The present invention discloses materials, systems and methods for creating metal foams to envelop targets, which involve the formulation of powdered thermite/metal matrices. Essentially, each matrix will include thermite and a foaming agent. Additionally, a thickening agent can be blended into the powdered thermite/metal matrix to create desirable foaming properties when the thermite is ignited. A heat sink agent can also be dispersed throughout the powdered thermite/metal matrix to limit temperature rise in the matrix during a thermite reaction. Further, a binder can be combined with the powdered thermite/metal matrix to hold the formulation together. In use, the formulation is delivered to the vicinity of the target where it is ignited. The resultant metal foam is intended to envelop and neutralize the target.
### TABLE
ACCESsIBLE VARIABLES FOR THERMITE FOAM FORMATION

<table>
<thead>
<tr>
<th>Category</th>
<th>Parameter</th>
<th>Examples from Literature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermite</td>
<td>constituents</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Iron oxide type</td>
<td>Red (Fe₂O₃) or black (Fe₃O₄)</td>
</tr>
<tr>
<td></td>
<td>iron oxide: aluminum</td>
<td>Wt. ratio of 8:3 or 3:1</td>
</tr>
<tr>
<td></td>
<td>composition</td>
<td>Mg, Ca, Ti, Zn, Si, or B</td>
</tr>
<tr>
<td></td>
<td>alternate compositions</td>
<td>B₂O₃, SiO₂, Cr₂O₃, MnO₂, or CuO</td>
</tr>
<tr>
<td></td>
<td>(Aluminum)</td>
<td>&lt;1 micron (Fe₂O₃); 3-130 microns (Al)</td>
</tr>
<tr>
<td></td>
<td>alternate compositions</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(Iron Oxide)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Particle sizes</td>
<td></td>
</tr>
<tr>
<td>Foaming agent</td>
<td>Foaming agent type</td>
<td>FeO+:C, Si/CO₃, VO₂+:C, Cr₂O₃+C, MnO₂+C, TiH₂</td>
</tr>
<tr>
<td></td>
<td>Foaming agent content</td>
<td>&lt;1 wt% to 2.5 wt% of foam</td>
</tr>
<tr>
<td></td>
<td>Foaming agent particle size</td>
<td>1-2 microns</td>
</tr>
<tr>
<td>Thickening agent</td>
<td>Thickening agent type</td>
<td>SiC, Al₂O₃, MgO</td>
</tr>
<tr>
<td></td>
<td>Thickening agent content</td>
<td>10-30 wt% of foam</td>
</tr>
<tr>
<td></td>
<td>Thickening agent particle size</td>
<td>5-20 microns</td>
</tr>
<tr>
<td>Heat sink agent</td>
<td>Heat sink agent type</td>
<td>TiC</td>
</tr>
<tr>
<td></td>
<td>Heat sink agent content</td>
<td>0-10 wt% of foam</td>
</tr>
<tr>
<td></td>
<td>Heat sink agent particle size</td>
<td>1-3 microns</td>
</tr>
<tr>
<td>Binder</td>
<td>Binder type</td>
<td>KBr, NaBr, CaBr₂, S</td>
</tr>
<tr>
<td></td>
<td>Binder content</td>
<td>5-8 wt%</td>
</tr>
<tr>
<td></td>
<td>Binder particle size</td>
<td>5 microns</td>
</tr>
</tbody>
</table>
THERMITE-METAL FOAM
FIELD OF THE INVENTION

[0001] The present invention pertains generally to materials, systems and methods for creating metal foams. More particularly, the present invention pertains to formulations wherein a foaming agent is combined with thermite to create a metal foam in response to an ignition of thermite. The present invention is particularly, but not exclusively, useful as a material, system and method for enveloping and neutralizing chemical and biological (C/B) warfare agent weapons and facilities.

BACKGROUND OF THE INVENTION

[0002] It is well known that many chemical and biological (C/B) agents are, by design, toxic or very hazardous materials. When released, they can be dispersed over a wide area where they pose serious threats to life and property. To prevent such potential situations, it is essential that enemy access to C/B agent storage and production facilities be denied while also ensuring the agents be somehow neutralized or destroyed. Often this requires immediate action under circumstances (e.g. combat) that are not conducive to a more methodical operation. Conventional explosive munitions have been considered as an immediate response. Explosive munitions, however, can exacerbate the situation by contributing to an unwanted dispersal of the C/B agents.

[0003] An effective way of denying access to C/B agents is to envelop them in a manner that will prevent their further dispersal. Specifically, such a restrictive confinement requires enveloping the C/B materials within a rigid barrier. Preferably, as alluded to above, this process can be accomplished quickly and efficiently under hostile conditions, without dispersing the C/B agents.

[0004] Any of several types of well known metal foams may be suitable for the purpose of enveloping C/B materials. In particular, foams generally known as closed cell foams are preferable in order to minimize the chance of agent release. The creation of such foams, however, typically requires elevated temperatures. In the context of a system for creating a metal foam that can be used to confine and neutralize C/B materials (i.e. where the system is an Agent Defeat Weapon), the metal foam is preferably created by a heat-activated-chemical (HAC) method that will generate the required elevated temperatures. Thermite provides such an HAC method.

[0005] In the most common form of thermite, aluminum-iron (III) oxide, aluminum (Al) reduces the iron oxide to produce a large exothermic heat of reaction and molten iron. The reaction is:

\[ \text{Fe}_2\text{O}_3 + 2\text{Al} \rightarrow 2\text{Fe} + \text{Al}_2\text{O}_3 + \text{heat} \]

[0006] Operational temperatures in excess of 2000° C. have been developed with the above stated reaction.

[0007] In light of the above, it is an object of the present invention to provide an HAC material, system and method for creating a metal foam that envelops and neutralizes a target thought to include C/B agents. The target may include warehouse or stored munitions, bulk materials, and/or manufacturing facilities and supplies related to C/B agents. Another object of the present invention is to provide a system and method for creating a metal foam that can be used to render C/B materials unusable by virtue of the solidified metal foam adhering to surfaces of the C/B material containers or facilities. Still another object of the present invention is to provide a material, system and method for creating a metal foam in response to the ignition of a thermite powder formulation. Yet another object of the present invention is to provide a material, system and method for creating a metal foam that is easy to use, simple to manufacture, and cost effective.

SUMMARY OF THE INVENTION

[0008] In accordance with the present invention, a material, system and method for creating a metal foam are provided. Specific purposes for this metal foam are to envelop and neutralize C/B targets or to disable facilities and munitions. Details of the present invention include the formulation creating a metal foam includes thermite, and a foaming agent that is admixed with the thermite. Together the resultant formulation creates a powdered thermite/metal matrix. In addition to the molten iron inherent to the reacting thermite, secondary melt-forming metals may be included in the formulation to adjust the necessary foaming conditions, such as temperature. The formulation may also include a thickening agent that is blended into the powder matrix (formulation) to provide the most favorable foaming properties as the thermite reacts. Additionally, the powder matrix (formulation) can include a heat sink agent that is dispersed throughout the powder matrix to moderate the temperature of the matrix during the thermite reaction. The powder matrix may also include a binder that is combined with the matrix for holding the constituents together.

[0009] As envisioned for the present invention, the thermite preferably comprises an aluminum (Al) powder fuel component having particles with diameters in a range of about three to one hundred and thirty microns (3-130 microns). The thermite will also include an iron oxide oxidant powder having particles less than about one micron (<1 microns) in diameter. In the preferred embodiment, the oxidant may be either red FeO or black Fe3O4. In the case of red Fe3O4, the aluminum (Al) and iron oxide will typically be mixed together in a weight ratio of approximately 8:3. For black Fe3O4, a weight ratio of approximately 3:1 will typically be used.

[0010] Alternative formulations for the thermite are also envisioned for the present invention. For example, the formulation may contain excess Al over that described in the preceding paragraph, resulting in a mixture of molten iron and aluminum that may be more easily foamed. In other alternate embodiments, the Al fuel component of the thermite may be replaced with Mg, Ca, Ti, Zn, Si or B. Further, along with the replacements for Al, the oxidant for alternate embodiments of the thermite may be selected from a group consisting of B2O3, SiO2, Cr2O3, MnO2 and CuO.

[0011] For the present invention, the foaming agent (a.k.a. blowing agent) may be selected from a group consisting of FeO+Cr2O3, VO4+Cr, Cr2O3+C, MnO+Cr and TiH2. In particular, the content of the foaming agent in the formulation will be, for example, less than about 2.5 wt% of the metal foam, and the foaming agent will be made of particles having diameters in the range of one to two microns (1-2 microns). The thickening agent may be selected from a group consisting of SiC, Al2O3 and MgO. Typically, the thickening agent will be about 10-30 wt% of the metal foam and will be made up, for example, of particles of five to twenty microns (5-20 microns) in diameter. The heat sink agent may be TiC and, for example, be less than about 10 wt% of the metal foam. In the powder formulation, the heat sink agent will have particle sizes between one and three microns (1-3 microns). As mentioned above, the powder formulation may include a...
binder. If so, the binder will typically be selected from a group consisting of KBr, NaBr, CaBr₂, and S. The binder will normally be between about 5-8 wt% of the metal foam and, in the powder formulation, will have particle sizes of about 5 microns diameter.

[0012] In the preceding concept, the metal foam is formed from the molten iron phase that results from the thermite reaction. In an alternative binary munition concept, the thermite constituents and metal foam constituents are not mixed together but, instead, packaged side-by-side. Heat from the thermite reaction is transferred to the foam forming mixture, allowing formation of foam from a molten phase other than that associated with the thermite reaction.

[0013] When used in a system, the powder formulation is placed in a canister and an igniter is provided to initiate a reaction in the formulation. This reaction will then create the metal foam. In use, the canister holding the formulation can be deployed to the C/B target by any of several means. Examples of possible delivery means include: manned or unmanned aircraft, rocket or artillery delivery systems, and hand delivery. The delivery means may include apparatus for dispersing the foam or foam forming constituents or canisters. Regardless of how it may be delivered, when ignited at or approaching the target, the formulation turns into a molten metal foam that surrounds and envelopes the target. In this process, as the metal foam is enveloping the target, it freezes to envelop and neutralize the target.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The novel features of this invention, as well as the invention itself, both as to its structure and its operation, will be best understood from the accompanying drawings, taken in conjunction with the accompanying description, in which similar reference characters refer to similar parts, and in which:

[0015] FIG. 1 is a visualization of the components used for making a formulation and a delivery system for the present invention;

[0016] FIG. 2 is a Table showing accessible variables for use in manufacture of the formulation for the present invention;

[0017] FIG. 3A is a perspective view of a system in accordance with the present invention, with the system shown positioned adjacent to a C/B target prior to envelopment of the C/B material by the system; and

[0018] FIG. 3B is a perspective view of the C/B material shown in FIG. 3A after envelopment by the system of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0019] Referring initially to FIG. 1, a formulation 10 for the present invention is shown to include both essential ingredients 12 and additives 14. During a manufacture of the formulation 10, both the essential ingredients 12 and the additives 14 will be in a powder form. Thus, the formulation 10 that results from mixing ingredients 12 with additives 14 will be essentially a powdered thermite/metal matrix.

[0020] In accordance with the present invention, the essential ingredients 12 of the formulation 10 are thermite 16 and a foaming agent 18. Further, the thermite portion of the formulation 10 will include both a metal component and an oxidant. Preferably, the component is a metal such as Al, and the oxidant is an iron oxide that can be either Fe₂O₃ or Fe₃O₄. There are, however, possible alternatives for the metal component Al. Also, there are possible alternatives for the oxidant (Fe₂O₃ or Fe₃O₄). For example, Al can be selectively replaced by Mg, Ca, Ti, Zn, Si or B, and the oxidant can be selectively replaced by Br₂, SiO₂, Cr₂O₃, MnO₂ or CuO. Additional details about these constituents of the thermite 16, as well as details for other possible constituents of the formulation 10, are set forth in the Table provided in FIG. 2.

[0021] Insofar as possible additives 14 for the formulation 10 are concerned, they may include a thickening agent 20, a heat sink agent 22, and a binder 24. Specifically, in order, the thickening agent 20 can be provided for the purpose of increasing the viscosity of the molten metal that results during a thermal reaction of the formulation 10. Specifically, if used, the thickening agent 20 will help the molten metal maintain suitable characteristics as it is being transformed into a metallic foam 26 (see FIG. 3B). For purposes of the present invention, the thickening agent 20 can be selected from a group comprised of KBr, NaBr, CaBr₂ and S. Next, the heat sink agent 22 can be provided to avoid excessive temperature within the formulation 10 and is, for example, TIC. And finally, the binder 24 can be used to provide cohesion to the body of the formulation 10. It (i.e. the binder 24) will preferably be selected from a group comprised of KBr, NaBr, CaBr₂ and S.

[0022] Still referring to FIG. 1, it will be appreciated that after the formulation 10 has been prepared (i.e. manufactured by mixing together its constituent powders), the formulation 10 can be placed in a canister 28. Further, an igniter 30 can be provided to initiate an ignition of the thermite 16 in the formulation 10. For purposes of the present invention, the igniter 30 is, for example, of a type that will create a magnesium spark of sufficient effect to ignite the thermite 16.

[0023] In use, a canister 28 that has been filled with the formulation 10 is somehow positioned in near proximity to a target 32 as shown in FIG. 3A. The actual delivery of the canister 28 to the site of the target 32 can be accomplished in any of several ways. For example, aircraft, missiles, rockets, conventional artillery, land vehicles, or ground troops may be used to position the canister 28. In any event, once the canister 28 has been positioned (see FIG. 3A), the igniter 30 is activated. With this activation, a reaction in the formulation 10 is initiated. Specifically, the metal 16 generated by the thermite 16 during this reaction will interact with the foaming agent 18 to create a metal foam 26. As intended for the present invention, the metal foam 26 that is a consequence of this reaction will surround and envelop the target 32 (see FIG. 3B). Thus, the target 32 is disabled, neutralized or otherwise rendered unusable. In addition, the heat from the thermite reaction can lead to desirable decomposition/deactivation reactions within the agent container.

[0024] Note that in some cases, it may be advantageous to initiate the foaming reaction while the device is still en route to the target to allow effective dispersal and envelopment from above. Furthermore, the delivery device may advantageously contain multiple submunitions and dispersal methods to facilitate more effective dispersal of the foam forming charges.

[0025] In an alternative binary munition concept, the thermite constituents and metal foam constituents are not mixed together but arranged side-by-side. Heat from the ignited thermite reaction is transferred to the foaming composition, allowing formation of foam from a molten phase other than
that associated with the thermite reaction. This embodiment can enable the use of lower-temperature molten metals that are easier to foam and less prone to penetrate the agent container, hence reducing the chance of unintended agent release.

While the particular Thermite-Metal Foam as herein shown and disclosed in detail is fully capable of obtaining the objects and providing the advantages herein before stated, it is to be understood that it is merely illustrative of the presently preferred embodiments of the invention and that no limitations are intended to the details of construction or design herein shown other than as described in the appended claims.

What is claimed is:

1. A system for creating a metal foam to envelop a target, the system including a formulation for creating the metal foam which comprises:
   - thermite; and
   - a foaming agent positioned with the thermite and responsive thereto to create the metal foam.

2. A system as recited in claim 1 wherein the foaming agent is admixed with the thermite to create a powdered thermite/metal matrix.

3. A system as recited in claim 1 further comprising a thickening agent positioned with the powdered thermite/metal matrix to facilitate action of the foaming agent upon an ignition of the thermite.

4. A system as recited in claim 3 wherein the thickening agent is selected from a group consisting of SIC, Al2O3, and MgO.

5. A system as recited in claim 1 further comprising a heat sink agent positioned with the powdered thermite/metal matrix.

6. A system as recited in claim 5 wherein the heat sink agent is TiC.

7. A system as recited in claim 1 further comprising a binder combined with the powdered thermite/metal matrix for holding the formulation together.

8. A system as recited in claim 7 wherein the binder is selected from a group consisting of KBr, NaBr, CaBr2, and S.

9. A system as recited in claim 1 wherein the thermite comprises aluminum and iron oxide mixed in a weight ratio of approximately 8:3.

10. A system as recited in claim 1 wherein the foaming agent is selected from a group consisting of FeO+C, SrCO3, VO2+C, Cr2O3+C, MnO+C and TiH2.

11. A system as recited in claim 1 wherein the thermite includes a fuel component and an oxidant, wherein the fuel component is selected from a group consisting of Mg, Ca, Ti, Zn, Si, and B, and wherein the oxidant is selected from a group consisting of B2O3, SiO2, Cr2O3, MnO2, and CuO.

12. A system as recited in claim 1 further comprising:
   - an igniter for initiating a reaction in the formulation to create the metal foam; and
   - a canister for holding the formulation and the igniter during deployment of the system to the target.

13. A system for neutralizing a target which comprises:
   - a powdered matrix formulation containing thermite and a foaming agent;
   - an igniter for initiating a reaction in the formulation to create a metal foam for enveloping the target; and
   - a canister for holding the formulation and the igniter during deployment of the system to the target.

14. A system as recited in claim 13 wherein the formulation further comprises:
   - a thickening agent;
   - a heat sink agent; and
   - a binder.

15. A system as recited in claim 13 wherein the target is selected from a group comprising chemical/biological agents, weapons and facilities.

16. A system as recited in claim 13 wherein the igniter initiates the reaction with a magnesium spark.

17. A system as recited in claim 13 wherein the thermite comprises aluminum (Al) and an iron oxide selected from a group consisting of Fe3O4 and Fe2O3, and further wherein the aluminum and iron oxide are mixed with approximately equal volumes.

18. A method for neutralizing a target which comprises the steps of:
   - delivering a powdered thermite/metal matrix formulation proximate the target;
   - igniting the powdered formulation to generate a molten metal;
   - expanding the molten metal with a foaming agent to establish a molten metal foam for enveloping the target; and
   - freezing the molten metal to create a solid metal foam for enveloping the target.

19. A method as recited in claim 18 wherein the thermite/metal matrix comprises aluminum (Al) and an iron oxide selected from a group consisting of Fe3O4 and Fe2O3, and wherein the aluminum and iron oxide are mixed with approximately equal volumes.

20. A method as recited in claim 18 further comprising the step of blending a thickening agent into the powdered thermite/metal matrix to facilitate action of the foaming agent upon an ignition of the thermite.

21. A method as recited in claim 18 further comprising the step of dispersing a heat sink agent throughout the powdered thermite/metal matrix to control temperature rise therein.

22. A method as recited in claim 18 further comprising the step of combining a binder with the powdered formulation to hold the formulation together.

23. A combination of materials for creating a metal foam to envelop a target, the materials comprising:
   - thermite; and
   - a foaming agent positioned with the thermite and responsive thereto to create the metal foam.

24. A combination of materials as recited in claim 23 wherein the foaming agent is admixed with the thermite to create a powdered thermite/metal matrix.

25. A combination of materials as recited in claim 23 further comprising a thickening agent positioned with the powdered thermite/metal matrix to facilitate action of the foaming agent upon an ignition of the thermite.

26. A combination of materials as recited in claim 25 wherein the thickening agent is selected from a group consisting of SIC, Al2O3, and MgO.

27. A combination of materials as recited in claim 23 further comprising a heat sink agent positioned with the powdered thermite/metal matrix.

28. A combination of materials as recited in claim 27 wherein the heat sink agent is TiC.

29. A combination of materials as recited in claim 23 further comprising a binder combined with the powdered thermite/metal matrix for holding the formulation together.
30. A combination of materials as recited in claim 29 wherein the binder is selected from a group consisting of KBr, NaBr, CaBr₂ and S.

31. A combination of materials as recited in claim 23 wherein the thermite comprises aluminum and iron oxide mixed in a weight ratio of approximately 8:3.

32. A combination of materials as recited in claim 23 wherein the foaming agent is selected from a group consisting of FeO+C, SrCO₃, VO₂+C, Cr₂O₃+C, MnO+C and TiH₂.

33. A combination of materials as recited in claim 23 wherein the thermite includes a fuel component and an oxidant, wherein the fuel component is selected from a group consisting of Mg, Ca, Ti, Zn, Si and B, and wherein the oxidant is selected from a group consisting of B₂O₃, SiO₂, Cr₂O₃, MnO₂ and CuO.

* * * * *