SILVER-SILICON ALLOYS

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No Drawing. Application December 18, 1951, Serial No. 262,337

Claims priority, application Germany December 22, 1950
5 Claims. (Cl. 75—173)

The present invention relates to novel silver-silicon alloys and especially hypoeutectic silver-silicon alloys containing 0.1 to 5% of silicon and phosphorus in a quantity between 0.001 and 0.1%.

Binary hypoeutectic silver-silicon alloys have already been used many times in the construction of corrosion-resistant apparatus and parts thereof which are subject to mechanical stresses, for example, valve seats, valve linings, pumps, stirrers and the like.

The structure of such alloys in cast state consists, depending upon the silicon content, of primary crystals of silver or silicon and both components in eutectic mixture. The silicon in the eutectic mixture usually is in the form of platelets or long needle-like structures which cannot be uniformly and finely distributed in the silver ground mass even during subsequent working of the alloy. Consequently, such alloys are difficult to work and numerous intermediate annealings are required. The relatively large sized silicon inclusions render it impossible to impart a high polish to the surface of such alloys. These drawbacks of the alloys have been found extremely disadvantageous for many uses of the alloys.

It has now been found, according to the invention, that the alloys, in accordance with the invention, containing from 0.1—5% of silicon and 0.001—0.1% of phosphorus, not only avoid the above-mentioned drawbacks, but also possess improved mechanical properties while still maintaining the same chemical properties as the binary alloys devoid of phosphorus or arsenic. It has been found that the presence of phosphorus in the quantities specified cause the silicon to crystallize in a fine-grained form in the eutectic mass. Comparative tests have shown that the silicon grains in the eutectic mass of cast alloys according to the invention are only about 1/2 to 1/40 as large as those in the binary silver silicon alloys devoid of phosphorus or arsenic. This produces a more uniform distribution of the silicon in the silver containing matrix so that a much more uniform and finer distribution of the silicon takes place upon working than occurs with the binary alloys devoid of phosphorus. The finest silicon distribution is achieved in alloys containing 1—4% of silicon and 0.01 to 0.05% of phosphorus or arsenic.

Further advantageous properties can be obtained by the addition of small quantities of copper or nickel. The copper content can be between 0.01 and 0.5% and the nickel content can be between 0.01 and 0.2%. It is also possible to add both copper and nickel within the ranges given, as long as their total does not exceed 0.5%.

The alloys according to the invention are not only more workable because of the fine-grained crystals of silicon, but they also have substantially improved mechanical properties over the binary silver silicon alloys. While a cast binary 97% silver 3% silicon alloy can only be cold worked about 15—20% before annealing, the same alloy with a 0.03% phosphorus addition can be cold rolled 40—50% before annealing. In view of the good workability of the alloys according to the invention, they are well suited as plating metals on base metal alloys while the binary alloys are uneconomical to use for plating purposes in view of their comparatively low workability.

The fine-grained structure of the alloys according to the invention also improves their hardness, as well as their tensile strength. The following table compares the tensile strength (TS) and the Brinell hardness (HB) of binary silver silicon alloys of various silicon contents with silver silicon alloys containing 0.05% of phosphorus.

<table>
<thead>
<tr>
<th>Silicon, Percent</th>
<th>Ag—Si</th>
<th>Ag—Si 0.05% P</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TS kg./</td>
<td>HB kg./</td>
</tr>
<tr>
<td></td>
<td>mm²</td>
<td>mm²</td>
</tr>
<tr>
<td>1.0</td>
<td>19.7</td>
<td>44</td>
</tr>
<tr>
<td>1.5</td>
<td>22.9</td>
<td>51</td>
</tr>
<tr>
<td>2.5</td>
<td>22.6</td>
<td>60</td>
</tr>
<tr>
<td>3.5</td>
<td>22.6</td>
<td>63</td>
</tr>
</tbody>
</table>

As may be seen from the table, the alloys according to the invention have tensile strengths and Brinell hardnesses which are 10% and more higher than those of the binary alloys.

The excellent workability of the phosphorus containing silver-silicon alloys according to the invention renders it possible to utilize more fully the improvements in mechanical properties which are engendered by cold working.

The following table shows the tensile strength (TS), elongation at break (E) and the Brinell hardness (HB) of a 96.97% by 3% silicon 0.03% phosphorus alloy at various stages of cold working.

<table>
<thead>
<tr>
<th>Cold Working, Percent</th>
<th>TS kg./ mm²</th>
<th>E, Percent</th>
<th>HB kg./ mm²</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>35.5</td>
<td>31.5</td>
<td>65</td>
</tr>
<tr>
<td>10</td>
<td>36.2</td>
<td>26.4</td>
<td>69</td>
</tr>
<tr>
<td>20</td>
<td>36.4</td>
<td>25.6</td>
<td>94</td>
</tr>
<tr>
<td>30</td>
<td>42.7</td>
<td>5.6</td>
<td>105</td>
</tr>
<tr>
<td>40</td>
<td>47.2</td>
<td>2.2</td>
<td>119</td>
</tr>
<tr>
<td>50</td>
<td>43.8</td>
<td>2.2</td>
<td>133</td>
</tr>
</tbody>
</table>

Corrosion tests have shown that the alloys in accordance with the invention have an unexpectedly high corrosion resistance which is substantially the same as that of pure silver. For example, an alloy consisting of 96.97% Ag, 3% silicon and 0.03% phosphorus has a yearly loss of thickness when exposed to acetic acid at 100° C. of 1.3 microns. Because of the known influence of phosphorus upon silver, it was rather to be expected that the corrosion resistance of the alloys according to the invention would be considerably below that of pure silver. Also, it was to be expected that the inclusion of phosphorus in the alloys according to the invention would have an unfavorable effect on such alloys in view of their normal embrittlement action. Consequently, it was entirely unexpected that the addition of phosphorus to the binary silver-silicon alloys would result in such improved mechanical properties that they would be suitable for uses for which the binary alloys were not practical.

The excellent polishing characteristics of the alloys according to this invention is of special importance, as it ensures good resistance to chemical and mechanical attacks. The addition of copper and nickel facilitates the inclusion of the easily volatilizable phosphorus because the compounds CuP or NiP are selected as carriers of the phosphorus to be added to the silver-silicon alloy. Contrary to elementary phosphorus these compounds do not show a significant phosphorus vapor pressure even at a temperature of about 1100° C. Furthermore, the addition of these small quantities of copper and/ or nickel have
no disadvantageous influence on the corrosion resistance
of the alloys.

The following are further examples of alloys according
to the invention which have been found to have sub-
stantially improved properties over the corresponding
binary silver-silicon alloys.

| Composition | Additions, percent | Grain size of
| Si, percent | Ag, percent | silicon in the cast alloy in
| 1.5 | rest | 0.03 Ag | comparison with alloys without
| 3 | rest | 0.30 Cu+0.05 P | addition of P
| 2.5 | rest | 0.15 Ni+0.02 P | 14 to 16μ
| 4 | rest | 0.02 Ag+0.03 P | 16 to 20μ

I claim:
1. A silver-silicon alloy consisting of 0.1 to 5% of
   silicon, 0.001 to 0.1% of phosphorus and the balance
   silver.
2. A silver-silicon alloy consisting of 1 to 4% of silicon,
   0.01 to 0.5% of phosphorus and the balance silver.
3. An alloy in accordance with claim 1, containing in
   addition at least one of the following metals; nickel in
   a quantity between 0.01 and 0.2% and copper in a quan-
   tity between 0.01 and 0.5%, the total quantity of such
   addition being up to 0.5%.
4. An alloy in accordance with claim 1, containing in
   addition 0.01 to 0.2% of nickel.
5. An alloy in accordance with claim 1, containing in
   addition 0.01 to 0.5% of copper.

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