A cartridge includes a case and a bullet received in the case. The bullet has an encrypted spectral taggant therein. Optionally, the bullet includes a slug and the encrypted spectral taggant may be embedded in the slug. The slug may have a metal matrix material and the encrypted spectral taggant may be mixed with the metal matrix material to form a generally uniform composition. The material of the slug may be doped with the encrypted spectral taggant. Optionally, the bullet includes a jacket surrounding the slug. At least one of the slug, the jacket and the case may have swage lubricant or sealer thereon with the encrypted spectral taggant part of the swage lubricant or sealer. Optionally, the encrypted spectral taggant may be coded for identification purposes. The encrypted spectral taggant may be luminescent and/or fluorescent.
Inserting a bullet into a case

Inserting a propellant and a primer into the case

Providing an encrypted spectral taggant
ENCRYPTED SPECTRAL TAGGANT FOR A CARTRIDGE

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 61/969,454 filed Mar. 24, 2014 entitled ENCRYPTED SPECTRAL TAGGANT FOR A CARTRIDGE, the subject matter of which is herein incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] The subject matter herein relates generally to encrypted spectral taggants.

[0003] There has long been a desire to identify bullets, such as to determine the source of a bullet, a gun that fired a bullet, who shot the bullet, and the like. Prior attempts to identify bullets included laser engraving of the bullet; however when the bullet strikes a target the bullet will shatter or fragment. There may not be enough material to recover for forensic testing of the pieces to properly identify the bullet. Other attempts to identify bullets included the addition of pollen, DNA or other organic material having encoded identifiers on the outside of the bullet. Gathering of such material allows for identification, however due to the ballistic nature of firing the bullet and the high pressures and temperatures, much or all of the encoded organic material is non-existent or un-recoverable for forensic analysis. For example, the material may burn away when the bullet is fired. Furthermore, such materials are unable to be mixed into the material of the slug of the bullet as the material will burn away at the high temperatures needed to form the slug. Additionally, the forensic analysis of such materials is tedious and difficult.

[0004] Accordingly, a need remains for a cartridge identification system and a machine readable Encrypted Spectral Taggant (EST) for a cartridge that may be manufactured, used and identified in a cost effective and reliable manner.

BRIEF DESCRIPTION OF THE INVENTION

[0005] In one embodiment, a cartridge is provided including a case and a bullet received in the case. The bullet has an encrypted spectral taggant therein.

[0006] Optionally, the bullet includes a slug and the encrypted spectral taggant may be embedded in the slug. The slug may have a metal matrix material and the encrypted spectral taggant may be mixed with the metal matrix material to form a generally uniform composition. The material of the slug may be doped with the encrypted spectral taggant. Optionally, the bullet includes a jacket surrounding the slug. At least one of the slug and the jacket may have swage lubricant thereon. The encrypted spectral taggant may be part of the swage lubricant. Optionally, the slug may have a pocket formed at a rear of the slug. An epoxy filler may be received in the pocket and the encrypted spectral taggant may be mixed with the epoxy filler. Optionally, the base of core may be affixed with a synthetic label/tag containing encrypted spectral taggant and then encapsulated by the bullet jacket.

[0007] Optionally, the bullet may include a slug and at least one of the slug and the case may have a sealer applied thereto with the encrypted spectral taggant being part of the sealer. Optionally, the cartridge may include a primer and the encrypted spectral taggant may be provided at the primer. The encrypted spectral taggant may be provided on the case. Optionally, the cartridge may include a wad and the encrypted spectral taggant may be provided on the wad.

[0008] Optionally, the encrypted spectral taggant may be coded for identification purposes. The encrypted spectral taggant may be luminescent. The encrypted spectral taggant may be fluorescent. The encrypted spectral taggant may be a luminescent composition. The encrypted spectral taggant may have a characteristic emission spectrum. The encrypted spectral taggant may have a crystalline structure. The encrypted spectral taggant may have a lumino phosphor that can be effected by irradiation with a wavelength in the infrared or ultraviolet range. The encrypted spectral taggant may include a lanthanide as a dopant. The encrypted spectral taggant may be in the form of particles.

[0009] Optionally, the encrypted spectral taggant may be a compound including rare earth metals. The encrypted spectral taggant may be a compound including more than one rare earth metal. The encrypted spectral taggant may be a compound including more than one lanthanoid elements. The encrypted spectral taggant may be a compound including yttrium and at least one or more lanthanoid elements.

[0010] In another embodiment, a cartridge identification system is provided that includes a cartridge having a case and a bullet received in the case. The bullet has an encrypted spectral taggant therein. The encrypted spectral taggant has a lumino phosphor. The cartridge identification system also includes a reading system having a radiation source and one or more optical detectors for the selective detection of specific emission lines of the lumino phosphor of the encrypted spectral taggant.

[0011] In a further embodiment, a method of manufacturing a cartridge is provided including inserting a bullet into a case of the cartridge, and providing an encrypted spectral taggant on or in at least one of the bullet and the case.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] FIGS. 1-4 illustrate a cartridge formed in accordance with an exemplary embodiment.

[0013] FIG. 5 illustrates a shotshell type cartridge formed in accordance with an exemplary embodiment.

[0014] FIG. 6 illustrates a method of assembling a cartridge in accordance with an exemplary embodiment.

[0015] FIG. 7 illustrates a cartridge identification system for identifying a cartridge.

[0016] FIG. 8 shows an X-ray powder diffraction measurement on a sample of a luminescent composition.

DETAILED DESCRIPTION OF THE INVENTION

[0017] FIGS. 1-4 illustrate a cartridge 100 formed in accordance with an exemplary embodiment. The cartridge 100 includes a case 102 with a propellant 103 and a bullet 104 received in the case 102. The bullet 104 has an encrypted spectral taggant 110 therein. The bullet 104 may be jacketed or unjacketed.

[0018] Optionally, the bullet 104 includes a slug 112 and the encrypted spectral taggant 110 may be embedded in the slug 112. FIG. 1 illustrates the encrypted spectral taggant 110 (not shown to scale, for example, may have particle size of micrometer or nanometer) embedded in the slug 112 and contained together. FIG. 2 illustrates the encrypted spectral taggant 110 embedded in the slug 112 and dispersed throughout the material of the slug 112. For example, the slug 112 may have a metal matrix material and the encrypted spectral taggant 110 may be mixed with the metal matrix material to
form a generally uniform composition. Optionally, the slug 112 may be a lead slug and the encrypted spectral taggant 110 may be mixed with the lead material, such as in or prior to the molten state. The encrypted spectral taggant 110 may have a high melting temperature to withstand temperatures of molten metal material. In other embodiments, the slug 112 may be a copper and tungsten metal matrix mixture and the encrypted spectral taggant 110 may be mixed with the copper and tungsten. The material of the slug 112 may be doped with the encrypted spectral taggant 110.

[0019] Optionally, the bullet 104 includes a jacket 114 surrounding the slug 112. For example, FIG. 3 illustrates a jacketed bullet. At least one of the slug 112 and the jacket 114 may have swage lubricant 116 thereon. For example, the swage lubricant 116 may be between the slug 112 and the jacket 114 or the swage lubricant 116 may be between the jacket 114 and the case 102. The encrypted spectral taggant 110 may be part of the swage lubricant 116. For example, the encrypted spectral taggant 110 may be mixed into the swage lubricant 116.

[0020] The encrypted spectral taggant 110 may be provided in other lubricants or sealers used with the cartridge 100. For example, the cartridge 100 may have a shell casing sealer used to prevent moisture from creeping in around the primer cap and bullet crimp. The shell casing sealer may serve as a tamper/reloaded casing witness mark. For example, some commercial manufacturers have color codes and in the event of a casing failure complaint, the manufacturer can see if the original primer was replaced in a reload failure. The encrypted spectral taggant 110 may be provided in the shell casing sealer and may be used to identify the cartridge, such as for tamper/reloading witness mark identification. The encrypted spectral taggant laced sealer may be transferred to the firing pin from the primer face and encrypted spectral taggant residue may be found in the bore, as the encrypted spectral taggant may be scraped off as the bullet moves down the barrel. Using the encrypted spectral taggant 110 as part of the sealant or elsewhere is a cost effective method to tag a round. The encrypted spectral taggant 110 would not affect the propellant or the physical/mechanical properties of the slug 112.

[0021] Optionally, as shown in FIG. 4, the slug 112 may have a pocket 118 formed at a rear of the slug 112. An epoxy filler 120 may be received in the pocket 118 and the encrypted spectral taggant 110 may be mixed with the epoxy filler 120. Portions of the epoxy filler 120 may be expelled during firing of the bullet 104 such that some of the encrypted spectral taggant 110 is deposited on the gun, such as on the lands, barrel, crown of the barrel, and the like, as residue that may be identified with forensic investigation. Even if there is cross-contamination from different bullets 104 fired from a gun, a reader system is still able to uniquely identify and differentiate different residue, such as when the encrypted spectral taggant 110 is coded. Optionally, a synthetic label/tag containing the encrypted spectral taggant 110 is encapsulated by the bullet jacket.

[0022] Optionally, the encrypted spectral taggant 110 may be a compound including rare earth metals. The encrypted spectral taggant 110 may be a compound including more than one rare earth metal. The encrypted spectral taggant 110 may be a compound including more than one lanthanoid elements. The encrypted spectral taggant 110 may be a compound including yttrium and at least one lanthanoid element. The encrypted spectral taggant 110 may be embodied in elements other than lanthanoid elements. The encrypted spectral taggant 110 may include an organic and inorganic luminophore as a dopant. The encrypted spectral taggant 110 may include an activator, such as a dopant activator. For example, the crystalline composition of the encrypted spectral taggant may include a fluoride material as a peak enhancer for the encrypted spectral taggant 110. The encrypted spectral taggant 110 may be in the form of particles. The encrypted spectral taggant 110 may have a crystalline structure. The encrypted spectral taggant 110 may be embodied in glass beads, garnet crystals, Kevlar strands, organic or inorganic dies, and the like.

[0023] Optionally, the encrypted spectral taggant 110 may be luminescent. The encrypted spectral taggant 110 may be fluorescent. The encrypted spectral taggant 110 can release radiation, such as light, which may be caused by chemical reactions, electrical energy, subatomic motions, or stress on the crystalline form of the encrypted spectral taggant 110. For example, when excited by an ultraviolet (UV) or infrared (IR) beam, the encrypted spectral taggant 110 may absorb the energy and release radiation. Such radiation may be detected by a reading system (FIG. 7) of a cartridge identification system having one or more detectors for the detection of emissions from the encrypted spectral taggant 110.

[0024] FIG. 5 illustrates a shotshell-type cartridge 200 formed in accordance with an exemplary embodiment. The cartridge 200 may be used with a shotgun or other type of firearm. The cartridge 200 includes a case or shell 202 with a propellant 203 and one or more bullets 204, also referred to as shots, received in the shell 202. The cartridge 200 includes a wad 206 between the propellant 203 and the bullets 204. The cartridge 200 includes a primer 208 at a base of the cartridge 200. The cartridge 200 has an encrypted spectral taggant 210 (represented schematically in various possible locations, the encrypted spectral taggant 210 may be used in one or more locations) therein.

[0025] Optionally, the encrypted spectral taggant 210 may be embedded in the bullets 204. For example, the bullets 204 may have a metal matrix material and the encrypted spectral taggant 210 may be mixed with the metal matrix material to form a generally uniform composition. The material of the bullets 204 may be doped with the encrypted spectral taggant 210. In various embodiments, the encrypted spectral taggant 210 may be applied to an exterior of the bullets 204.

[0026] Optionally, the encrypted spectral taggant 210 may be associated with the wad 206. For example, the encrypted spectral taggant 210 may coat at least a portion of the wad 206. The encrypted spectral taggant 210 may be embedded or sealed in the wad 206. The encrypted spectral taggant 210 may be applied to the wad 206 by other techniques in alternative embodiments.

[0027] Optionally, the encrypted spectral taggant 210 may be associated with sealant used in the cartridge 200. For example, sealant may be used at the primer 208, at the base, at the wad 206, or elsewhere. The encrypted spectral taggant 210 may be embedded in the sealant.

[0028] Optionally, the encrypted spectral taggant 210 may be associated with the shell 202. For example, the encrypted spectral taggant 210 may be applied to the shell 202. The encrypted spectral taggant 210 may be embedded in the plastic used to form the shell 202. The encrypted spectral taggant 210 may be applied to the shell 202 by other techniques in alternative embodiments.

[0029] Optionally, the encrypted spectral taggant 210 may be a compound including rare earth metals. The encrypted spectral taggant 210 may be a compound including more than
one rare earth metal. The encrypted spectral taggant 210 may be a compound including more than one lanthanoid elements. The encrypted spectral taggant 210 may be a compound including yttrium and at least one lanthanoid element. The encrypted spectral taggant 210 may be embodied in elements other than lanthanoid elements. The encrypted spectral taggant 210 may include an organic and inorganic luminophore as a dopant. The encrypted spectral taggant 210 may include an activator, such as a dopant activator. For example, the crystalline composition of the encrypted spectral taggant may include a fluoride material as a peak enhancer for the encrypted spectral taggant 210. The encrypted spectral taggant 210 may be in the form of particles. The encrypted spectral taggant 210 may have a crystalline structure. The encrypted spectral taggant 210 may be embodied in glass beads, garnet crystals, Kevlar strands, organic or inorganic dies, and the like.

[0030] Optionally, the encrypted spectral taggant 210 may be luminescent. The encrypted spectral taggant 210 may be fluorescent. The encrypted spectral taggant 210 can release radiation, such as light, which may be caused by chemical reactions, electrical energy, subatomic motions, or stress on the crystalline form of the encrypted spectral taggant 210. For example, when excited by a ultraviolet (UV) or infrared (IR) beam, the encrypted spectral taggant 210 may absorb the energy and release radiation. Such radiation may be detected by a reading system (FIG. 7) of a cartridge identification system having one or more detectors for the detection of emissions from the encrypted spectral taggant 210.

[0031] FIG. 6 is a method 300 of manufacturing a cartridge. The method 300 includes inserting 302 a bullet into a case of the cartridge. The method 300 includes inserting 304 a propellant and a primer into the case. The bullet may be a slug. The bullet may be shot. The bullet may be jacketed or unjacketed. The case may be metal, plastic or another suitable material. The case may be crimped to the bullet. Sealers or lubricants may be provided between the case and the bullet. The sealers or lubricants may be provided on the case, on the bullet or on both the case and the bullet.

[0032] The method 300 includes providing 306 an encrypted spectral taggant on or in at least one of the bullet and the case. For example, the encrypted spectral taggant may be embodied in the bullet, such as when the bullet is manufactured. The encrypted spectral taggant may be provided on the exterior of the bullet, such as a coating. The encrypted spectral taggant may be provided in the sealer or lubricant used with the bullet and the case. The encrypted spectral taggant may be provided in or on a wad of the bullet, such as when manufacturing a shotgun shell. The encrypted spectral taggant may be provided in or on the case. The encrypted spectral taggant may be provided in or on the primer. The encrypted spectral taggant may be provided at other locations or on other structures of the cartridge in various embodiments.

[0033] FIG. 7 illustrates a cartridge identification system 130 showing a reading system 132 having a radiation source 134 and one or more detectors 136. The detectors 136 may be optical detectors; however the detectors 136 are not limited to optical detectors. The detectors 136 may be used for the selective detection of specific emission lines of the radiated energy or luminophor of the encrypted spectral taggant 110. The cartridge identification system 130 may be able to reliably identify the encrypted spectral taggant 110 in small doses. For example, the bullet 104 may require less than 1000 parts per million (ppm) of the encrypted spectral taggant 110 for proper identification by the cartridge identification system 130. The bullet may require less than 500 ppm of the encrypted spectral taggant 110 for proper identification by the cartridge identification system 130.

[0034] Optionally, the encrypted spectral taggant 110 may be coded for identification purposes. In an exemplary embodiment, the encrypted spectral taggant 110 cannot be reproduced, copied, or faked making authentication reliable. Such coding may cause the encrypted spectral taggant 110 to have a characteristic emission spectrum that can be detected. For example, the waveform or frequencies of the radiated energy can be digitized and analyzed by the reading system 132. The cartridge identification system 130 uses a lock and key principal for a reliable authentication solution, where the encrypted spectral taggant 110 defines the lock with the coded data and the reading system 132 providing the key being able to decipher the coded data. The unique signature or code of the encrypted spectral taggant 110 may allow forensic analysis to determine characteristics of the bullet 104, such as the source of the bullet (e.g. the manufacturer, the batch of manufacture, the point of purchase, the owner, the shooter, and the like) and may be used to match the bullet 104 to a particular gun (e.g. forensic analysis of the gun could be performed by the reading system 132 because some of the encrypted spectral taggant 110 may be left on the gun).

[0035] The encrypted spectral taggant 110 may have a lumiphor that can be affected by irradiation with a wavelength in the infrared range. The encrypted spectral taggant 110 may be coded by forming the encrypted spectral taggant 110 with different combinations of elements, such as lanthanoid elements. For example, the crystalline form of the encrypted spectral taggant 110 may be changed by changing the combination of elements, creating a unique encrypted spectral taggant 110 that luminesces at different frequencies, causing a different or unique digital waveform. The encrypted spectral taggant 110 may be created from purified up-converting nanocrystal compounds with unique spectral properties capable of being encoded with specific encrypted information or data. The encrypted spectral taggant 110 may be encoded with encrypted information into well-defined absorption and emission spectra of specially formulated encrypted spectral taggant 110. By manipulating spectroscopic features such as temporal and spectral aspects of anti-Stokes shift and the shape and lifetime of luminescence emission decay curves, the encrypted spectral taggant 110 can be coded with many unique codes.

[0036] The encrypted spectral taggant 110 may be a luminescent composition, such as the luminescent composition described by Ebert in U.S. application Ser. No. 12/306,567 titled LUMINESCENT COMPOSITION, the subject matter of which is incorporated by reference herein. An exemplary embodiment of the luminescent composition is described below. The luminescent composition may be based on yttrium oxide sulfide and further oxide sulfides and at least one dopant may have been added. The composition has a characteristic emission spectrum and can, if appropriate together with a reading system matched to the emission spectrum, be used for marking materials or mixtures of materials.

[0037] Compounds containing lanthanide ions in the oxidation state +3 are often luminophors which on excitation with radiation in the infrared range emit shorter wavelength light, e.g. in the visible range and/or in the UV range. This property, referred to as "up conversion" or "anti-Stokes fluorescence", can be attributed to the electrons of the 4f shell of
lanthanide ions being raised by sequential multiple excitation on irradiation to an energy level which has been increased by more than the energy corresponding to absorption of a single photon. A photon which has a higher energy than the originally absorbed photon can be emitted from this energy level on relaxation.

[0038] The use of lanthanide oxide sulfides as anti-Stokes luminophors is described, for example, in WO 00/66527 and in the U.S. Pat. Nos. 6,802,992 and 6,686,974.

[0039] Optionally, the luminescent compositions may be based on the oxide sulfides of yttrium and at least three other elements and to which at least one dopant, preferably selected from among oxides and fluorides of main group and transition group elements.

[0040] The luminescent composition may include (a) an oxide sulfide of yttrium and oxide sulfides of at least three further elements selected from among lanthanum, cerium, praseodymium, neodymium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium and lutetium and (b) at least one dopant selected from among oxides and fluorides of main group and transition group elements.

[0041] The composition may be a luminophor having “up converter” and/or “anti-Stokes” properties. It may be in crystalline form. Furthermore, the composition may consist of a single phase, for example a crystalline phase, which can be established by X-ray diffraction methods. The composition is usually in the form of particles having an average particle size of ≤50 μm, or preferably ≤0.1 nm. The particle size is preferably in the range 1 nm-100 μm, preferably 5 nm-50 μm and particularly preferably about 100 nm-10 μm.

[0042] Component (a) of the composition is formed by an oxide sulfide of yttrium and oxide sulfides of at least three further elements as indicated above. Yttrium and the further elements are usually present as trivalent cations, so that component (a) of the composition can preferably be represented as follows:

\[ Y_{2+}O_{3-x}S_{1-x}(M_1^{3+}O_xS_{x}) \]

where M1, M2 and M3 are trivalent cations of at least three of the abovementioned elements and X is a number in the range from 0 to 0.5, preferably from 0 to 0.2. Particular preference is given to X being 0.

[0043] In the total composition (a), the yttrium oxide sulfide is preferably present in a proportion of at least 90 mol %, particularly preferably ≥92 mol %, even more preferably ≥94 mol % and most preferably ≥96 mol %. The further oxide sulfides are preferably present in a proportion of at least 2 mol % based on the total composition (a). The further oxide sulfides are preferably selected from among oxide sulfides of erbium, ytterbium and at least one further element, in particular lutetium, gadolinium, holmium, thulium, dysprosium and/or europium. The oxide sulfides of erbium and ytterbium are preferably present in a proportion of each case 0.5-2 mol %, particularly preferably 1-2 mol %, based on the total composition (a). The further oxide sulfides are preferably used in smaller proportions of, for example, 0.1-1 mol %, particularly preferably 0.1-0.5 mol %, based on the total composition (a).

[0044] For example, the component (a) of the composition can contain oxide sulfides of 3, 4, 5, 6, 7 or even more further elements in addition to the oxide sulfide of yttrium.

[0045] The composition additionally contains, as component (b), at least one dopant selected from among oxides and fluorides of main group and transition group elements. The dopants are preferably present in a proportion of each case up to 5 mol %, particularly preferably in each case up to 2 mol %, even more preferably in each case up to 1 mol %, even more preferably 0.05-1 mol % and most preferably 0.1-0.2 mol %, based on the sum of the components (a) and (b).

[0046] A preferred dopant or activator is a fluoride, which can be used, for example, as an alkaline earth metal fluoride or as an alkali metal fluoride, e.g., as potassium fluoride. The fluoride is preferably present in a proportion of 0.1-0.2 mol %, based on the sum of the components (a) and (b).

[0047] Further preferred dopants are alkaline earth metals and/or transition group elements which are present as cations bearing two or even more positive charges, preferably in the form of oxides and/or fluorides. Particularly preferred dopants are calcium, zinc and/or titanium, for example in the form of the oxides calcium oxide, zinc oxide or titanium dioxide. The cationic dopants are preferably present in a proportion of each case 0.1-0.2 mol %, based on the sum of the components (a) and (b).

[0048] The luminescent compositions comprising the components (a) and (b) firstly have a high luminescence intensity and secondly have emission lines or peaks which are characteristic of the presence and proportions of the individual components. Thus, specific combinations of oxide sulfides and dopants make it possible to obtain a virtually unlimited number of different emission spectra which can be detected by means of a reading system matched specifically to the respective spectrum.

[0049] The compositions can be produced by homogenizing yttrium oxide (Y2O3) powder with oxides of the other elements, e.g., ytterbium oxide (Yb2O3), erbium oxide (Er2O3) and other oxides such as La2O3, Lu2O3, and/or Gd2O3, and also the dopants or precursors thereof, e.g., TiO2, CaCO3, ZnO and/or KF, by milling and subsequently sintering the mixture at elevated temperature, e.g., 1200-1700 °C, in a furnace, preferably in air, in order to achieve homogeneous distribution of the cations in the crystal lattice. The sintered product is subsequently milled and reacted with H4S at temperatures in the range from 700 °C to 1000 °C, preferably for 2-12 h, giving a uniform phase based on Y2O3S containing further oxide sulfides and also the dopants. The addition of fluoride as dopant leads to a homogeneous distribution of the lanthanide ions in the host lattice during the sintering process. The addition of dopants, e.g. polyvalent cations and/or fluoride, brings about drastic changes in the position and intensities of individual emission wavelengths. Furthermore, a large increase in the total luminescence intensity occurs. It is assumed that a three-photon absorption takes place in addition to the two-photon absorption known for anti-Stokes materials.

[0050] The luminophors can be used as detection and marking materials, for example as safety marking of materials or mixtures of materials. In this way, the authenticity of products or documents can be determined. The luminophor can, since it is chemically inert, be introduced into any solid and/or liquid materials or mixtures of materials or be applied thereto. For example, the luminophor can be applied to or introduced into carrier substances such as surface coating compositions, toners, inks, paints, etc., or products such as plastics, metals, glass, silicones, paper, rubber, etc. The luminophor is preferably added to the product or part of the product in an amount of 10-50 ppm, preferably 50-200 ppm. The luminophor is also suitable for use in biological systems, e.g. cell cultures, samples of body fluids or tissue sections or as contrast
enhancer. Here, the luminophor in nanoparticulate or micro-
particulate forms can be coupled to biological detection reagents. Furthermore, the surfaces of particles of the lumi-
nophor can be modified by means of deoxygenating or other bonding substances in order to improve the suspending prop-
eties, e.g. in organic liquids such as oils, naphthas, liquefied gases, etc., in aqueous liquids such as body fluids, in aqueous-
organic liquid systems and flowable powders such as toners. The smaller the particles, the lower is the tendency for sedi-
mentation to occur. The particle size can, for example, be reduced by intensive milling to such an extent, e.g. to ≤100
pm, that a stable suspension of the particles in liquids is achieved even without the addition of bonding substances.

[0052] Security against falsification of the marking is pro-
vided by the emission lines characteristic of the respective luminophor representing a cryptic graphic key which can be
detected by a detector, i.e. the lock, matched to the respective material.

[0053] The detection of the presence of the luminophor can
be effected by irradiation with a wavelength in the infrared
range, in particular with IR monochromatic laser light or with
an IR light-emitting diode having wavelengths in the range
from about 850 to 1500 nm, preferably from about 920 to
1000 nm, particularly preferably about 950-1000 nm, most
preferably from 920 to 985 nm, with the luminophor being
excited and the emitted radiation in the range of wavelengths
characteristic for the respective luminophor, for instance in
the range from 300 to 1700 nm, being detected. Irradiation is
preferably carried out at a power of 1-200 mW, in particular
10-80 mW. The irradiation of the product containing the
luminophor can be carried out directly or by means of an
optical waveguide or another optically relevant transfer
medium, e.g. an optical solid body, a fluid, gas, etc. Detection
can be effected visually or by means of detectors.

[0054] It is possible to use, for example, optical waveguides
whose heads are ground as collecting lenses so that incident
light (IR light) and light emitted by the luminophor (specific
emission spectrum) form one unit and can be focused at the
same point. An advantage is that no mechanical misalignment
between receiver and transmitter can occur. The damping
factor of the optical waveguide, e.g. of glass or plastic, can
vary, with the transition from the optical components (radia-
tion source or detection element) to the optical waveguide
being constructed so as to be low in cession. The length of
the optical waveguide can vary and is typically in the range
from 1 cm to 50 cm.

[0055] In a particularly preferred embodiment, a luminoph-
or having a characteristic emission spectrum is detected by
means of a reading system matched to this emission spec-
trum. The reading system comprises a radiation source, pref-
errably a radiation source in the IR range, and one or more
optical detection elements which are provided for the select-
tive detection of specific emission lines of the luminophor,
e.g. in respect of the wavelength and/or intensity. The detec-
tion elements can be, for example, diodes, photoelements or
electronic detectors. Preference is given to using detector
matrices having a plurality of preferably differently set detec-
tors, e.g. diode matrices, photoelement matrices or CCD
matrices. The detectors or individual detectors of the detector
matrix can be combined with optical filters, e.g. bandpass
filters, which can also be vapor deposited on the detection
element. The filters are preferably selected so that they allow
passage of light in only a particular wavelength range, e.g. a
range of 5-15 nm, preferably about 10 nm. The filters prefer-
ably contain high- and low-refraction layers such as TiO₂ and
SiO₂. This ensures that bandpass filters having very small
rise-fall flanks per optical element are provided. The passage
of light which does not correspond to the wavelength char-
acteristic of the luminophor is prevented.

[0056] The use of detectors or detector matrices which detect
a plurality of emission lines of differing wavelength,
e.g. 2, 3, 4 or more emission lines, which are characteristic of
a particular luminophor makes it possible to provide a veri-
fication system having a high degree of security. The reading
system may, if appropriate, also contain detectors which oper-
ate at wavelengths at which there is no emission line and thus
serve as negative control.

[0057] The reading system can also, if appropriate, contain
a programmable electronic unit which can be reprogrammed
to other emission lines when required.

[0058] Furthermore, a plurality of different luminophors
which can be evaluated either visually on the basis of different
colors and/or by means of detectors can be applied to a prod-
uct or a carrier. These different applications can be arranged
beneath, above or next to one another, so that a complex and
characteristic pattern is obtained. For example, when two
different luminophors are applied next to one another on a
product, irradiation with a suitable IR source results in emis-
sion of two different colors, giving a flip-flop effect.

[0059] Furthermore, embodiments of the luminescent com-
position may be illustrated by the following example.

EXAMPLE 1

Production of a Luminophor

[0060] Pulverulent yttrium oxide was milled together with
pulverulent oxides of ytterbium and erbium, in each case in
proportions of 1-2 mol %, and other lanthanide oxides such as
oxides of holmium, lutetium and/or gadolinium, in each case in
proportions of 0.1-0.5 mol %, and also dopants TiO₂,
CaCO₃, ZnO and/or KF, in each case in proportions of 0.1-0.2
mol %, in a ball mill for 3 hours. The resulting mixtures were
sintered in air at 1500°C in a furnace for 24-72 hours. The
phase purity of the resulting sintered products was confirmed
by X-ray diffraction. The sintered products were subse-
quently milled and the resulting powders were reacted with
H₂S at temperatures in the range from 800°C to 900°C for
2-12 hours. Phase-pure crystalline compounds of the Y₃O₅S
type were obtained, as was confirmed by X-ray diffraction.

[0061] FIG. 8 shows the X-ray powder diffraction measure-
ment on a sample of the composition (Yb, Er, Lu, Y)₂O₅ in the
ratio 1:0.1:0.5:0.5:97.5. The measurement was carried out
using a Siemens D5000 diffractometer (copper K-alpha
radiation). Only lattice reflections of the host lattice Y₂O₃/S
could be seen (formation of mixed crystals by substitution).
Only a slight shift in the reflections caused by other ions
incorporated into the host lattice can be observed. Since no
further reflections are present, the material is a phase-pure
crystalline product containing no further crystalline phases
(secondary phases).

[0062] It is to be understood that the above description is
intended to be illustrative, and not restrictive. For example,
the above-described embodiments (and/or aspects thereof)
may be used in combination with each other. In addition,
many modifications may be made to adapt a particular situa-
tion or material to the teachings of the invention without
departing from its scope. Dimensions, types of materials,
orientations of the various components, and the number and
positions of the various components described herein are intended to define parameters of certain embodiments, and are by no means limiting and are merely exemplary embodiments. Many other embodiments and modifications within the spirit and scope of the claims will be apparent to those of skill in the art upon reviewing the above description. The scope of the invention should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms “comprising” and “wherein.” Moreover, in the following claims, the terms “first,” “second,” and “third,” etc. are used merely as labels, and are not intended to impose numerical requirements on their objects. Further, the limitations of the following claims are not written in means-plus-function format and are not intended to be interpreted based on 35 U.S.C. §112(f), unless and until such claim limitations expressly use the phrase “means for” followed by a statement of function void of further structure.

What is claimed is:

1. A cartridge comprising:
   a case; and
   a bullet received in the case, at least one of the case and the bullet having an encrypted spectral taggant therein.

2. The cartridge of claim 1, wherein the bullet includes a slug, the encrypted spectral taggant being embedded in the slug.

3. The cartridge of claim 1, wherein the bullet includes a slug having a metal matrix material and the encrypted spectral taggant being mixed with the metal matrix material to form a generally uniform composition.

4. The cartridge of claim 1, wherein the bullet includes a slug, the material of the slug being doped with the encrypted spectral taggant.

5. The cartridge of claim 1, wherein the bullet includes a slug and a jacket surrounding the slug, at least one of the slug and the jacket having swage lubricant thereon, the encrypted spectral taggant being part of the swage lubricant.

6. The cartridge of claim 1, wherein the bullet includes a slug, at least one of the slug and the case having a sealer applied thereto, the encrypted spectral taggant being part of the sealer.

7. The cartridge of claim 1, wherein the bullet includes a slug having a pocket formed at a rear of the slug, the bullet including an epoxy filler in the pocket, the encrypted spectral taggant being mixed with the epoxy filler.

8. The cartridge of claim 1, further comprising a primer, the encrypted spectral taggant provided at the primer.

9. The cartridge of claim 1, wherein the encrypted spectral taggant is provided on the case.

10. The cartridge of claim 1, further comprising a wad, the encrypted spectral taggant provided on the wad.

11. The cartridge of claim 1, wherein the encrypted spectral taggant is coded for identification purposes.

12. The cartridge of claim 1, wherein the encrypted spectral taggant is a compound comprising more than one rare earth metal.

13. The cartridge of claim 1, wherein the encrypted spectral taggant is a compound comprising more than one lanthanoid element.

14. The cartridge of claim 1, wherein the encrypted spectral taggant is a compound comprising yttrium and at least one lanthanoid element.

15. The cartridge of claim 1, wherein the encrypted spectral taggant is luminescent.

16. The cartridge of claim 1, wherein the encrypted spectral taggant has a characteristic emission spectrum.

17. The cartridge of claim 1, wherein the encrypted spectral taggant has a luminophor that can be excited by irradiation with a wavelength in the infrared range.

18. The cartridge of claim 1, wherein the encrypted spectral taggant includes a fluoride as a dopant.

19. A cartridge identification system comprising:
   a cartridge comprising a case and a bullet received in the case, the bullet having an encrypted spectral taggant therein, the encrypted spectral taggant having a luminophor; and
   a reading system comprising a radiation source and one or more detectors for the selective detection of specific emission lines of the luminophor of the encrypted spectral taggant.

20. A method of manufacturing a cartridge comprising:
   inserting a bullet into a case of the cartridge; and
   providing an encrypted spectral taggant on or in at least one of the bullet and the case.

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