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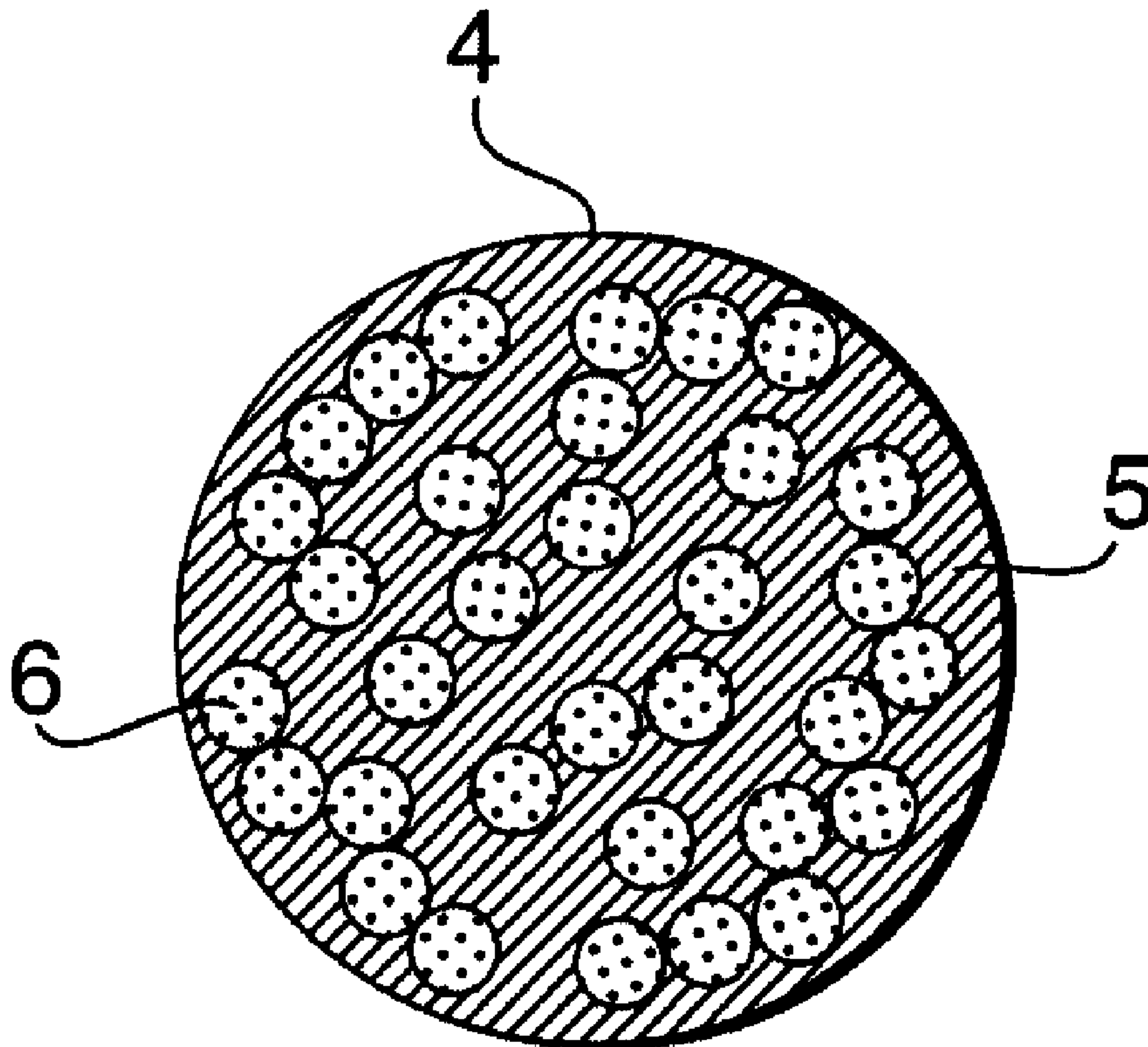
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(54) Titre : COMPOSITION EXEMPT DE PLOMB ET METHODE POUR PRODUIRE DES PROJECTILES ET DES
NOYAUX DE PROJECTILES EXEMPTS DE PLOMB AU MOYEN DE CELLE-CI

(54) Title: NON-LEAD COMPOSITION AND METHOD OF MANUFACTURING NON-LEAD PROJECTILES AND
PROJECTILE CORES THEREWITH



(57) Abrégé/Abstract:

A composition and method of manufacturing a non-lead, high density matrix that may be used as a replacement for lead in those instances where lead is used, but its toxicity is undesirable. The composition comprises metal particles combined with synthetic or

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natural rubber, and is particularly useful in manufacturing non-lead projectiles such as shot and bullets, as well as bullet cores for jacketed bullets.

ABSTRACT

A composition and method of manufacturing a non-lead, high density matrix that may be used as a replacement for lead in those instances where lead is used, but its toxicity is undesirable. The composition comprises metal particles combined with synthetic or natural rubber, and is particularly useful in manufacturing non-lead projectiles such as shot and bullets, as well as bullet cores for jacketed bullets.

NON-LEAD COMPOSITION AND METHOD OF MANUFACTURING NON-LEAD PROJECTILES AND PROJECTILE CORES THEREWITH

5 FIELD OF THE INVENTION

The present invention relates to non-lead compositions suitable for replacing lead in those instances where lead is used. The invention also relates to projectiles, particularly non-lead shot, bullet cores and solid bullets, and methods of manufacture thereof.

10 BACKGROUND OF THE INVENTION

Traditionally, ammunition for hunting has been manufactured using lead or lead alloys due to the high density, malleability and low melting points of these materials. However, the toxicity of lead has resulted in recent government restrictions against using lead shot for hunting, and particularly for hunting waterfowl.

The use of lead shot-filled shotgun shells for hunting, typically for ducks and geese, results in the release of thousands of tonnes of lead into the environment each year. The lead shot builds up in the bottom sediments of lakes and wetlands, and breaks down, transferring lead into the environment and contaminating source water. Additionally, lead shot is frequently ingested by birds causing lead toxicosis.

Waterfowl most often die from ingesting lead shot, and due to its widespread use, from northern breeding grounds to southern wintering grounds, it is available to waterfowl feeding in hunting areas from fall through spring. As a result, mortality accrues throughout most of the year, although the majority of lead toxicosis mortalities occur after the hunting season - in winter and early spring.

The full impact of lead toxicosis on waterfowl populations has been difficult to determine, since predators quickly dispose of moribund birds. Also, poisoned birds frequently hide themselves and die in out-of-the-way places where they are never found. However, it is estimated that thousands of migrating waterfowl die from lead poisoning every year, and many others suffer from a milder form of the disease.

In order to reduce the impact of lead on the environment, and to preserve the waterfowl population, many governments have restricted the use of lead shot and bullets. In particular, a nationwide ban on the use of lead shot for hunting waterfowl was implemented in the United States in 1991. More recently, Canada implemented a set of regulations requiring the use of non-toxic shot in all areas of Canada for hunting most migratory game birds (including ducks, geese, brant, cranes, rails, gallinules, coots, and snipe) by September 1, 1999.

Canada and the United States have approved several types of non-toxic shot, including steel, bismuth, tungsten-iron, tungsten-polymer, tungsten-matrix and tungsten-nickel-iron. Canada also allows use of tin, although tin shot is no longer approved for hunting waterfowl in the United States.

Steel shot is the most common and affordable of the non-toxic shot options. However, steel does not share the same physical and ballistic characteristics as lead. Steel is much harder, meaning there is a potential risk that older shotgun barrels may be damaged when firing steel shot. Also, steel shot does not deform during flight, and tends to penetrate completely through the target. This results in an increased incidence of wounding rather than humane killing. In contrast, lead shot flattens due to lead's high degree of malleability, thus providing a higher surface area for impact. This results in a higher amount of energy to be transferred directly to the target, thereby providing a more humane kill. Steel is also relatively lightweight, meaning that to attain similar energy levels as lead, a hunter must switch to a larger steel shot size. Steel shot also loses energy more quickly than lead, reducing the ranges at which it is most effective.

Bismuth, on the other hand, is roughly 85 per cent as dense as lead, resulting in somewhat similar ballistic properties. Bismuth shot sizes appropriate for a given hunting situation are similar to those of lead, and effective shooting ranges are virtually identical. However, bismuth is less abundant than lead and steel, and therefore more costly. Additionally, tests of the Bismuth Cartridge Company's No-Tox™ shot found this type of shot to be too fragile ("Steel 3-inch Magnum Loads Our Pick For Waterfowl Hunting", January 1998 issue of Gun Tests). This is not surprising, since bismuth alloys used for manufacturing this type of shot are inherently brittle.

Tungsten-iron shot is a blend of tungsten powder and iron powder pressed into the shape of a pellet and heated to bond the material. Methods of manufacturing this type of shot are

described in United States Patent No. 5,831,188 (Amick). Tungsten-iron shot is roughly 95 per cent as dense as lead, which results in excellent ballistic properties. However, this type of shot is limited in the available shot sizes, and is quite expensive by comparison. Tungsten-iron shot is also extremely hard, and like steel, tends to penetrate through game with a reduced energy transfer, and can damage the barrels of some older shotguns.

Tungsten-polymer shot is manufactured by mixing powdered tungsten and other metals with a polymer, such as nylon, and then pressing and heating the mixture to form pellets. This type of shot, manufactured by Kent Cartridge Manufacturing Company Ltd. under the name Tungsten Matrix™, and by Federal Cartridge Company under the name of Tungsten-Polymer, is designed and constructed to have the same density as lead, and is safe to use in older shotguns. However, these tungsten-polymer products are quite expensive.

Additionally, these tungsten-polymer shot materials, as well as those described in the prior art, such as United States Patent No. 6,216,598 (Godfrey Phillips), tend to be too brittle for effective game hunting when heavier shot is required. This is because relatively low density polymer materials are used to increase the hardness of the shot material. Therefore, higher density shot material must comprise reduced quantities of polymer, thus increasing the brittleness of the shot.

Other references pertaining to tungsten-polymer shot, including United States Patents No. 5,719,352 (Griffin), and 6,048,379 (Bray et al.), fail to address or improve upon the limitations of current tungsten-polymer shot materials.

Tungsten-nickel-iron shot is a type of non-toxic shot which has recently been approved for use in Canada and the United States. ENVIRON-Metal Inc. markets a version under the name HEVI-SHOT™. While tungsten-nickel-iron shot is more dense than lead shot, and has good ballistic properties, the raw materials are expensive, causing the cost of this type of shot to be high. Additionally, versions of this type of shot, such as those described in United States Patent No. 6,527,880 (Amick) can be too hard to shoot in older types of shotguns.

Non-lead materials may also be used to replace the lead cores found in conventional jacketed hunting bullets, and to produce solid lead-free bullets. These forms of non-toxic

ammunition are certainly desirable in view of proposed bans on lead bullets in Europe and Asia.

5 Presently, there are few manufacturers of non-toxic bullets designed for hunting. These bullets generally are made of copper or copper alloys, and some have a polymer insert in the frontal cavity. United States Patent No. 5,131,123 describes a method for manufacturing a bullet made out of solid metal, such as copper. However, since copper is less dense than lead, finished copper bullets must be longer than their lead counterparts.

10 The increased length of copper bullets presents a significant problem for the accuracy of these bullets. This is because longer bullets are less stable during flight, which reduces the accuracy. However, increasing the twist of a bullet during flight can increase the stability, which gives better accuracy. Therefore, for a copper bullet to have a comparable accuracy to its counterpart lead bullet, it requires more twist. Accordingly, for shooters to achieve good
15 accuracy with such bullets, they must buy custom-made barrels for their rifles which provide the required twist. Since most shooters cannot afford to buy custom-barrelled rifles, copper bullets are often used with sub-standard accuracy.

20 Other examples of non-toxic bullets have been described in United States Patents No. 5,616,642 (West, et al.), 6,090,178 (Benini), and 5,399,187 (Mravic, et al.). While the bullets described in these documents are typically constructed of non-toxic metal particles and metal or polymer binders, they are intended for use in shooting ranges, rather than hunting applications. These frangible bullets mimic the ballistic properties of lead bullets, but are intended to disintegrate on impact to reduce the hazard of ricocheting bullet fragments within
25 the range. Therefore, the brittleness of these bullets renders them ineffective for hunting game. Additionally, it has been found that these bullets sometimes crack during the crimping operation.

30 In light of the known deficiencies of materials currently used for manufacturing non-toxic hunting ammunition, there exists the need for a new material having properties comparable to those of lead.

SUMMARY OF THE INVENTION

Accordingly, it is an object of the present invention to provide a non-lead composition suitable for use in those applications where lead is traditionally used. Another object of the invention is to provide a method for manufacturing non-lead projectiles using such a composition.

According to one aspect of the present invention, there is provided a non-lead composition comprising metal particles and rubber, wherein the rubber is a moldable, curable rubber having a sufficiently low viscosity to ensure homogeneous mixing of the particles throughout substantially the whole of the composition.

Such a composition is particularly useful in manufacturing projectiles and projectile cores, such as non-lead shot, bullet cores and solid, jacketed bullets. However, it is also envisioned that such composition may be used in applications other than hunting ammunition, such as in wheel weights and fishing weights/sinkers. The composition may also be useful as a replacement for lead in typical X-ray protecting vests and other such applications.

The metal particles which may be used in the composition may comprise one or more metals including copper, tungsten, iron, tin or any other non-lead metal having a high specific gravity. A particularly preferred metal for use in this composition is tungsten. Additionally, the metal particles may be in the form of powders, granules, flakes, other compactable particulate forms, or a combination thereof.

The varieties of rubber used in the composition may be synthetic or natural. The viscosity of the rubber ranges from about 48 KU to about 125 KU, although the preferred viscosity ranges from about 75 to 80 KU. Rubbers which are suitable for the composition of the present invention include natural rubber, neoprene, polyisoprene and styrene-butadiene rubber. Natural rubber is particularly preferred.

The ratios of metal to rubber used in the present invention range from about 25 : 1 to about 70 : 1 in parts by weight metal particles to parts by weight rubber, and depend upon the metal used. However, a ratio of 15 parts metal particles to 3 parts rubber is advantageously used in the preferred method of manufacturing non-lead shot. When manufacturing bullet cores and solid, non-jacketed bullets, a ratio of 7 parts metal particles to 2 parts rubber is used for the preferred embodiment.

The typical size of the metal particles used in the present invention ranges from approximately 5 to 30 microns in diameter. A metal particle size range of about 5 to 10 microns is preferred for non-lead shot, while the preferred particle size range for non-lead bullet cores and solid, non-jacketed bullets is approximately 20 to 25 microns. A particle size of 5 microns is especially preferred for non-lead shot, and a particle size of 25 microns is especially preferred for the bullet cores and solid, non-jacketed bullets of the present invention.

According to a second aspect of the present invention, there is provided a method of manufacturing non-lead projectiles and cores used in projectile manufacturing comprising the steps of mixing metal particles and moldable, curable rubber to form a matrix, molding the matrix under pressure in a molding apparatus to form a molded projectile or projectile core, and curing the rubber to form a finished non-lead projectile or projectile core.

A variety of means are available for molding the matrix into the required form. Accordingly, any apparatus for molding may be used. However, rotary or single stage tablet pressing machines, similar to those used for manufacturing pharmaceutical tablets, have been found to be particularly useful.

The rubber used in the above method may be liquid rubber, although other forms are envisioned. In the case of liquid rubber, the matrix formed with the metal particles should be dried, eg. by air drying, in order to allow the volatile liquids to evaporate. It is then preferred for the dried matrix to be granulated by means of a roller compactor and milling machine, or another suitable device, and then for the granulation to be passed through a 20 mesh sieve in order to minimize weight variance throughout the matrix.

When manufacturing non-lead shot using the method of the present invention, the matrix is typically molded in a shot-molding apparatus to form shot having a density ranging from approximately 7 g/cm³ to 15 g/cm³, and preferably from 10.5 g/cm³ to 13.5 g/cm³. The hardness of such shot frequently ranges from about 2 Bh to about 20 Bh on the hardness scale.

In one embodiment of the method for manufacturing non-lead shot, the rubber within the matrix is cured following removal of the shot from the shot-molding apparatus. In another

embodiment, the rubber is cured prior to removal of the shot from the shot-molding apparatus.

When manufacturing projectiles and projectile cores, the finished projectiles and projectile cores may be plated with a metal selected from the group consisting of zinc, copper, copper alloy, iron, steel, antimony, nickel and tungsten. In some instances, the weight of the applied plating is advantageously less than 1% of the total weight. In a particularly preferred embodiment of manufacturing shot, the weight of the applied plating is about 0.0999% of the total weight of the plated shot.

When manufacturing non-lead bullet cores using the method of the present invention, the matrix is generally pressed within a bullet core-forming die or mold and cured to form a bullet core having a density ranging from approximately 2 g/cm³ to 15 g/cm³, and preferably 5 g/cm³ to 13.5 g/cm³. The hardness of such bullet cores frequently range from about 2 Bh to about 20 Bh on the hardness scale. The bullet core may also be seated inside a bullet jacket and point-formed within a point-forming die to produce a bullet.

The bullet core may be formed in the molding step by swaging the matrix in a core-swaging die, followed by a separate step wherein the formed core is seated inside a bullet jacket. Alternatively, the pressing and seating steps may be performed simultaneously by pressing the matrix within a bullet jacket using a core-seating die.

The rubber within the matrix may be cured before or after the point-forming step, although it is preferred that the curing occurs after the point-forming step.

When manufacturing solid, jacketless, non-lead bullets using the method of the present invention, the matrix is typically pressed in a bullet forming die or mold and cured to form a bullet having a density ranging from approximately 2 g/cm³ to 15 g/cm³, and preferably from about 5 g/cm³ to 13.5 g/cm³. The hardness of such projectiles frequently ranges from about 2 Bh to about 20 Bh on the hardness scale. In this method, the rubber within the matrix may be cured prior to removal of the bullet from the mold, or following removal of the bullet from the mold.

In particularly preferred embodiments, the non-lead shot produced according to the present method has a density of approximately 11.3 g/cm³, the bullet cores have a density of

approximately 11 g/cm³ and the solid, non-jacketed bullets have a density of approximately 11 g/cm³.

When manufacturing shot and solid, non-jacketed bullets using the inventive method, the molding pressure will vary depending upon the particular application for the projectile or core produced. However, the applied pressure typically ranges from about 4,000 PSI to 35,000 PSI, and more typically from about 26,000 PSI to 32,000 PSI. A pressure of about 28,000 PSI is particularly preferred for manufacturing shot and solid bullets. In the method of manufacturing bullet cores, the molding/seating pressure is often lower, ranging from about 4,000 PSI to 6,000 PSI, and more optimally about 5,000 PSI.

The rubber material within the matrix is generally cured using known curing conditions typical for the type of rubber used. These temperatures commonly range from about 235 to about 485 degrees Fahrenheit, for a duration ranging from about 1 to 20 minutes. In certain preferred methods of manufacturing shot and solid, jacketless bullets, the optimal curing time is about 12 minutes at about 294 degrees Fahrenheit. The preferred curing condition for manufacturing certain types of bullet cores is about 11 minutes at about 275 degrees Fahrenheit.

It is also envisioned that the finished bullets produced according to the method of the present invention, ie. solid and jacketless or jacketed and cored bullets, may be coated with one or more coating selected from polyester TGIC powder coating, polyurethane powder coating and epoxy powder coating. Such coatings are often preferred to have a maximum thickness of about 0.001 inches.

The preferred hardness of the shot and solid, jacketless bullets manufactured according to the invention is about 8 Bh, whereas the preferred hardness of the bullet cores is preferably about 5 Bh.

BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the present invention will be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a diagrammatic cross-sectional view of a shot molding apparatus;

Figure 2 is a diagrammatic cross-sectional view of a finished shot produced using the method of the present invention;

Figure 3 is a diagrammatic cross-sectional view of a matrix core of the present invention being seated into a bullet jacket;

5 Figure 4 is a diagrammatic cross-sectional view of a matrix core of the present invention seated inside a bullet jacket;

Figure 5 is a diagrammatic cross-sectional view of a solid, non-jacketed bullet being formed with the matrix material of the present invention; and

10 Figure 6 is a diagrammatic cross-sectional view of a finished solid bullet produced using the method of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

15 In order to overcome the disadvantages of known non-lead materials and methods for manufacturing non-lead hunting projectiles, the inventors of the present invention have developed a novel non-lead composition and a method for manufacturing non-lead projectiles using the novel composition.

20 The novel composition typically comprises non-lead metal particles having a specific gravity greater than 3 g/cm³ and uncured moldable rubber. These materials are mixed in ratios which are defined by the requirements of a particular application, such as to produce shot, bullet cores, solid bullets, or other projectiles.

25 For the purposes of the present invention, it is to be understood that the metal particles used in the matrix composition may be in the form of metal powder, granules, flakes, another compactable form, or a combination thereof, providing that they are compactable and have a sufficiently high density. Metal particles which are particularly useful are those which comprise metals having high densities, such as copper, tungsten, iron, and tin, although other non-lead metals may be used. Tungsten metal particles are especially preferred.

30 When compared to the size of metal particles used for manufacturing bullet cores and bullets, the size of the metal particles used for manufacturing shot is significantly smaller. This reflects the relatively small size of shot, and the requirement for the metal particles to compact tightly. For bullet cores and solid, jacketless bullets, expansion is very important,
35 and larger particles have been found to be more advantageous versus smaller particles. The

preferred size of the metal particles used for manufacturing shot ranges between about 5 to 10 microns, while methods for manufacturing bullet cores and solid bullets preferably utilise metal particles with a size ranging from about 20 to 25 microns. For shot, a 5 micron particle size is preferred, whereas 25 micron particles are advantageously used for manufacturing bullet cores and solid, jacketless bullets.

It is also to be understood that the rubber which is used in the composition may be a natural or synthetic rubber providing that it has a sufficiently low viscosity that the uncured rubber can be thoroughly mixed with the metal particles. Some examples of rubber materials which may be used to manufacture the projectiles of the present invention include natural rubber, neoprene, polyisoprene and styrene-butadiene rubber, although combinations thereof may also be used in some embodiments. The rubber material which is especially preferred for the purposes of this invention is natural rubber.

The viscosity of the uncured rubber may range from approximately 48 Krebs Units (KU) to approximately 125 KU. The preferred viscosity is between about 75 and 80 KU, slightly thinner than ordinary household paint. Heavier or larger particles may require a more fluid rubber, which may require the addition of a thinning agent. While thinning agents are not required for the preferred embodiments of the invention, it is to be understood that addition of suitable thinning agents to the rubber in order to increase its fluidity is also provided by the present invention.

The relative amounts of metal particles to rubber in the novel composition depend largely upon the particular metals and rubbers being used. For instance, copper particles may be mixed with rubber in a completely different ratio compared to tungsten particles. Furthermore, the ratio of metal particles to rubber also depends upon the application of the desired product. If the end product is intended to have properties similar to lead, then the metal to rubber ratio will generally be the same for shot, bullet cores and solid bullets. However, in other cases a higher ratio of rubber to metal may be required, especially when manufacturing bullet cores. For instance, in order to achieve favourable bullet balance, a core which is lighter than lead is often desirable. Advantageously, the ratios of metal to rubber used in the present invention range from about 25 : 1 to about 70 : 1 in parts by weight metal particles to parts by weight rubber, and depend upon the metal used. The preferred non-lead shot has a ratio of 15 parts metal particles to 3 parts rubber, and the preferred bullet cores and solid, jacketless bullets have a ratio of 7 parts metal to 2 parts rubber.

The composition of the present invention may be used to manufacture non-lead hunting projectiles and cores, such as shot for shotguns, bullet cores and solid bullets. When manufactured according to the following methods, these projectiles have a density comparable to or higher than the density of lead, and have excellent ballistic properties.

In an example of the method of manufacturing shotgun shot, the metal particles and uncured moldable rubber are mixed together to form a matrix in a particular weight ratio such that the required density is achieved. For instance, a weight ratio of 15 parts metal particles to 3 parts rubber is frequently used in order to meet the specific ballistic requirements of shot. After the correct proportion of metal particles and rubber is mixed, the matrix is forced into a mold or die having an array of shot cavities cut or drilled therein. A minimum pressure of about 4,000 PSI is normally required for proper molding of the shot, although the shot is preferably molded at pressures between about 26,000 PSI and about 32,000 PSI, and most effectively at a pressure of about 28,000 PSI. The shot may remain in the molding apparatus during the curing process or may be removed from the apparatus and then cured.

In certain embodiments, the finished shot may be plated with copper, copper alloy, zinc, nickel, iron, steel, antimony, tungsten or any other non-lead metal which is suitable for metal plating. The shot is generally plated using standard electroplating processes that are known in the art. Although plating is not essential for the production of non-lead shot in accordance with the invention, it is often performed in order to increase the hardness of the shot, and to help the shot flow easier when dispensing.

The actual plating weight depends upon the shot size. For example, a #6 shot will have less plating than a #2 shot. In all cases, the weight of the plating is preferably less than 1% of the total weight of the plated shot, in order to comply with current regulations enforced by the United States Fish and Wildlife Service. The preferred plating weight is about 0.0999% of the total weight of the plated shot.

During the manufacturing process, the hardness or brittleness of the shot can be controlled by adjusting the time and temperature of the curing process without reducing the density of the shot. This is particularly advantageous when high density shot is required, since the amount of high density metal particles may be increased without causing the shot to become brittle.

In an example of the method of manufacturing non-lead bullet cores, metal particles and moldable, uncured rubber are mixed together to form a matrix in ratios specific to the properties of the desired product. The metal particle/rubber matrix is then placed in a core-forming die or mold and compressed at a pressure ranging from about 4,000 PSI to about 6,000 PSI to form the desired core. However, a pressure of about 5,000 PSI is especially preferred. The core is cured, and then seated inside a jacket, followed by finishing of the bullet using a point-forming die.

In this example of the inventive method, the bullet core may be compressed inside a core-swaging die and then seated inside a bullet jacket. Alternatively, the pressing and seating steps may be performed simultaneously by pressing the matrix within a bullet jacket using a core-seating die.

The rubber within the core may be cured before or after the point-forming operation. However, it is frequently advantageous to cure the rubber after the point-forming operation, particularly when manufacturing highly dense bullet cores. This is because the cores often become too hard after curing to be effectively finished in the point-forming die.

In a preferred embodiment, the bullet core is finished to have an open tip profile. However, other profiles such as hollow point, flat point, round nose and other tip profiles are within the parameters of the present invention.

In an example of the method of manufacturing solid, non-jacketed bullets which are non-lead based, metal particles and moldable, uncured rubber are mixed together to form a matrix using ratios specific to the properties of the desired product. Following mixing of these materials, the matrix is placed inside a mold or die having the shape and size of the desired bullet. The matrix is then pressed at a minimum pressure of about 4,000 PSI. However, for optimum molding of the solid bullet, the molding pressure ranges from about 26,000 PSI to about 32,000 PSI, and is preferably about 28,000 PSI. The rubber within the matrix may be cured during the molding phase or cured after the bullet is removed from the molding apparatus.

The conditions used for curing the rubber within the matrix are particularly important, and care must be taken to ensure that the appropriate curing time and temperature are used when manufacturing the shot, bullet cores and solid, non-jacketed bullets of the present

invention. While the preferred curing conditions will vary depending on the rubber which is used, the rubber within the matrix is advantageously cured in a heat-controlled oven at a temperature ranging from 235 to 485 degrees Fahrenheit, for a duration ranging from 1 to 20 minutes. Alternatively, the curing process may be performed in a hydraulic heated press with a temperature ranging from 260 to 330 degrees Fahrenheit, or in an autoclave pressurized to 40 PSI with a temperature ranging from 250 to 320 degrees Fahrenheit. In preferred methods of manufacturing shot and solid, jacketless bullets, the optimal curing time is about 12 minutes at about 294 degrees Fahrenheit. A preferred curing condition used in the method of manufacturing bullet cores is about 11 minutes at about 275 degrees Fahrenheit.

Presently, heat is the preferred means for curing of the rubber. However, it is conceivable that curing of the rubber using chemical curing agents may also be used within the scope of the present invention.

When manufacturing non-lead projectiles described above, care must be taken to ensure that the pressure does not exceed the recommended upper limit. For instance, if too much core seating pressure is used, it may be difficult to remove the bullet from the core seating die, thus distorting the bullet somewhat. Additionally, excessive pressures can cause the die to break when the swaging pressure approaches the die breaking pressure. This is particularly relevant when manufacturing shot or solid bullets, since high pressures are used.

The projectiles which are manufactured in accordance with the methods outlined above will advantageously meet the applicable standards for the projectile produced. For instance, the shot should be hard enough that upon ignition of the ammunition, the shot is not altered in terms of its shape. This is important because "unround" shot is detrimental to shot patterning. However, the shot must not be so hard as to cause it to be harmful to shotgun barrels. The projectiles manufactured in accordance with the present invention will not damage the barrels of older firearms, but are not brittle. When using the methods described herein, the resulting projectiles have a hardness ranging from about 2 Bh to about 20 Bh on the hardness scale. The preferred hardness of the shot is about 8 Bh, which is close to the hardness of 3% antimony hardened lead. The solid, jacketless bullets are also preferred to have a hardness of approximately 8 Bh. However, the bullet cores manufactured using the method of the present invention preferably have a hardness of 5 Bh, which is the same hardness as pure lead.

The non-lead shot manufactured according to the present invention will advantageously have a density ranging from approximately 10.5 g/cm^3 to 13.5 g/cm^3 . However, it is preferable that the density is slightly higher than the density of lead, or approximately 11.3 g/cm^3 . The bullet cores will also typically have a density close to the specific gravity of lead, and similar malleability. This is mainly due to the many different bullet manufacturing methods, so if lead can be substituted with a very similar core material, a more accurate result will be achieved when using different manufacturing methods. Accordingly, the density of the bullet cores of the present invention generally have a density ranging from about 5 g/cm^3 to about 13.5 g/cm^3 , and optimally about 11 g/cm^3 . In regards to solid bullets, it is also favourable to produce a product having a similar density and malleability to lead. However, if a shooter is concerned with accuracy, such as during target shooting, a metal with a lower specific gravity is preferable. In such cases, copper is generally used instead of heavier metals such as tungsten. The bullets manufactured according to the present invention can be made to have a density ranging from about 5 g/cm^3 to 13.5 g/cm^3 , although the preferred bullets have specific gravities very close to that of lead, or approximately 11 g/cm^3 .

With reference to the drawings, preferred embodiments of the methods of manufacturing non-lead shot, bullet cores and solid bullets will be described in further detail.

In the method of manufacturing non-lead shot of the present invention, non-lead metal particles **6** and rubber **5** are mixed together to form a matrix. The matrix is then forced via injection orifice **3** into a die or molding apparatus **1** having an array of shot cavities **2** cut or drilled therein (Figure 1). A minimum pressure of 4,000 PSI is required for proper molding of the resulting shot **4** (Figure 2). The rubber **5** in the matrix is then cured. The shot **4** may remain within the molding apparatus **1** during the curing process, or the shot **4** may be removed from the molding apparatus **1** prior to curing the rubber **5**. The resulting finished shot **4** comprises a dense matrix of metal particles **6** and cured rubber **5** (Figure 2).

The finished shot **4** may also be plated with metal or metal alloys, such as copper, zinc, nickel or any other non-lead metal. This process is performed using known electroplating techniques, and is commonly performed to produce a shot having a plating weight less than 1% of the total weight of the finished shot **4**.

In the method of manufacturing non-lead bullet cores of the present invention, non-lead metal particles **6** and rubber **5** are mixed together to form a matrix. In this preferred embodiment,

a specific amount of the matrix is placed in a core seating die **9** and compressed between an external punch **7** and an internal punch **8** at a minimum pressure of about 4,000 PSI. The bullet core **11** is seated directly inside a metal bullet jacket **10** using the core seating die **9** (Figure 3). Alternatively, the bullet core **11** may be swaged separately in a core swaging die and seated inside a metal bullet jacket **10** in a separate step. The rubber **5** in the matrix is then cured, and the resulting bullet is point-formed using a point-forming die. In another embodiment of this method, the rubber **5** within the matrix of the bullet core **11** may be cured after the point-forming process.

In an example of manufacturing solid, jacketless, non-lead bullets of the present invention, non-lead metal particles **6** and rubber **5** are mixed together to form a matrix in a specified ratio. Following mixing, the matrix is placed inside a bullet-forming die **12** and compressed at a pressure of at least 4,000 PSI by external punch **7'** and internal punch **8'** (Figure 5). It is to be understood that external punch **7'** and internal punch **8'** are distinct from external punch **7** and internal punch **8** used for the forming of bullet cores **11**, and are selected based of the desired shape and size of bullet **13**. The rubber **5** within the matrix of bullet **13** may be cured during the molding step, or after the bullet **13** is removed from the bullet-forming die **12**.

The foregoing are exemplary embodiments of the present invention and a person skilled in the art would appreciate that modifications to these embodiments may be made without departing from the scope and spirit of the invention.

THE EMBODIMENTS OF THE PRESENT INVENTION IN WHICH AN EXCLUSIVE PROPERTY OR PRIVILEGE IS CLAIMED ARE DEFINED AS FOLLOWS:

1. A non-lead composition comprising metal particles and rubber, wherein the rubber is a moldable, curable rubber having a sufficiently low viscosity to ensure homogeneous mixing of said particles throughout substantially the whole of said composition.
2. The composition according to claim 1, wherein the metal particles include any one or more of the metals selected from the group consisting of copper, tungsten, iron, tin, and other non-lead metals having a high specific gravity, and the rubber is selected from the group consisting of natural rubber, neoprene, polyisoprene and styrene-butadiene rubber.
3. The composition according to claim 1 or 2, wherein the metal particles are in the form of powder, granules, flakes, other compactable particulate forms, or a combination thereof.
4. The composition according to any one of claims 1 to 3, wherein the rubber has a viscosity ranging from about 48 KU to about 125 KU.
5. The composition according to any one of claims 1 to 3, wherein the rubber has a viscosity ranging from about 75 to 80 KU.
6. The composition according to any one of claims 1 to 5, wherein the metal particles and rubber are mixed in a ratio ranging from about 25 : 1 to about 70 : 1 in parts by weight metal particles to parts by weight rubber.
7. Use of the composition according to any one of claims 1 to 6 for manufacturing projectiles, projectile cores, wheel weights or fishing weights.
8. A method of manufacturing non-lead projectiles and cores utilized in projectile manufacturing comprising the steps of:
 mixing metal particles and moldable, curable rubber to form a matrix,

molding the matrix under pressure in a molding apparatus to form a molded projectile or projectile core, and
curing the rubber to form a finished non-lead projectile or projectile core.

9. The method according to claim 8, wherein the molding apparatus is a rotary or single stage tablet pressing machine.
10. The method according to claim 8 or 9, wherein the moldable, curable rubber is liquid rubber, and the matrix is dried prior to molding to remove volatile liquids present in the liquid rubber.
11. The method according to claim 10, wherein the dried matrix is granulated by means of a roller compactor and milling machine and passed through a 20 mesh sieve prior to molding.
12. The method according to any one of claims 8 to 11, wherein the curing is conducted at a temperature ranging from about 235 F to about 485 F for a duration ranging from about 1 minute to about 20 minutes, and is performed following removal of the molded projectile or projectile core from the molding apparatus, or within the molding apparatus prior to removal.
13. The method according to any one of claims 8 to 12, wherein the finished projectile or projectile core is plated using electroplating or other plating methods with a metal selected from the group consisting of zinc, copper, copper alloy, iron, steel, antimony, nickel and tungsten.
14. The method according to any one of claims 8 to 13, wherein the metal particles and rubber are mixed in a ratio of about 25 : 1 to about 70 : 1 in parts by weight metal particles to parts by weight rubber, and the metal particles range from approximately 5 microns to approximately 30 microns in diameter.
15. The method according to any one of claims 8 to 14, wherein the molding pressure ranges from approximately 4,000 PSI to approximately 35,000 PSI, the molding apparatus is a shot molding apparatus, and the projectile formed is non-lead shot having a density ranging from approximately 7 g/cm³ to 15 g/cm³.

16. The method according to any one of claims 8 to 14, wherein the molding pressure ranges from approximately 4,000 PSI to approximately 35,000 PSI, the molding apparatus is a bullet-core molding apparatus, and the projectile formed is a bullet-core having a density ranging from approximately 2 g/cm³ to 15 g/cm³.
17. The method according to claim 16, further comprising the steps of seating the bullet core inside a bullet jacket and point-forming to produce a bullet, wherein the seating step is performed separately following the molding step, or simultaneously with the molding step by molding the matrix within the bullet jacket.
18. The method according to any one of claims 8 to 14, wherein the molding pressure ranges from approximately 4,000 PSI to approximately 35,000 PSI, the molding apparatus is a bullet molding apparatus, and the projectile formed is a solid, jacketless, non-lead bullet having a density ranging from approximately 2 g/cm³ to 15 g/cm³.
19. The method according to any one of claims 8 to 18, wherein the finished non-lead projectile or projectile core is coated with one or more of the coatings selected from polyester TGIC powder coating, polyurethane powder coating and epoxy powder coating.
20. Non-lead shot, bullet cores or solid, jacketless bullets comprising the composition according to any one of claims 1 to 6, or manufactured according to the method as defined in any one of claims 8 to 19.

