ABSTRACT

An ignition composition comprising a low electron affinity material, an oxidizer and a binder. The ignition composition may be made by A1) preparing a coagulation composition by a shock-gel process using the ingredients of the ignition composition disclosed herein, which comprises: A1-a) dissolving the binder in a low-boiling-point polar solvent to provide a binder solution; A1-b) mixing the low electron affinity material and the oxidizer with the binder solution; and A1-c) adding a low-boiling-point non-polar solvent to the mixture provided by step 1-b) to precipitate the binder and form the coagulation composition; and A2) converting the coagulation composition into granular composition using a suitable method.
Magnesium/Barium Nitrate Burn Rate Curve

Burn Rate Equation
\[ y = 0.6743x^{0.3164} \]

\[ R^2 = 0.912 \]

Fig. 2
IGNITION COMPOSITIONS, AND PREPARATIONS AND USES THEREOF

PRIORITY CLAIM

This application claims the benefit of and priority to U.S. Provisional Patent Application No. 61/696,063, titled Ignition Compositions, filed on Aug. 31, 2012, which is incorporated herein by reference thereto.

TECHNICAL FIELD

This invention relates to ignition compositions, including ignition compositions usable with decoy countermeasures.

BACKGROUND

Conventional decoy countermeasures for re-entry vehicles rely on chaff, decoy balloons or warhead simulators for long range ballistic missiles. There is a need for an ignition composition that can be used with, among other things, decoy countermeasures. Novel ignition compositions are disclosed herein to use pyrotechnic means that can be used alone or in conjunction with other ballistic missile decoy mechanisms for decoy countermeasures.

SUMMARY OF THE INVENTION

One aspect of the invention relates to a composition comprising a low electron affinity material, an oxidizer and a binder.

Another aspect of the invention relates to methods of preparing the ignition compositions disclosed herein.

Another aspect of the invention relates to a method of using the ignition composition disclosed herein for decoy countermeasures, comprising the following step:

Discharging a decoy composition comprising the ignition composition disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic graph illustrating Thermogravimetric Analyzer (TGA) analysis (top graph) and ignition composition in an embodiment of the present disclosure, as set forth in Example 1, and the graph includes Differential Scanning Calorimeter (DSC) analysis (bottom graph) of the ignition composition.

FIG. 2 is a burn rate curve illustrating a burn rate analysis of the ignition composition according to Example 1.

DETAILED DESCRIPTION

One aspect of the application relates to a composition comprising a low electron affinity material, an oxidizer and a binder. In at least one embodiment, the ignition composition is held together in a granular matrix formed by the binder, resulting in a pyrotechnic composition that produces thrust with an exhaust containing low electron affinity chemical species with high mass flux. This low electron affinity ignition composition can be configured using varying quantities of the components such that the mass flux and burn rate can be tailored to meet a desired mass flux and burn time, such as for use as a decoy material for re-entry vehicle countermeasures.

In at least one embodiment, the low electron affinity material is a metal. Examples of metal suitable for the ignition composition disclosed herein include, without limitation magnesium (Mg), zirconium (Zr), tungsten (W), tantalum (Ta), aluminum (Al), iron (Fe), manganese (Mn), and other low electron affinity metals. In another embodiment, the low electron affinity material is a non-metal (e.g. boron (B)).

Examples of the oxidizer include, without limitation, nitrates (e.g. barium nitrate, or calcium nitrate), perchlorates (e.g. ammonium perchlorate), and oxides (e.g. CuO). In certain embodiments, the oxidizer does not comprise a salt of alkali metal.

Another aspect of the invention includes at least one embodiment, the low electron affinity material is about 20% to about 80% of the mass of the ignition composition, preferably about 40% to about 60%. The oxidizer is about 20% to about 80% of the mass of the ignition composition, preferably about 30% to about 50%. The ignition composition comprises the binder and optionally other desired additives. The ratio of ingredients of the ignition composition is such that the electron affinity of the ignition composition is less than about 1 eV. In certain embodiments, the ignition composition disclosed herein is to provide a high mass flux of low electron affinity material desirable for anti-ballistic missile systems.

In at least one embodiment, the ignition composition includes finely divided magnesium metal powder, finely divided tantalum metal powder, finely divided barium nitrate, and Fluorel rubber binder blended together using a high shear style mixer that results in a granular material after a shock-gel process. In certain embodiments, the resulting mixed ignition composition has a calorific output of about 1,250 calories per gram and is stable to about 400°C.752°F. The ignition composition provides a stable burn rate of about 500 psi and with a burn rate coefficient of less than about 0.5. Burning of the ignition composition results in an exhaust wave that has chemical species with low electron affinity and high mass flux that presents a target for use with anti-ballistic missile systems or other countermeasure systems.

Another aspect of the application relates to a method of preparing the ignition compositions disclosed herein, comprising the following steps:

A1) preparing a congelation composition by a shock-gel process using the ingredients of the ignition composition disclosed herein, which comprises:

A1-a) dissolving the binder in a low-boiling-point polar solvent to provide a binder solution;

A1-b) mixing the low electron affinity material and the oxidizer with the binder solution; and
[0023] A1-c) adding a low-boiling-point non-polar solvent to the mixture provided by step I-b) to precipitate the binder and form the coagulation composition; and

[0024] A2) converting the coagulation composition into granular composition.

[0025] Examples of the low-boiling-point polar solvent in step A1-a) can be, without limitation, a ketone or a mixture of multiple ketones, e.g. acetone, methyl ethyl ketone, or a combination thereof. In certain embodiments, the low-boiling-point polar solvent has a boiling point of about 60-98°C. (140-208°F.).

[0026] Examples of the low-boiling-point non-polar solvent in step A1-c) can be, without limitation, a saturated hydrocarbon or a mixture of multiple saturated hydrocarbons such as isohexane, hexane, heptane or a combination thereof. In certain embodiments, the low-boiling-point non-polar solvent has a boiling point of about 60-98°C. (140-208°F.).

[0027] In one embodiment, the ratio of polar solvent and the non-polar solvent is about 1:3, and the granular pyrotechnic composition yield is greater than about 98%.

[0028] In another embodiment, all ingredients (solvents, low electron affinity material, and oxidizers) are equilibrated to ambient temperature (e.g. about 20°C/68°F. to about 26°C/78°F.) prior to mixing. The relative humidity is about 40% to about 70%.

[0029] Examples of suitable method in step A2) can be, without limitation, using a hi-shear style mixer, e.g. Cowles, IKA, or Silverson.

[0030] In certain embodiments, the mixing step A1-b) occurs in a hi-shear mixer (e.g. Cowles, IKA, or Silverson). The low electron affinity material and the oxidizer may be added into the binder solution at the same or different time. In one embodiment, the low electron affinity material is first added into the binder solution and mixed for about 10 minutes to about 15 minutes, and then the oxidizer is added into the solution and mixed for about 10 minutes to about 15 minutes.

[0031] In another embodiment, the method of preparing the ignition compositions further comprises steps A1-d) and A1-e) after step A1-c) and before step A2):

[0032] A1-d) decanting the solvents from the mixture obtained from step A1-c); and

[0033] A1-e) drying the obtained coagulation composition to a constant weight.

[0034] In certain embodiments, step A1-e) is performed at a temperature higher than room temperature (e.g. about 70°C/158°F.).

[0035] Another aspect of the application relates to a method of preparing the ignition compositions disclosed herein using a static mixer, comprising the following steps:

[0036] B1) introducing a first stream of binder/polar solvent/low electron affinity material/oxidizer mixture to the static mixer;

[0037] B2) intersecting the first stream in step B1) with a second stream of non-polar solvent in the static mixer; and

[0038] B3) forming granules of the ignition compositions through the turbulence of the static mixer.

[0039] In certain embodiments, the method of preparing the ignition compositions further comprises steps B4) and B5) after step B3) described above:

[0040] B4) decanting the solvents from the mixture obtained from step B3); and

[0041] B5) drying the obtained granule composition to a constant weight.

[0042] Step B5) may be performed at a temperature higher than room temperature (e.g. about 70°C/158°F.).

[0043] Examples of polar solvent and non-polar solvent are the same as described above.

[0044] In one embodiment, the ratio of polar solvent and the non-polar solvent is about 1:3, and the granular pyrotechnic composition yield is greater than about 98%.

[0045] In another embodiment, all ingredients (solvents, low electron affinity material, and oxidizers) are equilibrated to ambient temperature (e.g. about 20°C/68°F. to about 26°C/78°F.) prior to mixing. The relative humidity is about 40% to about 70%.

[0046] Another aspect of the application relates to a method of preparing the ignition compositions disclosed herein, comprising the following steps:

[0047] C1) mixing all ingredients of the ignition composition using a mixer; and

[0048] C2) granulating the mixture obtained from step C1.

[0049] Examples of mixers that can be used in this method include, without limitation, Simpson Mix-Muller and Vibro/Acoustic© Mixers, and mixers working with similar mixing mechanisms. For example, Simpson Mix-Muller mixes the components using a wheel/scraping mechanism, and Resodyn Vibro/Acoustic© mixer uses vibrations to create mixing on a micro scale wherein the composition components are placed into a mixing container sealed and placed upon the mixer to go through a prescribed routine.

[0050] In certain embodiments, the method of preparing the ignition compositions further comprises step C3 after step C2) described above:

[0051] C3) drying the obtained granule composition to a constant weight.

[0052] Step C3) may be performed at a temperature higher than room temperature (e.g. about 70°C/158°F.).

[0053] In another embodiment, all ingredients (solvents, low electron affinity material, and oxidizers) are equilibrated to ambient temperature (e.g. about 20°C/68°F. to about 26°C/78°F.) prior to mixing. The relative humidity is about 40% to about 70%.

[0054] Another aspect of the application relates to a method of using the ignition composition disclosed herein for decoy countermeasures, comprising the following step:

[0055] D1) discharging a decoy composition comprising the ignition composition disclosed herein.

[0056] In one embodiment, the decoy composition provides radar signatures to confound interceptor threats to vehicles upon atmospheric reentry. In another embodiment, the decoy composition is used for missile defense systems training.

[0057] In another embodiment, the ignition composition disclosed herein is used alone for decoy countermeasures. In another embodiment, the ignition composition disclosed herein is used with one or more other ballistic missile decoy mechanisms (e.g. chaff, decoy balloons, warhead simulators and/or electronic countermeasures) for decoy countermeasures.

[0058] The following provides one or more examples related to the ignition composition in accordance with embodiments of the present disclosure:
Example 1. Magnesium-barium nitrate composition:

A composition was prepared to have 56% Mg (by weight) (~400 atomized), 39% Ba(NO₃)₂, and 5% Fluorel (using 25% solution in acetone) according to the method described herein.

1. Mg and Ba(NO₃)₂ were checked for moisture content and if greater than 0.05% moisture they were dried to constant weight at 70°C/158°F.

2. Fluorel stock solution in acetone (25% by weight) was prepared by mixing the appropriate amount of Fluorel solid with acetone.

3. Solvent was equilibrated to mix bay temperature, typically 21°C/70°F at relative humidity 40-70%.

4. Mixing Process:

I. Fluorel solution was added to the mix bowl and Ba(NO₃)₂ was added and agitated for about 10-15 minutes.

II. Mg was added to the mix bowl and agitated for about 10-15 minutes.

III. Isohexane was added to the mix bowl with agitation to precipitate the composition granules out of solution, after complete solvent addition agitation continues for 1-2 minutes.

IV. The solvents were decanted and the granules were rinsed with fresh isohexane and solvents were decanted.

V. The pyrotechnic composition was dried to constant weight at 70°C/158°F.

The dried pyrotechnic composition was subjected to calorific output, burn rate, and TGA/DSC testing.

The performance of the ignition compositions were carried out using Propellant Evaluation Program (PEP).

The resulting ignition composition had a calorific output of about 1,200-1,300 calories per gram. Thermogravimetric Analyzer (TGA) analysis showed that the ignition composition was stable at about 400°C/752°F (Fig. 1, top graph). Differential Scanning Calorimeter (DSC) analysis of the ignition composition showed two peaks at about 500°C/932°F and about 570°C/1068°F, showing the thrust capability of the ignition composition (Fig. 1, bottom graph).

The ignition composition was tested for burn rate at the pressure of about 200 psi to about 500 psi using conventional methods. For example, composition burn rate was determined by pressing a pellet of the pyrotechnic material to provide a sample that can be burned only on the ignition face and not on the sides (i.e., to produce a “cigarette burn.”) The sample was placed in a Crawford style test bomb that was pressurized to the desired test pressure. Several samples were tested at each pressure and a regression analysis was conducted. The results indicated a stable burn rate to about 500 psi and showed a burn rate coefficient of less than about 0.5 (Fig. 2).

The results showed that the ignition composition had desired properties to provide a high mass flux of low electron affinity material with a thrust capability, and can be used for anti ballistic missile systems.

From the foregoing, it should be appreciated that specific embodiments of the disclosure have been described herein for purposes of illustration, and not for limitation. Various modifications may be made without departing from the spirit and scope of the disclosure. Furthermore, while various advantages associated with certain embodiments of the disclosure have been described above in the context of those embodiments, other embodiments may also exhibit such advantages, and not all embodiments necessarily exhibit all such advantages to fall within the scope of the disclosure.

We claim:

1. An ignition composition comprising a low electron affinity material, an oxidizer and a binder.

2. The ignition composition according to claim 1, wherein the low electron affinity material is selected from the group consisting of boron (B), magnesium (Mg), zirconium (Zr), tungsten (W), tantalum (Ta), aluminum (Al), iron (Fe), and manganese (Mn).

3. The ignition composition according to claim 1, wherein the oxidizer is selected from the group consisting of nitrates, perchlorates, and oxides.

4. The ignition composition according to claim 3, wherein the oxidizer is selected from the group consisting of barium nitrate, calcium nitrate, ammonium perchlorate, and CuO.

5. The ignition composition according to claim 1, wherein the binder is selected from the group consisting of Fluorel, acrylic rubbers, Hytemp, Kraton rubbers, and any combinations thereof.

6. The ignition composition according to claim 1, further comprising additives selected from the group consisting of antioxidants, moisture scavengers, and combinations thereof.

7. The ignition composition according to claim 6, wherein the ignition composition comprises antioxidant of about 0.1% to about 0.15% by weight.

8. The ignition composition according to claim 6, wherein the antioxidant is A02246 (2,2’-Methylenebis(4-methyl-6-tert-butylphenol)).

9. The ignition composition according to claim 6, wherein the moisture scavenger is molecular sieves.

10. The ignition composition according to claim 6, wherein the electron affinity of the ignition composition is less than 1 eV.

11. A method of making the ignition composition according to claim 1, comprising:

A) preparing a coagulation composition by a shock-gel process using the ingredients of the ignition composition disclosed herein, which comprises:

A1) dissolving the binder in a low-boiling-point polar solvent to provide a binder solution;

A1-b) mixing the low electron affinity material and the oxidizer with the binder solution; and

A1-c) adding a low-boiling-point non-polar solvent to the mixture provided by step I-b) to precipitate the binder and form the coagulation composition; and

A2) converting the coagulation composition into granular composition using a suitable method.

12. The method according to claim 11, wherein the low-boiling-point polar solvent is a ketone or a mixture of multiple ketones.

13. The method according to claim 11, wherein the low-boiling-point non-polar solvent is a saturated hydrocarbon or a mixture of multiple saturated hydrocarbons.

14. The method according to any of claim 11, wherein the ratio of polar solvent and the non-polar solvent is about 1:3.

15. A method of preparing the ignition composition according to claim 1 using a static mixer, comprising the following steps:

B1) introducing a first stream of binder/polar solvent/low electron affinity material/oxidizer mixture to the static mixer;
B2) intersecting the first stream in step B1) with a second stream of non-polar solvent in the static mixer; and
B3) forming granules of the ignition compositions through the turbulence of the static mixer.

16. The method according to claim 15, wherein the low-boiling-point polar solvent is a ketone or a mixture of multiple ketones.

17. The method according to claim 15, wherein the low-boiling-point nonpolar solvent is a saturated hydrocarbon or a mixture of multiple saturated hydrocarbons.

18. The method according to claim 15, wherein the ratio of polar solvent and the non-polar solvent is about 1:3.

19. A method of preparing the ignition composition according to claim 1, comprising the following steps:
   C1) mixing all ingredients of the ignition composition using a mixer; and
   C2) granulating the mixture obtained from step C1.

20. A method of using the ignition composition according to claim 1 for decoy countermeasures, comprising discharging a decoy composition comprising the ignition composition.

21. The method of claim 20, wherein the ignition composition is used with one or more other ballistic missile decoy mechanisms.

22. The method of claim 21, wherein the one or more other ballistic missile decoy mechanisms are selected from the group consisting of chaff, decoy balloons, warhead simulators and electronic countermeasures.

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