

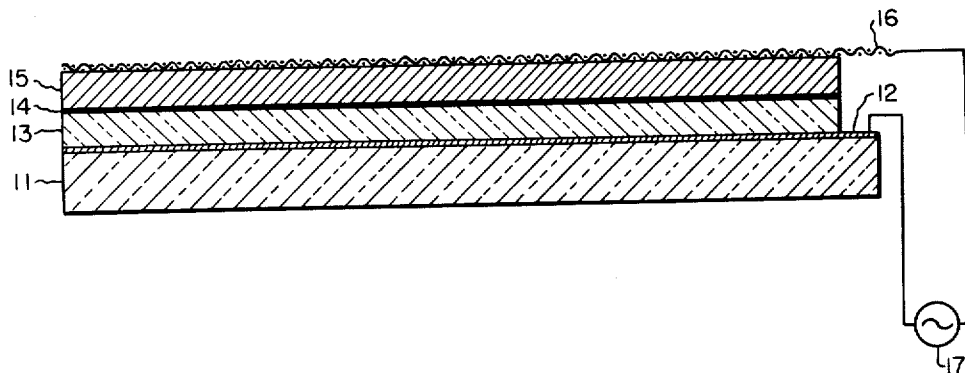
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LIGHT AMPLIFIER AND STORAGE DEVICE

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LIGHT AMPLIFIER AND STORAGE DEVICE

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6 Claims. (Cl. 250—80)

This invention relates in general to devices for the storage, amplification and conversion of radiant energy. Specifically, the invention relates to a device which includes a photoconductive member and an electroluminescent member, input energy being applied to the photoconductive member and an output being derived from the electroluminescent member.

Various devices for the amplification and storage of energy in the form of light have been made in the past. Quite commonly they have depended upon the combination of a photoconductive layer and an electroluminescent layer for their operability. By way of example, in my copending application for patent entitled, "Light Amplification and Storage Device," Serial No. 631,131 filed December 28, 1956, I have disclosed a device of such a nature. However, to improve the efficiency of that device I made my photoconductive layer foraminous. Subsequently, I made other and further improvements in the foraminous type of device.

However, I have adopted a simpler mechanical structure than the foraminous photoconductive layer in my present invention. This structure is best described as "laminated". By this I mean that various layers are built up, one upon the other to form the finished product. An early form which the laminated structure took is disclosed in the application for patent of S. C. Peek, Jr., entitled, "Light Amplifier," Ser. No. 485,131, filed January 31, 1955 and assigned to the same assignee as my present invention.

Devices constructed in accordance with the invention of S. C. Peek, Jr. operate in a satisfactory manner, but fabrication techniques are somewhat difficult to perform to maintain consistent operating characteristics in the finished product. Furthermore, requirements of more recent date have imposed demands for closer control of such devices than was once the case.

I have found that it is possible to make a light amplifier, following the principles of my invention, which is of the laminated type and which can be used, for example, in the amplification of television images at a rate of twenty to forty frames per second without loss of resolution and without blurring. In fact, resolution in my laminated structure is limited only by the particle size of the phosphors of the electroluminescent material. Such a limitation is, of course, of no consequence in the presentation of television or moving pictures because in normal circumstances, finer resolution in the device would be of no value to the human eye.

In addition to improvements in resolution and absence of blurring, the response time of the laminated light amplifier is greatly improved. Both the rise time and the decay time are much shorter than those previously attained.

These and other advantages, features and objects of my invention will become apparent from a reading of the following specifications of a particular embodiment of my invention which should be read in connection with the appended drawing the single figure of which is a sche-

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matic illustration of a laminated device for light amplification, storage and conversion embodying principles of the present invention.

In the drawing there is illustrated a glass panel 11 which serves as a base for my laminated structure. The thickness of the panel is not of critical importance, but I prefer to use a standard commercial panel which may run from about .060" to .085". Mechanical strength and transparency to the light frequencies developed are necessary conditions, but in most instances common forms of glass are quite suitable.

To the panel 11 I apply a very thin conductive film 12. The conductive film 12 may be formed of any one of several well-known compounds and a thickness in the range of one to a few thousandths of an inch is sufficient. The material which I prefer to use, however, is a tin chloride such as that disclosed in U. S. Patent No. 2,624,851 to Eric L. Mager which is assigned to the same assignee as is the present invention.

In carrying out the process of applying the film 12 I first clean the panel 11 thoroughly, then heat it to about 600° C. Next, I spray the tin chloride solution on one surface of the panel while the panel is still at an elevated temperature. To achieve the proper transparency and conductivity, the tin compounds must be sufficiently decomposed, and the heating of the panel prior to spraying aids the decomposition process.

Upon the transparent conductive film 12 I form an electroluminescent layer 13. The layer 13 may typically consist of an electroluminescent phosphor embedded in a solid dielectric material. One such phosphor of the many which are suitable is the copper and lead activated zinc sulphide disclosed in United States Patent No. 2,728,730, issued December 27, 1955 to Butler and Homer, and the dielectric material in which the phosphor is embedded can be, for example, of the ceramic or of the glass type which is shown in the pending application of Rulon, Ser. No. 365,617 filed July 2, 1953. Both the patent and the application for patent cited immediately above, are assigned to the same assignee as is the present application. I prefer to limit this layer to a thickness of about .004" to .005".

Now, to either prevent or limit feedback of light, depending upon the application to which the finished device will be put, I coat the surface of the electroluminescent layer with an opaque material. The layer of opaque material 14 is held to a very thin dimension, one to two thousandths of an inch being sufficient. In the event that I desire to limit the opacity of the layer 14, I may actually use an even thinner layer. The material used may be opaque black frit in a vehicle such as xylol, carbon black particles suspended in a dielectric or any one of numerous materials.

Insofar as the limiting of opacity of the opaque layer 14 is concerned, I have found it desirable to establish limits which are from one to five percent transmission of light as a lower limit and 20 percent transmission of light as an upper limit. The lower limit is reasonably well established as a practical matter by diminishing returns. In other words, the thickness necessary to obtain less than one percent light transmission would be impractical.

On the other hand, the upper limit is set because if more than 20 percent light transmission is permitted, a deleterious positive feedback effect which will be explained in greater detail hereinbelow is encountered.

Over the layer of opaque material, I form a photoconductive layer 15. The materials used and the method of application of the photoconductive layer 15 are of considerable importance in my invention. Although an operative device could be obtained using only cadmium sulphide properly activated as for example, by copper and halogens, I have found that the best results have

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been obtained by using a mixture of cadmium sulphide, cadmium chloride, and copper chloride. The ratio of materials in the mixture runs in the order of their listing above preferably 1000 to 50 to 1. They may be mixed in a relatively dry state or in a slurry of distilled water.

I have found it undesirable to suspend by photoconductive material in such vehicles as benzene or in nitrocellulose which contains amyl acetate. I have also found that the various esters and ketones inhibit the photoconductivity of my photoconductive material and for that reason should not be used. An ethyl cellulose with xylol has turned out to be most suitable and it is in such a vehicle that I prefer to disperse my photoconductive material.

To achieve such structure I spray successive layers of photoconductive material on the unit, each layer being of the order of .002" to .003". After each layer is sprayed on, I fire the unit in air at 525-550° C. for a period of 15 to 25 minutes. The spraying and firing process continues until I have built up a layer 15 composed of dense sintered photoconductive particles. The vehicle is completely driven off in the various firing steps, and the particles are held together by being actually sintered one to another. The total layer which may include four or five sprayed and fired constituent layers runs about .008" to .012". If thinner layers were used, as will be seen in the final product, a bypassing capacitor would be presented to an applied signal and the electroluminescent layer might be directly energized by the capacitive coupling of the signal to that layer.

After I build up my photoconductive layer 15, there are several feasible techniques which I may employ to apply proper electrical potentials to the device. In any event it is desirable that an electrode 16 be formed or attached over the photoconductive layer 15. This electrode must meet certain requirements, particularly in regard to transparency. In other words, if an input image or other information in the form of visible light, infrared, ultra violet or other electromagnetic radiation is to be applied to the photoconductive layer, the electrode 16 must be transparent in some degree to that radiation.

Among the materials which have proven suitable is a 500 mesh nickel screen which may be attached to the photoconductive layer with a transparent wax or other suitable adhesive. Such a structure gives a minimum of 60% transmission of visible light which is sufficient for most applications. Another suitable electrode may be constituted by a transparent conductive film similar to the film 12. In this case, the film would preferably be formed on a glass base and attached to the photoconductive layer with that layer directly in contact with the conductive film. What is shown in the drawing is the mesh screen which I have illustrated as extending outwardly beyond the remainder of the structure to facilitate the attachment of electrical leads. The transparent conductive film 12 and its supporting glass panel are similarly shown extended beyond the body of the device for ease in attaching electrical leads.

A generator 17 connected to the electrode 16 and to the film 12 is shown schematically. To provide a variety of modes of operation of the device of the invention, it is desirable that the generator be one capable of supplying an alternating voltage of roughly 450 to 800 volts R. M. S. Further, it should also be possible to vary the frequency of the voltage to be applied to the device from 400 cycles per second to about 10 kilocycles per second.

The fundamental principles underlying the operation of my invention are substantially similar to those of other devices which utilize a photoconductive member and an electroluminescent member in series. The photoconductive member is a poor conductor when not exposed to light. Only a very small proportion of the voltage from generator 17 appears across the electroluminescent layer

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at such times. However, a small amount of light incident on the surface of the photoconductive layer changes the resistance of that layer by a factor as great as a thousand. Under this condition, the voltage across the electroluminescent screen is correspondingly greatly changed as is its light output.

The opaque layer between the photoconductive and electroluminescent layers serves to prevent excess feedback of light from the electroluminescent layer to the photoconductive layer. If the opaque layer is not included in the structure, the feedback will cause electroluminescence to persist once it is started until voltage is removed or some other electrical quenching is utilized. This characteristic is of value in information storage.

In connection with this characteristic, it is also noteworthy that if the opacity of the interposed layer is limited, as by the use of a relatively thin layer, a small amount of feedback is useful even in light amplification because a faster response is attained. I believe this is due to the activation of both sides of the photoconductive layer simultaneously.

As I have stated above, an upper limit of 20 percent transmission of light through the opaque layer is desirable because when the transmission exceeds that figure, there is a tendency for a chain reaction to occur. Considering a bundle of rays of light forming a cylinder impinging upon the photoconductive layer, a disk of illumination is created at the interface of the electroluminescent layer and the opaque layer. If the opaque layer does not sufficiently block the transfer or transmission of light from the electroluminescent layer back to the photoconductive layer, transverse spreading will occur. The spreading is conical, spreading the image obtained, and feeding back a larger cylinder of conductivity through the photoconductive layer. This in turn, causes a larger light circle or disk at the electroluminescent layer causing further spreading of the image and additional feedback of still larger cones of conductivity. Ultimately, the output image is spread and blurred to the point of uselessness as a storage member. Storage without such spreading is obtainable only by observance of the limits of opacity specified for the layer 14.

Variation of the magnitude of the applied voltage as well as variation of the incident light permits storage (or continued light emission), to be varied over a period ranging from a few microseconds to days. Still another parameter which is subject to variation and which gives corresponding variation in storage is the frequency of the applied voltage. The electroluminescent layer is capacitive in nature and draws greater current for a given voltage at high frequencies than at low frequencies. Thus, at high frequencies the increased current flows through the photoconductive layer in series with the electroluminescent layer causing the voltage drop across the photoconductive layer to be increased and that across the electroluminescent layer to be decreased. Corresponding changes in light output from the electroluminescent layer result. These changes are most apparent in the rate of decay of light output.

The various storage effects outlined above are of value in computer and read-out circuits as well as in other information handling components. Still other applications of the invention derive from its ability to produce a visible light output when triggered by ultra-violet, infrared and other types of radiation.

Although what has been defined constitutes a preferred embodiment of my invention, numerous modifications of my device and process will occur to those skilled in the art. The invention should, then, not be limited to details shown and described but only by the spirit and scope of the appended claims.

I claim:

1. The method of making a laminated device for the storage, amplification or conversion of radiant energy which comprises spraying a conductive film transparent

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to energy on a similarly transparent surface, depositing an electroluminescent layer on said transparent conductive film, coating said electroluminescent layer with a layer of relatively opaque material having a transmission characteristic in the range of 1 to 20 percent of light from said electroluminescent layer, applying sequentially a plurality of photoconductive layers on said layer of relatively opaque material to form a total photoconductive layer of two to three times the thickness of said electroluminescent layer, and applying an electrode on said total layer of photoconductive material.

2. The method of making a laminated device for the storage, amplification or conversion of energy incident thereon which comprises spraying a conductive film transparent to energy on a similarly transparent surface, depositing an electroluminescent layer on said transparent conductive film, coating said electroluminescent layer with a layer of relatively opaque material having a range of 1 to 20 percent transmission of light from said electroluminescent layer, applying sequentially a plurality of relatively thin layers of photoconductive material to said layer of opaque material, sintering said relatively thin layers together to form a total photoconductive layer of two to three times the thickness of said electroluminescent layer, and applying a conductive electrode to said total photoconductive layer, said conductive electrode being at least partially transparent to energy incident on said laminated device.

3. The method of making a laminated device for the storage, amplification or conversion of radiant energy which comprises spraying a conductive film transparent to energy on a similarly transparent surface, depositing an electroluminescent layer on said transparent conductive film, coating said electroluminescent layer with a layer of relatively opaque material having a transmission characteristic in the range of 1 to 20 percent of light from said electroluminescent layer, spraying a thin layer of photoconductive material in a vehicle of xylol on said layer of opaque material, baking the assembly to drive off said vehicle, similarly applying a plurality of additional thin layers of photoconductive material to build a total layer of sintered photoconductive material at least two times as thick as said layer of electroluminescent material, and applying an electrode on said total layer of photoconductive material.

4. The method of making a laminated device for the storage, amplification or conversion of radiant energy which comprises spraying a conductive film transparent

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to energy on a similarly transparent surface, depositing an electroluminescent layer on said transparent conductive film, coating said layer of electroluminescent material with a layer of relatively opaque material having a transmission characteristic in the range of 1 to 20 percent of light from said electroluminescent layer, preparing photoconductive material by mixing cadmium sulfide, cadmium chloride and copper chloride in the approximate ratio of weights of 1000 to 50 to 1, spraying a layer of said photoconductive material on said layer of opaque material, and attaching a conducting member to said layer of photoconductive material to provide an electrode on said layer of photoconductive material.

5. The method defined in claim 4 wherein said layer of photoconductive material is formed by spraying a first film of photoconductive material in a vehicle of xylol on said layer of opaque material, baking the assembly to drive off said vehicle, and sequentially spraying and baking additional films of photoconductive material over said first film to form said layer of photoconductive material in a dense sintered condition.

6. The method of making a laminated device for the storage, amplification or conversion of radiant energy which comprises heating a support member to a point above room temperature, said support member being transparent to light energy, spraying a similarly transparent conductive film on said support member while said support member is at a temperature above room temperature, depositing an electroluminescent layer of inorganic materials on said conductive film, spraying a layer of opaque inorganic material on said electroluminescent layer, spraying a plurality of constituent photoconductive layers on said layer of opaque material to form a total photoconductive layer of at least two times the thickness of said electroluminescent layer, baking said assembly to remove all traces of organic material from said photoconductive layer and to sinter said photoconductive layer into a dense mass, and sealing to said total photoconductive layer an electrode transparent to incident radiation of a predetermined type.

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