

[54] **METHOD OF VERIFYING THE AUTHENTICITY OF A DOCUMENT AND IDENTIFIABLE DOCUMENT PRODUCED THEREBY**

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[58] Field of Search **250/71 R, 83 CD**

[56] **References Cited**

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[57]

ABSTRACT

The invention disclosed herein pertains to a means of verifying the authenticity of a document, identification card, or any object for which a means of establishing authenticity is desired, whereby such document, I.D. card or other object, hereinafter referred to generically as "document," is treated with a suitable thermoluminescent phosphor in a coded manner and for subsequent verification is exposed to a means for detecting the presence of said thermoluminescent phosphor and for deciphering the message thereby embodied in such document.

10 Claims, No Drawings

METHOD OF VERIFYING THE AUTHENTICITY OF A DOCUMENT AND IDENTIFIABLE DOCUMENT PRODUCED THEREBY

BACKGROUND OF THE INVENTION

1. Field of the Invention

The invention relates to a method or means of verifying the authenticity of a document. More specifically, it relates to a means of identifying and verifying the identification of a document by embodying a coded message in said document in the form of a thermoluminescent phosphor and subsequently detecting and deciphering the embodied message.

2. Related Prior Art

Phosphors of the type which respond to excitation by ultraviolet, or so-called "black light", emit visible light or infra-red light which can be detected in the former case by the naked eye, or in both cases by suitable radiation-sensitive instruments, have been used in the past to identify documents or objects which have been deliberately marked with a pattern or design.

Such types of phosphors have the disadvantage of being relatively obvious to a would-be forger or counterfeiter, since the light output is spontaneous and concurrent with the application of the exciting or stimulating radiation; and some have a persistent output, or "afterglow", after the stimulating radiation has been removed. They also have the disadvantage of being subject to accidental contamination by the many substances which exhibit spontaneous fluorescence to ultra-violet light or other shorter wave length sources. Such contaminating substances include everyday materials such as starch, naphthalene (moth balls), quinine and a host of other aromatic organic compounds and inorganic compounds which could obscure the original imprint or code, or add a false reading which would confuse a photosensitive readout.

STATEMENT OF THE INVENTION

In accordance with the present invention, it has now been found that a document can be identified by the embodiment therein of a thermoluminescent phosphor, preferably in the form of a coded message, such as a number of several or more digits, and the authenticity or identification of the document can be verified by activating said phosphor by exposure to appropriate radiation, and thereafter determining whether radiation is discharged from said activated document, generally at a temperature above that at which the document is exposed to the activating radiation. Such identifying means or method can be used on various valuable bonds, currency, credit cards, identification cards and the like. Equipment for activating and identifying such documents can be installed in banks, department stores, hotels, gasoline stations, etc., and can be of simple and less expensive types as well as more elaborate and possibly more expensive types.

Thermoluminescent (T.L.) phosphors are a special class of luminescent materials first noticed by Farrington Daniels at the University of Wisconsin. This discovery is disclosed in U.S. Pat. No. 2,616,051, dated Oct. 28, 1952. Their emissions have frequencies characteristic to the individual T.L. phosphor. These materials differ from other phosphors in that they are capable of storing a significant percentage of the exciting energy for long periods of time until they are heated to critical

temperatures which are specific to each material, at which temperatures the stored energy is released or discharged spontaneously in the form of radiation (usually at a longer wave length than the original exciting energy). These critical temperatures generally occur at higher than the ambient temperatures usually encountered, and in any case higher than the temperature needed to excite them to a state of potential fluorescence. However, it has been determined that some T.L. phosphors have readout, or emission, temperatures at less than usual room temperature ambients. One example is zinc oxide activated with zinc ($\text{ZnO}_{(zn)}$) which has emission peaks below room temperature as well as above; and has an afterglow (after the stimulating radiation has been removed) corresponding to a half life of 100 seconds.

T.L. phosphors are occasionally encountered in natural minerals (for instance, calcium sulfate and calcium fluoride) with suitable amounts of accidental impurities which activate the otherwise inactive lattice so that the phenomenon of thermoluminescence is present. More efficient T.L. phosphors have been prepared synthetically by growing crystals of purified materials into which controlled amounts of activators or "dopants" have been introduced into the crystal lattice. Two of the more convenient of these, for the purpose of the application disclosed herein, are synthetically made lithium fluoride (LiF), doped with various materials, and calcium sulfate doped with Manganese ($\text{CaSO}_{4(Mn)}$).

The former material is described in U.S. Pat. No. 3,320,180, issued May 16, 1967 to Carl F. Swinehart. The activators, or dopants, are manganese (Mn), Calcium (Ca), barium (Ba), aluminum (Al), titanium (Ti) or europium (Eu). The main product of commerce is denoted as T.L.D.100, available from the Harshaw Chemical Co., Division of Kewanee Oil Co., and is one of the materials suitable for use in the practice of the present invention.

A second material, ($\text{CaSO}_{4(Mn)}$), suitable for use in the practice of this invention is prepared according to the method described in "Luminescent Dosimetry", A.E.C. Symposium, Series No. 8; Clearing House for Federal Scientific and Technical Information; National Bureau of Standards; U.S. Dept. of Commerce, Springfield, Va., Doc. No. CONF: 650637; Pg. 205, "Thermoluminescent Readout Instruments for Measurement of Small Doses", by J. Lippert and V. Mejdahl. Material prepared by the procedure described therein is suitable for use in the practice of this invention.

Both of the above materials are presently available commercially and their cost is within a range to make them economically feasible for the uses disclosed herein. Other materials in the class of T.L. phosphors may be available in the future.

Up to this time these T.L. materials have been used primarily in the fields of radio-medicine and physics. In medicine they provide a convenient means of determining and preserving a quantitative record of the amount of radiation from gamma and x-ray sources to which a patient has been subjected, either deliberately as a therapeutic treatment, or accidentally as an occupational hazard. In the field of physics they are used for purposes similar to the above, but also for other purposes such as mapping radiation patterns around nuclear reactors. The sole purpose of these prior uses is to determine the quantitative exposure to radiation of

an object, either in a single, or multiple or continuous exposure.

In the present invention the main objective is to determine if such a T.L. material is present in or on a document, I.D. card or other object as a means of determining its authenticity or officiality by means of a coding system. The specific quantitative exposure is relatively immaterial, so long as it is strong enough to satisfy the parameters of the code. The simplest code is the presence or non-presence in a quantity significantly above background or casual, accidental contamination.

In the applications herein claimed the exciting radiation need not be gamma or x-rays, but for some materials can be a simple ultra-violet source.

Another significant difference from previous applications of T.L. materials is that for the simple confirmation of their presence the user can activate the T.L. materials immediately prior to the readout (or confirmation procedure), thereby eliminating any significant energy loss with time, or energy storage from accidental exposure to exciting radiation. T.L. materials lose various amounts of stored energy with time, a typical case being T.L.D.-100 which dissipates about 5 percent per year. Their stored energy can also be augmented by unintentional exposure to x-ray or gamma ray sources.

For most purposes of this application, long-term storage properties, in terms of pickup or loss characteristics, are of no consequence. In other words, previous uses have been confined to a means of detecting levels of radiation to which an object has been exposed, whereas this disclosure deals with a means of confirming the presence of T.L. phosphors according to some code or configuration which is appropriate to the degree of complexity desired, and gains or losses with time are eliminated. The coding choices are discussed below.

The exposing radiation levels are of no significance to the user so long as they are strong enough to excite the phosphor to a point where the eventual emission, upon heating, confirms its presence by a sufficient margin to discriminate against casual or accidental contamination.

T.L. phosphors can be applied to an object in a variety of ways. In the case of paper, the phosphors in fine powder form can be incorporated into the paper itself so long as enough is present at or near the surface so that the emitted light is not absorbed below detectable levels. T.L. powders can also be printed onto the surface of any object with a binder that is essentially transparent to the wave length of emitted radiation. In the case of plastics or other objects which are usually formed by casting or molding, in addition to the above methods, small chips or aggregates of T.L. material can be incorporated into the surface or in the body, if the body is sufficiently transparent to the emitted radiation.

It is not necessary to deal with the specific T.L. phosphors which are most suitable for each specific type of material to be authenticated, or the specific design of the detector or "readout" equipment to be employed. However, a general discussion of these is in order.

At the present time readout equipment for T.L. phosphors, or "readers", consist of a light-proof drawer or compartment in which the sample is placed, an electrical resistance heater placed so that the sample is warmed to the desired temperature, a light-sensitive

device to detect the emitted radiation, and a means of displaying this signal. At present the detector employed is a photomultiplier tube (P.M. tube) which is capable of multiplying the incident energy many thousands of times. Such a detector can register energy far below visual levels. Other types of detectors are available, such as silicon photo-transistors and other "solid state" energy converters. These are presently less sensitive than P.M. tubes, but could be practical. For some applications, high speed photographic film could be used as the detector. This is more cumbersome, but has the advantage of being able to record special configurations, or patterns quite simply.

Obviously, the T.L. phosphor selected must be one such that it possesses a low enough emission or "readout" temperature so that the article to be authenticated will not be damaged by the heat necessary to release the stored energy in the form of detectable radiation. T.L. materials usually have several emission levels in terms of temperature. For instance, T.L.D.-100 has several in a range from 80° C. to 245° C. Since one of the strongest emissions occurs at 80° C., this is a convenient material with which to authenticate or "tag" paper or plastic documents because neither the paper, plastic, nor ink will be damaged at this emission temperature if the proper materials are chosen. With as little as 1 milligram in the field of view of a photomultiplier tube, a reading of approximately 10 times the intensity of untreated paper is obtained with an exciting exposure of 1 roentgen. Higher exposure levels can reduce the quantity of T.L. phosphor needed, per unit of area.

The phosphor $\text{CaSO}_4(\text{Mn})$ has an even higher emission for the same exposure dose and can therefore be used in smaller concentrations per unit of area to be surveyed by a detector in order to obtain a significant differentiation from ambient and non-intentional signals. It also has a low emission peak.

In some cases the simple verification of the significant presence of a T.L. phosphor, as opposed to their casual presence on a document, I.D. card, or other object, may not be as sophisticated or encoded as the user might wish, from the standpoint of guarding against unlikely but possible coincidences. In such cases it is relatively simple to use several different T.L. phosphors which have emissions at different wave lengths, and to apply these in a coded pattern such that the probability of an accidental coincidence is reduced by several orders of magnitude, and to a point where it would be nearly statistically impossible to duplicate without the pattern code combined with the wave length emission code in the proper sequence or position.

Since P.M. tubes, and most other detectors, cannot discriminate one wave length from others within the wave length range or frequency band to which they are sensitive, it is necessary in the above example to provide some means of decoding a pattern caused by the use of several T.L. phosphors in different spatial configurations, each of which is emitting its own frequency (or wave length). This is conveniently accomplished by using "band pass filters" with patterns or windows coinciding with the original coded design, such that the filter will pass the proper frequency either in (1) the proper sequence, or (2) the proper spatial configuration, or (3) the proper integrated total of all signals. If the readout is done by method (1) above, a single detector can be used with a suitable filter to read out the

first phosphor; then the filter is changed to read out the second phosphor, etc. This would be the case where all phosphors are mixed together or located in juxtaposition such that the field of view of the P.M. tube does not need to shadow mask in register with the location of the various phosphors.

In example (2) above, several different filters may be located in a shadow mask such that each filter is in register with the spatial location of its corresponding T.L. phosphor. In this case, either a single detector can be moved from one location of phosphor to the next, taking a separate reading each time, or a multitude of detectors can be used, each viewing only one phosphor location, thereby reading all locations simultaneously but also keeping the readings separate. This would be quicker but more expensive in terms of equipment.

Example (3), above, would use the same shadow mask described in example (2), but a single P.M. tube would view all locations simultaneously and a single readout would not keep these signals separate but integrate them into a single reading to coincide with the coded input.

As a simpler alternate to examples (2) and (3) above, the same phosphor can be used in different concentrations in each location, eliminating the need for differentiating band pass filters. In other words, the spatial coding can be accomplished by the concentration and, therefore, the intensity of emission, at various spatial locations, but all at the same wave length. Therefore, one has the choice of coding by presence or non-presence, augmented by amplitude modulation and frequency modulation and spatial modulation, and any combination of the above. The choice among these more complicated coding systems is simply a question of balancing the cost with the need for certainty that the code has not been broken by comprehension, or confused accidentally.

In experiments with U.S. paper currency, sections of Federal Reserve notes of approximately 2 square centimeters are used to establish casual and incidental background radiation levels. The readout temperature is 85° C. and the readout time is 30 seconds. This readout time is arbitrarily selected in order to make sure that all the available energy will be collected, but in actual practice the readout time can be reduced substantially since most of the signal is released within 2 seconds. The readings are as follows, as obtained on a Harshaw Chemical T.L.D. Reader, Model 2000:

1. Using no sample at all the background radiation or "dark current energy" is 0.043 nano-coulombs from two different specimens.
2. A section of a used One Dollar (\$1.00) bill gives a reading of 0.050 nanocoulombs.
3. A section of a new Twenty Dollar (\$20.00) bill gives a reading of 0.049 nano-coulombs.
4. Repeat readings of example (3) give 0.046 nanocoulombs on the second reading, and 0.046 on the third reading.
5. Example (4) is repeated with an addition of a fresh thumb print and the reading is 0.049 nanocoulombs. In addition, floor dust, by wiping the sample on the floor, gives a reading of 0.046 nanocoulombs.
6. The addition to example (5) above of 1 milligram of T.L.D.—100 as the phosphor, gives a reading of 0.47 nano-coulombs, or over 10 times the background.

All the above samples are irradiated or activated by a gamma ray source to an exposure of 1 roentgen. Therefore, it is obvious that the presence of T.L. phosphor is easily detectable as opposed to ambient background and casual contamination.

In other experiments with (CaSO_{4(Mn)}) a one milligram sample is exposed with 1 roentgen, and the readout time is 10 seconds at 85° C. The readout equipment is the same as in the preceding example. The following results are obtained:

Item	Charge or Dark Current	Peak Current
no sample (to establish equipment background)	0.015 nano-coulombs	1.5×10 ⁻¹² amps
15 1 mg. (CaSO _{4(Mn)}) (activated)	1.9 nano-coulombs	1000×10 ⁻¹² amps

In the above case the total charge is approximately 129 times the dark current energy, and the peak current is approximately 667 times the peak dark current. For this material the peak current is therefore a more sensitive measurement than total charge.

For purposes of this disclosure, the use of T.L. materials as a means of authenticating articles or objects as to a predetermined code, it is difficult to set specific quantitative parameters as to minimum amounts of T.L. phosphors to be applied to the article or object. The factors governing such a minimum quantity will depend on many factors, including the following:

1. The specific T.L. phosphor employed.
2. The background thermoluminescence (if any) of the object to which it is applied.
3. The specific input, or activating energy.
4. The efficiency of the detector system used to survey the discharge emissions at the temperature which is practical for the object or material to be verified or authenticated.
5. The output of secondary emission energy, or, alternatively, the peak current, on discharge as a function of the primary or activating energy. (This is the efficiency factor of the specific T.L. phosphor.)
6. The readout time, at or above the discharge emission temperature.

All of the above parameters add up to defining a total system. In order to obtain a significant readout signal for any total system, as described above, the output of secondary emission in terms of energy or peak current measurement for a given system when the T.L. phosphor is activated, should exceed the same measurement for the same system, inactivated, by a factor of at least two. It would be preferable to have this factor higher, and in actual practice it can easily be exceeded by many times, but a factor of two should generally be enough to discriminate against accidental surface contamination.

The maximum factor, as defined above, is not material, except that it is desirable, in the interest of security, that the readout energy, or intensity, be less than that which could be visible to the naked eye in a dark room, so that the presence of T.L. phosphors is not obvious.

In some cases it may be useful to take advantage of the long term storage capabilities of some phosphors or the relatively short term storage capabilities of others. As mentioned before, T.L.D.—100 loses about 5 percent of its charge per year. However, (CaSO_{4(Mn)}) has

a half-life (loses half its charge) of one hundred 100 hours.

Some T.L. phosphors are capable of giving off emissions of a part of the activating energy shortly after activation even without heating. Such phosphors can therefore be read at ambient temperatures for a substantial period after activation.

In the case of long term storage, such materials can be used to detect stolen airline tickets or other documents which are used only once. Contrary to the previously mentioned applications, where the tagged object is activated immediately prior to readout, a ticket can be activated, and thereby validated when delivered to a customer. It would therefore contain a long life message which can be read out at the time of presentation to the carrier. Unissued tickets would have no message. Other examples of such use are numerous.

In the case of long or short term storage, such materials can be useful in determining the age of a tagged material. For instance, many materials lose their usefulness, or become dangerous after a certain length of time. Food products and medicines are two prime examples. Tagging labels with a T.L. material of suitable half-life can provide a positive means of establishing age.

For example, in order to verify the authenticity of a credit card, an arbitrary or random number is assigned to the owner of the card which is known to him alone (other than the issuer of the card) and does not appear on the card except as a coded pattern as described below. This number is composed of as many digits as can conveniently be remembered, such as five or six digits. In terms of binary digital language, the formula for "on-off", "yes-no" or "go-no-go" signals commonly called "bits", is a function of two to the nth power (2^n). In specific terms 2^{14} equals 16,384, 2^{17} equals 131,072, etc. Therefore, with 14 "on-off" combinations one can count to 16,384 in binary language. This should be enough to discriminate against the coincidental guessing of a number not known to the user of a credit card.

For this purpose such a number is easily encoded into the card by embedding very small quantities of a suitable T.L. material into or under the surface of the card, so that it is not easily rubbed off. The quantities required for each "bit" are very small and should be unnoticeable, since most T.L. materials are essentially transparent. It is practical to arrange at least 18 or more such signal generators in one continuous line, horizontally or vertically or otherwise on the usual credit card dimensions without having them spaced too closely for readout purposes. The "on" signal would be a small dot of T.L. phosphor. The "off" signal would be either a blank space or a dot of the same chemical compound without the "dopant" which causes it to emit significantly detectable radiation when it is above the readout temperature.

In the above example the specific wave length can be ignored as long as the detector system will respond to it, and the specific amplitude is not important as long as it is enough to discriminate against accidental contamination as discussed above.

The readout mechanism can consist of a single P.M. tube, or other suitable detector, which is arranged so as to have a sufficiently narrow field of view so that it can "see" only one dot or signal location at a time. The

credit card can be inserted into a box which contains:

1. A source of energy to activate the T.L. phosphor, i.e., ultra-violet, x-ray, or gamma-ray source.
 2. A source of heat, if necessary, for readout of the T.L. phosphor employed. (See (6) below.)
 3. A means for the card-owner, or "customer" to dial or punch-in (via disc or keyboard) his own secret identification number.
 4. A means of storing the above signal for comparison with the signal created by "reading" the card with a detector as described below. Such "comparison circuits" are well known in electronics.
 5. A P.M. tube or other detector which can see or read only one signal at a time from the card.
 6. A mechanical means of advancing or moving the card from one signal location to the next. This can be a spring loaded device which is activated by inserting the card and ejects the card in a ratchet type movement, so that each signal or "bit" is positioned under the detector in sequence. In this example it is simple to select a T.L. material that reads out below ambient temperatures and has a persistent afterglow, or half life, long enough for readout of all signals without needing a heater.
 7. A readout signal which could consist of one red and one green light tube or window mounted so as to be visible to the clerk or salesperson. One of these lights would indicate that the numbers coded into the device by the customer matches the numbers coded into the device by the signals on the card. The other light would indicate that they do not match. (This process is handled by the comparison circuit mentioned in (4) above.)
- This example is only one of many possibilities for variations on the principles included in the claims for systems which follow.

A method of practicing this invention is illustrated by the following example. This example is intended merely to illustrate the invention and not in any sense to limit the manner in which the invention can be practiced. The parts and percentages recited therein and all through the specification, unless specifically provided otherwise, are by weight.

EXAMPLE

A laminated plastic credit card is assembled and sealed with a number of "bits" or traces of T.L.D.-100 phosphor embedded in an appropriate pattern to give the number 167,489 in accordance with the arrangement shown below where the X's indicate the location of a trace of phosphor; and the 0's indicate a blank or false phosphor. (To code the above number requires 18 bits when one dimensional coding is employed.):

0	X	X	0	X	0	0	0	0	X	X	0	0	0	0	X	0	X
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This series can represent any number up to 2^{18} , but can be assigned the value 167,489 in a master code. The cured or sealed card is placed in an activating radiation field and exposed to 1 roentgen of gamma radiation in a few seconds and then in a readout device having a single P.M. tube as described above which surveys each location in sequence. The presence or absence of light emission above a pre-set level is distinguished by the detector. Impulses from the detector are matched to

the code stored in the device's logic circuit and the corresponding number is recognized. This number can be displayed visually and compared to the number given by the user; or preferably not displayed, but compared electronically to a number dialed or keyboarded into the reader by the cardholder so that the actual number is not made visible to anyone.

While certain features of this invention have been described in detail with respect to various embodiments thereof, it will, of course, be apparent that other modifications can be made within the spirit and scope of this invention and it is not intended to limit the invention to the exact details shown above except insofar as they are defined in the following claims:

The invention claimed is:

1. A process for identifying a document comprising the steps of:

- a. embedding a small amount of a thermoluminescent phosphor in one or more small confined areas of the document, said areas being arranged to give a coded message upon subsequent readout;
 - b. exposing said document to an activating radiation for said phosphor at a temperature at which the energy imparted by activating radiation will not be immediately discharged;
 - c. thereafter positioning said document in a readout device capable of interpreting the coded message; and
 - d. increasing the temperature of said document to a temperature at which said phosphor will discharge the radiation energy stored therein.
2. The process of claim 1 in which said activation is effected at room temperature.

3. The process of claim 2 in which the temperature in said readout device is increased to about 80°-85° C.

4. The process of claim 1 in which the amount of phosphor in different areas is varied to give different amplitudes of energy upon readout.

5. The process of claim 1 in which said message is encoded by using two or more thermoluminescent phosphors with different emission frequencies.

6. The process of claim 5 in which said message is coded and decoded by the spatial arrangement of said different phosphors.

7. The process of claim 5 in which said message is coded and decoded by the use of band-pass filters to separate the emission from said phosphors.

8. The process of claim 1 in which said document is dated by the use of a phosphor having a half-life appropriate for the time lapse desired to be identified.

9. The process of claim 1 in which said phosphor is one that discharges at least a portion of the activating energy at ambient temperature so that deliberate heating of the document is not required.

10. An identifiable document having a small amount of thermoluminescent phosphor embedded in one or more small confined areas of said document, the number and positioning of said areas being designed by predetermined code to give specific identifying information, said phosphor being capable of activation by radiation at room temperature and capable of discharging the stored radiation energy therein and thereby the identifying information upon increasing the temperature of said document.

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