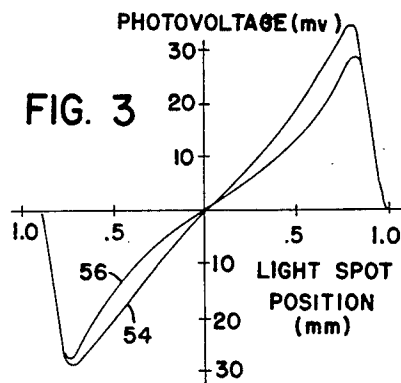
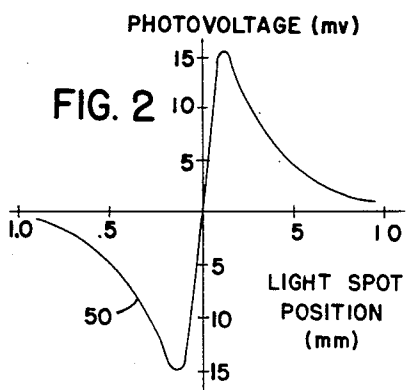
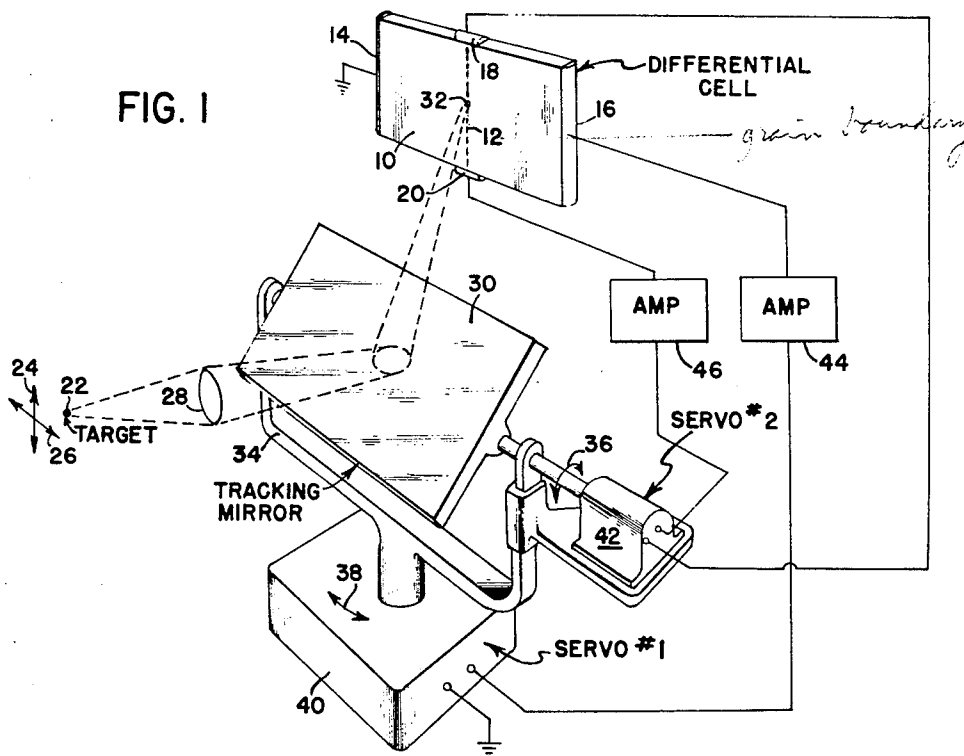


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SEMICONDUCTIVE DIFFERENTIAL PHOTODETECTOR
FOR TWO DIMENSIONAL DISCRIMINATION
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SEMICONDUCTIVE DIFFERENTIAL PHOTODE-
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This invention relates generally to photoelectric systems and pertains more particularly to a system of this character in which a semiconductive member containing a grain boundary is used in the two dimensional discrimination of a moving light spot.

The utilization of semiconductive material having a grain boundary for one dimensional discrimination is not new, as it is well known that the transversal photovoltage changes as a light spot crosses the grain boundary. See, for instance, the article written by G. L. Pearson appearing in the Physical Review, vol. 76, page 459 (1949) and U.S. Patent 2,740,901, issued to Robert E. Graham on April 3, 1956. However, the usefulness of semiconductive devices for discrimination, and more specifically tracking of a light spot, in only one dimension is somewhat limited, as one can readily understand.

Accordingly, one object of the present invention is to provide a grain boundary photovoltaic cell capable of discrimination in two dimensions. More specifically, it is an aim of the instant invention to employ the more basic ohmic contact scheme heretofore used at either end of a semiconductive member or cell having a grain boundary, but to supplement these end contacts with additional contacts applied at the grain boundary itself, whereby the movement of a light spot may be accurately tracked or followed, even though it moves in two directions.

Through the envisaged multiple contact arrangement it is possible to make use of a lateral photovoltaic effect in addition to the previously realized transversal photovoltaic effect. The combined photovoltaic manifestations so achieved provide accurate indications or signals of the digressions or deviations of the light spot from intersecting reference lines. This is because any shifting of such a light spot in a direction away from either of two reference lines will cause a change in the polarity of the voltage, depending on the direction of spot movement, and in voltage magnitude, depending on the degree of displacement. In this way, the light spot can be tracked as it travels in any two coordinate directions.

Other objects will be in part obvious, and in part pointed out more in detail hereinafter.

The invention accordingly consists in the feature of construction, combination of elements and arrangement of parts which will be exemplified in the construction hereafter set forth in the scope of the application which will be indicated in the appended claims.

In the drawing:

FIG. 1 is a schematic view in perspective of a photoelectric tracking system embodying the teachings of the present invention;

FIG. 2 constitutes a curve depicting the transversal photovoltaic response as a function of light spot position for a given light intensity and spot diameter, and

FIG. 3 presents a pair of curves graphically illustrating the respective lateral photovoltaic responses for two different light spot positions but with equal light intensities and spot diameters.

Referring now in detail to FIG. 1, a semiconductive cell denoted generally by the reference numeral 10 is schematically pictured. While other semiconductive materials, such as silicon, and the III-V compounds, may be employed, it will be assumed for the sake of discussion that the cell 10 is a small slab of n-type germanium of rec-

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tangular cross section. Since the cell 10 has been greatly enlarged in FIG. 1 with respect to the rest of the apparatus, it might be well to explain that exemplarily dimensions for the cell 10 are as follows: length, 6.0 millimeters; width, 2.0 millimeters; and height, 0.5 millimeter. Of course, these dimensions are in no way restrictive as a wide choice of sizes is possible. The cell 10 has a grain boundary at 12 extending perpendicularly to its main axis which renders the cell differential in character, as will be more fully understood as the description progresses. A pair of ohmic contacts 14, 16 are applied at the end of the cell and a pair of indium contacts 18, 20 are alloyed on opposite sides of the grain boundary 12.

To illustrate a practical application of the invention for tracking purposes, it will be assumed that the movable target is in the form of a small light source 22. As denoted by the arrows 24, 26 the target source or spot 22 may move in opposite directions in either of two dimensions.

The target spot 22 may originate from a number of different sources. For instance, it may be a star, a light mounted on an airborne vehicle, a source of illumination carried on a movable machine tool, and so on.

Light from the target spot 22 is directed through a fixedly located focusing lens 28 onto a tracking mirror 30. From the mirror 30 the light is reflected onto the differential cell 10 in the form of a minute, concentrated spot 32. More will be said presently concerning the role played by this spot.

Since the purpose of the mirror 30 is to actually track or follow the movement of the source 22, the mirror must be mounted in a way that it can be moved into various angular positions. To do this the mirror 30, in the illustrative instance, has been mounted for tilting movement about a horizontal axis provided by an upstanding gimbal 34, the gimbal in turn being rotatable about a vertical axis. The tilting or rotating movement of the mirror 30 about a horizontal axis has been indicated by the arrow 36, whereas the rotation about the vertical axis has been denoted by the arrow 38.

The rotation of the mirror 30 about a vertical axis is effected by a first servomechanism 40 at the base of the gimbal 34, and the vertical rotation is accomplished by a servomechanism 42, mounted on the gimbal so as to be movable therewith. The servomechanisms 40, 42 are of conventional construction and need not be described in detail other than to say that each is responsive to voltage polarity and preferably to magnitude, too. Inasmuch as we will be dealing with relatively small potential signals, an amplifier 44 is connected in circuit with the servo 40, and an amplifier 46 is similarly connected in circuit with the servo 42. One side of the amplifier 44 is connected to the contact 16 and by grounding the contact 14 and the servo 40 any photovoltaic signal developed between the contacts 14, 16 is impressed on the servo 40 via the amplifier 44. By the same token, one side of the amplifier 46 is connected to the contact 20, and by connecting the contact 18 and servo 42 any photovoltaic signal developed between the contacts 18, 20 is applied to the servo 42 by way of the amplifier 46.

To provide a better understanding of the invention, FIG. 2 has been presented and shows a typical response curve, designated by the numeral 50, involving the photovoltage as a function of the position of the light spot 32. As a matter of interest, it can be pointed out that the particular cell 10 from which the curve shown in FIG. 2 has been derived contains a 25° tilt boundary. In FIG. 2 the photovoltage has been plotted in millivolts against light spot position in millimeters. Consequently it is evident that as the light spot 32 crosses the grain boundary 12 there is a sudden reversal in polarity.

It has already been pointed out that there is a sudden

reversal in polarity in voltage as the light spot crosses the grain boundary 12 of the cell 10. More specifically, it can be said that the extremes in the response curve 50 occur when the perimeter of the light spot 32 is adjacent to the boundary.

In any event, use is made of the reversal in polarity of the transversal photovoltage to control the direction in which the servo 40 acts. If no voltage is developed, then the spot 32 is on the grain boundary 12, and no correction of the mirror 30 is needed. On the other hand, if the spot 32 has been shifted to, say, the right, a positive voltage signal is generated that calls for a rotation of the gimbal 34 in a counter-clockwise direction when viewing the arrow 38. Such a rotation will re-orient or reposition the mirror 30 so that the spot 32 is returned to a null position straddling the grain boundary 12. If, instead, the spot 32 has been displaced to the left of the grain boundary 12, as viewed in FIG. 1, then an opposite correction takes place, for under these circumstances a negative photovoltage will have been developed.

Coming now to an explanation of the lateral photovoltaic effect attention is now directed to FIG. 3. In FIG. 3, two separate and distinct curves 52 and 54 are presented. The curve 52 was derived from a light spot 32 moving along the grain boundary 12, much as it appears to be doing in FIG. 1. In other words, the light spot which we have labeled 32 would be straddling the grain boundary 12 and would be moving, say, from the indium contact 18 toward the opposite indium contact 20. On the other hand, the curve 54 was derived by moving the light spot 32 parallel to the boundary 12, and, in the present instance, the distance or spacing from the boundary was 0.2 millimeter. Explained somewhat differently the light spot 32 in producing the curve 54 could be considered to be shifted 0.2 millimeter to the right from the position depicted in FIG. 1. After having done so, then the light spot 32 could be considered as moving in the same direction as when it was straddling the grain boundary to produce the curve 52. This response, contrary to the transversal effect represented by curve 50, depends on the separation of the indium contacts 18 and 20 and increases with decreasing separation. The lateral photoeffect is connected with the p-type inversion layer at the boundary 12.

Thus, while a transversal photovoltaic effect is observed when the light spot 32 moves between the ohmic contacts 14 and 16, a lateral of photovoltaic effect is observed when the light spot 32 moves between the indium contacts 18 and 20. In both instances a change in polarity results if the light spot is moved through a pair of intersecting reference lines. In the first instance, that is where the transversal photovoltaic manifestation is involved, the reference line is the grain boundary 12, and with respect to the lateral photovoltaic effect, it is a line of symmetry which is an imaginary line intersecting the grain boundary at right angles and passing through a point midway between the contacts 18, 20. With further respect to the lateral photovoltaic effect, it will be seen that the response for any given deviation from the symmetry line is highest if the light spot straddles the boundary, such a condition being represented by the curve 52. The maximum response for a given distance from the boundary 12 occurs with the light spot 32 close to either indium contact 18 or 20.

Consequently, in the latter instance, when the spot 32 has been shifted to a point, say, above the line of symmetry, a positive photovoltage signal will have been developed that will require that the mirror 30 be tilted in a clockwise direction when viewing arrow 36. The servo 42 does this as it receives an amplified signal calling for its operation in such a direction. The converse is, of course, true when the spot 32 dips below the line of symmetry, for then the polarity reverses, as is evident from the illustrative curves 52, 54, the servo 42 then acting in an opposite direction to raise the spot 32.

From the foregoing information, it can be appreciated that two dimensional discrimination can readily be achieved with a single semiconductive cell 10 containing a grain boundary which has been equipped with additional contacts 18, 20 alloyed thereto at the opposite sides of the cell and at the ends of the grain boundary. Obviously my system and method are not limited to tracking as use thereof can be made for other purposes where two dimensional discrimination is required. In this regard, instead of the servomechanisms 40, 42 suitable voltmeters, cathode ray oscilloscope and the like might be substituted.

As many changes could be made in the above construction and many apparently widely different embodiments of this invention could be made without departing from the scope thereof, it is intended that all matter contained in the above description or shown in the accompanying drawings shall be interpreted as illustrative and not in a limiting sense.

It is also to be understood that the language used in the following claims is intended to cover all of the generic and specific features of the invention herein described and all statements of the scope of the invention which, as a matter of language, might be said to fall therebetween.

What is claimed is:

1. A two dimensional discriminating system of the photoelectric type comprising a semiconductive cell containing a grain boundary, a first pair of contacts at the opposite ends of the cell remote from said grain boundary, a second pair of contacts at the opposite sides of the cell at said grain boundary, means for impinging light onto said cell in the form of a spot from a movable light source, first means in circuit with said first contacts for providing an indication of the transversal photovoltaic effect produced by said light spot, and second means in circuit with said second contacts for providing an indication of the lateral photovoltaic effect, whereby the relative position of said light source may be determined from said photovoltaic effects.

2. A photoelectric system in accordance with claim 1 in which said cell is of germanium, said first contacts form an ohmic connection with said cell, and said second contacts are of indium and are joined to said cell at the terminations of said boundary.

3. A two dimensional discriminating system of the photoelectric type comprising a semiconductive cell containing a grain boundary, a first pair of contacts at the opposite ends of the cell remote from said grain boundary, a second pair of contacts at the opposite sides of the cell at said grain boundary, a movable source of light, means for directing light from said source onto said cell in the form of a spot, first means in circuit with said first contacts for providing a first signal in accordance with the transversal photovoltaic effect produced by said light spot, means responsive to said first signal for returning said light spot to a reference location in one direction on said cell when it has shifted due to movement of said source in one dimension, second means in circuit with said second contacts for providing a second signal in accordance with the lateral photovoltaic effect produced by said light spot, and means responsive to said second signal for returning said light spot to a second reference location in a second direction on said cell when it has shifted due to movement of said source in a second dimension.

4. A photoelectric system in accordance with claim 3 in which the grain boundary constitutes the first reference location and the line of symmetry between said second contacts constitutes the second reference location.

5. A two dimensional discriminating system of the photoelectric type comprising a semiconductive cell containing a grain boundary, a first pair of contacts at the opposite ends of the cell remote from said grain boundary, a second pair of contacts at the opposite sides of the cell at said grain boundary, a movable source of

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light, a mirror for directing light from said source onto said cell in the form of a spot, first motive means for moving said mirror in a direction to return said spot to said grain boundary, second motive means for moving said mirror in a direction to return said spot to a position on the line of symmetry between said second contacts, first means in circuit with said first contacts for energizing said first motive means in accordance with the transversal photovoltaic effect produced by said light spot when shifted away from said grain boundary to effect its return to said boundary, and second means in circuit with said second contacts for energizing said second motive means in accordance with the lateral photovoltaic effect produced by said light spot when shifted away from said line of symmetry to effect its return to said line.

6. A dimensional discriminating photodetector com-

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prising a light sensitive semiconductive cell containing a single grain boundary separating regions of like semiconductive material for generating signals indicative of the location of light on said cell, ohmic contacts connected to said separate regions and remote from said boundary, boundary contacts joining said regions at the terminations of said boundary, means for directing a concentrated light onto said cell from a movable light source, and means connected to said ohmic and boundary contacts and responsive to said signals for orienting said directing means in accordance with said signals.

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