical radiation to be detected is first incident is approximately 10–20 microns. For the shortest wavelengths in the 1–5.6 micron band to be detected, i.e., between 1 and 3 microns, there is a relatively low quantum efficiency because photogenerated charge carriers created in the N-type bulk substrate in response to the incident optical energy do not proceed in an unimpeded manner to the N-type bulk substrate. Instead, the free charge carriers resulting from absorption of optical energy photons frequently interact with the InSb crystal lattice and crystal defects prior to reaching the P-N junction, causing the carriers to lose energy and recombine with other carriers of the opposite type and therefore go undetected In addition, very little of the shortest wavelength energy is able to reach the junction without being absorbed in the N-type material and create photogenerated carriers therein.

In the prior art arrangement illustrated in FIGS. **1** and **2**, an indium antimonide N-type bulk substrate **23**, having a thickness of approximately 15 mils with an array of P-type regions **24** formed thereon, is connected to multiplexer substrate **25** by indium columns **26**, which can be grown on metal contact pads (not shown), typically of gold, nickel or chromium for the P-type regions or on the multiplexer substrate or on a combination of both. A P-N junction, forming a diode, exists at each location of P-type region **24** on N-type bulk substrate **23**. After the detector assembly including N-type bulk substrate **23** and an array of P-type regions **24**, formed by gaseous diffusion or ionic bombardment, has been connected to multiplexer substrate **25**, the bulk material substrate is mechanically and/or chemically thinned and polished to a thickness of approximately 10 microns, as illustrated in FIG. **2**. Multiplexer substrate **25** includes electronic circuitry having switching elements with substantially the same topography as the topography of P-type regions **24**. The electronic circuitry in multiplexer substrate **25** selectively reads out the signal from a selected diode of the electro-optical detector array through the indium bump to one or a few common signal leads on the multiplexer chip. This causes readout of the optical energy incident on a surface of N-type bulk substrate **23** corresponding generally with the P-type region **24** connected to the indium column or bump **26** which is selected by the circuitry on multiplexer N-type bulk substrate **25**.

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