Title: REDUCED CONDUCTIVITY AND UNIQUE ELECTROMAGNETIC SIGNATURE ZINC ALLOY

Abstract: An alloy, comprising up to 2% by weight of manganese and the balance zinc broadens the use of low cost zinc in coinage and token applications as well as in electrical and electronic applications. Additions of small amounts of manganese can have a significant effect on lowering the conductivity of zinc and its alloys.
— as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii))
— of inventorship (Rule 4.17(iv))

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— with international search report (Art. 21(3))
Reduced Conductivity and Unique Electromagnetic Signature Zinc Alloy

CROSS REFERENCE TO RELATED APPLICATION

This application claims the benefit and priority of U.S. provisional patent application number 61/870,485, filed on August 27, 2013 and is incorporated herein by reference in its entirety.

BACKGROUND

Various metals are used in the coinage, electrical and electronics markets with each metal having unique properties. Rolled and die cast zinc products have been long standing product offerings in these markets. The various base metal zinc alloys currently on the market have measured electrical conductivity values in the range of about 25% to 30% IACS based on the International Annealed Copper Standard (IACS) which uses substantially pure copper as a 100% conductivity reference (100% IACS). These conventional zinc alloy electrical conductivity values, although providing certain unique electrical properties, have limited zinc alloys from broader use in coinage, electrical and electronics markets.

In the coinage market, the electrical conductivity and permeability of the metal provides a unique electromagnetic signature that is used for security purposes. This electromagnetic signature provides an additional source of security in coin differentiation systems used in both the vending and banking industries. The more common metals and alloys used in this industry, such as low carbon steels, stainless steels, nickel, copper, brasses, bronzes, cupronickel, aluminum bronze, and aluminum, have electrical conductivities either at or below 15% IACS or above 25% IACS.

There is a range from about 15% to 25% IACS in which a cost-effective metal or alloy could provide a unique range of electromagnetic signatures to provide additional security options for new or redesigned coinage products. In addition, a more cost-effective zinc metal or alloy option that can duplicate the electromagnetic signature of an existing coinage product can provide
a more economical solution to the coinage market while maintaining current coin differentiation parameters.

In the electrical and electronics market, the effective range of electrical conductivity of a material, along with other properties, can limit its use. By expanding this effective range, the ease and/or cost of production can be improved for existing uses and the range of applications for that material can also be expanded. Currently, rolled zinc alloys have been used in the automotive fuse market, as well as for shielding applications from electromagnetic and radio frequency interference and counterpoise grounding applications all utilizing the zinc alloys conventional electrical conductivity property range. Expanding the current effective electrical conductivity range for rolled zinc products would allow for additional uses in these existing markets as well as expand the use of zinc alloys for additional applications within this industry.

SUMMARY

Coins should inherently be lower in cost than their stated value to prevent destruction and manipulation of the coins for monetary gain. Zinc base alloys provide a low cost base metal from which to produce coinage which is less likely to be destroyed for its inherent material value than more costly metals.

Coins can be identified as genuine by many methods including coin design features, color, size, weight and shape, but are increasingly identified by their unique electromagnetic properties. This allows for quick and accurate authentication by machines. These properties are inherent within the base metal or are an artifact of a combination of the base metal and plated or coated surfaces, base metal and clad materials, and/or inclusion in a bi-metal coin system (two piece coin).

A range of new zinc alloys has been developed that has lower electrical conductivity than conventional zinc alloys thereby providing a wider and more unique range of electromagnetic properties. This broadens current security options in coins.
A farther advantage of this new range of conductivity of zinc alloys is a series of alloys with controllable conductivity for applications in electrical and electronic markets. The alloy may be produced as a rolled product or in a traditional die-casting process for various applications.

As noted above, current rolled zinc strip alloys and die cast zinc materials have a limited conductivity range of about 25% to 30% IACS. This limits their use in both the coinage, electrical and electronics markets. The alloys described herein expand the effective conductivity range and electromagnetic signature of rolled and die cast zinc products allowing for expansion of use in current markets and application into new markets.

BRIEF DESCRIPTION OF THE DRAWINGS
In the drawings:

Fig. 1 is a graph depicting the effect on electrical conductivity of a zinc based alloy by the addition of manganese to zinc;

Fig. 2 is a graph similar to Fig. 1 depicting the expanded effect on electrical conductivity of a zinc based alloy by the addition of manganese and additional alloying agents;

Fig. 3 is a series of plots derived from a coin sorting machine depicting the electromagnetic signatures of two zinc-manganese alloys formulated as described herein and compared with five other common coinage materials; and

Fig. 4 is a schematic perspective view of a blade fuse having a fuse wire constructed with a zinc-manganese alloy.

DETAILED DESCRIPTION

A range of new zinc based alloys has been produced which contain manganese in the weight range of 0.01 to 2.0 percent for reducing the electrical conductivity of zinc. These alloys show unique properties, most notably, an electrical conductivity lower than typical zinc and zinc alloys produced as strip. The initial alloys tested were simple binary compositions of zinc and manganese and later, alloys containing other elements were tested. That is, alloys of zinc and manganese in the weight range noted above were combined with stabilizing agents, such as copper in the amount of 0.1% to 1.2% by weight, aluminum in the amount of 0.001 % to 0.60% by weight,
titanium in the amount of 0.050% to 1.0% by weight, magnesium in the amount of 0.0001% to 0.050% by weight, cadmium in the amount 0.0001% to 0.50% by weight, chromium in the amount of 0.0001% to 0.50% by weight, iron in the amount of 0.0001% to 0.50% by weight and antimony in the amount of 0.0001% to 0.50% by weight. Stabilization refers to the ability of the zinc manganese alloy to maintain a substantially constant IACS conductivity over time and over varying temperature conditions. Any variation is referred to as "drift."

For example, copper in the amount of about 0.1% to 1.2% by weight can be added as a hardener to a zinc manganese alloy of 0.05% to 2% by weight manganese, balance zinc. Titanium, magnesium, cadmium and chromium serve as grain refiners to produce smaller grains in the zinc manganese alloy and form intermetallic compounds which resist conductivity drift.

Titanium not only serves as a grain refiner in the zinc manganese alloy, it also lowers the IACS conductivity of the zinc alloy in its as cast state. Moreover, by adding titanium to the alloy, conductivity drift is reduced at any given level of manganese. A useful weight range of titanium is 0.05% to 1% by weight of the alloy.

Testing has shown that the IACS test results places the conductivity of these new alloys in the range of 12% to 25% of IACS. Again, zinc alloys generally lie in the range of 25% to 30% of IACS. The conductivity of the alloys can be controlled with secondary effects based on rolling, heat treating and plating practice yielding processes for creating a range of electronic signatures within the zinc and manganese alloy system. This range of conductivity is unique compared to general commercial alloys of common metals.

The ability to significantly adjust the conductivity of a zinc based alloy with small amounts of manganese has many potential applications. This unique conductivity space of the alloy initially provides two potential applications. The first is in the production of coinage with a unique electromagnetic signature (EMS). Coins for purposes of sorting or vending are often identified within a machine by a variety of criterion. The first is the physical parameters such as size and weight that are clearly evident and generally easy to copy. But the electro-magnetic signature of
a coin consisting of a base metal that may or may not have one or more plated layers, can be unique.

As described further below, the second application for this new range of low conductivity alloys is within the electronics and fuse market, where the protective value of the fuse (amperage at the point of planned failure) is controlled by conductivity and geometry. Typically, a fuse is designed from a particular alloy and then the geometry is changed to control the final fuse value. In some cases, it is desirable to make a fuse for low amperage control, but which is complicated by the ability to reliably produce small geometric cross-sections. An alloy of 50% lower conductivity would allow more manufacturability within the fuse industry.

The key to this controlled conductivity is dominated by the quantity of manganese in the zinc, but the full range of potential alloys possible may need exploration to best control the space. Alloys with 0 to 2% by weight of manganese balance zinc, and preferably 0 to 1% by weight of manganese balance zinc have been found to produce conductivity in ranges not previously achievable. The addition of copper to the zinc-manganese alloys acts as a hardener in the range of 0.1 to 1.2 weight percent. This addition increases the hardness without adverse affects on adjustment of conductivity by the manganese content in the zinc. Elements that fall in this grouping of increasing hardness and/or strength of zinc-manganese alloys include copper, titanium, magnesium, aluminum, chromium, iron, antimony and/or cadmium. These elements also act as stabilizing agents to prevent IACS drift.

A cast alloy of zinc and manganese exhibits a certain initial conductivity. When rolled into a coil, the conductivity increases by about 3% to 4% on the IACS scale. By adjusting the rolling process to roll at a lower metal temperature, the increase in conductivity can be minimized to about 1% to 2% IACS. Lower annealing temperature can also have an effect on lowering the conductivity of rolled alloys.

As shown in Fig. 1, the binary alloy of zinc and manganese in the range of 0.0 to 1.0% manganese produces a vast range of conductivities. The addition of manganese trends to lower conductivity. However, with variation in processing conditions, such as rolling and plating

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practice, a range of conductivities can be produced at varying manganese levels. The lower boundary of the plot in Fig. 1 represents the as cast alloy conductivity while the upper boundary of the plot represents the alloy conductivity after an aging process at about 220°F producing a drift of about 5% IACS. Noticeable effects on the conductivity of zinc can be seen beginning around 0.01% by weight manganese and clearly at 0.05% by weight manganese. These alloys contain from about 0.01% up to 2% manganese, balance zinc, and more preferably 0.05% manganese up to 2% manganese balance zinc. More desirable effects on conductivity can be achieved with 0.05% to 1.0% by weight manganese, balance zinc. Of course, additional stabilizing agents such as those noted above can be added to any of these zinc-manganese alloys.

As noted above, the electrical conductivity of a zinc-manganese alloy can be further modified with the introduction of stabilizing agents into the binary zinc-manganese alloys. As observed in Fig. 2, a larger range of conductivities can be produced with the addition of, for example, two of the stabilizing agents noted above, thereby forming a quaternary alloy with zinc and manganese. In this example, copper and titanium were added in the ranges noted herein to the zinc-manganese alloy as described herein. Further expansion of the potential conductivity ranges can be achieved with varying the alloy processing conditions. The lower boundary curve again represents the conductivity of the as-cast alloy and the upper boundary represents the conductivity of the alloy based on varying process parameters and alloying agents.

The conductivity of a material is a strong driver in many parameters of the material's electromagnetic signature (EMS). Adjusting the conductivity of the base alloy for a through-alloy coin or plated coin will impact the EMS of the coin and drive towards unique signals that can be used to differentiate a coin from other coins or slugs.

Blanks from two different representative zinc-manganese alloys were produced and coined using a common token die. These blanks were run through a coin sorting machine common to the industry (ScanCoin 4000) and the data compared to other common base or through alloy materials used in coinage production, such as aluminum, bronze, cupronickel, stainless steel material and low carbon steel. The output data is shown in Fig. 3. Differences from other materials in only one of these variables or in the dimensions of the coin is all that is required to consider a product
unique. Differences in more than one characteristic strengthens the security of the coinage product. These zinc-manganese based alloys can create unique electromagnetic signatures as compared to most commonly used metals used in the coinage market. The signals circled in the plots in Fig. 3 highlight the different EMS signatures which can be used to differentiate coinage for security purposes.

As noted above, a second application for these lower conductivity alloys is within the electronics and fuse markets, where the protective value of the component is often controlled by conductivity and geometry, such as the amperage at the point of planned failure in a low-voltage blade fuse. An electronic component, such as a fuse, would be designed from a particular alloy and then the geometry would be changed to control the final resistance or conductivity value required. In the case of a fuse used for low amperage control, the manufacturability is complicated by the geometric cross-section required due to the inherent conductivity of the standard zinc alloys used.

A schematic example of a fuse 10 is shown in Fig. 4 wherein two electrical blade leads 12, 14 are connected by a thinner cross-sectional area element 18. Element 18 and/or the entire fuse 10 can be constructed from any of the zinc-manganese alloys described herein. Because of the higher electrical resistance of the zinc-manganese alloys, the element 18 can be increased in cross-sectional area to produce the same resistance as a smaller conventional fuse element. Reducing conductivity of the fuse 10 and/or element 18 metal allows for an increase in cross-sectional area of the element of a fuse to maintain an amperage rating which can aide in manufacturing. Increasing the cross-sectional area of the element can also result in increased reliability and consistency of performance.

It will be appreciated by those skilled in the art that the above reduced conductivity and unique electromagnetic signature zinc alloy is merely representative of the many possible embodiments of the invention and that the scope of the invention should not be limited thereto, but instead should only be limited according to the following claims.
What is claimed is:

1. An alloy, comprising:
   up to 2% by weight of manganese and the balance zinc.

2. The alloy of claim 1, further comprising an electrical conductivity in the range of 12 to 25% IACS.

3. The alloy of claim 1, wherein said manganese comprises 0.01% to 2% by weight of said alloy.

4. The alloy of claim 1, further comprising copper in the range of 0.1% to 1.2% by weight.

5. The alloy of claim 1, further comprising titanium.

6. The alloy of claim 1, further comprising at least one of the group consisting of copper, aluminum, magnesium, titanium, cadmium, chromium, iron and antimony.

7. The alloy of claim 1, formed into a coin or token.

8. The alloy of claim 1, formed into a fuse.

9. The alloy of claim 1, having an as-cast IACS conductivity modified by a rolling process.

10. The alloy of claim 1, further comprising a plating layer over said alloy.

11. The alloy of claim 1, wherein said manganese comprises 0.05% to 1% of said alloy.

12. The alloy of claim 1, wherein said manganese comprises 0.01% to 1% of said alloy.
13. The alloy of claim 1, further comprising aluminum in the amount of 0.001% to 0.60% by weight.

14. The alloy of claim 1, further comprising magnesium in the amount of 0.0001% to 0.50% by weight.

15. The alloy of claim 1, further comprising titanium in the amount of 0.050% to 1.0% by weight.

16. The alloy of claim 1, further comprising chromium in the amount of 0.0001% to 0.50% by weight.

17. The alloy of claim 1, further comprising iron in the amount of 0.0001% to 0.50% by weight.

18. The alloy of claim 1, further comprising antimony in the amount of 0.0001% to 0.50% by weight.
ZINC-MANGANESE BINARY ALLOY EFFECT ON CONDUCTIVITY

CONDUCTIVITY RANGE THAT CAN BE ACHIEVED AT VARYING Mn LEVELS DEPENDING ON PROCESSING CONDITIONS

FIG 1
ZINC-MANGANESE BASED QUATERNARY ALLOY EFFECT ON CONDUCTIVITY

QUATERNARY ALLOY EFFECT ON CONDUCTIVITY

CONDUCTIVITY RANGE THAT CAN BE ACHIEVED AT VARYING Mn LEVELS DEPENDING ON PROCESSING CONDITIONS AND ADDITIONAL ALLOYING AGENTS

% IACS (CONDUCTIVITY)

Mn CONTENT (wt %)

FIG 2
ELECTROMAGNETIC SIGNATURES

MATERIALS INCLUDED:

- STANDARD ZINC PRODUCT ALLOY "1"
- REPRESENTATIVE ZINC-MANGANESE ALLOY "A"
- REPRESENTATIVE ZINC-MANGANESE ALLOY "B"
- ALUMINUM BRONZE ALLOY "2"
- CUPRO-NICKEL (75/25) ALLOY "3"
- STAINLESS STEEL 316 ALLOY "4"
- RAW LOW-CARBON STEEL ALLOY "5"

ALLOY 1
ALLOY 2
ALLOY 3
ALLOY 4
ALLOY 5

HEIGHT +0.2 INNER C1
HEIGHT +0.2 INNER C2
HEIGHT +0.5 INNER P
HEIGHT +1.0 OUTER C1
HEIGHT +0.8 OUTER C2
HEIGHT +0.8 OUTER P

FIG 3
A.  CLASSIFICATION OF SUBJECT MATTER
C22C 18/00(2006.01)i

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

B.  FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C22C 18/00; B22D 31/00; B22D 17/00; C22B 9/10; C22C 18/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & keywords: zinc, manganese, electrical conductivity, copper, and titanium

C.  DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>EP 0899349 A (MITSUI MINING &amp; SMELTING CO., LTD.) 03 March 1999</td>
<td>1-8, 10-16</td>
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<td></td>
<td>See paragraphs [0011]; [0016] and claims 1-7.</td>
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<td>A</td>
<td>JP 09-041057 A (MITSUI MINING &amp; SMELTING CO., LTD.) 10 February 1997</td>
<td>1-18</td>
</tr>
<tr>
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<td>See abst act; paragraphs [0020]; [0022]; and claims 1,2.</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>JP 2001-049370 A (MITSUI MINING &amp; SMELTING CO., LTD.) 20 February 2001</td>
<td>1-18</td>
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<tr>
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<td>See abst act; paragraphs [0006], [0007]; and claim 1.</td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>JP 2007-084869 A (SINTO BRATOR CO., LTD.) 05 April 2007</td>
<td>1-18</td>
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<tr>
<td></td>
<td>See abst act; paragraphs [0042], [0043]; and claims 1,6.</td>
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<td>See abst act; paragraphs [0017], [0018]; and claims 1,2.</td>
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Further documents are listed in the continuation of Box C. See patent family annex.

* Special categories of cited documents:
  "A" document defining the general state of the art which is not considered to be of particular relevance
  "E" earlier application or patent but published on or after the international filing date
  "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  "O" document referring to an oral disclosure, use, exhibition or other means
  "P" document published prior to the international filing date but later than the priority date claimed
  "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
  "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
  "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
  "&" document member of the same patent family

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Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongna-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer
BAE, Geun Tae
Telephone No. +82-42-481-5580

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<tr>
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<td>03/03/1999</td>
<td>JP 11-061299 A</td>
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