A boron-free, low-gold, and low-palladium metal alloy composition formulated to provide an alloy with an attractive yellow color, improved tarnish resistance, and enhanced castability. In certain implementations, the alloy contains gold, silver, copper, palladium and indium. The alloy preferably contains less than 25% by weight gold and the weight percent ratio of silver to copper is between 0.65 and 2.65 and the weight percent ratio of palladium to indium is between 1 and 5.
TARNISH RESISTANT LOW GOLD AND LOW PALLADIUM YELLOW JEWELRY ALLOYS WITH ENHANCED CASTABILITY

BACKGROUND OF THE INVENTION

[0001] Field of the Invention

[0002] This invention relates generally to metal alloys, and more particularly relates to compositions of certain low gold and low palladium alloys for use in jewelry.

[0003] Description of the Related Art

[0004] Traditionally, alloys that are used in gold jewelry typically contain not less than 41.67% gold by weight, which corresponds to 10 karat or higher gold alloys. The recent rising and instability of the price of gold as well as other precious metals such as palladium impose rigid restrictions on the material cost when manufacturing jewelry articles. As such, there is an increasing demand for alloys with significantly lower gold content and yet still maintaining favorable properties such as an aesthetically pleasing yellow gold color and tarnish resistance.

[0005] U.S. Pat. No. 3,925,066 discloses an alloy that contains, by weight, 25%-30% gold, 45%-57% silver, 0%-5% zinc, and 18%-25% of a combination of copper and nickel. The disclosed gold content still makes such alloys expensive. It is also known that nickel in the alloy may cause an allergic reaction when brought into direct contact with the skin. Moreover, the alloy does not appear to contain any additives to improve castability.

[0006] U.S. Pat. No. 4,264,359 discloses an alloy that contains, by weight, 25% gold, between 11.75%-12.6% palladium, 8%-10.25% zinc and 0.045%-0.65% of boron, and balance copper. Fairly high content of both gold and palladium makes these alloys more expensive. Also, the presence of palladium in higher concentrations will likely pate the yellow color of the alloys. While boron is a common additive for improving the castability of the alloy, in general practice, it is difficult to control the amount of boron in the alloy, especially in the re-melts, as this element is volatile and does not alloy readily with other metals.

[0007] U.S. Pat. No. 4,370,164 discloses an alloy containing, by weight, 4%-10% gold, 54%-61% silver, 14%-19% copper, 4%-7% palladium, 9%-14% indium, 1%-3% zinc, and 0.015%-0.04% boron. Relatively high indium content in such alloys is a potential cause for embrittlement.

[0008] U.S. Pat. No. 4,446,102 describes a yellow jewelry alloy that contains, by weight, between 17%-25% gold, 10%-27% silver, 40%-60% copper, 3%-12% zinc. Optional elements include up to 2% lead, up to 2% palladium, up to 3% platinum, up to 1% bismuth, up to 2% tin, up to 10% cadmium, up to 5% gallium, up to 3% aluminum, and up to 3% iron. The tarnish resistance of such an alloy with or low palladium is likely to be low.

[0009] U.S. Pat. No. 5,045,411 discloses another alloy that contains 25%-52% by weight gold, but does not contain palladium. Alloys with 25% gold content and no palladium are susceptible to accelerated tarnish. Naturally, higher gold content increases the cost. It is also known that nickel in the alloy may cause an allergic reaction when brought into direct contact with the skin.

[0010] U.S. Pat. No. 5,330,713 discloses a gold colored alloy that contains, by weight, 6%-19.8% gold, 5%-12% indium, 6.2%-12% zinc, 6.2%-12% palladium, 23%-40% copper, and 23%-40% silver. In these alloys, the higher palladium content contributes to higher material costs. The yellow color of such alloys is typically enhanced by formation of a colored palladium/indium intermetallic compound. However, relative high indium content in such alloys is a potential cause for alloy embrittlement. Boron additions using copper boride or calcium boride are also difficult to control.

SUMMARY OF THE INVENTION

[0011] U.S. Pat. No. 5,409,663 discloses an indium-free alloy that contains no greater than 10% gold, 0.5%-3% platinum, 6%-11% palladium, 18%-35% copper, 19.5%-22.5% silver, 22%-32% zinc, and 0.1%-2% aluminum. Such indium-free low gold alloys with the disclosed platinum and palladium content are likely to be pale in color. Moreover, high zinc content tends to make alloys less ductile and difficult to cast. The presence of platinum and palladium together add to the cost of the alloy.

[0012] U.S. Pat. No. 6,835,252 discloses a palladium-free alloy with 13%-25% gold. Such low gold, palladium-free alloys may exhibit inferior tarnish properties when compared with other palladium-containing alloys with similar gold content.

[0013] The preferred embodiments of the present invention provide certain improved low-gold yellow jewelry alloy compositions that are formulated to ameliorate at least some of the shortcomings of prior art metal alloys. However, no single one of the disclosed parameters and compositions is solely responsible for their desirable attributes and not all of the parameters and compositions are necessary to achieve the advantages of the metal alloys of the preferred embodiments. After considering this discussion, and particularly after reading the section entitled “Detailed Description of the Preferred Embodiments,” one will understand how the features of the preferred embodiments provide advantages over prior art.

[0014] In one aspect, the preferred embodiments of the present invention provide a metal alloy composition consisting essentially of about 1%-25% by weight gold, about 15%-51% by weight silver, about 2%-9% by weight palladium, about 0.5%-7% by weight indium, about 0.5%-10% by weight zinc, about 0.1%-10% by weight tin, about 0.1%-5% by weight gallium, about 0%-5% by weight platinum, about 0%-1% by weight silicon, and balance copper. Preferably, the alloy composition has a copper to silver weight percent ratio of between 0.65 and 2.65 and a palladium to indium weight percent ratio of between 1 and 5.

[0015] In another aspect, the preferred embodiments of the present invention provide a metal alloy composition consisting essentially of about 5% by weight gold, about 51% by weight silver, about 4% by weight palladium, about 1.4% by weight indium, about 0.1% by weight platinum, about 0.5% by weight zinc, about 34.13% by weight copper, about 3.75% by weight tin, about 0.02% by weight silicon, and about 0.1% by weight gallium.

[0016] In yet another aspect, the preferred embodiments of the present invention provide a metal alloy composition consisting essentially of about 5% by weight gold, about 30% by weight silver, about 7% by weight palladium, about 1.4% by weight indium, about 0.1% by weight platinum, about 0.85% by weight zinc, about 50.78% by weight copper, about 4.75% by weight tin, about 0.02% by weight silicon, and about 0.1% by weight gallium.

[0017] In yet another aspect, the preferred embodiments of the present invention provide a metal alloy composition consisting essentially of about 10% by weight gold, about 35% by weight silver, about 7% by weight palladium, about 7% by weight indium, about 7% by weight zinc, about 33.8% by weight copper, about 0.1% by weight tin, and about 0.1% by weight gallium.
In yet another aspect, the preferred embodiments of the present invention provide a metal alloy composition consisting essentially of about 15% by weight gold, about 22% by weight silver, about 7% by weight palladium, about 5% by weight indium, about 5.5% by weight zinc, about 45.1% by weight copper, about 0.1% by weight tin, and about 0.3% by weight gallium.

In yet another aspect, the preferred embodiments of the present invention provide a metal alloy composition consisting essentially of about 19% by weight gold, about 17% by weight silver, about 8% by weight palladium, about 5% by weight indium, about 5.5% by weight zinc, about 44.9% by weight copper, about 0.1% by weight tin, and about 0.5% by weight gallium.

In yet another aspect, the preferred embodiments of the present invention provide a metal alloy composition consisting essentially of about 20% by weight gold, about 25% by weight silver, about 6.5% by weight palladium, about 3.75% by weight indium, about 1.25% by weight zinc, about 18.4% by weight copper, about 5% by weight tin, and about 0.1% by weight gallium.

In yet another aspect, the preferred embodiments of the present invention provide a metal alloy composition consisting essentially of about 1%-25% by weight gold, about 15%-51% by weight silver, about 2%-9% by weight palladium, about 0.5%-7% by weight zinc, about 0.1%-10% by weight tin, about 0.1%-5% by weight silicon, about 0.1%-5% by weight copper, about 0.1%-5% by weight indium, about 0.1%-1% by weight copper, and about 0.1%-5% by weight silicon, and balance copper.

In yet another aspect, the preferred embodiments of the present invention provide a boron-free alloy composition comprising gold, silver, copper, palladium, and indium, wherein the weight percent ratio of copper to silver is between 0.65 and 2.65 and the weight percent ratio of palladium to indium is between 1 and 5.

**DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

Prefered embodiments of the present invention provide certain metal alloys that are formulated with compositions that provide alloys with an aesthetically attractive yellow color, greater tarnish resistance, and well controlled enhanced castability. In one preferred embodiment, the improved alloy composition comprises about 1%-25% by weight gold, about 15%-51% by weight silver, about 2%-9% by weight palladium, about 0.5%-7% by weight zinc, about 0.1%-10% by weight tin, about 0%-1% by weight silicon, about 0.1%-5% by weight gallium, about 0%-5% by weight platinum, and balance copper. In another preferred embodiment, the improved alloy composition consists essentially of about 1%-25% by weight gold, about 15%-51% by weight silver, about 2%-9% by weight palladium, about 0.5%-7% by weight indium, about 0.5%-10% by weight zinc, about 0.1%-10% by weight tin, about 0%-1% by weight silicon, about 0.1%-5% by weight gallium, about 0%-5% by weight platinum, and balance copper.

In certain implementations, the alloy composition is formulated to provide an alloy with an attractive yellow color by maintaining the weight percent ratios of copper to silver and palladium to indium within certain ranges. In one implementation, the weight percent ratio of copper to silver is preferably between 0.65 and 2.65 and the weight percent ratio of palladium to indium is preferably between 1 and 5. In another implementation, the presence of palladium between 4 and 8 weight percent provides adequate tarnish resistance. Additions of tin and gallium improve castability in certain other implementations. Such additions of tin and gallium are well controlled as these elements are not as volatile as boron, and more readily alloy with other metals. Silicon in these alloys is a common de-oxidizing additive. Small amount of platinum may be also added to increase an as cast hardness and to enhance grain refining.

A number of the alloys were prepared in accordance with alloy compositions of certain preferred embodiments of the present invention and tested for color, tarnish behavior and castability. The color of tested alloys was compared visually with that of a commercially available 10K yellow alloy consisting essentially of 41.7% by weight gold, 12% by weight silver, 5.8% by weight zinc and 40.5% by weight copper. The tarnish test was carried out by exposing the polished alloy samples to a vapor of dilute solution of ammonium sulfide. The tarnish behavior was determined as a rate of color change determined visually in comparison with the sample of a regular sterling silver alloy consisting essentially of 92.5% by weight silver and 7.5% by weight copper. For reference, it was found that tarnish behavior of 10K yellow alloy is about 7 times (7x) better than that of regular sterling.

Each of the tested alloys was used in investment casting, and showed good castability, namely, good fluidity and full filling the investment cavity. The experimental data on tested alloys is summarized in Table 1.

**Table 1**

<p>| Tested alloy compositions (%) by weight, color and tarnish behavior. |
|-----------------|---|---|---|---|---|---|---|---|---|---|---|---|---|---|</p>
<table>
<thead>
<tr>
<th>Alloy</th>
<th>% Au</th>
<th>% Ag</th>
<th>% Pd</th>
<th>% In</th>
<th>% Pt</th>
<th>% Zn</th>
<th>% Cu</th>
<th>% Sn</th>
<th>% Si</th>
<th>% Ga</th>
<th>Cu/Ag</th>
<th>Pd/In</th>
<th>Color</th>
<th>Tarnish</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alloy #1</td>
<td>5</td>
<td>51.0</td>
<td>4</td>
<td>1.4</td>
<td>0.1</td>
<td>0.5</td>
<td>34.13</td>
<td>3.75</td>
<td>0.02</td>
<td>0.1</td>
<td>0.08</td>
<td>2.86</td>
<td>Pale</td>
<td>3-5X</td>
</tr>
<tr>
<td>Alloy #2</td>
<td>5</td>
<td>30</td>
<td>7</td>
<td>1.4</td>
<td>0.1</td>
<td>0.85</td>
<td>50.78</td>
<td>4.75</td>
<td>0.02</td>
<td>0.1</td>
<td>1.69</td>
<td>5</td>
<td>Pale</td>
<td>4-5X</td>
</tr>
<tr>
<td>Alloy #3</td>
<td>10</td>
<td>35</td>
<td>7</td>
<td>7</td>
<td>0</td>
<td>7</td>
<td>33.8</td>
<td>0.1</td>
<td>0.1</td>
<td>0.97</td>
<td>1</td>
<td>yellow</td>
<td>4-5X</td>
<td></td>
</tr>
<tr>
<td>Alloy #4</td>
<td>15</td>
<td>22</td>
<td>0.0</td>
<td>5.0</td>
<td>0.0</td>
<td>5.0</td>
<td>45</td>
<td>10</td>
<td>0.10</td>
<td>0.30</td>
<td>2.05</td>
<td>1.4</td>
<td>yellow</td>
<td>5-6X</td>
</tr>
<tr>
<td>Alloy #5</td>
<td>19</td>
<td>17</td>
<td>8</td>
<td>5</td>
<td>0</td>
<td>5.5</td>
<td>44.9</td>
<td>0.1</td>
<td>0.5</td>
<td>2.64</td>
<td>1.6</td>
<td>yellow</td>
<td>5-7X</td>
<td></td>
</tr>
<tr>
<td>Alloy #6</td>
<td>20</td>
<td>25</td>
<td>6.5</td>
<td>3.75</td>
<td>0</td>
<td>1.25</td>
<td>38.4</td>
<td>5</td>
<td>0.1</td>
<td>1.54</td>
<td>1.73</td>
<td>yellow</td>
<td>5-7X</td>
<td></td>
</tr>
</tbody>
</table>
Alloy #1 was prepared in accordance with a composition consisting essentially of about 5% by weight gold, about 51% by weight silver, about 4% by weight palladium, about 1.4% by weight indium, about 0.1% by weight platinum, about 0.5% by weight zinc, about 34.13% by weight copper, about 3.75% by weight tin, about 0.02% by weight silicon and about 0.1% by weight gallium. In this alloy, Cu/Ag = 0.68 and Pd/In = 2.86. The alloy exhibits a pale yellow color, and its tarnish behavior is 3.5 times (3-5x) better than that of sterling silver.

Alloy #2 was prepared in accordance with a composition consisting essentially of about 5% by weight gold, about 30% by weight silver, about 7% by weight palladium, about 1.4% by weight indium, about 0.1% by weight platinum, about 0.85% by weight zinc, about 50.78% by weight copper, about 4.75% by weight tin, about 0.02% by weight silicon and about 0.1% by weight gallium. In this alloy, Cu/Ag = 1.69 and Pd/In = 5. The alloy also exhibits a pale yellow color, and its tarnish behavior is 4-5 times (4-5x) better than that of sterling silver.

Alloy #3 was prepared in accordance with a composition consisting essentially of about 10% by weight gold, about 35% by weight silver, about 7% by weight palladium, about 7% by weight indium, about 7% by weight zinc, about 33.8% by weight copper, about 0.1% by weight tin and about 0.1% by weight gallium. In this alloy, Cu/Ag = 0.97 and Pd/In = 1. The alloy exhibits a yellow color, and its tarnish behavior is 4-5 times (4-5x) better than that of sterling silver.

Alloy #4 was prepared in accordance with a composition consisting essentially of about 15% by weight gold, about 22% by weight silver, about 7% by weight palladium, about 5% by weight indium, about 5.5% by weight zinc, about 45.1% by weight copper, about 0.1% by weight tin, and about 0.3% by weight gallium. In this alloy, Cu/Ag = 2.64 and Pd/In = 1.4. The alloy also exhibits a yellow color, and its tarnish behavior is 5-6 times (5-6x) better than that of sterling silver.

Alloy #5 was prepared in accordance with a composition consisting essentially of about 19% by weight gold, about 17% by weight silver, about 8% by weight palladium, about 5% by weight indium, about 5.5% by weight zinc, about 44.9% by weight copper, about 0.1% by weight tin, and about 0.5% by weight gallium. In this alloy, Cu/Ag = 2.05 and Pd/In = 1.4. The color of this alloy is bright yellow, and its tarnish behavior is 5-7 times (5-7x) better than that of sterling silver.

Alloy #6 was prepared in accordance with a composition consisting essentially of about 20% by weight gold, about 25% by weight silver, about 6.5% by weight palladium, about 3.75% by weight indium, about 1.25% by weight zinc, about 38.4% by weight copper, about 5% by weight tin, and about 0.1% by weight gallium. In this alloy, Cu/Ag = 1.54 and Pd/In = 1.73. The alloy also exhibits bright yellow color, and its tarnish behavior is 5-7 times (5-7x) better than that of sterling silver, practically approaching that of 10K yellow alloy.

Although the foregoing description of the preferred embodiments of the present invention has shown, described and pointed out the fundamental novel features of the invention, it will be understood that various omissions, substitutions, and changes in the form of the details of the invention as illustrated as well as the uses thereof, may be made by those skilled in the art, without departing from the spirit of the invention. Consequently, the scope of the invention should not be limited to the foregoing discussions.

What is claimed is:

1. An alloy composition consisting essentially of about 1%-25% by weight gold, about 15%-51% by weight silver, about 2%-9% by weight palladium, about 0.5%-7% by weight indium, about 0.5%-10% by weight zinc, about 0.1%-10% by weight tin, about 0.1%-5% by weight gallium, about 0%-5% by weight platinum, about 0%-1% by weight silicon, and balance copper, wherein the alloy composition has a copper to silver ratio of between 0.65 and 2.65 and a palladium to indium ratio of between 1 and 5.

2. The alloy composition of claim 1, wherein the composition consists essentially of about 5% by weight gold, about 51% by weight silver, about 4% by weight palladium, about 1.4% by weight indium, about 0.1% by weight platinum, about 0.5% by weight zinc, about 34.13% by weight copper, about 3.75% by weight tin, about 0.02% by weight silicon, and about 0.1% by weight gallium.

3. The alloy composition of claim 1, wherein the composition consists essentially of about 5% by weight gold, about 30% by weight silver, about 7% by weight palladium, about 1.4% by weight indium, about 0.1% by weight platinum, about 0.85% by weight zinc, about 50.78% by weight copper, about 4.75% by weight tin, about 0.02% by weight silicon, and about 0.1% by weight gallium.

4. The alloy composition of claim 1, wherein the composition consists essentially of about 10% by weight gold, about 35% by weight silver, about 7% by weight palladium, about 7% by weight indium, about 7% by weight zinc, about 33.8% by weight copper, about 0.1% by weight tin, and about 0.1% by weight gallium.

5. The alloy composition of claim 1, wherein the composition consists essentially of about 15% by weight gold, about 22% by weight silver, about 7% by weight palladium, about 5% by weight indium, about 5.5% by weight zinc, about 45.1% by weight copper, about 0.1% by weight tin, and about 0.3% by weight gallium.

6. The alloy composition of claim 1, wherein the composition consists essentially of about 19% by weight gold, about 17% by weight silver, about 8% by weight palladium, about 5% by weight indium, about 5.5% by weight zinc, about 44.9% by weight copper, about 0.1% by weight tin, and about 0.5% by weight gallium.

7. The alloy composition of claim 1, wherein the composition consists essentially of about 20% by weight gold, about 25% by weight silver, about 6.5% by weight palladium, about 3.75% by weight indium, about 1.25% by weight zinc, about 38.4% by weight copper, about 5% by weight tin, and about 0.1% by weight gallium.

8. An alloy composition consisting essentially of about 1%-25% by weight gold, about 15%-51% by weight silver, about 2%-9% by weight palladium, about 0.5%-7% by weight indium, about 0.5%-10% by weight zinc, about 0.1%-10% by weight tin, about 0.1%-5% by weight gallium, about 0.1%-5% by weight platinum, about 0.1%-1% by weight silicon, and balance copper.

9. A boron-free alloy composition, said composition comprises gold, silver, copper, palladium, and indium, wherein the weight percent ratio of copper to silver is between 0.65 and 2.65 and the weight percent ratio of palladium to indium is between 1 and 5.

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