METHOD OF CODED DATA STORAGE BY MEANS OF CODED INKS IN WHICH THE CODE COMPONENTS HAVE PARTICULAR ABSORPTION BANDS IN THE INFRARED

ABSTRACT: A data storage method is described in which inks with code components of compounds having narrow absorption bands in the infrared are impressed on a substrate which is transparent to the infrared in the regions of the absorption bands of the code components. Decoding is effected by passing infrared radiation through the areas of the substrate where the symbols have been placed in the coded inks and the infrared radiation detected in the particular bands of the coded components to produce electrical signals which are then analyzed to produce a readout corresponding to the particular symbol.
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REALTED APPLICATIONS

This application is a continuation-in-part of my earlier application, Ser. No. 526,183, filed Feb. 9, 1966, and now abandoned.

BACKGROUND OF THE INVENTION

In the patent of Freeman and Halverson, U.S. Pat. No. 3,473,027, Oct. 14, 1969, there is described a method and apparatus for recording and retrieving information by means of photoluminescent materials. In the patent so-called coded inks are utilized in which various symbols, such as numbers, are represented by the presence or absence of particular photoluminescent material rather than representing the symbols themselves, which are distinguishable either visually, magnetically or by other characteristics. When dealing with numbers, for example, four different photoluminescent materials may be used, and this gives the possibility of 15 different codes, the general formula being 2°-1. Larger numbers of coded materials permit representing still larger numbers of different symbols. For example, with six different photoluminescent materials 63 symbols are distinguishable. The different coded inks contained the necessary mixtures of materials which fluoresced under ultraviolet illumination in definite colors.

SUMMARY OF THE INVENTION

The present invention provides symbols which have one or more components having sharp absorption bands in the infrared. The choice of materials is wide, as most transparent or organic compounds have one or more sharp absorption bands in the infrared. The substrate on which the symbols are written or printed must, of course, transmit infrared at least in the ranges in which the absorption bands of the components are located. This is, however, no problem as there are plastics, such as for example polyethylene, which are transparent to the infrared through a wide range. As most of the infrared absorbers are colorless or transparent, the symbols are not visible to the eye, and therefore any message is secret. Of course the same advantages as with fluorescent materials are shared, namely that the symbol can be read regardless of its shape and is, therefore, machine readable even if somewhat mutilated.

For certain purposes it is desirable that the symbols be readable under visible light. This can be effected in the present invention by introducing a small amount of a suitable dye stuff in the coded inks. Of course the colorant used must be one which has reasonable transmission in the ranges of infrared in which the absorption bands of the symbol components are located and does not have itself sharp absorption bands in these ranges which would interfere with recognition of the components.

In readout or retrieving the information according to the present invention, an infrared source shines on the transparent or translucent substrate containing the symbols, the source radiating over a sufficiently wide infrared band to include all of the strong absorption bands of the different components of the symbols. On the other side of the transparent substrate are located a series of light pipes, which may be suitable plastic rods, glass fiber bundles, and the like. The end of each light pipe carries the radiation through a narrow band filter to a radiation detector, one for each component. The filter corresponds to the absorption band of the particular component and is preferably narrow band, but this presents no problem with modern narrow band filters, such as interference filters. It goes without saying that the light pipes must be capable of transmitting radiation in the proper wavelengths in the infrared where the components have strong absorption bands.

It will be found that there are a large number of compounds, such as organic plastics, with bands located in the near infrared, for example wavelengths shorter than 3μ, so that glass fiber light pipes can be employed. If components having absorption bands in the further infrared are used, the light pipes must of course be modified accordingly. Fibers or rods of different plastics or even a hollow pipe with its inner surfaces in the form of a good infrared mirror can be used. When fiber or rod light pipes are used of particular plastics, these may be the same plastics as the substrate or a different component.

Typical materials are polymethylmethacrylate, polyacrylamide, polynyl alcohol; various amides and polyamides, such as N,N-dialkyl amides; super polyamides, such as for example nylon-6, which is a polymer of α-amino caproic acid, and the like. Many of these components are not readily soluble in solvents such as benzene, toluene, cyclohexane, and the like which do not exhibit bands that conflict with the absorption bands of the components. In such cases finely divided powders may be dispersed in inks having a film-forming substance which also does not have absorption bands in the infrared which conflict with the bands of the components. Such inks normally require a film-forming substance, for which polyolefins are suitable, for example solid polyisobutylene. Of course all of the various components can be distributed in inks in this form even through some of them, such as polymethylmethacrylate, are readily soluble in suitable solvents.

The amounts of the components are not critical, but they must be sufficient in the residue form when the volatile solvents of the inks evaporate so that the components are represented by a layer of at least 20 to 50 microns.

Radiation detectors may be of conventional types for use in infrared. For example, if all of the components or some of them are in the very near infrared, it is possible to use special photomultiplier tubes, and where this is feasible it constitutes an advantage, as the sensitivity of the photomultiplier tube is so great that amplification of the signal from the tube can often be dispensed with. In other ranges in the infrared, it is necessary to use a different type of radiation detector, which may be either photoresistive or photovoltaic. For example, a lead sulfide or lead selenide cell.

Some of the typical components, such as polymethylmethacrylate; nylon-6; or N,N-dialkyl amides, such as N,N-dibutylpropionamide; and polyacrylonitrile have infrared absorption bands at wavelengths longer than 4μ and ranging up to slightly over 6μ for some of the amides, such as nylon-6. In such cases it is possible to use a photoresistive detector, such as indium antimonide.

It is also possible to use thermal detectors, such as thermocouples or thermopiles, thermistors and the like, which are of course responsive through very wide ranges of the infrared. In the case of these detectors which are less sensitive, it is normal to provide signal amplification and standard preamplifiers, such as for example solid state preamplifiers, are used. As the nature of the detector and/or the amplification of its signal are not changed by the present invention, it is not desired to limit it to any particular design.

The signals from the various radiation detectors are then read out in standard readout circuits, which also are not changed by the present invention and which can be the same as are used in the readout of the Freeman and Halverson patent above referred to. One may consider that the novelty of the present invention ceases when signals are produced from the various radiation detectors, and it is an advantage of the invention that no new design of detectors, amplifiers or readout circuitry is required.

BRIEF DESCRIPTION OF THE DRAWING

The drawing shows in diagrammatic form an apparatus for reading a code containing four components.
DESCRIPTION OF THE PREFERRED EMBODIMENTS

In the drawing an infrared lamp of conventional design 1, which radiates infrared in the range in which all of the components have absorption bands, shines infrared onto a substrate 2 which is transparent to infrared and may, for example, be polyethylene. On this substrate there are printed various symbols: A, B, C, and D, which for simplicity are shown as containing a single component only, though of course any particular symbol may have two, three or four components. The thickness of the symbols is enormously exaggerated for clearness and in actual fact they are no thicker than ordinary printing.

As a typical illustration, component A is polymethylmethacrylate with an infrared absorption band at 5.8 μm, B is nylon-6 or N,N-dibutylpropionamide with an infrared absorption band at about 6.1 μm, C is polycrylonitrile with an absorption band at 4.4 μm, and D is polyvinyl alcohol with an absorption band at 2.9 μm. If separate inks are used for each component, component A can be a benzene solution of the polymer, but the other three components are not readily soluble in suitable solvents and therefore in the form of very finely divided powder uniformly dispersed in an ink which is a solution of solid polyisobutylene in cyclohexane. Of course if inks are used with a number of components mixed in them, it is preferable to have the polymethylmethacrylate also in the form of a fine powder. While the thickness of the symbols is exaggerated, the layer of the component material should be at least 20 μm to 50 μm in thickness.

The entrance pupil of the infrared source after the radiation has passed through the substrate 2 passes through a field lens 3 which focuses the entrance pupil onto a plane in which four light pipes 4, 4A, 4B, 4C, and 4D are located. The light pipes are capable of transmitting infrared radiation in the range including the strong absorption band of the particular components respectively. The entrance of the light pipes is shown with the pipes quite widely separated for clarity. In an actual device they are of course quite closely adjacent, which is made possible by the fact that the pipes can be bent to bring the radiation out into a wider area. The radiation from each light pipe passes through a sharp cutting infrared filter 5, 5A, 5B, 5C, and 5D respectively, each filter passing only the wavelength range corresponding to the absorption band of a particular component or a little beyond, the filters being arranged so that there is no overlap in transmission. Back of the filters 5A to 5D are four radiation detectors shown diagrammatically as 6, 6A, 6B, 6C, and 6D. The detectors may be of indium antimonide or of course thermopiles or thermistor bolometers with suitable amplification to make up for the lower sensitivity of these detectors. With components which have absorption bands in the sufficiently short wave infrared, infrared sensitive photomultiplier tubes may be used as the detectors and have the advantage of enormously enhanced sensitivity.

Each radiation detector produces an electrical signal if its particular component is absent but produces no signal if it is present, although the reverse effect can be achieved by changing the electronics. The electrical signals from the detectors pass into an amplifier and readout circuitry 7 of the conventional design which reads out the particular symbols. This element is of conventional design and may be a multichannel analyzer, an oscilloscope with timing so that each signal appears at a particular point of the horizontal sweep, or any other standard form of readout circuit. Since it is an advantage of the present invention that any known circuit may be used and the invention is not limited to any particular design, this element is shown in the drawings as a block.

The preferred modification of the invention using light pipes and spatially separated filtering means and detector is not the only form in which the present invention can be developed. Where solid state infrared detectors are used, such as indium antimonide, these can be very tiny and provided with equally small filters, the detectors being arranged in the form of a mosaic on which the field lens images the infrared beam after passing through any particular coded symbol. The signals from the different detectors pass to preamplifiers and the readout circuit in the conventional manner. Very small apparatus is thus made possible and for certain uses this compactness is of primary importance. However, the modification described in the drawing using light pipes and more widely separated filters and radiation detectors permits using a wider choice of detectors, including some of higher efficiency, such as for example photomultiplier tubes, where the absorption band of a particular component is the sufficiently short wave infrared. Therefore, the modification described in the drawing using light pipes is preferred, but the invention is in no sense limited thereto.

1. In a process for encoding and retrieval of information in which the encoding is with coded inks having various components, the code constituting the absence of presence of particular components to represent a symbol, the improvement which comprises:
   a. applying to a substrate transparent to infrared radiation symbols encoded in inks having various components with narrow absorption bands within the wavelength range in the infrared in which the substrate is transparent;
   b. shining infrared radiation in the wavelength range containing the narrow absorption bands through the substrate, detecting radiation encountering the coding components by infrared detectors, each detector being responsive to wavelength in the infrared including the absorption band of a coding component and being unresponsive to wavelengths in the range of absorption of the other components, the detectors transforming infrared radiations into an electrical signal; and
   c. transforming said signal into a readout of a coded symbol represented by the presence and absence of the coding components.

2. A process according to claim 1 comprising focusing the infrared radiation passing through the ink component on the substrate corresponding to a symbol onto a fixed plane and conducting said radiation to each detector individually.

3. A process according to claim 2 in which the individual detectors are in the plane and receive infrared radiation directly.