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FLEXIBLE EXPLOSIVE COMPOSITIONS CONTAINING BLOCK COPOLYMERS

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ABSTRACT OF THE DISCLOSURE

This invention relates to an explosive composition consisting essentially of an explosive component comprising a cap-sensitive high-explosive compound such as nitric esters and nitramines which may be easily initiated under a released condition by the conventional detonator and if required, an oxidizing agent, and a non-explosive component comprising a thermoplastic elastomer which is a block copolymer consisting of conjugated diolefin segments and monovinyl aromatic hydrocarbon segments. The explosive composition may be formed into a sheet or strand. The shaped explosive has a good flexibility and a great utility as an explosive to be used in various fabrication of metals.

BACKGROUND OF THE INVENTION

This invention relates to an explosive composition, and more particularly, it relates to an explosive composition for a shaped explosive in sheet or strand form.

Nowadays, shaped explosives in the form of a sheet or a strand are widely used in the field of fabrication of metals, for example, shaping, joining or welding and surface hardening of various metals.

These shaped explosives are required to have sufficient flexibility as well as self supporting ability, and the explosive compositions for these shaped explosives must be shaped into any desired configuration depending upon the shapes of the workpiece and the conditions under which they are used. Thus, a good processability is highly desirable for the explosive compositions for shaped explosives, in addition to the flexibility and self-supporting ability.

Heretofore, explosive compositions for shaped explosives consisting of an explosive component comprising a cap-sensitive high explosive compound such as organic nitric esters or nitramines and metal oxides as an oxidizing agent, and a non-explosive component comprising a binding agent consisting mainly of paraffin or nitrocellulose are known well.

However, the shaped explosives containing paraffin as a binding agent has a disadvantage in that the flexibility is greatly reduced at a low temperature since the paraffin used as a main component of the binding agent tends to harden and become brittle at a low temperature due to its instability against temperature variations, whereas at a high temperature it becomes difficult to maintain its self-supporting ability due to the softening of paraffin.

On the other hand, the shaped explosives containing nitrocellulose as a binding agent has rather unsatisfactory mechanical properties with regards to the tensile strength and the bending strength and particularly, this type of shaped explosive has a drawback in that it tends to be easily broken once a part thereof is cracked, though the inconvenience involved in the shaped explosives containing paraffin can be fairly avoided since nitrocellulose is relatively stable to the temperature variations.

Besides, there are known as issued patents an explosive composition consisting of a cap-sensitive crystalline high explosive compound such as nitric esters or nitramines and a binding agent comprising an organic rubber and a thermoplastic terpene hydrocarbon resin, and a fibrous explosive composition consisting of a cap-sensitive crystalline high explosive and an elastomeric binding agent which is chemically inert with the system containing high explosive.

However, since natural or synthetic rubbers and rubber-like copolymers used as elastomeric component in these explosive compositions have poor plasticity, they must be dissolved in a suitable solvent before mixing with high explosive compound. Thus, there has been required a drying process to remove the solvent after the mixing of high explosive compound with the binding agent, and the manufacturing of such explosive composition has been burdened with the requirement for a considerable amount of labor and complications in the operation.

SUMMARY OF THE INVENTION

It is, therefore, an object of this invention to provide an explosive composition having an excellent mouldability from which shaped explosives may be produced in a simple manner.

Another object of this invention resides in the provision of an explosive composition useful in the production of shaped explosives having excellent flexibility and self-supporting ability.

These objects mentioned above have been found to be accomplished according to the explosive composition of this invention which consists essentially of an explosive component comprising a cap-sensitive high explosive compound as a main component, e.g. nitric esters or nitramines and, if required, an oxidizing agent and a non-explosive component comprising a thermoplastic elastomer as a main component of a binding agent. More specifically, a feature of the explosive composition of this invention resides in the use of a thermoplastic elastomer as a main component of the binding agent in admixture with the conventional explosive component known heretofore.

Thermoplastic elastomers which may be used in the explosive compositions of this invention are block copolymers having both a processability similar to that of thermoplastic resins and an elasticity similar to that of vulcanized rubbers. They include block copolymers substantially comprising conjugated diolefin segments and mono-vinyl aromatic hydrocarbon segments, and the like block copolymers which will be explained more in detail hereinafter.

For example, thermoplastic elastomers known heretofore which may be used in the explosive compositions of this invention include polystyrene/polybutadiene/polystyrene block copolymer or polystyrene/polyisoprene/polystyrene block copolymer obtained by polymerizing styrene in the presence of mono-lithium hydrocarbon as a catalyst, copolymerizing the resulting active polystyrene with 1,3-butadiene or isoprene, and further copolymerizing the resulting active polystyrene/polybutadiene block copolymer or active polystyrene/polyisoprene block copolymer with styrene as disclosed in Belgian Patent No. 627,652 and U.S. Patent No. 3,231,635; polystyrene/polybutadiene/polystyrene block copolymer or polystyrene/polyisoprene/polystyrene block copolymer obtained by coupling the above-mentioned active polystyrene/polybutadiene block copolymer or active polystyrene/polyisoprene block copolymer with divinylbenzene as described in Belgian Patent No. 646,853; polystyrene/polybutadiene/polystyrene block copolymer or

polystyrene/polyisoprene/polystyrene block copolymer obtained by coupling the above-mentioned active polystyrene/polybutadiene copolymer or active polystyrene/polyisoprene block copolymer with dihalogenated hydrocarbon as described in Belgian Patent No. 647,860; polystyrene/polybutadiene/polystyrene block copolymer or polystyrene/polyisoprene/polystyrene block copolymer obtained by polymerizing 1,3-butadiene or isoprene in the presence of dilithium hydrocarbon as a catalyst, and copolymerizing the resulting active polybutadiene or active polyisoprene with styrene as described in British Patent No. 895,980 and U.S. Patent No. 3,251,905; and polystyrene/polybutadiene/polystyrene copolymer or polystyrene/polyisoprene/polystyrene copolymer obtained by polymerizing a mixture of 1,3-butadiene and styrene, or a mixture of isoprene and styrene in the presence of dilithium hydrocarbon as a catalyst as described in Australian Patent Nos. 22559/56 and 22560/56.

Conjugated diolefins referred to herein are those having 4–6 carbon atoms and include, for example, 1,3-butadiene, 2-methyl-1,3-butadiene (isoprene), 2,3-dimethyl-1,3-butadiene, and 1,3-pentadiene (piperylene).

Aromatic mono-vinyl hydrocarbons referred to herein include, for example, styrene, vinyltoluene, vinylxylene, ethylstyrene, isopropylstyrene, ethyl vinyltoluene, tert-butylstyrene, diethylstyrene and vinylnaphthalene.

In accordance with this invention, the use of these thermoplastic elastomers as a main component of the binding agent enables a thorough mixing of the explosive component with the binding agent by heating and kneading them without using any solvent in the manufacturing of the explosive composition of this invention, and the explosive composition thus obtained can be easily and safely worked as it is to form the shaped explosives by compressing or rolling while still hot. Thus, the drying process for the removal of solvent is unnecessary and the manufacturing of the shaped explosives can be made easy according to this invention. This advantage is attributable to the excellent processability, similar to that of thermoplastic resin, of the thermoplastic elastomer used as a main component of the binding agent in the explosive composition of this invention.

On the other hand, the mechanical strength of the shaped explosives obtained according to this invention can be remarkably improved by the excellent tensile strength and elasticity of the thermoplastic elastomers used, which are similar to those of vulcanized rubbers.

Above all, the shaped explosives obtained according to this invention are superior with respects to the elasticity, recovery and self-supporting ability over known shaped explosives. Thus, they remain in safety from hazardous friction or impact and can be handled quite safely without any fear of easy breaking by bending or stretching.

In the explosive composition of this invention, in addition to the known thermoplastic elastomers mentioned above, the following novel block copolymers are particularly advantageously used as a main component of the binding agent in this invention. For example, polystyrene/polybutadiene/polystyrene block copolymers having improved heat- and oil-resistances in which polystyrene segments are copolymerized with a small amount of divinylbenzene may also be used.

Moreover, 1,3-butadiene-styrene block copolymer obtained by copolymerizing a monomeric mixture consisting of 1,3-butadiene and styrene, and additionally copolymerizing the resulting active copolymer with a monomeric mixture consisting of 1,3-butadiene and styrene; isoprene-styrene block copolymer obtained by first copolymerizing a monomeric mixture consisting of isoprene and styrene in the presence of monolithium hydrocarbon as a catalyst, and additionally copolymerizing the resulting active copolymer with a monomeric mixture consisting of isoprene and styrene; 1,3-butadiene-isoprene-styrene block copolymer obtained by first copolymerizing a monomeric mixture consisting of 1,3-butadiene, isoprene and styrene in the presence of mono-lithium hydrocarbon as a catalyst and additionally copolymerizing the resulting block copolymer with a monomeric mixture consisting of 1,3-butadiene, isoprene and styrene; and thermoplastic elastomers obtained by copolymerizing a small amount of divinylbenzene with the above-mentioned monomeric mixtures in which mainly polystyrene segments are cross-linked, are particularly preferable as a main component of the binding agent in the explosive composition of this invention.

When these novel thermoplastic elastomers as mentioned above are used as a main component of the binding agent in accordance with this invention, the resulting shaped explosives have not only as good hot-processability and elasticity as with the known thermoplastic elastomers mentioned above, but also advantages in that when heated, the deformation in the shaped configuration is smaller due to the excellent heat-resistance and that, such inconvenience as so-called "necking," i.e. the formation of constricted part at the point of stretching, hardly occurs, upon stretching. It can be readily appreciated that the latter advantage mentioned above is particularly desirable in explosive strands.

Thus, the explosive composition of this invention is superior with regards not only to the mouldability in the manufacture of shaped explosives and the mechanical strength of the resulting shaped explosives but also to the self-supporting ability thereof over the explosive compositions known heretofore.

In the thermoplastic elastomers mentioned above substantially comprising conjugated diolefin recurring segments and mono-vinyl aromatic hydrocarbon segments, said conjugated diolefin recurring segments may be replaced by random copolymer of ethylene and olefins having 3 to 18 and, preferably 3 to 6 carbon atoms, and most preferably with α-olefins; random copolymer of styrene and 1,3-butadiene; random copolymer of styrene and isoprene, and random copolymer of 1,3-butadiene and isoprene. By the same token, acrylonitrile, methyl methacrylate, chlorostyrene, ethylene and propylene segments may be substituted for the mono-vinyl aromatic hydrocarbon segments in the thermoplastic elastomers.

In the production of these thermoplastic elastomers used in this invention, in addition to lithium catalysts mentioned hereinbefore, catalysts mainly comprising other alkali metals such as potassium, sodium, rubidium and cesium, or any of the so-called Zieglar-type catalysts may also be used.

Polymerization solvents which may be used in the production of the thermoplastic elastomer used in this invention include naphthenic, aromatic and paraffinic hydrocarbons.

Explosive compounds which may be used in this invention include nitric esters and nitramines such as pentaerythritol tetranitrate (PETN), cyclotrimethylenetrinitramine (RDX), cyclotetramethylenetetramine (HMX) and tetranitromethyl aniline, which may be easily initiated under a released condition by using the conventional detonators.

If required, various oxidizing agents, for example, metal oxides such as zinc oxide, titanium oxide, chromium oxide, silicon oxide, red lead, lead dioxide, iron sesquioxide, triiron tetroxide; chlorates such as potassium chlorate; perchlorates such as potassium perchlorate and ammonium perchlorate; and nitrates such as potassium nitrate and barium nitrate may be used in admixture with the explosive compounds exemplified above.

The processability of the explosive composition is greatly improved by admixing a suitable amount of polypropylene glycohol, solid paraffin or polyethylene with the thermoplastic elastomers.

When the explosive composition of this invention is kneaded or worked by compression- or roll-moulding at a relatively low temperature, it is desirable to incorporate a suitable amount of naphthenic, aromatic or paraffinic hy-

drocarbons having good compatibility with the thermoplastic elastomers.

The explosive composition of this invention can be successfully used not only for the manufacture of shaped explosives in sheets or strand forms for use in the working of metals, but also for the explosive strands of high detonating speed used for the conventional coated detonating fuzes.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following examples will serve to illustrate this invention more fully. It should not be construed, however, that these examples restrict this invention as they are given merely by way of illustration:

Example 1

There was obtained an explosive composition for shaped explosives as a sample (A) in accordance with the following recipe by using an oil extended "Thermoplastic ST–125" (Trade name of Shell Chemical Co., U.S.A.), a known thermoplastic elastomer comprising polystyrene, polybutadiene and polystyrene segments and containing 40% by weight of styrene which contains 250 parts by weight of naphthenic process oil per 100 parts by weight of said thermoplastic elastomer, as a binding agent.

Recipe

	Parts
PETN	25
Pb_3O_4	50
Binding agent	25

Subsequently, there was obtained another explosive composition for shaped explosives as a sample (B), in accordance with the following recipe by using a novel oil extended thermoplastic elastomer containing 250 parts by weight of naphthenic process oil per 100 parts by weight of the thermoplastic elastomer as a binding agent, which was obtained in a process described hereinafter:

Recipe

	Parts
PETN	25
Pb_3O_4	50
Binding agent	25

The novel thermoplastic elastomer mentioned above was obtained according to the following procedures:

To 15% by weight n-hexane solution containing 9.5 kg. of monomeric mixture consisting of 1,3-butadiene and styrene in a weight ratio of 40:60, was added 220 mmol of n-butyl lithium calculated as active lithium under nitrogen atmosphere and the copolymerization reaction was conducted at 60° C. for 4 hours. After more than 99% of the total monomers were copolymerized, to the resulting solution of active copolymer was further added 15% by weight n-hexane solution containing 19.0 kg. of monomeric mixture consisting of 1,3-butadiene and styrene in a weight ratio of 70:30, and the copolymerization reaction was conducted first at 70° C. for 4 hours and subsequently at 85° C. for about another one hour. After practically all of the monomers additionally charged were copolymerized, there was added 0.285 kg. of phenyl-β-naphthylamine as a stabilizer and the resulting mixture was dried to yield the desired block copolymer. The resulting copolymer was a novel thermoplastic elastomer comprising 1,3-butadiene and styrene segments, and containing 40% by weight of styrene, and having an excellent heat-resistance.

The explosive composition for shaped explosives in the instant example, the samples (A) and (B), were prepared by mixing the PETN and Pb_3O_4 in the respective composition uniformly and kneading the resulting mixture at 80° C. together with the binding agent which was preheated beforehand at 70° C. The resulting explosive compositions were formed into sheets by compression or rolling while maintaining the elevated temperature of 80° C.

For comparison, still another explosive composition was prepared as a comparative sample (C) according to the following recipe and to the same procedures as in the preparations of samples (A) and (B) except that paraffin containing 11 parts by weight of petrolatum as a plasticizer and 3 parts by weight of ester rubber as a sticking agent per 100 parts by weight of paraffin was used as a binding agent, and the composition thus obtained was formed into a sheet by rolling.

Recipe

	Parts
PETN	25
Pb_3O_4	55
Binding agent	20

For further comparison, there was prepared another explosive composition for shaped explosives as a comparative sample (D) according to the following recipe by using nitrocellulose containing 21 parts by weight of dibutyl phthalate as a plasticizer per 100 parts by weight of nitrocellulose was used as a binding agent, and the resulting composition was kneaded at room temperature to give a conventional explosive composition for shaped explosives, and then it was formed into a sheet by rolling.

Recipe

	Parts
PETN	25
Pb_3O_4	37
Starch	13
Binding agent	25

The physical properties of the resulting explosive sheets were measured, respectively, and the results are as shown in the following Table 1:

TABLE 1

Samples	Tensile strength (g./cm.²)	Breaking elongation (percent)	Residual [1] elongation (percent)
Sample (A)	1,250	165	30
Sample (B)	1,130	150	28
Comparative sample (C)	355	57	53
Comparative sample (D)	177	60	57

[1] Rate of residual elongation immediately after the breaking with respect to the original length. The same definition applies hereinafter.

As can be clearly noted from the above, samples (A) and (B) in accordance with this invention which were obtained by using the thermoplastic elastomers as a main component of the binding agents exhibit better flexibility and elasticity and particularly excellent tensile strength and self-supporting ability as compared with the Comparative samples (C) and (D) in which the conventional paraffin or nitrocellulose was used as main components of the binding agents, respectively. This advantage is attributable to the use of the thermoplastic elastomer as a main component of the binding agent according to this invention.

Example 2

To 15% by weight n-hexane solution containing 9.5 kg. of a monomeric mixture consisting of 1,3-butadiene, styrene and divinylbenzene in a weight ratio of 40:60:0.0750, said divinylbenzene being a mixture of m- and p-forms in a ratio of 80:20, was added under nitrogen atmosphere 240 mmol of sec-butyl lithium as an active lithium and the copolymerization reaction was conducted at 60° C. for 4 hours.

After more than 99% of the total monomers were copolymerized, to the resulting solution of active copolymer was further added 15% by weight n-hexane solution containing 19.0 kg. of a monomeric mixture consisting of 1,3-butadiene, styrene and divinylbenzene in a weight ratio of 70:30:0.0375, said divinylbenzene being a mixture of m- and p-forms in a ratio of 80:20, and the copolymerization reaction was first conducted at 70° C. for 4 hours and subsequently at 85° C. for another one hour.

After practically all of the monomers additionally charged were copolymerized, there was added 0.285 kg. of phenyl-β-naphthylamine as a stabilizer and the resulting mixture was dried to yield a novel thermoplastic elastomer (referred to as e_0 hereinafter), consisting of 1,3-butadiene, styrene and divinylbenzene, having styrene content of 40% by weight and further having good heat-resistance and oil-resistance.

Similarly, another three samples of thermoplastic elastomer were prepared as follows.

5 parts by weight of polypropylene glycohol having molecular weight of 1000 was admixed with 100 parts by weight of the thermoplastic elastomer (sample e_0) produced as above to prepare a sample e_1.

15 parts by weight of solid paraffin having melting point of 80° C. was admixed with 100 parts by weight of the thermolplastic elastomer (sample e_0) to prepare a sample e_2. 20 parts by weight of polyethylene having melt index of 100 was admixed with 100 parts by weight of the thermoplastic elastomer (sample e_0) to prepare sample e_3.

The explosive compositions containing shaped explosives as samples E_0, E_1, E_2 and E_3 were obtained according to the following recipe by using the above thermoplastic elastomer samples e_0, e_1, e_2 and e_3, respectively extended with 250 parts by weight of naphthenic process oil per 100 parts by weight of the thermoplastic elastomer as a binding agent:

Recipe

	Parts
PETN	25
Pb_3O_4	50
Binding agent	25

The resulting explosive compositions were kneaded, rolled and formed into a sheet under the same conditions as in Example 1 to obtain an explosive sheet. The physical properties of the explosive sheet thus obtained were measured. The results are shown in the following Table 2.

TABLE 2

Sample	Tensile strength (g./cm.²)	Breaking elongation (percent)	Residual elongation (percent)
E_0	920	135	18
E_1	905	105	12
E_2	908	110	15
E_3	914	120	13

The results show that each of the samples E_0, E_1, E_2 and E_3 obtained according to this invention has excellent tensile strength, elasticity and flexibility as well as self-supporting ability over the conventional explosive compositions, i.e. the Comparative samples (C) and (D) obtained in the preceding example.

This specific advantage of this invention has been brought about by the use of thermoplastic elastomer as a main component of the binding agent.

Example 3

To 15% by weight n-hexane solution containing 5 kg. of a monomeric mixture consisting of isoprene and styrene in a weight ratio of 20:80, was added 130 mmol of n-butyl lithium calculated as active lithium under nitrogen atmsophere and the copolymerization reaction was conducted at 60° C. for 4 hours. After more than 99% of the total monomers were copolymerized, to the resulting solution of the active copolymer was further added 15% by weight n-hexane solution containing 15 kg. of a monomeric mixture consisting of isoprene and styrene in a weight ratio of 73.3:26.7, and the copolymerization reaction was conducted first at 70° C. for 4 hours, and subsequently at 85° C. for an hour. After practically all of the monomers additionally charged were copolymerized, there was added 0.20 kg. of phenyl-β-naphthylamine as a stabilizer and the resulting mixture was dried to yield a novel thermoplastic elastomer consisting of isoprene and styrene, containing 40% by weight of styrene and having a good heat-resistance.

An explosive composition for shaped explosives was obtained as sample (F) according to the following recipe by using the thermoplastic elastomer prepared as above extended with 300 parts by weight of naphthenic process oil per 100 parts by weight of the thermoplastic elastomer as a binding agent.

Recipe

	Parts
PETN	25
Pb_3O_4	50
Binding agent	30

The resulting explosive composition was kneaded, rolled and formed into a sheet under the same conditions as in Example 1 to obtain an explosive sheet. The physical properties of the explosive sheet thus obtained were measured. The results are shown in the following Table 3:

TABLE 3

Sample	F
Tensile strength (g./cm.²)	1040
Breaking elongation (percent)	185
Residual elongation (percent)	25

As can be noted from the results shown above, the sample (F) obtained according to this invention has excellent tensile strength, elasticity and flexibility as well as the self-supporting ability over the conventional explosive compositions, i.e. the Comparative sample (C) and (D) obtained in the preceding Example 1. This specific advantage of this invention has been brought about by the use of the thermoplastic elastomer as a main component of the binding agent.

Example 4

To 15% by weight cyclohexane solution containing 4 kg. of styrene was added 130 mmol of n-butyl lithium calculated as active lithium and the polymerization reaction was conducted at 45° C. for 4 hours. After more than 99% of stryene was polymerized, to the resulting solution of the active polystyrene was added 15% by weight cyclohexane solution containing 12 kg. of isoprene and the copolymerization reaction was conducted at 55° C. for 3 hours. After the substantial completion of the copolymerization of isoprene, to the resulting solution of the active copolymer was further added 15% by weight cyclohexane solution containing 4 kg. of styrene and the copolymerization was conducted at 60° C. for another 3 hours. After the completion of the reaction, there was added 0.20 kg. of phenyl-β-naphthylamine as a stabilizer and the resulting mixture was dried to yield a known thermoplastic elastomer consisting of isoprene and styrene, and containing 40% by weight of styrene.

An explosive composition for shaped explosives was obtained as a sample (G) according to the following recipe by using the thermoplastic elastomer prepared above extended with 250 parts by weight of naphthenic process oil per 100 parts by weight of the thermoplastic elastomer as a binding agent.

Recipe

	Parts
PETN	25
Pb_3O_4	50
Binding agent	25

The resulting explosive composition was kneaded, rolled and formed into a sheet under the same conditions as in Example 1 to obtain an explosive sheet. The physical properties of the explosive sheet thus obtained were measured. The results are shown in the following Table 4:

TABLE 4

Sample	G
Tensile strength (g./cm.²)	1070
Breaking elongation (percent)	150
Residual elongation (percent)	23

As can be noted from the results, the sample (G) obtained according to this invention has excellent tensile strength, elasticity and flexibility as well the self-supporting ability over the conventional explosive compositions, i.e., the Comparative samples (C) and (D).

This specific advantage of this invention has been brought about by the use of the thermoplastic elastomer as a main component of the binding agent.

Example 5

To 15% by weight n-hexane solution containing 600 g. of 1,3-butadiene was added 20 mmol of 1,2-dilithium-1,2-diphenylethane calculated as active lithium and the polymerization reaction was conducted at 50° C. for 4 hours. After practically all of 1,3-butadiene charged was polymerized, there was added 15% by weight n-hexane solution containing 400 g. of styrene and the copolymerization was conducted at 55° C. for 2 hours. After the completion of the reaction, to the reaction mixture was added 10 g. of phenyl-β-naphthylamine and there was obtaned a known thermoplastic elastomer consisting of 1,3-butadiene and styrene and containing 40% by weight of styrene.

An explosive composition for shaped explosives was obtained as a sample (H) according to the following recipe by using the thermoplastic elastomer prepared as above extended with 250 parts by weight of paraffinic process oil per 100 parts by weight of the thermoplastic elastomer as a binding agent.

Recipe

	Parts
PETN	25
Pb_3O_4	50
Binding agent	25

The resulting explosive composition was kneaded, rolled and formed into a sheet under the same conditions as in Example 1 to obtain an explosive sheet. The physical properties of the explosive sheet thus obtained were measured. The results are shown in the following Table 5:

TABLE 5

Sample	H
Tensile strength (g./cm.^{2})	820
Breaking elongation (percent)	110
Residual elongation (percent)	32

As can be noted from the results, the sample (H) obtained according to this invention has excellent tensile strength, elasticity and flexibility as well as the self-supporting ability over the conventional explosive compositions, i.e. the Comparative samples (C) and (D) obtained in Example 1. This specific advantage of this invention has been brought about by the use of the thermoplastic elastomer as a main component of the binding agent.

What is claimed is:

1. An explosive composition consisting essentially of an explosive component comprising a capsensitive high-explosive selected from the group consisting of organic nitrates and nitramines and a non-explosive component essentially comprising, as a binding agent, a block copolymer which is a thermoplastic elastomer comprising segments of conjugated diolefin having 4 to 6 carbon atoms and segments of monovinyl aromatic hydrocarbons.

2. An explosive composition as claimed in claim 1 containing an oxidizing agent selected from the group consisting of metal oxide, nitrate, chlorate or perchlorate.

3. An explosive composition as claimed in claim 1 wherein said thermoplastic elastomer is polystyrene/polybutadiene/polystyrene block copolymer or polystyrene/polyisoprene/polystyrene block copolymer obtained by polymerizing styrene in the presence of monolithium hydrocarbon catalyst, copolymerizing the resulting active polystyrene with 1,3-butadiene or isoprene, and further copolymerizing the resulting active polystyrene/polybutadiene or polystyrene/polyisoprene block copolymer with styrene.

4. An explosive composition as claimed in claim 1 wherein said thermoplastic elastomer is polystyrene/polybutadiene/polystyrene block copolymer or polystyrene/polyisoprene/polystyrene block copolymer obtained by polymerizing styrene in the presence of monolithium hydrocarbon catalyst, copolymerizing the resulting active polystyrene with 1,3-butadiene or isoprene, and coupling the resulting active polystyrene/polybutadiene or polystyrene/polyisoprene block copolymer with divinylbenzene.

5. An explosive composition as claimed in claim 1 wherein said thermoplastic elastomer is polystyrene/polybutadiene/polystyrene block copolymer or polystyrene/polyisoprene/polystyrene block copolymer obtained by polymerizing styrene in the presence of monolithium hydrocarbon catalyst, copolymerizing the resulting active polystyrene with 1,3-butadiene or isoprene, and coupling the resulting active polystyrene/polybutadiene or polystyrene/polyisoprene block copolymer with dihalogenated hydrocarbon.

6. An explosive composition as claimed in claim 1 wherein said thermoplastic elastomer is polystyrene/polybutadiene/polystyrene block copolymer or polystyrene/polyisoprene/polystyrene block copolymer obtained by polymerizing 1,3-butadiene or isoprene in the presence of dilithium hydrocarbon catalyst, and copolymerizing the resulting active polybutadiene or polyisoprene with styrene.

7. An explosive composition as claimed in claim 1 wherein said thermoplastic elastomer is polystyrene/polybutadiene/polystyrene block copolymer or polystyrene/polyisoprene/polystyrene block copolymer obtained by copolymerizing a monomeric mixture consisting of 1,3-butadiene and styrene or a monomeric mixture consisting of isoprene and styrene in the presence of dilithium hydrocarbon catalyst.

8. An explosive composition as claimed in claim 1 wherein said thermoplastic elastomer is polystyrene/polybutadiene/polystyrene block copolymer having improved heat- and oil-resistances obtained by copolymerizing a predominant proportion of polystyrene segment with a small amount of divinylbenzene.

9. An explosive composition as claimed in claim 1 wherein said thermoplastic elastomer is 1,3-butadiene-styrene block copolymer obtained by copolymerizing a monomeric mixture consisting of 1,3-butadiene and styrene in the presence of monolithium hydrocarbon catalyst and additionally copolymerizing the resulting active copolymer with a monomeric mixture consisting of 1,3-butadiene and styrene.

10. An explosive composition as claimed in claim 1 wherein said thermoplastic elastomer is isoprene-styrene block copolymer obtained by copolymerizing a monomeric mixture consisting of isoprene and styrene in the presence of monolithium hydrocarbon catalyst and additionally copolymerizing the resulting active copolymer with a monomeric mixture consisting of isoprene and styrene.

11. An explosive composition as claimed in claim 1 wherein said thermoplastic elastomer is 1,3-butadiene-isoprene-styrene block copolymer obtained by copolymerizing a monomeric mixture consisting of 1,3-butadiene, isoprene and styrene in the presence of monolithium hydrocarbon catalyst and additionally copolymerizing the resulting active copolymer with a monomeric mixture consisting of 1,3-butadiene, isoprene and styrene.

12. An explosive composition as claimed in claim 1 wherein said thermoplastic elastomer is 1,3-butadiene-styrene block copolymer, in which styrene segments are cross-linked, obtained by copolymerizing a monomeric mixture consisting of 1,3-butadiene, styrene and divinylbenzene, in the presence of monolithium hydrocarbon catalyst and additionally copolymerizing the resulting

active copolymer with a monomeric mixture consisting of 1,3-butadiene, styrene and divinyl benzene.

13. An explosive composition as claimed in claim **1** wherein said thermoplastic is isoprene-styrene block copolymer, in which styrene segments are cross-linked, obtained by copolymerizing a monomeric mixture consisting of isoprene, styrene and divinylbenzene in the presence of monolithium hydrocarbon catalyst, and additionally copolymerizing the resulting active copolymer with a monomeric mixture consisting of isoprene, styrene and divinylbenzene.

14. An explosive composition as claimed in claim **1** wherein said thermoplastic elastomer is 1,3-butadiene-isoprene-styrene block copolymer, in which styrene segments are cross-linked, obtained by copolymerizing a monomeric mixture consisting of 1,3-butadiene, isoprene, styrene and divinylbenzene and additionally copolymerizing the resulting active copolymer with a monomeric mixture consisting of 1,3-butadiene, isoprene, styrene.

15. An explosive composition as claimed in claim **1** wherein said thermoplastic elastomer is a block copolymer comprising polymer segments of random copolymer of ethylene and -olefin having 3–18 carbon atoms; random copolymer of styrene and 1,3-butadiene; random copolymer of styrene and isoprene; or random copolymer of 1,3-butadiene and isoprene, and polymeric segments of polyacrylonitrile, polymethyl methacrylate, polychlorostyrene, polyethylene or polypropylene.

16. An explosive composition as claimed in claim **1** wherein said thermoplastic elastomer composed of conjugated diolefin having 4–6 carbon atoms and monovinyl aromatic hydrocarbons is produced by polymerizing a monomeric mixture comprising a conjugated diolefin and a monovinyl aromatic hydrocarbon in a hydrocarbon solvent in an inert atmosphere in the presence of a lithium base catalyst and, after substantial completion of the polymerization, additionally polymerizing the resulting active copolymer with a monomeric mixture comprising said conjugated diolefin and said monovinyl aromatic hydrocarbon.

17. An exposive composition as claimed in claim **1** wherein said thermoplastic elastomer composed of conjugated diolefin and monovinyl aromatic hydrocarbon is produced by polymerizing 8–65 parts by weight of a monomeric mixture (A) comprising a conjugated diolefin and a monovinyl aromatic hydrocarbon in a weight ratio of 85–10:15–90 in a hydrocarbon solvent in an inert atmosphere in the presence of 0.2–20 mmol per 100 g. of the total amount of the monomeric mixture (A) and a monomeric mixture (B) mentioned hereinafter, of a monolithium hydrocarbon calculated as active lithium and, after substantial completion of the polymerization, additionally copolymerizing the resulting copolymer with 92–35 parts by weight of a monomeric mixture (B) comprising the same ingredients as those of said mixture (A) in a weight ratio of 95–20:5–80 so that the total amount of said mixtures (A) and (B) makes 100 parts by weight, thereby obtaining a final copolymer having a monovinyl aromatic content of 10–70% by weight based on the total weight of said mixtures (A) and (B).

18. An explosive composition as claimed in claim **1** wherein said thermoplastic elastomer composed of conjugated diolefin and monovinyl aromatic hydrocarbon is produced by polymerizing a monomeric mixture (C) consisting of 8–65 parts by weight of a monomeric mixture (A) comprising a conjugated diolefin and a monovinyl aromatic hydrocarbon in a weight ratio of 85–10:15–90, and 0–4.5 parts by weight of a divinyl aromatic hydrocarbon per 100 parts by weight of said mixture (A), in a hydrocarbon solvent in an inert atmosphere in the presence of 0.2–20 mmol per 100 g. of the total amount of said mixture (A) and a monomeric mixture (B) mentioned hereinafter, of a monolithium hydrocarbon calculated as active lithium and, after substantial completion of the polymerization, additionally copolymerizing the resulting active copolymer with a monomeric mixture (D) consisting of 92.35 parts by weight of a monomeric mixture (B) comprising the same ingredients as those of said mixture (A) in a weight ratio of 95–20:5–80, and 0–0.55 part by weight of divinyl aromatic hydrocarbon per 100 parts by weight of said mixture (B), so that the total amount of the divinyl aromatic hydrocarbon in said mixtures (A) and (B) makes 0.001–0.5 part by weight per 100 parts by weight of the total amount of said mixtures (A) and (B), and that the total amount of said mixtures (A) and (B) makes 100 parts by weight, thereby obtaining a final copolymer having a monovinyl aromatic hydrocarbon content of 10–70% by weight based on the total amount of said mixtures (A) and (B).

19. An explosive composition as claimed in claim **1** wherein said thermoplastic elastomer is the one having an improved processability and comprising 1–40 parts by weight of polyether per 100 parts by weight of the thermoplastic elastomer, said polyether having a molecular weight of 200–50,000 and having a recurring unit containing divalent aliphatic hydrocarbon having 2–10 carbon atoms.

20. An explosive composition as claimed in claim **1** wherein said thermoplastic elastomer is the one having an improved processability and comprising 1–100 parts by weight of solid paraffin per 100 parts by weight of the thermoplastic elastomer, said solid paraffin having a melting point of 35–160° C.

21. An explosive composition as claimed in claim **1** wherein said thermoplastic elastomer is the one having an improved processability and comprising 1–100 parts by weight of polyethylene per 100 parts by weight of the thermoplastic elastomer, said polyethylene having a melt index of 1–1,000 as measured according to ASTM–1238–57T, Condition E.

22. An explosive composition as claimed in claim **1** wherein said binding agent contains as a plasticizer at least one of naphthenic, aromatic and paraffinic hydrocarbons having compatibility with said thermoplastic elastomer.

23. An explosive composition as claimed in claim **1** in the form of sheet or strand for use with the fabrication of metals.

24. An explosive composition as claimed in claim **1** in the form of explosive cords of high-detonating speed.

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CERTIFICATE OF CORRECTION

Patent No. 3,449,179 Dated June 10, 1969

Saburo Minekawa, et al.

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 12, line 8, "92.35" should read --92 - 35--.

SIGNED AND
SEALED
MAR 10 1970

(SEAL)
Attest:

Edward M. Fletcher, Jr.
Attesting Officer

WILLIAM E. SCHUYLER, JR.
Commissioner of Patents