In accordance with aspects of the invention, an infrared signature powder ("IR powder") suitable for marking targets and other objects is provided. The IR powder primarily includes porous, pyrophoric iron and moderators. The duration, temperature, and intensity of the emitted infrared radiation can be tailored during the powder's production process by adjusting the proportion or properties of the moderators in the IR powder. Additionally, a method of producing the IR powder is provided. The method can include the following general steps: heat a blend of aluminum and iron powders to cause an inter-metallic reaction; leach the aluminum from the iron; and mix a selected moderator and a binder with the iron in selected proportions to create the IR powder. Many of these steps are performed in an oxygen-free environment to prevent the iron from prematurely oxidizing. Similarly, the IR powder is encapsulated in an oxygen-free frangible ampoule or other container.
INFRARED SIGNATURE POWDER AND METHODS OF CONTROLLING THE TEMPERATURE, DURATION, AND INTENSITY OF INFRARED SIGNATURE RADIATION

CROSS-REFERENCE TO RELATED APPLICATIONS


TECHNICAL FIELD

[0002] The present disclosure relates generally to infrared signature radiation and, more particularly, to infrared signature powder and methods of controlling the temperature, duration, and intensity of infrared signature radiation.

BACKGROUND

[0003] Industries have many uses for infrared marking materials. For example, these materials are used as part of law enforcement or military training exercises and in operations to mark targets and other objects. The users of infrared marking materials may desire to have control over certain attributes of the marking materials in order to accommodate varied uses. For instance, it might be ideal for a marking material used during a training exercise to burn at a desired intensity for adequate visibility, but at a low enough temperature to avoid a risk of starting a fire or otherwise damaging the training ground. Similarly, users might want to control the duration and temperature of the infrared radiation emission as needed for different operations or training situations. Conventional materials and production methods do not allow for adequate control of the temperature, duration, and intensity of the infrared signature radiation.
SUMMARY

[0004] In accordance with aspects of the invention, an infrared signature powder ("IR powder") suitable for marking targets and other objects is provided. The IR powder primarily includes pyrophoric iron and moderators. The moderators can include boron nitride, activated carbon, in combination with a suitable binder. In at least one embodiment, the IR powder includes the pyrophoric iron and a small amount of one or more moderators to provide a selected duration or intensity IR signature. In other embodiments, the production of the IR powder is controlled to provide a desired duration and/or intensity for the IR signature. For example, the production process allows for a range of IR signatures, including, at one end of the spectrum, providing an IR powder that does not include moderators to provide the maximum intensity of the IR signature with a short duration.

[0005] In one embodiment, the IR powder is encapsulated, such as in an ampoule, to isolate the material from oxygen until activation of the IR powder is required. When the ampoule is broken and the IR powder is exposed to oxygen, the iron oxidizes. The moderators absorb the resultant heat and re-emit it in the form of infrared radiation. The infrared radiation can be used as a signature visible to humans or to light- or heat-detecting equipment to mark a target or other object. The duration, temperature, and intensity of the emitted infrared radiation can be controlled during the powder's production process by adjusting the proportion or properties of the moderator in the IR powder. If a target is marked with an IR powder having a high proportion of a moderator, the resulting signature can have low intensity and the radiation emission will be slow and cool. Conversely, if a target is marked with an IR powder having a low proportion of the moderator (or even no moderator), the resulting signature will have higher intensity and the radiation emission will be faster and hotter.

[0006] The IR powder is produced using a process that includes the following general steps: heat a blend of aluminum and iron powders to cause an inter-metallic reaction; grind the resultant mixture; leach the aluminum from the iron; rinse and dry the iron powder; and mix a selected moderator with the iron in selected proportions to create the IR powder. Many of these steps are performed in an oxygen-free environment to prevent the iron from oxidizing or otherwise prematurely activating.
Similarly, the IR powder is encapsulated in an oxygen-free frangible ampoule or other suitable container.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Figure 1 is a flow chart illustrating one method of producing the infrared signature powder.

[0008] Figure 2 is an embodiment of the invention wherein an ampoule of the IR powder is attached to a delivery device, such as an ammunition round.

DETAILED DESCRIPTION

[0009] The present disclosure describes various embodiments of an infrared signature powder and methods of producing and using this powder. In one embodiment, for example, the IR powder includes porous iron, a moderator comprised of boron nitride and activated carbon, and a binder. As described in greater detail below, the amount of moderator in proportion to the amount of porous iron can vary in different embodiments of the invention. By controlling the proportion of moderator during the production process, the temperature, duration, and intensity of the emitted infrared radiation upon activation of the IR powder is controlled.

[0010] Certain details are set forth in the following description and in Figures 1 and 2 to provide a thorough understanding of various embodiments of the disclosure. Other details describing well-known structures and systems often associated with infrared powder material and/or corresponding handling techniques and uses have not been set forth in the following disclosure to avoid unnecessarily obscuring the description of the various embodiments of the disclosure.

[0011] The features shown in the Figures are merely illustrative of particular embodiments of the disclosure. Accordingly, other embodiments can add other steps, materials, processes, or other features without departing from the spirit or scope of the present invention. In addition, those of ordinary skill in the art will appreciate that further embodiments of the invention can be practiced without several of the details described below.

[0012] An infrared signature powder 100 suitable for marking targets and other items was prepared. In one embodiment, the IR powder 100 primarily includes
pyrophoric iron and moderators. The moderators can comprise boron nitride and/or activated carbon in combination with a suitable binder. The IR powder 100 may further include an anti-caking agent to prevent the formation of lumps. Trace amounts of aluminum that have not been leached out may also be present. The IR powder 100 is configured so the pyrophoric iron will oxidize and activate when the powder is exposed to a sufficient concentration of oxygen (e.g., in ambient air); the moderators absorb the resulting heat and then emit infrared radiation at a selected intensity, duration, and temperature.

[0013] The flow chart in Figure 1 illustrates one method of producing the IR powder 100. In other embodiments of the invention, the number of steps, the specific processes of each step, and the order of the steps relative to one another can vary. As is known, pure or substantially pure iron oxidizes very quickly. Accordingly, all or portions of the processes of generating the pyrophoric iron and the IR powder 100 are performed in a substantially oxygen-free environment.

Referring to Figure 1, the initial steps of the production process generate the pyrophoric iron component of the IR powder 100. Dry powder forms of first and second metals, such as aluminum and iron, are weighed and mixed together using a mixer, such as a Hobart Mixer. The aluminum and iron is a mixture; in one embodiment, having approximately equal parts aluminum and iron. Other embodiments can have mixtures with different ratios of aluminum and iron. In further embodiments, other metals such as nickel, cobalt, titanium, manganese, tin, and/or zirconium can be used in place of or in addition to iron.

[0014] The mixture is then heated to approximately 820°C Celsius, which is above the melting point of the aluminum but below the melting point of the iron, so that the aluminum will melt and alloy with the iron so as to form an intermetallic compound of the mixture. This process can be a self-sustained exothermic reaction. This heating may be done in a heat-treating furnace with a conveyor or other appropriate apparatus. The intermetallic compound is then cooled to room temperature.

[0015] Once the formed intermetallic compound cools, it is placed in a grinder machine. In one embodiment, the cooled compound is ground for approximately 2-3 hours until it is approximately -200 mesh particle size. Other embodiments can grind
the compound to different sizes, or to a mixture of sizes. A classifier can be used to separate the ground material as a function of size.

[0016] The ground formed compound is then added to a leaching solution under a fume hood. The reaction between the compound and the leaching solution can be very active, so in some embodiments the compound is added to the leaching solution in small increments. In one embodiment, the leaching solution is 15% NaOH and 0.5% SnCl\(_2\) \(\times\) \(2\)H\(_2\)O. To ensure proper leaching, the amount of the sodium hydroxide used can be 4 or 5 times the amount (by mass) of the aluminum in the formed compound. For example, if 200 grams of moderator includes 100 grams of aluminum, 400-500 grams of sodium hydroxide can be used in the leaching solution. In other embodiments, other proportions of sodium hydroxide to aluminum can be used. A mixer can be used to ensure proper mixing between the leaching solution and the formed compound. In one embodiment, the solution is heated to 80° Celsius until most of the aluminum is leached out, or until intense bubbling ceases, indicating that the reaction is substantially complete. During this process, approximately 1 liter of hydrogen gas is produced per gram of aluminum. The leaching process serves to dissolve the aluminum from the formed compound to leave behind pyrophoric iron. In one embodiment, an exhaust scrubber is used to ensure proper recycling and regeneration of the gases generated during the leaching process. Due to the properties of the pyrophoric iron and its propensity to aggressively oxidize when exposed to the oxygen in ambient air, the porous iron is processed and handled in an oxygen-free environment to prevent the iron from prematurely oxidizing.

[0017] The solid pyrophoric iron is removed from the caustic leaching solution and rinsed. It is dried in a vacuum oven inside a glove box. In one embodiment, a glove box is used that has a transfer box with a nitrogen curtain to help ensure that the iron is not exposed to oxygen, thereby avoiding premature oxidation and subsequent deactivation of the iron. In some embodiments, the drying process takes approximately 3-4 hours and one or more glove box/vacuum ovens can be used.

[0018] In certain embodiments, the pyrophoric iron is blended with a suitable binder solution and a moderator until the moderator sufficiently coats the pyrophoric
iron with a desired thickness and/or covering to achieve the desired duration, intensity, and/or temperature upon selected exposure of the resulting IR powder 100 to air. This process can take place in a multi-person vacuum-sealed glove box or other suitable oxygen-free environment. In one embodiment, the moderator is mixed with a binder solution, which includes a dissolved resin or other binder in a solvent, to facilitate delivery onto the pyrophoric iron. The solvent is selected so that, during processing with the porous iron, the solvent evaporates or otherwise dissipates until the solvent is essentially gone, leaving the pyrophoric iron coated with the moderator. Elevated temperature can be applied to drive off the remaining solvents.

In one embodiment, the moderator and solvent are blended using a mixer, such as a Hobart Mixer. The moderator can be a combination of boron nitride and activated carbon ratioed between approximately 25/75 and 75/25. In one embodiment the boron nitride and activated carbon is an approximately 50/50 mix. Examples of a suitable moderator can include Diatomaceous earth, vermiculite, sodium alumina silicate, calcium silicate, calcium alumina silicate, and cab-o-sil. The solvent can include toluene, hexane, or cyclohexane. In other embodiments, Acetone, MEK, MBA, Alcohol, and/or water can be used as or with the moderator. The binder can include polyvinyl alcohol, pine resin, Kraton, or other resins. A scrubber is again used in connection with the glove box to ensure proper recycling and regeneration of the solvent and/or other gases generated during the blending process. In one embodiment, a granulator in a section of a multi-section glove box (which also includes the mixer and a vacuum oven in the other sections) is used to break the solvent and moderator mixture into a powder. An anti-caking agent may be added to the dry mixture of iron and moderator after the mixture is processed in the granulator to minimize or reduce clumping or caking of the powder material and to produce a substantially homogeneously-fine powder. In one embodiment, the amount of anti-caking agent added to the mixture is approximately 1/2% - 1% of the mixture. In other embodiments different chemicals or combinations of chemicals can be used as the moderator, solvent, and/or anti-caking agent, or the moderator, solvent, and/or anti-caking agent may be excluded from the IR powder 100 altogether.
The mixture is dried in a vacuum oven, which may take approximately one hour. The resultant dried powder is the infrared signature powder 100. When moderators are used, they make up a proportionate amount of the IR powder 100 that can vary from approximately 10/90 to 90/10 by mass. The different proportions of moderators in the IR powder 100 is carefully controlled to accurately control the duration, intensity, and temperature of the material and/or associated infrared signal upon deployment and activation of the IR powder material 100, as discussed in greater detail below.

The IR powder 100, while in the oxygen-free environment, is encapsulated in an oxygen free carrier to ensure that the IR powder 100 is not prematurely activated while in the carrier. In one embodiment, a selected amount of the IR powder 100 is encapsulated in individual ampoules 140. The ampoules 140 are made of a material substantially impervious to air-penetration and that has a suitable shelf-life. For example, if the IR powder 100 will be used as military training ammunition, it must have a shelf-life of at least 5 years. If it will be used as military tactical ammunition, it must have a shelf-life of at least 20 years. The ampoules 140 can be made of a frangible material, such as glass, that can be broken, or otherwise opened, upon launch or impact to expose and/or distribute the IR powder 100. In one embodiment, the ampoule 140 is made of boro-silicate, although embodiments may use other suitable frangible materials.

When the IR powder 100 is exposed to air outside the ampoule 140, the pyrophoric iron oxidizes. This activates the moderator which absorbs the heat from the oxidizing iron. The oxidation properties (e.g., the duration, temperature, and intensity of the infrared radiation emitted) can be tailored during the production process by varying the proportion of moderator in the IR powder 100. If the target is marked with a powder 100 having a high proportion of moderator, the resulting signature will be of low intensity and the radiation emission will be slow and cool. Conversely, if the target is marked with a powder 100 having no moderator or a low proportion of moderator, the resulting signature will be of high intensity and the radiation emission will be faster and hotter. For low-intensity signatures, an assistive device, such as goggles designed for this purpose, is needed to view the signature, and no marking would be obvious to the naked eye. For high-intensity signatures,
no assistive device would be necessary to see the IR powder 100 oxidize. In the embodiments wherein the desired performance of the IR powder 100 dictates that no moderator is used during production, the IR powder 100 will result in the maximal intensity and visual signature.

5 [0023] As illustrated in Figure 2, in some embodiments, the ampoule 140 can be configured to attach or releasably attach to a projectile 120. The ampoule 140 can be attached to the projectile 120 by various mechanical connection means known in the art. In some embodiments, for example, the ampoule can be fixedly or removably attached to an interior portion of the projectile 120. In another embodiment, the ampoule 140 may be an integral component of the projectile 120 (such as a projectile referenced in any of US Patent Nos. 6748870, 6901866 or 6779463), or the ampoule 140 may be the projectile 120. In a particular embodiment, the projectile 120 can comprise a tracer and the ampoule 140 can be configured to open upon launch and expose the IR powder 100 to ambient air, thereby activating the tracer functionality. Depending on the proportion of moderator in the IR powder 100, the tracer can be visible to the naked eye or can be an infrared tracer.

[0024] The following examples are provided for further illustrating various embodiments of the invention, but are not to be construed as limitations thereof.

20 [0025] Example 1: In one embodiment of the invention, the infrared signature powder 100 is used to mark targets or other places or items of interest. Referring to Figure 2, an ampoule 140 containing the IR powder 100 discussed above is attached to the projectile 120, such as a marking round. Upon impact, the ampoule 140 breaks to disperse the powder 100 onto the target. In other embodiments of the invention, the IR powder 100 can be delivered to the target by means other than firing a round and ampoule 140 at the target.

[0026] In this embodiment, the ampoule 140 can contain a combination of approximately 50% of moderator and approximately 50% of porous iron. In the manufacturing process of producing 100 grams of pyrophoric iron, approximately 47.27 grams of aluminum and 47.27 grams of iron are combined in the manner described above. 1-1.5 liters of leaching solution is used. Approximately 23.6 grams of boron nitride, 23.6 grams of activated carbon, and 5.53 grams of Kraton
binder are used to generate the moderator by the process detailed above. The radiation of the resulting IR powder 100 emits at a low intensity for about 5 minutes. The IR powder 100 oxidizes at about 200-300° Celsius. The infrared signature can draw the attention of a device with infrared-seeking capabilities. Because the radiation emits at a low intensity, the target is marked for observation or destruction without advance notice to others.

[0027] **Example 2:** The IR powder 100 can be used in military or law enforcement training exercises to practice marking targets. A marking round with an attached ampoule 140 of IR powder 100 is fired at a target or applied to a target by other means. To produce 100 grams pyrophoric iron, 50 grams of aluminum and 50 grams of iron are combined in the manner described above. 1-1.5 liters of leaching solution is required. The radiation of the resulting IR powder 100 emits at a high intensity for about 2-3 seconds. The IR powder 100 oxidizes at about 900° Celsius. In this embodiment, the IR powder does not include a moderator, so the oxidizing IR powder 100 is visible to the naked eye and it is quickly and easily determined whether the trainee successfully and accurately marked the target.

[0028] The IR Powder 100 described in this Example can also be used in less-than-lethal payloads designed to temporarily stun combat opponents. For example, an ampoule having the IR Powder 100 described above can be broken near an adversary (actual or simulated) to create an intense flash of light and heat. The intense flash can disorient the opponent’s senses, temporarily impairing vision and creating an uncomfortable sensation of heat.

[0029] Despite the high temperature of these reactions, the IR powder 100 can be configured to fully activate very quickly without causing a fire to structures or the environment near the target. More specifically, the IR powder 100 has a relatively low thermal mass and a small particle size which provides for a short oxidation time. Because of the quick nature of the reaction, the high oxidation temperature spikes and quickly drops, and the heat generated is not sufficient to heat the surrounding environment long enough to cause combustion.

[0030] **Example 3:** In an alternate embodiment of the invention, the IR powder 100 can be applied to a movable structure, such as a vehicle. The powder 100 can be applied by a number of methods, including firing the ampoule 140 at the vehicle
in a manner similar to that described above, or simply by breaking the ampoule 140 open on the vehicle to distribute the IR powder 100. The pyrophoric iron is generated in the manner described in Example 1 above. However, for this embodiment, the quantities of aluminum and iron are decreased from the amounts given in Example 1 by approximately 5-10% and the quantities of boron nitride and activated carbon are increased from the amounts given in Example 1 by approximately 5-10%. 7-8 grams of Kraton binder are used. The radiation emits at a low intensity for about 5 minutes. The powder 100 oxidizes at about 60-80° Celsius. At this intensity, the moving object can be tracked or targeted without alerting its occupants, as specialized goggles or other assistive device would be needed to notice the visual signature.

[0031] From the foregoing, it will be appreciated that specific embodiments of the invention have been described herein for purposes of illustration, but that various modifications may be made without deviating from the spirit and scope of the various embodiments of the invention. Further, while various advantages associated with certain embodiments of the invention have been described above in the context of those embodiments, other embodiments may also exhibit such advantages, and not all embodiments need necessarily exhibit such advantages to fall within the scope of the invention. Accordingly, the invention is not limited, except as by the appended claims.
I/We claim:

1. A method of manufacturing infrared signature powder, the method comprising:
   mixing granular first and second metals;
   heating the mixture of the metals to form an intermetallic compound;
   leaching the second metal from the intermetallic compound to provide a porous pyrophoric metal;
   processing the porous pyrophoric metal to provide a pyrophoric metal powder;
   coating the pyrophoric metal powder with a moderator, wherein the ratio of moderator to pyrophoric metal powder is selected to control oxidation properties of the coated pyrophoric metal powder; and
   encapsulating the coated pyrophoric metal powder.

2. The method of claim 1 wherein mixing granular first and second metals comprises mixing iron and aluminum.

3. The method of claim 1 wherein mixing granular first and second metals comprises mixing at least one of nickel, cobalt, titanium, manganese, iron, tin, or zirconium with aluminum.

4. The method of claim 1 wherein processing the porous pyrophoric metal comprises grinding the porous pyrophoric metal to 200 mesh particle size.

5. The method of claim 1 wherein leaching the second metal from the intermetallic compound comprises leaching the second metal with a sodium hydroxide leaching solution.

6. The method of claim 1 wherein coating the pyrophoric metal powder with a moderator comprises mixing the pyrophoric metal powder, the moderator, and
a binder solution comprising a resin dissolved in solvent, and wherein the solvent is at least one of toluene, hexane, cyclohexane, or acetone.

7. The method of claim 1 wherein the moderator includes a binder comprising of at least one of polyvinyl alcohol, pine resin, or Kraton.

8. The method of claim 1 wherein coating the pyrophoric metal powder with a moderator comprises coating the pyrophoric metal powder with a moderator at a ratio of from about 1:9 to about 9:1 by mass.

9. The method of claim 1 wherein the moderator comprises a mixture of boron nitride and activated carbon, mixed at a ratio of from about 1:3 to about 3:1 by mass.

10. The method of claim 1 wherein the first metal comprises iron, the second metal comprises aluminum, and the moderator comprises an approximately 50/50 mixture of boron nitride and activated carbon.

11. The method of claim 1 wherein encapsulating the coated pyrophoric metal powder comprises encapsulating the coated pyrophoric metal powder in a frangible, airtight container.

12. A method of controlling the duration and temperature of infrared signature radiation, the method comprising:

forming an intermetallic compound of a first metal and aluminum;

leaching the aluminum from the intermetallic compound to provide a porous pyrophoric metal;

grinding the porous pyrophoric metal into a pyrophoric metal powder;

selecting an amount of a moderator in proportion to an amount of the pyrophoric metal powder, wherein the proportion is controlled to achieve a pre-selected temperature and duration of emitted radiation;

coating the pyrophoric metal powder with the moderator; and

encapsulating the coated pyrophoric metal powder.
13. The method of claim 12 wherein forming an intermetallic compound of a first metal and aluminum comprises forming an intermetallic compound of iron and aluminum.

14. The method of claim 12 wherein selecting the amount of a moderator in proportion to the amount of the pyrophoric metal powder comprises selecting a proportion of moderator to pyrophoric metal powder from about 48%/52% to about 52%/48% to achieve low-intensity infrared radiation emission for at least 3 minutes at about 200 degrees Celsius or hotter.

15. The method of claim 12 wherein selecting the amount of a moderator in proportion to the amount of the pyrophoric metal powder comprises selecting no moderator to achieve high-intensity infrared radiation emission for approximately 2-5 seconds at about 800 degrees Celsius or hotter.

16. The method of claim 12 wherein selecting the amount of a moderator in proportion to the amount of the pyrophoric metal powder comprises selecting a proportion of moderator to pyrophoric metal powder from about 60%/40% to about 55%/45% to achieve low-intensity infrared radiation emission for at least 3 minutes at about 60 degrees Celsius to about 80 degrees Celsius.

17. A munitions round, comprising:
   a projectile having an internal portion and an external portion;
   a frangible ampoule positioned in the internal portion; and
   an infrared signature powder sealed within the ampoule, the infrared signature powder comprising pyrophoric porous metal powder coated with a moderator, wherein the proportion of the moderator to the porous metal powder in the infrared signature powder is controlled to emit radiation at a pre-selected temperature and intensity for a pre-selected duration upon exposure to ambient air.
18. The munitions round of claim 17 wherein the projectile comprises a tracer, and wherein the frangible ampoule is configured to break upon launch of the tracer to expose the infrared signature powder to ambient air.

19. The munitions round of claim 17 wherein the frangible ampoule is configured to break upon impact with a target, thereby exposing the infrared signature powder to the ambient air.

20. The munitions round of claim 17 wherein the infrared signature powder comprises a powder that is about 200 mesh particle size or smaller.
**FIG. 1**

**Powder Blend**
- Weigh and blend a 50/50 dry mix of Al and Fe
- Hobart Mixer (220lb capacity/batch)
- 3 HOURS

**Inter-metallic Reaction**
- 820°C
- Heat-treating Furnace with Conveyor
- 4-5 HOURS (this includes cooling and the total time depends on the quantities)

**Grinding**
- Break it up – need to have -200 mesh particle size
- Grinder (will cost ~$19k)
- Processes 800lbs/day Classifier
- 2-3 HOURS

**Leaching**
- 15% solution – under a fume hood
- Leaching solution contents: 15% NaOH + .5% SnCl₂ x 2H₂O (80°C heating element)
- Don’t start the leaching process if there isn’t enough time to go through the drying process the same day
- Scrubber, heat source, (maybe mixer also) needed
- Reaction info: 1 liter of Hydrogen gas produced/gram of Al (~400 liters)
- 5 MINUTES

**Rinsing**
- Must maintain an inert atmosphere (or submerged in solvent) for the rest of the process until packaging
- Reaction info: 1 liter of Hydrogen gas produced/gram of Al (~400 liters)
- 5 MINUTES

**Drying**
- (Current)
- Vacuum oven inside glove box (with transfer box for Nitrogen curtain) May need multiple dryers in one glove box to process the necessary quantity of material
- 3-4 HOURS

**Blending**
- (Currently a manual process)
- Blend the solvent (suitable to dissolve binders) with 2 materials (Boron Nitride and Activated Carbon, and a suitable binder, such as Viton, Kraton, or organic tree gum binder) until almost all the solvent is gone, then dry until it is just a powder.
- Large multi-person glove box (VAC) with 3 sections: mixing with Hobart Mixer, Granulator, and vacuum oven. (Add Anti-caking agent for a better consistency of material) Scrubber is needed for solvent recycling and regeneration
- 20 MINUTES (BLENDING)
- 1 HOUR (DRYING, DEPENDS ON HOW MUCH SOLVENT IS REMOVED BEFORE VACUUM OVEN)

**Encapsulation**
- Packaging the material in individual ampoules for shipping
- 3-4 HOURS
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER

INV. B22F1/00 B22F1/02 C22C1/08 F42B12/40

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B22F C22C F42B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, COMPENDEX, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search

23 August 2011

Date of mailing of the international search report

05/09/2011

Name and mailing address of the ISA

European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk
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Authorized officer

Foresti er, Gilles
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