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(54) **COPPER CONTAINING IGNITER  
COMPOSITION FOR A GAS GENERANT**

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(57) **ABSTRACT**

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An igniter composition for a gas generant and a related method of igniting a gas generant are provided in which, in addition to a boron fuel component and an oxidizer component, the igniter composition additionally includes a gas-forming source of a condensable metal effective for transferring heat to the gas generant.

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## COPPER CONTAINING IGNITER COMPOSITION FOR A GAS GENERANT

### BACKGROUND OF THE INVENTION

[0001] This invention relates generally to the ignition of a gas generant such as those used for the inflation of inflatable devices like airbag cushions included in inflatable restraint systems for automobile passengers. In particular, the invention relates to an igniter composition which, upon combustion, produces a quantity of gaseous products and a quantity of condensable copper metal effective to conduct heat to and ignite a gas generant.

[0002] 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 a gas when a vehicle experiences sudden deceleration, such as in the event of a collision. Such airbag restraint systems normally include: one or more airbag cushions, housed in an uninflated and folded condition to minimize space requirements; one or more crash sensors mounted on or to the frame or body of the vehicle to detect sudden deceleration of the vehicle; an activation system electronically triggered by the crash sensors; and an inflator device that produces or supplies a gas to inflate the airbag cushion. In the event of a sudden deceleration of the vehicle, the crash sensors trigger the activation system which in turn triggers the inflator device which begins to inflate the airbag cushion in a matter of milliseconds.

[0003] Many types of inflator devices have been disclosed in the art for inflating one or more inflatable restraint system airbag cushions. Inflator devices which form or produce inflation gas via the combustion of a gas generating material, e.g., a "gas generant", are well known. For example, inflator devices that use the high temperature combustion products, including additional gas products, generated by the burning of the gas generant to supplement stored and pressurized gas to inflate one or more airbag cushions are known. In other known inflator devices, the combustion products generated by burning the gas generant may be the sole or substantially sole source for the inflation gas used to inflate the airbag cushion.

[0004] A number of gas generant compositions are known that include a copper-containing fuel or oxidizer. Such fuels or oxidizers are typically employed in gas generant compositions because they produce a lower level of undesirable gas products and limited amounts of toxic or irritating particulate material. Furthermore, copper complex fuels often utilized in gas generant compositions may advantageously produce filterable solid slag that can be relatively easily removed from the gas stream. In some cases, a fuel such as boron is included in a small quantity to enhance gas generation during combustion. Generally, the copper complexes are present in such gas generant compositions in a significant amount such as greater than about 30 composition weight percent. Some copper complex-containing gas generant compositions are disclosed in, for example, U.S. Pat. No. 5,635,668 issued to Barnes et al., and U.S. Pat. Nos. 6,077,372 and 6,143,102 issued to Mendenhall et al., the disclosures of which are hereby incorporated by reference.

[0005] Often such inflator devices also include an initiator, such as a squib, and an igniter composition to ignite the gas generant. In practice, upon receipt of an appropriate triggering signal from a crash or deceleration sensor, the ini-

tiator activates causing the rapid combustion of the igniter composition, which in turn ignites the gas generant. The igniter composition may be incorporated into the igniter device in various forms such as a granular material in a separate container within the inflator housing, may be present as a pressed sleeve surrounding the gas generant, or may be coated directly onto the gas generant granules or tablets.

[0006] Igniter compositions are generally formulated to be very hot burning materials that rapidly combust and readily ignite the gas generant. Unfortunately, such compositions can generate undesirable toxic gas species such as carbon monoxide or nitric oxide. Therefore, the quantity of igniter composition present in the inflator device is kept as low as possible but in a quantity sufficient to provide the desired ballistic response (e.g., low delay time and proper pressure rise rate for the correct timing between the accident and the provision of safety via the inflated airbag cushion).

[0007] However, the ignition of a gas generant by an igniter composition is a function of various factors including the heat output of the igniter composition, the gas output of the igniter composition, and the thermodynamic properties of the gas generant, for example. Thus, if the igniter composition is present in a relatively low quantity it must both generate heat and effectively transfer heat to the gas generant to achieve the proper ballistic response. Heat conduction to the gas generant from the gas products produced by combustion of the igniter composition is governed by heat content and the flow rate of the gas products. The presence of condensable ignition products can also play an important role in the ignition process by transferring heat by conduction to the gas generant. In considering the relative efficiency between the two mechanisms (heat transfer from gases or condensed phase products) both are necessary to achieve rapid and efficient ignition of the gas generant.

[0008] Several igniter compositions have been formulated to include boron as a significant ingredient because it generates a significant quantity of heat. Often, however, the boron fuel is present in a significant amount such as greater than about 10 composition weight percent. For example, U.S. Pat. No. 6,077,372 to Mendenhall et al., incorporated above, also discloses an igniter composition which is coated onto a gas generant material including boron fuel and an oxidizer. Additionally, U.S. Pat. No. 6,132,420 to Barnes et al., which is hereby incorporated by reference, discloses a gas-forming igniter composition including boron fuel, a gas-producing fuel such as guanidine nitrate, and an oxidizer. Unfortunately, boron fuels are relatively expensive materials and can form undesirable combustion products that are difficult to remove from the gas stream within the inflator. Furthermore, if the boron content of an igniter composition is decreased other mechanisms such as gas flow and heat transfer may need to be adjusted to provide the desired ballistic response.

[0009] Thus, there is a need and a demand for an igniter composition that provides efficient heat transfer from the gas products and from condensed phase products to the gas generant. In particular, there is need and a demand for igniter compositions that generate both a significant amount of heat and condensable products to more effectively transfer heat to the gas generant to promote uniform ignition of the gas generant. There is a further need and a demand for an igniter composition that is cost effective to prepare.

## SUMMARY OF THE INVENTION

[0010] A general object of the invention is to provide an improved igniter composition and method of igniting a gas generant to inflate an airbag cushion of an inflatable restraint system of a motor vehicle.

[0011] A more specific objective of the invention is to overcome one or more of the problems described above.

[0012] The general object of the invention can be attained, at least in part, through providing a gas-forming source of condensable copper metal effective for transferring heat to a gas generant in an igniter composition containing a boron fuel component and an oxidizer, wherein the gas-forming source of condensable copper metal is a copper complex that includes at least one ligand selected from the group consisting of anionic ligands, neutral alkyl ligands having at least one balancing anion, neutral ammonia ligands having at least one balancing anion, and combinations thereof.

[0013] The prior art has generally failed to provide an igniter composition and a method of igniting a gas generant which is as effective as desired in satisfying one or more of the above-identified performance criteria. Further, the prior art has generally failed to provide an igniter composition and associated method of igniting a gas generant related to utilizing a condensable copper metal to efficiently and uniformly ignite a gas generant.

[0014] The invention further comprehends an igniter composition which contains:

[0015] about 8 to about 20 composition weight percent boron fuel;

[0016] about 30 to about 80 composition weight percent oxidizer; and

[0017] about 10 to about 40 composition weight percent gas-forming source of condensable copper metal including a copper complex having at least one ligand selected from anionic ligands, neutral alkyl ligands having at least one balancing anion, neutral ammonia ligands having at least one balancing anion, and combinations thereof.

[0018] The invention still further comprehends a method for igniting a gas generant to inflate an airbag cushion of an inflatable restraint system of a motor vehicle wherein an igniter composition including a gas-forming copper complex is ignited such that the copper complex reacts with a boron fuel and an oxidizer to form condensable copper metal that conducts heat to the gas generant. In accordance with one embodiment, the method includes an igniter composition containing about 10 to about 40 composition weight percent of a gas-forming copper complex.

[0019] References herein to a material or component as a "gas producer" or the like are to be understood to refer to high yield gas producing material or components such as, when combusted with a standard oxidizer such as sodium nitrate, produces at least about 2.5 moles of gas per 100 grams of composition and preferably at least about 3.0 moles of gas per 100 grams of composition.

[0020] 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

[0021] The present invention provides an igniter composition such as for a gas generant material used in the inflation of inflatable devices such as vehicle occupant restraint airbag cushions. Such combustible igniter compositions typically include a fuel component, an oxidizer component and a gas-form source of condensable copper metal effective for transferring heat to the gas generant material.

[0022] It has been found that the nature of condensable products formed via the combustion of an igniter composition plays an important role in the ignition process. Condensable products which have a high initial temperature, high heat content, and high thermal conductivity and which are easily condensed upon an initially cool gas generant material are desired to promote efficient and uniform ignition of the gas generant material. Copper metal meets these criteria because it is condensed to a liquid at a high temperature and has a high thermal conductivity which results in more effective transfer of heat to the gas generant material and thereby enhanced ignition of the gas generant. While it is generally known to include copper complexes as fuels or oxidizers in gas generant compositions because they produce lower levels of undesirable gas products, lower levels of irritating or toxic particulate matter, and slag material that are easily removed from the gas stream, the use of copper complexes as heat conductors to promote efficient ignition of a gas generant material has heretofore not been explored.

[0023] In accordance with certain preferred embodiments of the invention, the gas-forming source of condensable copper metal used in the practice of the invention desirably produces both a high level of gas and an amount of copper metal condensate effective to transfer heat to a gas generant material. In particular, the gas-forming source of condensable copper metal can advantageously take the form of a copper complex including at least one ligand selected from anionic ligands, neutral alkyl ligands having at least one balancing anion, neutral ammonia ligands having at least one balancing anion, and combination thereof. Suitably, the copper complex includes a copper II cation.

[0024] Examples of anionic ligand include, but are not limited to, oxalic acid, bitetrazole, aminotetrazole, guanyleurea nitrate, acetic acid, tartaric acid, 5-nitrouracil and combinations thereof. Examples of neutral alkyl ligands include, but are not limited to, 1,2-diaminopropane, 1,3-diaminopropane, and 1,3-diaminopentane. Examples of neutral ammonia ligands include, but are not limited to, diamine and ethylene diamine. Suitably, when the copper complex includes a neutral alkyl or neutral ammonia ligand at least one of the balancing anions includes nitrate.

[0025] In general, copper complexes such as copper oxalate, copper aminotetrazole, copper guanyleurea nitrate, copper tartrate, copper bis-ethylene diamine dinitrate, and combination thereof have been found to be particularly desirable gas-forming copper complexes for use in the practice of the invention. The desirability of the use of these compounds in the igniter compositions of the invention is generally based on a combination of factors such as relating to cost, level of gas generation, ease of combustion, and amount of condensable copper metal produced.

[0026] Generally, the igniter compositions of the invention may advantageously contain such gas-forming copper com-

plex in a relative amount in the range of about 10 to about 40 composition weight percent. Practice of the invention utilizing the inclusion of such gas-forming sources of condensable copper metal within such range has been generally found to provide efficient heat transfer and thereby effective and uniform ignition of a gas generant material.

[0027] While various fuel materials, including boron, zirconium, titanium, magnesium, and aluminum have in the past been used in igniter compositions in various metallic, combination or alloy forms, the practice of the invention employing boron has been found to generally result or provide the most desirable level of heat production. However, the use of boron fuels result in low gas yields. Thus, it is desirable to keep the boron levels in the igniter composition as low as possible.

[0028] While the invention can be practiced utilizing such fuel component in a wide range of relative amounts, in accordance with certain preferred embodiments, such boron fuel may advantageously be present in the range of from about 8 to about 20 composition weight percent, and preferably, in some embodiments, of about 8 to about 10 composition weight percent. For example, operation within such ranges, particularly operation within such preferred range, can beneficially serve to reduce the cost of production of the ignition composition since boron is a relatively expensive fuel material while providing an effective level of heat generation to promote efficient and uniform ignition of a gas generant. Furthermore, use of a relatively small amount of boron fuel reduces the production of undesirable levels of boron combustion products which are difficult to remove from the gas stream within the inflator.

[0029] Useful igniter composition oxidizers include alkali or alkaline earth metal nitrates, particularly preferred are the nitrates of sodium, potassium, and strontium with potassium nitrate being a particularly preferred oxidizer component for use in the practice of the invention. While the chlorates and perchlorates of alkali and alkaline earth metals, if desired, could be used, such chlorates and perchlorates generally exhibit too great a sensitivity to satisfy most practical inflatable restraint applications.

[0030] In practice, the igniter compositions of the present invention contain such an oxidizer component in a relative amount of between about 30 to about 80 composition weight percent. One particularly preferred igniter composition contains about 60 to about 75 composition weight percent of potassium nitrate oxidizer component.

[0031] If desired, an igniter composition in accordance with the invention may also advantageously include an auxiliary fuel. In particular, the auxiliary fuel may be an organic gas-producing fuel in the form of a nitrate of at least one amine or urea derivative. Examples of such material include, but are not limited to, guanidine nitrate, aminoguanidine nitrate, diminoguanidine nitrate, triaminoguanidine nitrate, dicyanamide, biuret, biguanide nitrate, guanylurea nitrate, nitrotriazalone, nitrouracil, aminotetrazole, diammonium bitetrazole, bitetrazole, azodicarbonamide, cyanuric acid, alloxan, barbituric acid, nitrobarbituric acid, cyclotrimethylenetrinitramine, cyclotetramethylenetetranitramine, and combinations thereof.

[0032] In practice, the igniter compositions of the present invention may include an auxiliary fuel in the range of up to

about 25 composition weight percent. In one embodiment, a particularly preferred auxiliary fuel is guanidine nitrate. The desirability of the use of guanidine nitrate in the igniter compositions of the invention is generally based on a combination of factors such as relating to cost, stability (e.g., thermal stability), availability and compatibility (e.g., compatibility with other standard or useful igniter composition ingredients, for example).

[0033] If desired, an igniter composition in accordance with the invention may also advantageously contain or include a relatively low level or amount of a binder material. Suitable binders include, for example, cellulose based binders such as cellulose acetate, cellulose acetate butyrate or cellulose propionate, vitons, polyvinyl pyrrolidone, polyethylene carbonate, propylene carbonate, polyvinyl chloride, and silicone polymers and combinations thereof. While the inclusion of such binder material can serve various functions, in certain preferred embodiments of the invention it may be desirable to include such binder material such as to facilitate subsequent processing, such as to facilitate subsequent granulation of the igniter composition such as to facilitate the formation of comparatively larger sized granules. In practice, the inclusion of such binder material in an amount of no more than about 5 composition weight percent has been found to be generally effective for such uses.

[0034] Additional additives such as flow aids, burn rate catalysts, viscosity modifiers, pressing aids, dispersing aids, or phlegmatizing agents may also be included in the igniter composition to facilitate processing or to provide enhanced properties. Generally, such additives may be included in the igniter composition in an amount of no more than about 5 composition weight percent.

[0035] The igniter compositions of the invention are advantageously and preferably ignitable by means of standard squib devices. Such squib devices typically include a bridgewire, an initiating explosive and a pyrotechnic output charge such as zirconium potassium perchlorate (commonly referred to as "ZPP"), for example. In practice, such pyrotechnic means of initiation commonly produce or form reaction products which in turn contact or otherwise initiate reaction of the igniter composition used in association therewith.

[0036] As will be appreciated, the compatibility of the subject igniter compositions with such standard squib devices facilitates the incorporation and use of such igniter compositions in various inflator or airbag systems without requiring special or possible costly design or processing modifications. As a result, various of the beneficial aspects of the igniter compositions of the invention and the uses thereof for gas generation such as relating to effective heat transfer from the combustion products of the igniter composition to a gas generant material to efficiently and uniformly ignite a gas generant, can more readily and practically be realized.

[0037] 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

[0038] TABLE 1, below, provides the compositional make-up of five specific igniter compositions in accordance with the present invention. The igniter compositions were prepared by slurry mixing the solid raw ingredients with a 50/50 mixture of water and ethyl alcohol. The mixtures were then dried in an air stream until the liquid concentration was about 10 percent by weight. At this point the mixtures were granulated to a 14 mesh size and dried to completeness in a vacuum oven. The dried mixtures were again granulated to a 14 mesh size to yield the final igniter compositions.

TABLE 1

| Ingredient (wt %)                     | Composition |       |       |       |       |
|---------------------------------------|-------------|-------|-------|-------|-------|
|                                       | 1           | 2     | 3     | 4     | 5     |
| Boron                                 | 9.00        | 9.00  | 9.47  | 9.00  | 8.0   |
| Guanidine nitrate                     | 15.35       | 12.34 | 9.33  | —     | —     |
| Potassium nitrate                     | 60.05       | 68.89 | 67.50 | 73.49 | 62.90 |
| Copper oxalate                        | 15.00       | —     | —     | —     | —     |
| Copper aminotetrazole                 | —           | 10.23 | —     | —     | —     |
| Copper tartrate                       | —           | —     | 14.13 | —     | —     |
| Copper bis-ethylene diamine dinitrate | —           | —     | —     | 17.50 | —     |
| Copper guanylurea nitrate             | —           | —     | —     | —     | 29.10 |

## Example 1

[0039] Two grams of each of the Compositions in TABLE 1 was burned under laboratory conditions and the rate of burning of each composition was visually compared with that of a standard boron/potassium nitrate igniter composition including about 25 composition weight percent boron and about 75 composition weight percent potassium nitrate. The rate in each case was visually observed to be greater than or equal to that of the standard composition. All of the compositions of TABLE 1 exhibited signs of having produced condensable copper metal in the form of copper vapor since copper metal deposits were observed around the cooled burn area.

## Example 2

[0040] Compositions 1 and 2 of TABLE 1 were further subjected to ballistic testing by firing two grams of each composition into a standard vented bomb and using two grams of each composition to ignite 34 grams of a standard gas generant in an inflator device (inflator test). In each test, the performance of both compositions exceeded the performance of the standard boron/potassium nitrate igniter composition described above. In the vented bomb test, the peak pressures obtained for compositions 1 and 2 were higher (at shorter time) as compared to the standard igniter composition. In the inflator test, higher peak pressures were measured for compositions 1 and 2 at shorter times as compared to the standard igniter composition.

[0041] 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.

[0042] 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. An igniter composition comprising:

boron fuel:

an oxidizer: and

a gas-forming source of condensable copper metal effective for transferring heat to a gas generant,

wherein the gas-forming source of condensable copper metal is a copper complex that includes at least one ligand selected from the group consisting of anionic ligands, neutral alkyl ligands having at least one balancing anion, neutral ammonia ligands having at least one balancing anion, and combinations thereof.

2. The igniter composition of claim 1 wherein the copper complex comprises a copper II cation.

3. The igniter composition of claim 1 wherein the copper complex comprises at least one anionic ligand selected from the group consisting of oxalic acid, bitetrazole, aminotetrazole, guanylurea nitrate, acetic acid, tartaric acid, 5-nitroureacil, and combinations thereof.

4. The igniter composition of claim 1 wherein the copper complex comprises at least one neutral alkyl ligand selected from the group consisting of 1,2-diaminopropane, 1,3-diaminopropane, and 1,3-diaminopentane.

5. The igniter composition of claim 4 wherein at least one balancing anion comprises nitrate.

6. The igniter composition of claim 1 wherein the copper complex comprises at least one neutral ligand selected from the group consisting of diamine and ethylene diamine.

7. The igniter composition of claim 6 wherein at least one balancing anion comprises nitrate.

8. The igniter composition of claim 1 further comprising an auxiliary fuel.

9. The igniter composition of claim 1, further comprising a binder composition.

10. An igniter composition comprising:

about 8 to about 20 composition weight percent boron;

about 30 to about 80 composition weight percent oxidizer; and

about 10 to about 40 composition weight percent gas-forming source of condensable copper metal effective for transferring heat to a gas generant,

wherein the gas-forming source of condensable copper metal includes a copper complex having at least one ligand selected from the group consisting of anionic ligands, neutral alkyl ligands having at least one balancing anion, neutral ammonia ligands having at least one balancing anion, and combinations thereof.

11. The igniter composition of claim 10 wherein the copper complex comprises a copper II cation.

12. The igniter composition of claim 10 wherein the copper complex comprises at least one anionic ligand selected from the group consisting of oxalic acid, bitetrazole, aminotetrazole, guanylurea nitrate, acetic acid, tartaric acid, 5-nitroureacil, and combinations thereof.

13. The igniter composition of claim 12 wherein the copper complex comprises copper oxalate, copper aminotetrazole, copper guanylurea nitrate, or copper tartrate.

14. The igniter composition of claim 10 wherein the copper complex includes at least one neutral alkyl ligand selected from the group consisting of 1,2-diaminopropane, 1,3-diaminopropane, and 1,3-diaminopentane.

15. The igniter composition of claim 14 wherein at least one balancing anion comprises nitrate.

16. The igniter composition of claim 10 wherein the copper complex includes at least one neutral ammonia ligand selected from the group consisting of diamine and ethylene diamine.

17. The igniter composition of claim 16 wherein at least one balancing anion is nitrate.

18. The igniter composition of claim 17 wherein the copper complex comprises copper bis-ethylenediamine dinitrate.

19. The igniter composition of claim 10 wherein the oxidizer comprises potassium nitrate.

20. The igniter composition of claim 10 further comprising up to about 25 composition weight percent auxiliary fuel.

21. The igniter composition of claim 20 wherein the auxiliary fuel comprises guanidine nitrate.

22. The igniter composition of claim 10 further comprising up to about 5 composition weight percent binder.

23. A method for igniting a gas generant to inflate an airbag cushion of an inflatable restraint system of a motor vehicle comprising the steps of:

providing an igniter composition including boron fuel, an oxidizer and a gas-forming copper complex including at least one ligand selected from the group consisting of anionic ligands, neutral alkyl ligands having at least

one balancing anion, neutral ammonia ligands having at least one balancing anion, and combinations thereof; and

igniting the igniter composition such that the gas-forming copper complex reacts with the boron fuel and the oxidizer to form a gas and condensable copper metal that conducts heat to the gas generant.

24. The method of claim 23 wherein the igniter composition comprises:

about 8 to about 20 composition weight percent boron fuel;

about 30 to about 80 composition weight percent oxidizer; and

about 10 to about 40 composition weight percent gas-forming copper complex.

25. The method of claim 24 wherein the gas-forming copper complex is selected from the group consisting of copper oxalate, copper aminotetrazole, copper guanylurea nitrate, copper tartrate, copper bis-ethylenediamine dinitrate, and combinations thereof.

26. The method of claim 24 wherein the oxidizer is potassium nitrate.

27. The method of claim 24 wherein the igniter composition further comprises up to about 25 composition weight percent auxiliary fuel.

28. The method of claim 27 wherein the auxiliary fuel comprises guanidine nitrate.

29. The method of claim 24 further comprising the step of providing a pyrotechnic squib.

30. The method of claim 29 further comprising the step of contacting the igniter composition with reaction products from the pyrotechnic squib to ignite the igniter composition.

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