

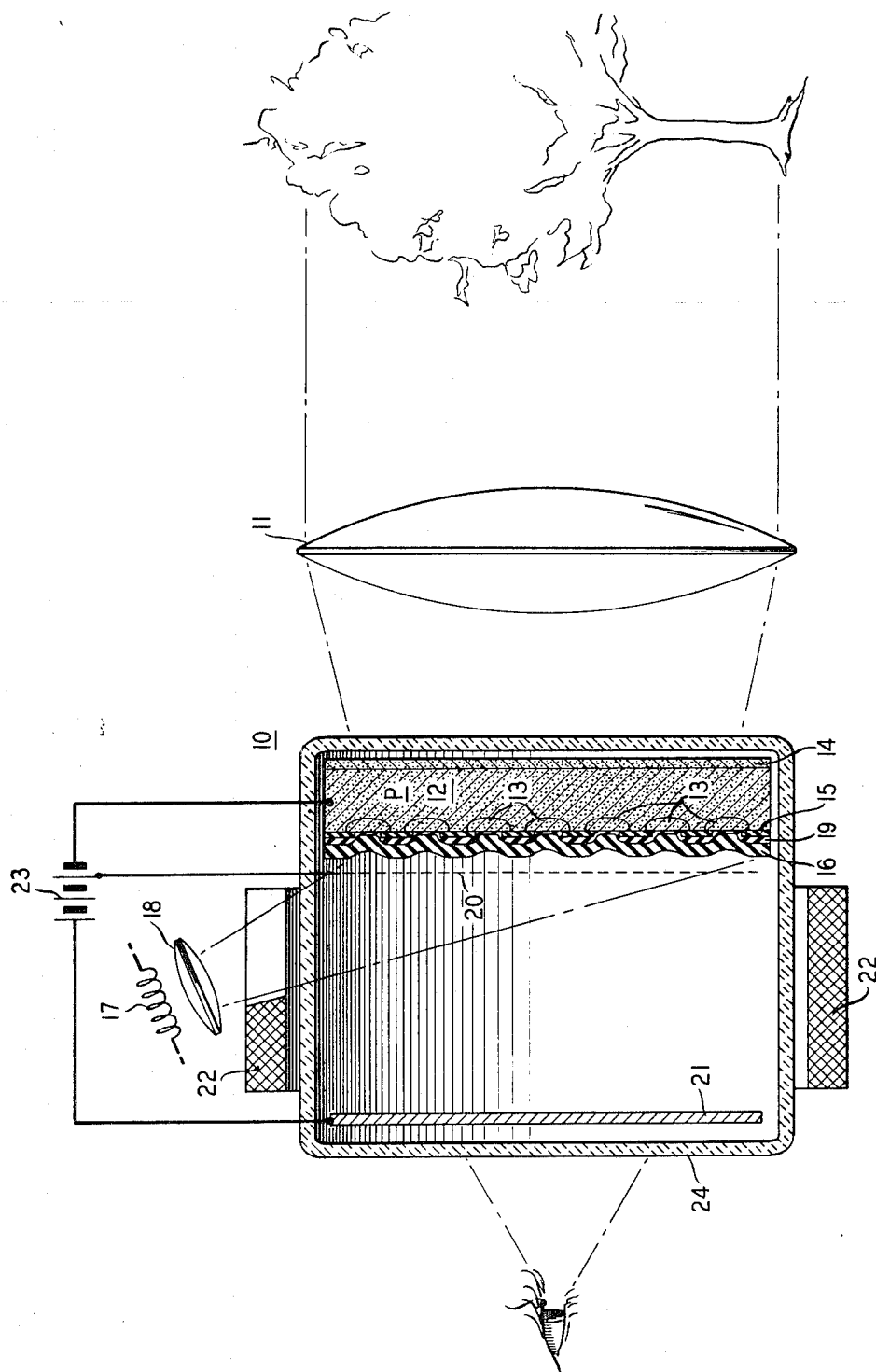
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DIODE-ARRAY PHOTOCATHODE WITH PHOTOEMITTER ACTIVATION

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PHOTOCATHODE WITH PHOTOEMITTER ACTIVATION CONTROLLED BY DIODE ARRAY

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5 Claims 10

ABSTRACT OF THE DISCLOSURE

The specification describes a new type of photocathode comprising a semiconductor diode-array light sensing element in combination with a photoemissive coating. The spatial pattern of electron emission from the photoemitter is controlled by the localized field in the diode array. The local intensity of this field gives a spatial representation of the image incident on the diode array. With a silicon diode array infrared and X-ray response are inherent.

This invention relates to photocathodes and to image intensifiers and image recording devices employing them.

The diode-array image storage tube described and claimed in U.S. Pat. No. 3,403,284 which issued Sept. 24, 1968 to T. M. Buck, M. H. Crowell, and E. I. Gordon, and No. 3,419,746 which issued Dec. 31, 1968 to M. H. Crowell, J. V. Dalton, E. I. Gordon, and E. F. Labuda is now well known in the art. The semiconductor diode-array storage element has proven very effective and versatile.

It has now been found that this element is useful in a new kind of photocathode. The function of the diode-array element in this new device is somewhat different from the familiar one in that its primary function is not for storage of a photon induced charge pattern but rather for locally controlling electron emission from a photoemissive element. The diode array serves at least one similar function, i.e., the preservation of spatial resolution through the use of discrete diode elements.

The novel photocathode comprises a semiconductor diode array having associated therewith a photoemissive element. The spatial distribution of electron emission from the photoemitter is controlled by the field pattern produced in the diode array by the incident light image.

Several advantages result from this structure. Quantum efficiency can be larger than in the conventional photocathode. This can be appreciated in a classic sense by considering the electrons produced by photon absorption not as the primary electron source, but rather as controlling the potentially large electron flow from the photoemissive element to the target. The diode-array element thus acts in a manner similar to the control grid of a triode amplifier.

Another advantage is the large spectral response inherent in, for example, a silicon diode array. This element is sensitive to light up to 1.1μ which is well into the infrared portion of the spectrum. The device is also inherently sensitive to X-ray radiation although the sensitivity to X-rays can be improved by following the teachings described in patent application Ser. No. 723,274, filed by M. H. Crowell and E. F. Labuda on May 27, 1968 and abandoned in 1969. The resulting X-ray device does not require an X-ray sensitive phosphor. The potential of the photocathode for X-ray applications is especially attractive.

The electron image produced by the photocathode of the invention can be used in several advantageous ways.

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The high sensitivity of the photocathode makes it attractive for use in image intensifiers. For example, the electron image can be accelerated, with standard electron optics, onto a cathodoluminescent phosphor screen for direct viewing. Alternatively, an electron sensitive recording medium can be used in place of the phosphor screen.

The image intensification feature can be used to increase the sensitivity of an otherwise standard video camera. For example, the silicon diode array of the above-mentioned Pat. No. 3,403,284 is highly sensitive to energetic electron images as well as photon images, and the conventional silicon diode array camera tube can employ the photocathode in combination with the image intensifier electron optics as the first detection stage to further improve its sensitivity. That sensitivity, already high due to the efficiency of both the photocathode and the diode array individually, is further enhanced by current multiplication resulting from high energy electrons accelerated from the photocathode onto the diode array.

In the devices already described the light for activating the photoemitter would ordinarily be a flood beam. The use of a scanning beam in its place adds to the device the capability of deriving a video signal. This is possible due to the inherent storage function of the diode array.

It is thus evident that the new photocathode element is versatile as well as efficient.

These and other aspects of the invention may be evident from the following detailed description. In the drawing:

The figure is a schematic representation of an image intensifier employing the photocathode of the invention.

In the figure, an image is focused onto the diode-array element 10 by lens 11 as shown. The diode-array element comprises a p-type substrate 12 of a semiconductor, such as silicon, with n-type regions 13 forming the diode array. The semiconductor can be selected for optimum absorption of the incident radiation or, alternatively, a light absorbing layer 14 can be added to improve the spectral response. For medium- or far-infrared wavelengths a germanium layer 14 would be useful. An X-ray absorbing layer of, for example, gold can be used for viewing X-ray images. The usual insulating sea 15 covers the inactive regions of the semiconductor to eliminate spurious signals.

The photoemissive coating 16 covers the diode array as shown. The photoemissive coating is activated by light from lamp 17 and its associated lens 18. The lamp and the thickness of the coating are chosen advantageously such that the light does not penetrate to the semiconductor diode array. However, since the photoemissive material may be somewhat transparent to the activating radiation, it may be desirable to use an auxiliary light absorbing, insulating coating 19 between the diode array and the photoemissive coating 16.

Exemplary materials useful for these elements are a standard infrared floodlight 17, the well-known S-1 photoemissive material as the coating 16, and a thin absorbing metal layer such as silver as the intermediate layer 19.

The mesh 20 provides the field for extracting photoemitted electrons toward the cathodoluminescent screen 21. Focusing elements 22 are provided unless the spacing between the diode array and the screen 21 is very small. A diverging electron lens can be employed for magnifying the image since the diode array element is typically small. The bias means 23 provides a moderate negative bias, e.g., 1 to 10 volts, between the diode array and the mesh 20 to extract electrons from the photoemissive coating, and an accelerating field of a few hundred to many thousand volts between the mesh and the screen 20. A vacuum envelope 24 completes the assembly.

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The operation of the device is implicit in the arrangement of these known functional elements. In the absence of any external light, the photoelectrons created by the activating light 17 will charge the n-regions 13 toward the adjacent mesh. This creates a reverse bias on the diodes. In addition, the photoemitted current is reduced by grid action so that in equilibrium it just equals the diode array dark current appropriate to the reverse bias voltage. If hole-electron pairs are created in the substrate due to an incident image, the minority carriers (i.e., electrons) will diffuse to the space charge region surrounding the nearest n-type region. They will then be swept across the space charge region, reduce the potential of each n-type region and the overlying area of the photocathode, and consequently increase the photoemitted current from that area. The photoemitted electrons are accelerated and focused toward the screen 21 where they activate the phosphor and form a visible image. One photoemitted electron will result from one collected minority carrier. Therefore, the overall response of the new photocathode is just that of the diode array. In some cases there is an advantage in operating the device in a pulse mode; that is, with the photoemitter illuminating means periodically inactive allowing the potentials in the target to build up. This gives greater dynamic range to the photocathode and reduces the possibility of redistribution effects.

Finally, with the benefit of the foregoing teachings and the recognition that the function of the array in the device described above is to provide an image sensing capability, the device can be dissected into a single photodiode-photoemitter element to give a photodetector having the same superior qualities that are attributable to the imaging device. With this alternative there is an advantage in using a large area photodiode. This gives a better signal-to-noise ratio in that the increase in photodiode current is disproportionate to the dark current. The latter is largely a function of the perimeter-to-area ratio as the bulk contribution is considerably less than the surface state leakage.

Various additional modifications and deviations of these basic teachings will occur to those skilled in the art. All such variations which rely on the teachings through which the invention has advanced the art are properly considered within the scope of this invention.

What is claimed is:

1. A photocathode comprising a photoemitter, means for activating the photoemitter comprising means for illuminating the photoemitter, and means for controlling the spatial electron emission of the photoemitter comprising a photosensitive semiconductor diode in contact with the photoemitter, means for focusing a light image on the diode, and electrode means for impressing a voltage

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across the photoemitter and the diode so that the spatial electron emission from the photoemitter can be controlled by charge locally present in the diode.

2. A photocathode comprising a photoemitter, means for activating the photoemitter comprising means for illuminating the photoemitter, means for controlling the spatial electron emission of the photoemitter comprising a semiconductor diode array in contact with the photoemitter, means for focusing a light image on the semiconductor diode array, and electrode means for impressing a voltage across the photoemitter and the diode array so that the spatial emission from the photoemitter can be controlled by the charge locally present in the diodes of the array.

3. An image intensifier comprising a vacuum envelope, a photoemitter within said envelope, an electron sensitive medium positioned to receive electrons emitted from the photoemitter, bias means for accelerating electrons emitted from the photoemitter toward the electron sensitive medium, means for activating the photoemitter comprising means for illuminating the photoemitter, means for controlling the spatial electron emission of the photoemitter comprising a semiconductor diode array in contact with the photoemitter, means for focusing the light image to be intensified on the semiconductor array to modify the charge on each diode in accordance with the spatial light intensity of the image, and electrode means for impressing a voltage across the photoemitter and the diode array so that the spatial emission from the photoemitter can be controlled by the charge locally present in the diodes of the array.

4. The photocathode of claim 2 further including means for focusing an electron image on the semiconductor diode array.

5. The photocathode of claim 2 in which the semiconductor is silicon.

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