An explosive composition can be produced by dissolving RDX in a volume of a first solvent to form a first solution, and adding a second solvent to the first solution. The second solvent is miscible with the first solvent, but RDX is soluble in the second solvent to an extent no greater than 1 g RDX/100 g of the second solvent. Precipitated RDX crystals can be recovered. The RDX crystals can have a crystal density of less than 1.80 g/cm³.
RDX COMPOSITION AND PROCESS FOR ITS MANUFACTURE

BACKGROUND OF THE INVENTION

[0001] The present invention relates generally to explosives and processes for manufacturing such explosives.

[0002] The explosive hexahydro-1,3,5-trinitro-s-triazine is often referred to as RDX. Two processes have been used commercially to manufacture RDX. The first is direct nitration, which produces type A RDX. In this process, hexamethylenetetramine is reacted with nitric acid at 30° C. or less. The direct nitration method is not widely used today for economic reasons. The second process, known as the Bachmann process, is currently the most common method used to manufacture RDX. It produces type B RDX. In this process, hexamethylenetetramine is reacted with nitric acid in the presence of ammonium nitrate and acetic anhydride.

[0003] The primary difference between the two types of RDX is that type A is essentially pure, while type B is contaminated with HMX. However, for practical purposes, both processes yield RDX of essentially identical utility. In both processes, the raw RDX is further purified and the crystal morphology is modified by recrystallization.

[0004] RDX is commonly manufactured in a wide range of particle sizes (grades) from 25 microns to 600 microns in diameter by recrystallization. Recrystallized RDX may also be ground, for example in a fluid energy mill, to obtain finer particles ranging from 2 to 25 microns in diameter. However, all RDX commercially produced today consists of orthorhombic crystals with a density in the range of 1.80-1.82 grams/cm³. This form of RDX has been designated as the α polymorph, or RDX(α). The exact crystal density of a given lot of RDX is a function of purity (i.e., HMX content), and the absence or presence of crystal defects and inclusions.

[0005] A β polymorph of RDX has been reported in the literature. The stability of β-RDX is unknown and no measurements of physical properties or sensitivity have been reported other than the crystal morphology is dendritic.

[0006] RDX is an explosive material and therefore is used in a variety of applications in which controlled explosions are useful. In these applications, it is necessary to initiate the detonation of the RDX, and of course it is important to do so in a safe way.

[0007] A slapper detonator is a device that offers a relatively high degree of initiation safety. Slapper detonators function by rapidly discharging voltage through a low inductance circuit. The circuit comprises a high-voltage spark gap switch (typically 500-3,500 volts), a high-voltage low-inductance capacitor (typically 500-3,500 volts and 0.1-0.2 μF), and an exploding-foil initiator (EFI) bridge. The entire circuit inductance is typically 20-50 nH, and sometimes less (1-20 nH). Discharging such a circuit causes a current of several thousand amperes to flow through the EFI bridge, which in turn causes the EFI bridge to explode. The exploding bridge then accelerates a polymeric flyer (typically a thin polyamide film) across a short gap, where it slaps a pellet of a secondary explosive, causing the secondary explosive to detonate.

[0008] Many explosives have been detonated in a laboratory setting by slapper detonators, such as HNS, PETN, CL-20, TNT, RDX, HMX, and various formulations made from such explosives. However, such laboratory initiation systems typically function at high voltages with large capacitors and discharge energies of 250 mJ to 1,225 mJ. Such systems are generally unsuitable for use outside the laboratory. To be useful outside the laboratory, experience has shown that it is desirable to significantly reduce the firing voltage and capacitor size (firing energy) of the circuit. While this can be accomplished to some degree by designing the electrical firing circuit to be more efficient, ultimately the minimum firing energy is controlled by the sensitivity of the explosive.

[0009] The current state of the art is the low-energy foil initiator (LEFI). These devices typically function with firing energies below 100 mJ. To this end, explosives have been developed that have fine particle size and high surface area, such as HNS-IV, PETN, and CL-20, which can be initiated with less than 100 mJ. However, each of these explosives has significant problems. HNS-IV is difficult to manufacture and purify, and therefore is expensive. PETN has excellent sensitivity and an acceptable price, but has marginal thermal stability for non-laboratory applications. CL-20 is expensive and cannot be recrystallized to a very small particle size. It is therefore just barely sensitive enough for a LEFI application.

[0010] There is a need for new explosive materials that can be initiated by LEFI devices, and that overcome at least some of the above-described problems.

SUMMARY OF THE INVENTION

[0011] One aspect of the present invention is a process for making an explosive. The process comprises dissolving RDX in a volume of a first solvent to form a first solution, and adding a second solvent to the first solution. The second solvent is miscible with the first solvent, but RDX is soluble in the second solvent to an extent no greater than 1 g RDX/100 g of the second solvent. RDX crystals are precipitated and can be recovered.

[0012] Another aspect of the invention is an explosive prepared by the above process. The explosive comprises primarily RDX, but can also contain smaller amounts of other materials such as HMX.

[0013] Another aspect of the invention is RDX crystals having a crystal density of less than 1.80 g/cm³.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] FIG. 1 is an enlarged illustration of type B RDX particles.

[0015] FIG. 2 is an enlarged illustration of RDX particles of the present invention.

[0016] FIG. 3 is a schematic diagram of a perforating system of the present invention.

DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

[0017] The present invention relates to a novel form of RDX that can be used in the perforation of well casing, among other applications.
The production of the novel form of RDX begins with a particulate RDX composition. This starting composition contains primarily RDX (e.g., at least about 90 wt% RDX on a dry solids basis, and in some embodiments at least about 99 wt% RDX), but it can also contain smaller amounts of other explosive or non-explosive substances, such as HMX. Type B RDX is one suitable starting material.

The RDX is dissolved in a first solvent to form a first solution. RDX should be soluble in this first solvent to an extent of greater than 1 g RDX/100 g solvent. In various embodiments of the invention, the solubility of RDX in the first solvent is greater than 5 g/100 g, 10 g/100 g, or 25 g/100 g. (All solubility figures in this patent are at room temperature unless otherwise stated.) The concentration of RDX in the solution will generally be about 1-50 wt%, although higher or lower concentrations can be used in some situations.

The first solvent will typically be an organic solvent, for example, one having about 2-10 carbon atoms. Ketones are one group of suitable solvents. Specific examples of suitable first solvents include acetone, dimethyl sulfoxide, and dimethylformamide.

A second solvent is then added to the solution, in order to cause "crash" precipitation of RDX particles. The second solvent is miscible with the first solvent, but RDX is much less soluble in the second solvent than in the first solvent. In various embodiments of the invention, RDX is soluble in the second solvent to an extent no greater than 1 g of RDX/100 g of the second solvent, or in some cases no greater than 0.1 g/100 g. Suitable examples of second solvents include water and various dilute aqueous solutions.

The second solvent can be added in an excess compared to the volume of the first solvent in the solution. For example, the second solvent can be added in a volume that is about 2-10 times greater than the volume of the first solvent. Even more of the second solvent can be used, although it may be economically undesirable in many cases. In contrast, if the amount of the second solvent used is too small, the resulting crystals will not have the desired properties and will not function as an E11 explosive. The solution can be agitated during and/or after the addition of the second solvent.

The addition of the second solvent will cause precipitation of RDX particles. The particles can be recovered, for example by filtration, and then washed and dried. The final RDX composition can be essentially pure RDX, or it can contain smaller amounts of other substances, such as HMX. In contrast to the RDX that has been commercially available in the past, the RDX has a crystal density of less than 1.80 g/cm³. In some cases, the RDX has a crystal density of about 1.65-1.73 g/cm³. In some embodiments of the invention, the RDX has a surface area of greater than about 1.15 m²/g.

The detonation of RDX produced by the above-described process can generally be initiated with less energy than what is required to initiate previously-known RDX compositions. In some embodiments of the invention, detonation of the RDX can be initiated with less than about 100 mJ, or in some cases, less than about 75 mJ.

FIG. 1 shows a sample of type B RDX at 100x magnification, while FIG. 2 shows a sample of the RDX of the present invention at 750x magnification.
What is claimed is:

1. A process for making an explosive, comprising:
   dissolving RDX in a volume of a first solvent to form a first solution;
   adding a second solvent to the first solution, wherein the second solvent is miscible with the first solvent, and wherein RDX is soluble in the second solvent to an extent no greater than 1 g RDX/100 g of the second solvent; and
   recovering precipitated RDX crystals.

2. The process of claim 1, wherein RDX is soluble in the first solvent to an extent greater than 5 g RDX/100 g of the first solvent.

3. The process of claim 1, wherein the first solvent is an organic solvent having about 2-10 carbon atoms.

4. The process of claim 1, wherein the first solvent is acetone, dimethylsulfoxide, or dimethylformamide.

5. The process of claim 1, wherein the second solvent is water.

6. The process of claim 1, wherein the second solvent is added in a volume that is about 2-10 times the volume of the first solvent.

7. The process of claim 1, wherein the recovered RDX crystals have a crystal density of less than 1.80 g/cm³.

8. The process of claim 7, wherein the recovered RDX crystals have a surface area of greater than about 1.15 m²/g.

9. An explosive prepared by a process comprising:
   dissolving RDX in a volume of a first solvent to form a first solution;
   adding a second solvent to the first solution, wherein the second solvent is miscible with the first solvent, and wherein RDX is soluble in the second solvent to an extent no greater than 1 g RDX/100 g of the second solvent; and
   recovering precipitated RDX crystals.

10. The explosive of claim 9, wherein RDX is soluble in the first solvent to an extent greater than 5 g RDX/100 g of the first solvent.

11. The explosive of claim 9, wherein the first solvent is an organic solvent having about 2-10 carbon atoms.

12. The explosive of claim 9, wherein the first solvent is acetone, dimethylsulfoxide, or dimethylformamide.

13. The explosive of claim 9, wherein the second solvent is water.

14. The explosive of claim 9, wherein the second solvent is added in a volume that is about 2-10 times the volume of the first solvent.

15. The explosive of claim 9, wherein the recovered RDX crystals have a crystal density of less than 1.80 g/cm³.

16. The explosive of claim 15, wherein the recovered RDX crystals have a surface area of greater than about 1.15 m²/g.

17. RDX crystals having a crystal density of less than 1.80 g/cm³.

18. The RDX crystals of claim 17, wherein the RDX crystals have a surface area of greater than about 1.15 m²/g.

19. The RDX crystals of claim 17, wherein detonation of the RDX crystals can be initiated with less than about 100 mJ.

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