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(54) **METHOD FOR PREPARING
PYROTECHNICS OXIDIZED BY BASIC
METAL NITRATE**

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(57) **ABSTRACT**

A method for preparing pyrotechnics oxidized by basic metal nitrate is provided wherein basic metal nitrate is formed in an aqueous slurry to which is added at least one additional pyrotechnic ingredient including at least one fuel material to form a pyrotechnic mixture. The so-formed pyrotechnic mixture is then dried to form a pyrotechnic powder and such may, if desired, be appropriately formed or shaped to assist or facilitate use in inflator devices such as used in vehicle occupant safety restraint systems.

METHOD FOR PREPARING PYROTECHNICS OXIDIZED BY BASIC METAL NITRATE

BACKGROUND OF THE INVENTION

[0001] This invention relates generally to pyrotechnic materials, such as those used in the inflation of automotive inflatable restraint airbag cushions and, more particularly, to such pyrotechnics oxidized by or with basic metal nitrate.

[0002] Pyrotechnic materials are useful in a number of different contexts. One significant use for such materials is in the operation of vehicle occupant safety restraint systems such as for the inflation of automotive inflatable restraint airbag cushions.

[0003] It is well known to protect a vehicle occupant using a cushion or bag, e.g., an "airbag cushion," that is inflated or expanded with gas when the vehicle encounters sudden deceleration, such as in the event of a collision. In such systems, the airbag cushion is normally housed in an uninflated and folded condition to minimize space requirements. Upon actuation of the system, the cushion begins to be inflated or expanded, in a matter of no more than a few milliseconds, with gas produced or supplied by a device commonly referred to as an "inflator." The airbag cushion is designed to inflate into a location within the vehicle between the occupant and certain parts of the vehicle interior, such as the doors, steering wheel, instrument panel or the like, to prevent or avoid the occupant from forcibly striking such parts of the vehicle interior. As a consequence, nearly instantaneous gas generation is generally desired and required for the effective operation of such inflatable restraint installations.

[0004] Various pyrotechnics and other gas generant compositions have heretofore been proposed for use in vehicular occupant inflatable restraint systems. Gas generant compositions commonly utilized in the inflation of automotive inflatable restraint airbag cushions have previously most typically employed or been based on sodium azide. Such sodium azide-based compositions, upon initiation, normally produce or form nitrogen gas. While the use of sodium azide and certain other azide-based gas generant materials meets current industry specifications, guidelines and standards, such use may involve or raise potential concerns such as involving the safe and effective handling, supplying and ultimate disposing of such gas generant materials. Thus, there remains a need for safe and effective gas generants such as composed of a fuel material and an oxidizer therefor such as upon actuation react to form or produce an inflation gas for inflating vehicular safety restraint devices.

[0005] Basic copper nitrate, such as having the empirical formula $\text{Cu}_2(\text{OH})_3\text{NO}_3$ or alternatively $(\text{Cu}(\text{NO}_3)_2 \cdot 3\text{Cu}(\text{OH})_2)$, (sometimes referred to herein by the notation "bCN"), has or exhibits various properties or characteristics including, for example, high gas output, density and thermal stability and relatively low cost such as to render basic copper nitrate attractive or desirable for the use as an oxidizer material in gas generant compositions. The use of such basic copper nitrate or related materials has been the subject of various patents including Barnes et al, U.S. Pat. No. 5,608,183, issued 04 Mar. 1997 and Barnes et al, U.S. Pat. No. 5,635,688, issued 03 Jun. 1997, the disclosures of which are fully incorporated herein by reference.

[0006] Unfortunately, the manufacture and production of basic copper nitrate has, in the past, generally proven to be more complicated or involved than would otherwise be desired. For example, a typical process for the preparation of a basic copper nitrate-oxidized pyrotechnic is via the following discrete steps:

- [0007] 1. react copper nitrate with sodium hydroxide in an aqueous solution;
- [0008] 2. filter the precipitated basic copper nitrate;
- [0009] 3. wash the basic copper nitrate precipitate with water to remove sodium nitrate by-product;
- [0010] 4. slurry the washed basic copper nitrate precipitate in water;
- [0011] 5. spray dry the slurry mixture;
- [0012] 6. combine the basic copper nitrate with the other pyrotechnic ingredients in an aqueous slurry;
- [0013] 7. spray dry the slurry mixture to form the pyrotechnic powder; and
- [0014] 8. press the pyrotechnic powder into tablets or wafers.

[0015] As will be appreciated, such a typical preparation process involves many steps, including steps directed to removal of various side products or other possibly undesired by-products.

[0016] Thus there is a need and a demand for a simplified method for preparing pyrotechnics oxidized at least in part by one or more basic metal nitrate, such as basic copper nitrate, and such as may desirably reduce the number of process steps such as by minimizing or avoiding the need for the separation of by-products and such as may serve to reduce or lower the costs associated with the manufacture or production of pyrotechnics so oxidized.

SUMMARY OF THE INVENTION

[0017] A general object of the invention is to provide an improved method for preparing pyrotechnics oxidized by or with basic metal nitrate.

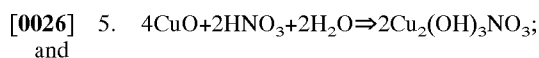
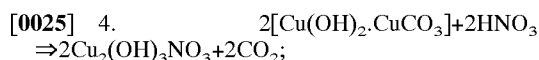
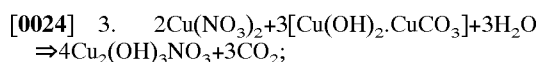
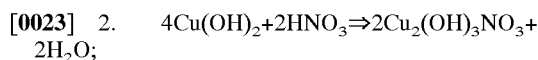
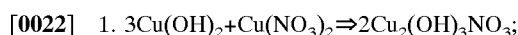
[0018] A more specific objective of the invention is to overcome one or more of the problems described above.

[0019] The general object of the invention can be attained, at least in part, through a method for preparing a pyrotechnic at least in part oxidized by at least one basic metal nitrate wherein the at least one basic metal nitrate is formed in an aqueous slurry. In accordance with the invention, at least one additional pyrotechnic ingredient including at least one fuel material is included in the slurry to form a pyrotechnic mixture. In accordance with one embodiment of the invention, the at least one such additional pyrotechnic ingredient is included in the aqueous slurry prior to the forming of the basic metal nitrate. In accordance with another embodiment of the invention, the at least one additional pyrotechnic ingredient is included in the aqueous slurry subsequent to the forming of the basic metal nitrate. In either case, the pyrotechnic mixture is subsequently dried to a pyrotechnic powder.

[0020] The prior art generally fails to provide a method for preparing or making pyrotechnics oxidized by or with a

basic metal nitrate, such as basic copper nitrate, that is as simple and as cost effective as may be desired. In particular, the prior art generally fails to provide a simplified method for preparing pyrotechnics oxidized by a basic metal nitrate, such as basic copper nitrate, which method may desirably reduce the number of process steps such as by minimizing or avoiding the need for the separation of by-products and such as may serve to reduce or lower the costs associated with the manufacture or production of such pyrotechnics.

[0021] In accordance with another preferred embodiment of the invention, a pyrotechnic at least in part oxidized by basic copper nitrate is prepared by a method wherein basic copper nitrate is formed in an aqueous slurry via a reaction selected from the group consisting of:



[0028] Additional pyrotechnic ingredients including at least one fuel material and at least one oxide additive selected from the group consisting of silicon dioxide, aluminum oxide, titanium dioxide, zinc oxide and combinations thereof are added to the slurry to form a mixture. The mixture is subsequently spray-dried to form a pyrotechnic powder. The pyrotechnic powder is subsequently press-formed into a desired form.

[0029] As used herein, references to a specific composition, component or material as a "fuel" are to be understood to refer to a chemical which generally lacks sufficient oxygen to burn completely to CO_2 , H_2O and N_2 .

[0030] Correspondingly, references herein to a specific composition, component or material as an "oxidizer" are to be understood to refer to a chemical generally having more than sufficient oxygen to burn completely to CO_2 , H_2O and N_2 .

[0031] Basic metal nitrates, as used herein, can generally be represented by the generalized empirical formula $(\text{Me}, \text{M})_3(\text{OH})_3\text{NO}_3$ or alternatively $(\text{Me}, \text{M})_5(\text{OH})_8(\text{NO}_3)_2$, where Me and M can be the same or different metals.

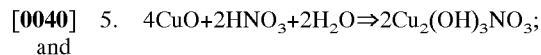
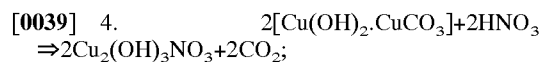
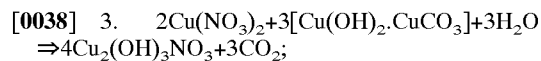
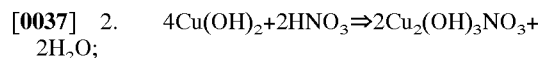
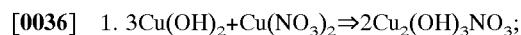
[0032] Other objects and advantages will be apparent to those skilled in the art from the following detailed description taken in conjunction with the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

[0033] The present invention provides a method for preparing a pyrotechnic at least in part oxidized by at least one basic metal nitrate and such as may desirably be used as a gas generant material for use in the inflation of inflatable devices such as vehicle occupant restraint airbag cushions.

[0034] In accordance with a preferred embodiment of the invention and as described in greater detail below, a method for preparing a pyrotechnic at least in part oxidized by at least one basic metal nitrate involves preparing or forming the basic metal nitrate in an aqueous slurry. While the invention will be described in greater detail hereinbelow making specific reference to the preparation and the pyrotechnic incorporation of the basic metal nitrate known as basic copper nitrate, those skilled in the art and guided by the teachings herein provided will appreciate that the broader practice of the invention is not necessarily so limited as, for example, other basic metal nitrates can be correspondingly prepared and used. In particular, in the generalized empirical formula $(\text{Me}, \text{M})_2(\text{OH})_3\text{NO}_3$ or, alternatively, $(\text{Me}, \text{M})_5(\text{OH})_8(\text{NO}_3)_2$, wherein the metals M and Me can be the same or different, metals whose oxides and nitrates that have been experimentally verified to react include copper, cobalt, zinc, chromium, and nickel. For instance, cupric oxide and cobalt nitrate react to form $(\text{Cu}, \text{Co})_2(\text{OH})_3\text{NO}_3$ and zinc oxide and zinc nitrate react to form $\text{Zn}_5(\text{OH})_8(\text{NO}_3)_2$. Those skilled in the art and guided by the teachings herein provided will appreciate that a wide range of combinations and permutations in accordance with the invention can be realized and obtained. Further, while each or various of such materials can find various applications such as in pyrotechnic formulation as an oxidizer, for example, basic copper nitrate is a currently preferred material for such use or application because of factors such as generally resulting in higher gas yields with generally lower or reduced costs and toxicities.

[0035] Those skilled in the art and guided by the teachings herein provided will appreciate that various reaction routes can be used in the formation of basic metal nitrates, such as basic copper nitrate, in accordance with the invention. Suitable reaction routes for use in the practice of the invention, making specific reference to the preparation of basic copper nitrate, include:



[0042] The reaction routes 1-6 have been generally listed above in the approximate order of preference, i.e., in general, route 1 is preferred to route 2, route 2 is preferred to route 3 and so forth, where such order of preference has been generally based on criteria such as cost of raw materials, degree of completeness of reaction, time to completeness of the reaction and potential material handling concerns. For example, reaction routes 5 and 6 are generally difficult to drive to completion and the product may undesirably include or be contaminated with unreacted cupric oxide. As will be appreciated, changes in one or more of the criteria, such as changes in raw material costs, may result in a change in reaction preference.

[0043] Additional required and/or desired pyrotechnic ingredients are added to or included with the slurry, either prior or subsequent to the formation of the basic metal nitrate, e.g., basic copper nitrate, as described above, to form a pyrotechnic mixture. Such additional pyrotechnic ingredients will include a fuel material. Suitable fuel materials for use in the practice of the invention generally include any of those mentioned in the cited reference documents. More particularly, categories of fuels useful in the practice of the invention include, but are not necessarily limited to, amine nitrates (such as guanidine nitrate, triaminoguanidine nitrate, ethylenediamine dinitrate and azobisforamidine dinitrate, for example), nitramines (such as HMX, RDX and nitroguanidine, for example) and heterocyclic nitro compounds (such as nitrotriazolone and dinitroammeline, for example). Guanidine nitrate, because of its relatively low cost, high gas yield and acceptable burn rate, is a preferred fuel material for use in certain preferred embodiments of the invention.

[0044] In accordance with one embodiment of the invention, a fuel material having a common ion (i.e., nitrate) with the basic metal nitrate is used. Guanidine nitrate is an example of one such fuel material in accordance with a preferred practice of such embodiment of the invention. It is to be understood, however, that other such fuel materials, such as identified above can be used in the practice of the invention. Those skilled in the art and guided by the teachings herein provided will appreciate that when the pyrotechnic composition being prepared includes a fuel material or other ingredient having or containing such a common ion, it may prove advantageous to include or have such common ion-containing ingredient present in the slurry prior to the forming of the basic metal nitrate therein such as may desirably serve to facilitate the forming of the basic metal nitrate.

[0045] Other pyrotechnic ingredients such as may also desirably be added to or included with the slurry, either prior to or subsequent to the formation of the basic metal nitrate, as described above, include oxide additives such as described in U.S. Pat. No. 6,143,102 to Mendenhall et al. and whose disclosure is hereby incorporated by reference in its entirety. Such oxide additives include one or more of: silicon dioxide, aluminum oxide, titanium dioxide, zinc oxide and combinations thereof. Of these oxide materials, aluminum oxide or a mixture of aluminum oxide and silicon dioxide is generally preferred.

[0046] In addition, one or more co-oxidizer materials such as nitrates or perchlorates of ammonia, alkali earth, metals or alkaline earth metals can also be included or added. Specific examples of such co-oxidizer materials include:

[0047] ammonium perchlorate, potassium perchlorate, strontium nitrate and others such as will be apparent to those skilled in the art and guided by the teachings herein provided. Of these materials, ammonium perchlorate is particularly preferred as the inclusion thereof can desirably result in an increase in gas yield and burn rate.

[0048] The pyrotechnic mixture can then be suitably dried to form a pyrotechnic powder. In accordance with one preferred embodiment of the invention, the pyrotechnic mixture is preferably spray-dried. As will be appreciated by those skilled in the art and guided by the teachings herein provided, spray drying may advantageously allow processing of large quantities of material quickly and economically.

[0049] It is to be understood, however, that additional pyrotechnic ingredients such as identified above can, if desired, be added, in part or in whole, to the mixture of basic metal nitrate and fuel subsequent to such drying such as by dry blending with an appropriate aliquot of the mixture of basic copper nitrate and fuel. Specific examples of suitable dry blending techniques include blending in a V-shell blender and various milling techniques including, for example, jar milling and other such techniques such as are well known to those skilled in the art.

[0050] While the so-prepared pyrotechnic material can, if desired, be used in a powder form, it will generally be preferred to form the pyrotechnic powder into particular shapes or forms as may be desired in particular applications. In practice, such forming will typically involve applying pressure to a quantity of pyrotechnic powder such as in press-forming the powder into tablets or wafers, for example. It is also possible to process the pyrotechnic via extrusion processing. Such extrusion processing typically would require the presence of a suitable water soluble binder such as guar gum, extrusion in the form of a perforated strand while water wet, chopping of the strand into small pieces (a.k.a. as "extrudlets") and drying of the extrudlets. Practice, however, has shown that this type of processing tends to yield product that has a higher than desired variability and thus such processing is generally not preferred.

[0051] The present invention is described in further detail in connection with the following examples which illustrate or simulate various aspects involved in the practice of the invention. It is to be understood that all changes that come within the spirit of the invention are desired to be protected and thus the invention is not to be construed as limited by these examples.

EXAMPLES

Examples 1-6 and Comparative Example 1

[0052] In these examples, a target pyrotechnic composition of basic copper nitrate (45.49 wt %), guanidine nitrate (51.51 wt %), alumina (2.75 wt %) and silica (0.25 wt %) was prepared via basic copper nitrate prepared by the current commercial route of reacting sodium hydroxide with copper nitrate (Comparative Example 1) and basic copper nitrate prepared in accordance with the invention, using the above-identified reactions 1-6.

[0053] The following represents the preparation of the target formulation wherein the basic copper nitrate was prepared by the above-identified reaction 4:

[0054] Guanidine nitrate (159.3 grams), basic copper carbonate (97.18 grams) and copper nitrate trihydrate (70.79 grams) were added to a glass, jacketed reactor equipped with a mechanical stirrer, a metal cover with two addition ports that could be clamped to the top of the reactor and four equally spaced baffles. Water (200 ml) was added to the mixture in the reactor. The cover was then put into place on the reactor, with one of the addition ports left open so that carbon dioxide could escape. The mixture was then heated at 75° C. for six hours by circulating water through the jacket. The mixture was then transferred to an evaporating tray and dried in a convection oven at 90° C. A mixture of alumina

(1.38 grams) and silica (0.125 grams) was dry blended with a 48.5 gram aliquot of the mixture dried in the convection oven. The amounts of the ingredients used in each of Examples 1-6 are shown below in

TABLE 1

Example	GN (g)	Cu(OH) ₂ (g)	A (g)	HNO ₃ 70% (ml)	B (g)	CuO (g)
1	159.3	85.76	70.79	—	—	—
2	159.3	114.34	—	36.6	—	—
3	159.3	—	70.79	—	97.18	—
4	159.3	—	—	36.6	129.6	—
5	159.3	—	—	36.6	—	93.2
6	159.3	—	70.79	—	—	69.9

where,

GN = guanidine nitrate

A = Cu(NO₃)₂·3H₂O

B = Cu(OH)₂·CuCO₃

[0055] Each of the samples was analyzed for composition. The amount of guanidine nitrate was determined by ion chromatography. The amount of basic copper nitrate was determined by measurement of the total copper content of the material. The aluminum oxide and silicon dioxide contents were quantified by x-ray fluorescence. The results of such compositional analysis are shown below in TABLE 2.

TABLE 2

Example	Reaction	GuNO ₃ (wt %)	bCN (wt %)	Al ₂ O ₃ (wt %)	SiO ₂ (wt %)
1	1	51.4	45.5	2.5	0.3
2	2	52.6	45.4	2.8	0.27
3	3	51.9	45.1	2.7	0.24
4	4	49.7	44.9	2.7	0.24
5	5	49.0	45.3	2.9	0.31
6	6	48.0	45.6	2.7	0.24
Comparative Example 1	—	48.5	45.6	2.6	0.24

where,

GuNO₃ = guanidine nitrate

bCN = basic copper nitrate

Example 7 and Comparative Example 2

[0056] In Example 7, the preferred reaction, i.e., the above-identified reaction 1, was used to make a 500 pound batch of a target formulation wherein the intended percentage of basic copper nitrate was 46.62. The added fuel was guanidine nitrate (50.38%) and the added oxide gas generant additive materials were alumina (2.7%) and silica (0.3%). The materials were slurried in water and spray dried to form a powder. Analysis of the spray-dried sample showed that the intended formulation was achieved.

[0057] In Comparative Example 2, a baseline formulation having the same composition as in Example 7 was prepared by the same process but instead using "pre-made" basic copper nitrate.

Example 8 and Comparative Example 3

[0058] The burn rate of the spray-dried sample of each of Example 7 and Comparative Example 2, respectively, was measured by pressing 3.0 gram samples into 0.5 inch

diameter slugs and burning in a burn rate bomb device at applied pressures ranging from 900 psi to 3000 psi. Knowing the length of the slug and the time period required for a complete burn of the sample allows one to calculate the burn rate at the applied pressure.

Results

[0059] For both the material of Example 7 and the material of Comparative Example 2 the burn rate at 1000 psi was 0.52 ips (inches per second) and at 3000 psi the burn rate 0.82 ips (inches per second).

Example 9 and Comparative Example 4

[0060] In these examples, a spray-dried powder sample of each of Example 7 and Comparative Example 2, respectively, was pressed into cylindrical, domed tablets, i.e., tablets having a diameter of 0.25 in., a dome height of 0.003 in. and a thickness of 0.07 in.

[0061] These tablets were then tested in a standard inflator with the results shown in TABLE 3, below.

TABLE 3

Parameter	Example 9	Comparative Example 4
P20 (kPa)	105	107
P40 (kPa)	161	163
Pmax (kPa)	179	180
Pmax comb. (psi)	3984	3919
CO (ppm)	195	182
NH ₃ (ppm)	23	17
NO (ppm)	17	21

[0062] In the above table, P20 and P40 refer to the pressure developed at 20 ms and 40 ms, respectively, in a 60 liter tank when the gasses from the inflator were vented into the tank. Pmax refers to the maximum pressure developed in the tank when the gasses from the inflator were vented therein.

[0063] The gases CO, NH₃ and NO are the principal undesired gaseous byproducts typically associated with such reaction processes. As shown in TABLE 3, the relative amounts of these gaseous byproducts were nearly identical for Example 9 and Comparative Example 4 and well within established limits for such byproducts.

Discussion of Results

[0064] The results from Examples 7-9 and Comparative Examples 2-4 show that the method of the invention provides a pyrotechnic material that has equivalent properties to the baseline material, thus verifying that the less expensive process of the invention results in a material that provides acceptable properties.

[0065] Thus, the invention provides a method for preparing or making pyrotechnics oxidized by or with basic metal nitrate, such as basic copper nitrate, that is generally simpler than methods of preparation heretofore used. In particular, the invention provides a method for preparing such pyrotechnics such as to desirably reduce the number of process steps such as by minimizing or avoiding the need for the separation of by-products and such as may serve to reduce or lower the costs associated with the manufacture or production of such pyrotechnics.

[0066] The invention illustratively disclosed herein suitably may be practiced in the absence of any element, part, step, component, or ingredient which is not specifically disclosed herein.

[0067] While in the foregoing detailed description this invention has been described in relation to certain preferred embodiments thereof, and many details have been set forth for purposes of illustration, it will be apparent to those skilled in the art that the invention is susceptible to additional embodiments and that certain of the details described herein can be varied considerably without departing from the basic principles of the invention.

What is claimed is:

1. A method for preparing a pyrotechnic at least in part oxidized by at least one basic metal nitrate, the method comprising:

forming the at least one basic metal nitrate in an aqueous slurry;

including, in the aqueous slurry, at least one additional pyrotechnic ingredient including at least one fuel material to form a pyrotechnic mixture; and

drying the pyrotechnic mixture to form a pyrotechnic powder.

2. The method of claim 1 wherein the at least one basic metal nitrate is selected from the group consisting of basic copper nitrate, basic cobalt nitrate, basic zinc nitrate, basic chromium nitrate, basic nickel nitrate and combinations thereof.

3. The method of claim 1 wherein the at least one additional pyrotechnic ingredient is included in the aqueous slurry prior to the forming of the at least one basic metal nitrate.

4. The method of claim 3 wherein the at least one additional pyrotechnic ingredient includes nitrate as a common ion.

5. The method of claim 4 wherein the at least one additional pyrotechnic ingredient is guanidine nitrate.

6. The method of claim 3 wherein a second at least one additional pyrotechnic ingredient is included in the aqueous slurry subsequent to the forming of the at least one basic metal nitrate.

7. The method of claim 1 wherein the at least one additional pyrotechnic ingredient is included in the aqueous slurry subsequent to the forming of the at least one basic metal nitrate.

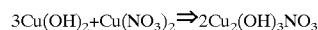
8. The method of claim 1 comprising including at least one co-oxidizer material in the aqueous slurry.

9. The method of claim 1 comprising including at least one oxide gas generant additive material in the aqueous slurry.

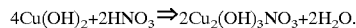
10. The method of claim 9 including in the aqueous slurry an oxide gas generant additive material selected from the group consisting of silicon dioxide, aluminum oxide, titanium dioxide, zinc oxide and combinations thereof.

11. The method of claim 1 wherein the at least one basic metal nitrate is basic copper nitrate.

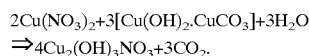
12. The method of claim 11 wherein the forming of the basic copper nitrate in an aqueous slurry comprises the following reaction:



13. The method of claim 11 wherein the forming of the basic copper nitrate in an aqueous slurry comprises the following reaction:



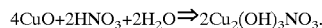
14. The method of claim 11 wherein the forming of the basic copper nitrate in an aqueous slurry comprises the following reaction:



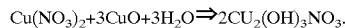
15. The method of claim 11 wherein the forming of the basic copper nitrate in an aqueous slurry comprises the following reaction:



16. The method of claim 11 wherein the forming of the basic copper nitrate in an aqueous slurry comprises the following reaction:



17. The method of claim 11 wherein the forming of the basic copper nitrate in an aqueous slurry comprises the following reaction:



18. The method of claim 1 wherein the at least one fuel material included in the aqueous slurry is guanidine nitrate.

19. The method of claim 1 wherein the drying of the mixture to form a pyrotechnic powder comprises spray drying.

20. The method of claim 1 additionally comprising:

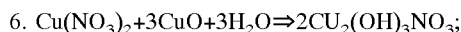
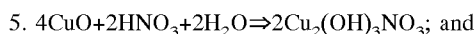
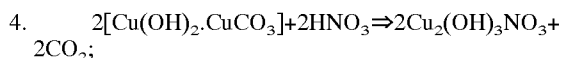
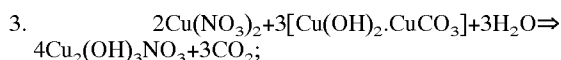
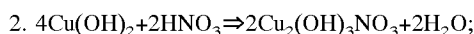
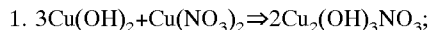
forming the pyrotechnic powder into a desired form.

21. The method of claim 20 wherein the pyrotechnic powder is pressed-form into tablets.

22. The method of claim 20 wherein the pyrotechnic powder is pressed-form into wafers.

23. A method for preparing a pyrotechnic at least in part oxidized by basic copper nitrate, the method comprising:

forming basic copper nitrate in an aqueous slurry via a reaction selected from the group consisting of:



adding, to the aqueous slurry, additional pyrotechnic ingredients including at least one fuel material and at least one oxide additive selected from the group consisting of silicon dioxide, aluminum oxide, titanium dioxide, zinc oxide and combinations thereof to form a mixture;

spray-drying the mixture to form a pyrotechnic powder; and

press-forming the pyrotechnic powder into a desired form.

24. The method of claim 23 wherein at least one of the additional pyrotechnic ingredients is included in the aqueous slurry prior to the forming of the basic copper nitrate.

25. The method of claim 24 wherein the at least one of the additional pyrotechnic ingredients included in the aqueous slurry prior to the forming of the basic copper nitrate includes nitrate as a common ion.

26. The method of claim 25 wherein the at least one of the additional pyrotechnic ingredients included in the aqueous slurry prior to the forming of the basic copper nitrate is guanidine nitrate.

27. The method of claim 23 wherein at least one of the additional pyrotechnic ingredients is included in the aqueous slurry subsequent to the forming of the basic copper nitrate.

28. The method of claim 23 comprising including at least one co-oxidizer material in the aqueous slurry.

29. The method of claim 23 wherein the at least one fuel material added to the aqueous slurry is guanidine nitrate.

30. The method of claim 23 wherein the pyrotechnic powder is pressed-form into tablets.

31. The method of claim 23 wherein the pyrotechnic powder is pressed-form into wafers.

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