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(54) **A gold alloy and a process for the manufacture thereof**

Goldlegierung und Verfahren zu deren Herstellung

Alliage en or et procédé pour sa fabrication

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Description

[0001] The present invention relates to a gold metal alloy and a process for the manufacture thereof. The gold alloy is particularly, though not exclusively, suitable for use in the manufacture of articles of jewellery.

[0002] In the United Kingdom, gold jewellery is classified and legally controlled by a gold standard known as the carat, which is measure of the purity (or fineness) of the metal. Accordingly, gold jewellery is legally controlled, depending on the gold content, at 24-carat (pure gold), 22-carat (91.7 wt.% minimum), 18-carat (75.0 wt.%), 14-carat (58.5 wt.%) and 9-carat (37.5 wt.%).

[0003] Pure gold metal is extremely soft and consequently does not generally provide a good or extended wear life for manufactured jewellery articles. It is therefore desirable to include alloying elements to provide an alloy with improved hardness and wear resistance, while still retaining a colour and lustrous finish that are associated with pure gold. Accordingly, gold alloys for manufactured jewellery articles are typically based on the ternary Au-Ag-Cu or quaternary Au-Ag-Cu-Zn alloy systems. The presence of zinc in the alloy in amounts in excess of 1 wt.% modifies the colour and workability of the alloy. These ternary and quaternary alloys are intrinsically harder than pure gold and, depending on composition, may be further heat-treated to modify the mechanical properties.

[0004] The improved hardness may result in ternary and quaternary alloys being less tolerant to cold working compared with pure gold. However, these same factors can lead to increased advantageous properties when used during the final fabrication stages of article production to give increased strength, hardness and resistance to wear.

[0005] Until recently, the study of gold has concentrated on alloys that have low intrinsic hardness values and which are easily cold-worked, i.e. formed/shaped at a temperature below the alloy recrystallization temperature.

[0006] US-A-2,042,155 relates to a gold alloy which consists of 33 to 50% Au, 10 to 18% Ag, 30 to 40% Cu, 1 to 5% Ni, and 5 to 10% Zn.

[0007] FR-A-2, 305, 503 relates to a 9 carat gold alloy with 3.5 to 9.0 % Ag.

[0008] The present invention aims to provide gold alloys having improved mechanical properties over the prior art alloys. This allows for the fabrication of jewellery articles using less alloy material compared with the prior art, while providing the same or enhanced strength and wear characteristics once heat-treated.

[0009] Accordingly, in a first aspect the present invention provides an age-hardened 9 carat yellow gold alloy suitable for use in the manufacture of jewellery, the alloy consisting of:

Gold	approximately 37.5 wt. %
Silver	from 13 to 20 wt. %
Zinc	from 4 to 10 wt. %

and optionally

Silicon	from 0.01 to 0.5 wt. %
Boron	from 0.001 to 0.15 wt. %

and the balance copper, together with unavoidable impurities, wherein the alloy has a Vickers Hardness (H_V) of ≥ 200 .

[0010] Vickers hardness testing may be carried out using conventional testing equipment using a 5 kg load.

[0011] If the alloy is diamond polished, and light from a tungsten filament using, for example, an EEL instrument is incident on the polished surface, then the surface reflectivity is preferably in the range of from 70 to 80%. The surface reflectivity is based on comparing incident and reflected light, but taking no account of colour.

[0012] For certain applications, for example investment casting alloys, the gold alloy may comprise:

Silicon	from 0.01 to 0.5 wt. %
Boron	from 0.001 to 0.15 wt. %

[0013] As already mentioned, for investment casting applications, the age-hardened 9 carat yellow gold alloy advantageously consists of:

Gold	approximately 37.5 wt. %
Silver	from 13 to 20 wt. %
Zinc	from 4 to 10 wt. %

(continued)

Silicon	from 0.01 to 0.5 wt. %
Boron	from 0.001 to 0.15 wt. %

and the balance copper, together with unavoidable impurities.

[0014] The alloy preferably has a Vickers hardness (H_V) for a 5 kg load in the range of from 220 to 300, more preferably from 250 to 300, still more preferably from 270 to 300. The alloy has a phase microstructure which includes the ordered compound $AuCu_3$. While not wishing to be bound by theory, it is thought that this compound may contribute to the improved final hardness of the material. The presence of zinc in the alloys according to the present invention is thought to reduce the height and breadth of the immiscibility (two-phase) region resulting in reduced precipitation of $((\alpha_1(Au-Ag) + \alpha_2(Au-Cu))$ and $AuCu_3$. This may improve workability through softening in both the solution-treated and aged states.

[0015] The alloy preferably comprises from 15 to 20 wt. % silver, more preferably from 17 to 20 wt. %.

[0016] The alloy preferably comprises from 5 to 10 wt. % zinc, more preferably from 8 to 10 wt. %.

[0017] The alloy preferably comprises from 37 to 43 wt. % copper, more preferably from 38 to 40 wt. % copper.

[0018] In a second aspect of the present invention there is provided an age-hardenable 9 carat yellow gold alloy consisting of:

Gold	approximately 37.5 wt. %
Silver	from 14.0 to 16.0 wt. %
Zinc	from 8 to 9 wt. %
Copper	from 38 to 40 wt. %

and optionally

Silicon	from 0.01 to 0.5 wt. %
Boron	from 0.001 to 0.15 wt. %

the sum constituting 100 wt. %, together with unavoidable impurities.

[0019] In the second aspect, the age-hardenable 9 carat yellow gold alloy preferably consists of:

Gold	approximately 37.5 wt. %
Silver	approximately 15.0 wt. %
Zinc	approximately 8.3 wt. %
Copper	approximately 39.2 wt. %

the sum constituting 100 wt. %, together with unavoidable impurities.

[0020] A particularly preferred gold alloy according to the second aspect of the present invention is a 9-carat yellow gold alloy consisting of:

Gold	37.50 wt. %
Silver	15.00 wt. %
Copper	39.17 wt. %
Zinc	8.33 wt. %

the sum constituting 100 wt. %, together with unavoidable impurities.

[0021] The alloy composition according to the second aspect may be provided in a solution treated state or may be heat-treated to effect age-hardening. By this process, the aged alloy may achieve a Vickers hardness (H_V) of ≥ 200 . Preferably, the alloy in age-hardened condition has a H_V in the range of from 220 to 300, more preferably from 250 to 300, still more preferably from 270 to 300. The alloy in age-hardened condition preferably has a phase microstructure which includes the ordered compound $AuCu_3$.

[0022] Prior to ageing, the alloy composition according to the second aspect, in annealed condition, will generally have a Vickers hardness (H_V) of from 80 to 150.

[0023] It will be appreciated that the alloys according the first and second aspects may contain unavoidable impurities,

although, in total, these will generally not exceed 1 wt.% of the composition, and preferably not more than 0.5 wt.% of the composition, more preferably not more than 0.25 wt.% of the composition.

[0024] The alloy according to the first and second aspects is age-hardenable. The alloy also exhibits reversible hardening behaviour. Accordingly, the alloy may be solution treated for maximum ductility and then aged for maximum hardness. Should a jewellery manufacturer, for example, then wish to resoften the alloy workpiece to carry out further work, the workpiece may be re-solution treated, worked, and re-aged with substantially no detrimental effects. This is an important feature of the present invention because reversible hardening behaviour enables optimum use over the full range of jewellery manufacturing techniques. Optimum hardenability can be achieved using a specific set of heat-treatments, in particular a solution-treatment, followed by a low temperature ageing operation.

[0025] While one or more grain refiners such as, for example, Co, Ir or Ru, may be included in the alloys according to the present invention, they are not an essential requirement to achieve the desired mechanical properties, in contrast to certain prior art gold alloys. Nor are elements, such as Fe, required to facilitate the reversibility of the hardening reaction.

[0026] The density of the gold alloys according to the present invention is typically in the range of from about 10.9 g/cm³ to about 11.5 g/cm³, more typically from about 11.0 g/cm³ to about 11.4 g/cm³, still more typically approximately 11.2 g/cm³.

[0027] The melting temperature of the gold alloys according to the present invention is typically in the range of from about 840°C to about 900°C, more typically from about 860°C to about 880°C.

[0028] The grain size, i.e. the statistical grain diameter in a random cross-section, of the gold alloys according to the present invention can vary depending upon the application, but will generally be in the range of from about 5 µm to about 60 µm, more typically from about 10 µm to about 30 µm.

[0029] The present invention further provides an article of jewellery in which at least a portion thereof is formed from an alloy as herein described. Such articles include, for example, rings, earrings, bracelets, necklaces and the like. The alloy may also be used in other decorative applications, for example objet d'art, goblets, cups, medals and badges.

[0030] The present invention also provides a process for the manufacture of a 9 carat yellow gold alloy suitable for use in the manufacture of jewellery, which process comprises:

(a) providing an alloy composition consisting of

Gold	approximately 37.5 wt. %
Silver	from 13 to 20 wt. %
Zinc	from 4 to 10 wt. %

and optionally

Silicon	from 0.01 to 0.5 wt. %
Boron	from 0.001 to 0.15 wt. %

and the balance copper, together with unavoidable impurities;

(b) solution treating the alloy composition at a temperature of up to the solidus temperature;

(c) cooling the solution-treated alloy from step (b) to ambient temperature; and

(d) age-hardening the cooled alloy from step (c) at a temperature in the range of from 200 to 400°C, followed by cooling to ambient temperature, wherein the age-hardening is performed for a time sufficient to achieve a Vickers hardness (Hv) of ≥ 200 in the final alloy.

[0031] The solution treatment in step (b) is preferably performed at a temperature up to approximately 860°C, more preferably in the range of from 500 to 860°C, more preferably from 700 to 800°C. It will be appreciated that the time spent at the solution-treatment temperature will depend on the size of the workpiece. However, the solution treatment will typically be performed for at least 5 minutes, more typically for from 10 to 60 minutes.

[0032] Cooling in step (c) is preferably effected by a quench from the solution-treatment temperature to ambient temperature to thereby substantially retain a solid solution. In this manner it is possible to obtain alloys, after step (d), having a Vickers hardness (Hv) in the range of from 220 to 300, preferably from 250 to 300, more preferably from 270 to 300. The quenching medium will typically comprise water.

[0033] Alternatively, cooling in step (c) may be effected by slowly cooling the alloy in air from the solution-treatment temperature to ambient temperature. This is a less rapid cooling than quenching and the ultimate alloy hardness is consequently not as high. Nonetheless, it is still possible to obtain a H_v of 200 or more. Accordingly, the alloys according to the present invention may still be hardened without a "pure" solution-treatment, i.e. the workpiece may not have

been quenched at a sufficiently rapid rate. Although the hardness values achieved may not be as high as those exhibited by rapidly quenched workpieces, they will generally still be acceptable to manufacturing jewellers.

[0034] It will be appreciated that the time spent at the age-hardening temperature will depend on the size of the workpiece and the desired hardness. However, age-hardening in step (d) will typically be carried out for from 5 to 60 minutes, more typically from 10 to 60 minutes, still more typically from 30 to 60 minutes.

[0035] It will also be appreciated that over-ageing of the alloy may result in a decrease in hardness.

[0036] Age-hardening in step (d) is preferably performed at a temperature in the range of from 275 to 400°C, more preferably from 275 to 350°C, still more preferably from 280 to 350°C. In general, alloys according to the present invention exhibit a reasonably flat hardening response over this temperature range. Because manufacturing jewellers do not generally have precise temperature control, an intermediate temperature of, for example, 310°C may be used to allow for any inaccuracies in the manufacturers process control.

[0037] Cooling in step (d) may be effected by slowly cooling the alloy in air from the age-hardening temperature to ambient temperature or, alternatively, quenching the alloy from the age-hardening temperature to ambient temperature using water, for example, as the quenching medium.

[0038] The final alloy after step (d) preferably has a phase microstructure which includes the ordered compound AuCu₃.

[0039] The bulk alloy composition in step (a) of the process may be as herein described with reference to the first and/or second aspects of the present invention. Advantageously, the alloy composition consists of:

Gold	approximately 37.5 wt.%
Silver	from 13 to 20 wt.%
Zinc	from 4 to 10 wt.%

and the balance copper, together with unavoidable impurities.

[0040] In general, the alloy composition will first be cold-worked prior to the solution-treatment in step (b). For example, the alloy composition may be formed and/or shaped into an article of jewellery prior to the solution-treatment in step (b). However, the alloy composition may be cold-worked after the solution-treatment in steps (b) and (c) and prior to the age-hardening treatment in step (d).

[0041] After undergoing the ageing heat treatment, the gold alloy according to the present invention will typically exhibit the following tensile properties: 0.2% proof stress from 700 to 760 N/mm², more typically from 730 to 740 N/mm², still more typically approximately 735 N/mm²; and ultimate tensile strength from 850 to 950 N/mm², more typically from 900 to 910 N/mm², still more typically approximately 905 N/mm². These properties are comparable to those expected from hard rolled 9ct yellow alloys.

[0042] A further advantage associated with the gold alloy according to the present invention is that it has at least as great and in some cases greater resistance to stress corrosion cracking than conventional 9 ct yellow alloys in all conditions. Furthermore, when the alloy is in the annealed condition, it shows far greater resistance to stress corrosion cracking than conventional 9ct yellow alloys.

[0043] The present invention also provides a gold alloy whenever produced by a process as herein described.

[0044] The present invention will be further described below with reference to the following Examples and Comparative Examples, and the following drawings, provided by way of example, in which:

Figure 1 is a graph of Vickers Hardness (H_v) vs ageing temperature for an alloy according to the present invention;

Figure 2 is an optical micrograph of an alloy according to the invention which has been cold worked (70%), heated to 700°C for 10 mins and then quenched;

Figure 3 is an optical micrograph of an alloy according to the invention which has been cold worked (70%), heated to 700°C for 10 mins and then slowly cooled;

Figure 4 is an optical micrograph of an alloy according to the invention which has been cold worked (70%), heated to 700°C for 10 mins, and then quenched, followed by ageing at 310°C for 30 mins;

Figure 5 is an optical micrograph of an alloy according to the invention which has been cold worked (70%), heated to 700°C for 10 mins, and then slowly cooled, followed by ageing at 310°C for 30 mins;

Figure 6 is a graph of Vickers Hardness (H_v) vs % Reduction of Thickness for a solution treated alloy according to the invention prior to ageing;

Figure 7 is a graph of Ultimate Tensile Strength/0.2% Proof Stress vs % Reduction of Area for a solution treated alloy according to the invention prior to ageing;

Figure 8 is a graph of Elongation after fracture vs % Reduction of Area for a solution treated alloy according to the invention prior to ageing;

Figure 9 is a graph of Youngs Modulus vs % Reduction of Area for a solution treated alloy according to the invention prior to ageing; and

Figure 10 is an XRD trace for an aged alloy according to the present invention.

Examples 1 to 3 and Comparative Examples 4 and 5

[0045] Chemical compositions for three gold alloys according to the present invention (Ex 1, Ex 2 and Ex 3) and two prior art gold alloys C Ex 4 and C Ex 5) are provided in Table 1 below. It will be appreciated that the alloys may contain unavoidable impurities, although, in total, these will generally not exceed 1 wt.% of the composition. Comparative Example 4 relates to a typical 9-carat red gold alloy, while Comparative Example 5 relates to a commercially available 9-carat yellow alloy known in the United Kingdom as 9DF or 375/DF.

[0046] The alloys were subjected to the following heat-treatment. First, samples of the alloys were solution-treated at approximately 700°C for about ten minutes, and then quenched into water from red heat. Vickers Hardness measurements were carried out on the solution-treated samples using a standard Vickers Pyramid Hardness Testing apparatus and a 5 kg load. Next, the alloys were age-hardened by heating the solution-treated samples at a temperature of approximately 310°C for about 30 minutes. This was then followed by slow cooling in air to ambient temperature (approximately 20 to 25°C). Vickers Hardness measurements were subsequently carried out on the age-hardened samples.

[0047] It can be seen from the Table 1 that for Comparative Example 4, there is no hardening on ageing. For Comparative Example 5, there is a moderate degree of hardening on ageing. Examples 1,2 and 3, however, exhibit significant hardening on ageing. This hardening behaviour is also reversible.

Table 1

Alloy	Au	Ag	Cu	Zn	Anneal Hv	Aged Hv
Ex 1	37.5	15.0	42.5	5.0	133	283
Ex 2	37.5	15.0	39.17	8.33	119	277
Ex 3	37.5	17.0	39.67	5.83	144	280
C Ex 4	37.5	5.0	57.5	0	85	85
C Ex 5	37.5	10.0	45.0	7.5	110	203

Examples 4 and 5

[0048] For these examples, the alloy composition according to Example 2 above was used. Samples of the alloy were first cold worked (70%). In this process the alloy, in soft condition, is reduced in thickness or area by 70%, so that its final size is 30% of the original size. One set of samples (Example 4) was then solution-treated at approximately 700°C for about ten minutes and then quenched from red heat into water. The samples were then age-hardened by heating to temperatures of approximately 275, 300, 310, 325 and 350°C for about 30 minutes. This was then followed by slow cooling in air to the ambient temperature. Separate samples (Example 5) of the cold-worked alloy were subjected to the same heat-treatment as the samples of Example 4, except, instead of quenching the samples after being held at the solution-treatment temperature, the samples were allowed to slowly cool in air to the ambient temperature. The results of Vickers Hardness (H_v) testing on the samples according to Example 4 and Example 5 are provided below in Table 2. The ageing temperature was 310°C. It can be seen that the quenched sample had a lower hardness after quenching compared with the slowly cooled sample, but a higher hardness after ageing. The hardness of the slowly cooled sample after ageing is still acceptable for many applications.

Table 2

Condition	Hardness (H_V) prior to ageing	Hardness (H_V) after ageing at 310°C
Example 4 Quenched	120	285
Example 5 Slow Cooled	165	225

[0049] The difference in Hardness (H_V) for Example 4 above compared with Example 2 in Table 1 can be attributed to experimental error.

[0050] Figure 1 is a graph of Vickers Hardness (H_V) vs the ageing temperature for the samples according to Example 4 and Example 5. It can be seen that the hardening response is fairly flat over the temperature range 275 to 350°C.

[0051] The microstructures for the samples according to Examples 4 and 5 are shown in Figures 2 to 5.

[0052] Figure 2 is an optical micrograph of a sample according to Example 4. The alloy was cold worked (70%), heated to 700°C for 10 mins and then quenched. A single-phase solid solution of α (Au-Ag-Cu) appears to be present.

[0053] Figure 3 is an optical micrograph of a sample according to Example 5. The alloy was cold worked (70%), heated to 700°C for 10 mins and then slowly cooled. A multi-phase structure appears to be present with areas of α and (α_1 (Au-Ag) + α_2 (Au-Cu)) bulk precipitate.

[0054] Figure 4 is an optical micrograph of a sample according to Example 4. The alloy was cold worked (70%), heated to 700°C for 10 mins, and then quenched, followed by ageing at 310°C for 30 mins. There is evidence of minimal bulk precipitate ($\alpha_1 + \alpha_2$) at the grain boundaries with perhaps micro-precipitation of these phases present but not visible using optical microscopy.

[0055] Figure 5 is an optical micrograph of a sample according to Example 5. The alloy was cold worked (70%), heated to 700°C for 10 mins, then slowly cooled, followed by ageing at 310°C for 30 mins. Again, there is evidence of further minimal bulk precipitate ($\alpha_1 + \alpha_2$) at the grain boundaries and perhaps micro-precipitation of these phases. However, the degree will be reduced compared with the Figure 4.

[0056] Figures 6 to 9 illustrate some other mechanical properties of samples of the alloy according to Example 4 prior to ageing. These figures demonstrate that the alloy according to the present invention performs in a similar manner to conventional gold alloys in the solution treated state.

[0057] 9-carat gold alloys are generally accepted to harden via a precipitation hardening mechanism associated with the Ag-Cu binary system. While not wishing to be bound by theory, it is speculatively suggested that hardening may at least be the result of precipitation of ($\alpha_1 + \alpha_2$) during the initial stages and further decomposition of α_2 into ordered $AuCu_3$ at higher temperatures and longer times. XRD analysis of quenched and aged samples according to the present invention indicates the presence of the ordered compound $AuCu_3$ as a major phase, present in an amount of over 10 %. This is shown in Figure 10, which is an XRD trace for an aged alloy according to Example 2.

[0058] Again, while not wishing to be bound by theory, the increase in hardness of the slowly cooled sample (Example 5) over the quenched sample (Example 4) prior to hardening may be the result of some micro-precipitated silver-rich α_1 , and then decomposition of small amounts of α_2 into ordered $AuCu_3$. The onset of precipitation of the modulated phases appears to be at approximately 650°C, although is dependent on the composition. The time interval between cooling from this temperature to the minimum decomposition temperature may also yield some ordered $AuCu_3$. However, this is likely to be substantially reduced when compared to an aged sample since the rate of ordering for $AuCu_3$ is thought to be time dependent.

Claims

1. An age-hardened 9 carat yellow gold alloy suitable for use in the manufacture of jewellery, the alloy consisting of:

Gold	approximately 37.5 wt.%
Silver	from 13 to 20 wt.%
Zinc	from 4 to 10 wt.%

and optionally

Silicon	from 0.01 to 0.5 wt.%
Boron	from 0.001 to 0.15 wt.%

and the balance copper, together with unavoidable impurities, wherein the alloy has a Vickers Hardness (H_V) of ≥ 200 .

2. An alloy as claimed in claim 1, wherein the alloy has a Vickers Hardness (H_V) in the range of from 220 to 300
3. An alloy as claimed in claim 2, wherein the alloy has a Vickers Hardness (H_V) in the range of from 250 to 300.
4. An alloy as claimed in claim 3, wherein the alloy has a Vickers Hardness (H_V) in the range of from 270 to 300.
5. An alloy as claimed in any one of the preceding claims, wherein the alloy has a phase microstructure which includes the ordered compound AuCu_3 .
6. An alloy as claimed in any one of the preceding claims which comprises from 15 to 20 wt.% silver.
7. An alloy as claimed in claim 6 which comprises from 17 to 20 wt.% silver.
8. An alloy as claimed in any one of the preceding claims which comprises from 5 to 10 wt.% zinc.
9. An alloy as claimed in claim 8 which comprises from 8 to 10 wt.% zinc.
10. An alloy as claimed in any one of the preceding claims which comprises from 37 to 43 wt.% copper.
11. An alloy as claimed in claim 10 which comprises from 38 to 40 wt.% copper.
12. An age-hardenable 9 carat yellow gold alloy consisting of:

Gold	approximately 37.5 wt. %
Silver	from 14.0 to 16.0 wt. %
Zinc	from 8 to 9 wt. %
Copper	from 38 to 40 wt. %

and optionally

Silicon	from 0.01 to 0.5 wt. %
Boron	from 0.001 to 0.15 wt. %

the sum constituting 100 wt. %, together with unavoidable impurities.

13. An age-hardenable 9 carat yellow gold alloy as claimed in claim 12 and consisting of:

Gold	approximately 37.5 wt. %
Silver	approximately 15.0 wt. %
Zinc	approximately 8.3 wt. %
Copper	approximately 39.2 wt. %

the sum constituting 100 wt. %, together with unavoidable impurities.

14. An article of jewellery, objet d'art, goblet, cup, medal or badge in which at least a portion thereof is formed from an alloy as defined in any one of the preceding claims.
15. A process for the manufacture of a 9 carat yellow gold alloy suitable for use in the manufacture of jewellery, which process comprises:

(a) providing an alloy composition consisting of

Gold	approximately 37.5 wt. %
Silver	from 13 to 20 wt. %
Zinc	from 4 to 10 wt. %

and optionally

Silicon	from 0.01 to 0.5 wt. %
Boron	from 0.001 to 0.15 wt. %

and the balance copper, together with unavoidable impurities,

(b) solution treating the alloy composition at a temperature of up to the solidus temperature;

(c) cooling the solution-treated alloy from step (b) to ambient temperature; and

(d) age-hardening the cooled alloy from step (c) at a temperature in the range of from 200 to 400°C, followed by cooling to ambient temperature, wherein the age-hardening is performed for a time sufficient to achieve a Vickers hardness (Hv) of ≥ 200 in the final alloy.

16. A process as claimed in claim 15, wherein the solution treatment in step (b) is performed at a temperature in the range of from 500 to 860°C.

17. A process as claimed in claim 16, wherein the solution treatment in step (b) is performed at a temperature in the range of from 700 to 800°C.

18. A process as claimed in any one of claims 15 to 17, wherein the solution treatment in step (b) is performed for at least 1 minute, and wherein age-hardening in step (d) is carried out for from 5 to 60 minutes.

19. A process as claimed in claim 18, wherein the solution treatment in step (b) is performed for from 5 to 60 minutes, and wherein age-hardening in step (d) is carried out for from 10 to 60 minutes.

20. A process as claimed in claim 19, wherein the solution treatment in step (b) is performed for from 10 to 60 minutes, and wherein age-hardening in step (d) is carried out for from 30 to 60 minutes.

21. A process as claimed in any one of claims 15 to 20, wherein the alloy composition is formed or shaped into an article of jewellery prior to the solution-treatment in step (b).

Patentansprüche

1. Ausgehärtete Gelbgoldlegierung mit 9 Karat, die für die Verwendung bei der Herstellung von Schmuckgegenständen geeignet ist, wobei die Legierung folgendes aufweist:

Gold	etwa 37,5 Gew.-%
Silber	13 bis 20 Gew.-%
Zink	bis 10 Gew.-%

und gegebenenfalls

Silicium	0,01 bis 0,5 Gew.-%
Bor	0,001 bis 0,15 Gew.-%

wobei der Rest aus Kupfer zusammen mit unvermeidbaren Verunreinigungen besteht, wobei die Legierung eine Vickershärte (H_V) von ≥ 200 aufweist.

2. Legierung nach Anspruch 1,
wobei die Legierung eine Vickershärte (H_V) im Bereich von 220 bis 300 aufweist.
3. Legierung nach Anspruch 2,
wobei die Legierung eine Vickershärte (H_V) im Bereich von 250 bis 300 aufweist.
4. Legierung nach Anspruch 3,
wobei die Legierung eine Vickershärte (H_V) im Bereich von 270 bis 300 aufweist.
5. Legierung nach einem der vorstehenden Ansprüche,
wobei die Legierung eine Phasenmikrostruktur aufweist, die die regelmäßige Verbindung $AuCu_3$ aufweist.
6. Legierung nach einem der vorstehenden Ansprüche,
die 15 bis 20 Gew.-% Silber aufweist.
7. Legierung nach Anspruch 6,
die 17 bis 20 Gew.-% Silber aufweist.
8. Legierung nach einem der vorstehenden Ansprüche,
die 5 bis 10 Gew.-% Zink aufweist.
9. Legierung nach Anspruch 8,
die 8 bis 10 Gew.-% Zink aufweist.
10. Legierung nach einem der vorstehenden Ansprüche,
die 37 bis 43 Gew.-% Kupfer aufweist.
11. Legierung nach Anspruch 10,
die 38 bis 40 Gew.-% Kupfer aufweist.
12. Aushärtende Gelbgoldlegierung mit 9 Karat, die folgendes aufweist:

Gold	etwa 37,5 Gew.-%
Silber	14,0 bis 16,0 Gew.-%
Zink	8 bis 9 Gew.-%
Kupfer	38 bis 40 Gew.-%

und gegebenenfalls

Silicium	0,01 bis 0,5 Gew.-%
Bor	0,001 bis 0,15 Gew.-%

wobei die Summe 100 Gew.-% ausmacht,
zusammen mit unvermeidbaren Verunreinigungen.

13. Aushärtende Gelbgoldlegierung mit 9 Karat nach Anspruch 12,
die folgendes aufweist:

Gold	etwa 37,5 Gew.-%
Silber	etwa 15,0 Gew.-%
Zink	etwa 8,3 Gew.-%
Kupfer	etwa 39,2 Gew.-%

wobei die Summe 100 Gew.-% ausmacht,
zusammen mit unvermeidbaren Verunreinigungen.

14. Schmuckgegenstand, Kunstgegenstand, Pokal, Becher, Medaille oder Abzeichen, wobei zumindest ein Teil davon aus einer Legierung nach einem der vorstehenden Ansprüche hergestellt ist.

15. Verfahren zum Herstellen einer Gelbgoldlegierung mit 9 Karat, die für die Verwendung bei der Herstellung von Schmuckgegenständen geeignet ist, wobei das Verfahren folgendes aufweist:

(a) Bereitstellen einer Legierungszusammensetzung, die folgendes aufweist:

Gold	etwa 37,5 Gew.-%
Silber	13 bis 20 Gew.-%
Zink	4 bis 10 Gew.-%

und gegebenenfalls

Silicium	0,01 bis 0,5 Gew.-%
Bor	0,001 bis 0,15 Gew.-%

wobei der Rest aus Kupfer zusammen mit unvermeidbaren Verunreinigungen besteht;

(b) Lösungsbehandeln der Legierungszusammensetzung bei einer Temperatur bis zum Soliduspunkt;

(c) Abkühlen der der Lösungsbehandlung unterzogenen Legierung gemäß Schritt (b) auf Umgebungstemperatur; und

(d) Aushärten der abgekühlten Legierung gemäß Schritt (c) bei einer Temperatur im Bereich von 200 bis 400 °C, gefolgt vom Abkühlen auf Umgebungstemperatur, wobei das Aushärten für einen ausreichenden Zeitraum erfolgt, um bei der fertigen Legierung eine Vickershärte (H_V) von ≥ 200 zu erzielen.

16. Verfahren nach Anspruch 15, wobei die Lösungsbehandlung im Schritt (b) bei einer Temperatur im Bereich von 500 bis 860 °C erfolgt.

17. Verfahren nach Anspruch 16, wobei die Lösungsbehandlung im Schritt (b) bei einer Temperatur im Bereich von 700 bis 800 °C erfolgt.

18. Verfahren nach einem der Ansprüche 15 bis 17, wobei die Lösungsbehandlung im Schritt (b) für mindestens 1 Minute durchgeführt wird und wobei das Aushärten im Schritt (d) für 5 bis 60 Minuten erfolgt.

19. Verfahren nach Anspruch 18, wobei die Lösungsbehandlung im Schritt (b) für 5 bis 60 Minuten durchgeführt wird und wobei das Aushärten im Schritt (d) für 10 bis 60 Minuten erfolgt.

20. Verfahren nach Anspruch 19, wobei die Lösungsbehandlung im Schritt (b) für 10 bis 60 Minuten durchgeführt wird und wobei das Aushärten im Schritt (d) für 30 bis 60 Minuten erfolgt.

21. Verfahren nach einem der Ansprüche 5 bis 20, wobei die Legierungszusammensetzung vor der Lösungsbehandlung im Schritt (b) zu einem Schmuckgegenstand umgestaltet oder geformt wird.

Revendications

1. Alliage d'or jaune de 9 carats durci par vieillissement adapté pour utilisation dans la fabrication de joaillerie, l'alliage consistant en :

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Or	environ 37,5 % en poids
Argent	de 13 à 20 % en poids
Zinc	de 4 à 10 % en poids

et facultativement

Silicium	de 0,01 à 0,5 % en poids
Bore	de 0,001 à 0,15 % en poids

et le complément en cuivre, conjointement avec des impuretés inévitables, dans lequel l'alliage a une dureté Vickers (H_V) ≥ 200 .

2. Alliage selon la revendication 1, dans lequel l'alliage a une dureté Vickers (H_V) dans la plage de 220 à 300.
3. Alliage selon la revendication 2, dans lequel l'alliage a une dureté Vickers (H_V) dans la plage de 250 à 300.
4. Alliage selon la revendication 3, dans lequel l'alliage a une dureté Vickers (H_V) dans la plage de 270 à 300.
5. Alliage selon l'une quelconque des revendications précédentes, dans lequel l'alliage a une microstructure de phase qui comprend le composé ordonné $AuCu_3$.
6. Alliage selon l'une quelconque des revendications précédentes qui comprend de 15 à 20 % en poids d'argent.
7. Alliage selon la revendication 6 qui comprend de 17 à 20 % en poids d'argent.
8. Alliage selon l'une quelconque des revendications précédentes qui comprend de 5 à 10 % en poids de zinc.
9. Alliage selon la revendication 8 qui comprend de 8 à 10 % en poids de zinc.
10. alliage selon l'une quelconque des revendications précédentes qui comprend de 37 à 43 % en poids de cuivre.
11. Alliage selon la revendication 10 qui comprend de 38 à 40 % en poids de cuivre.
12. Alliage d'or jaune de 9 carats durcissable par vieillissement consistant en :

Or	environ 37,5 % en poids
Argent	de 14,0 à 16,0 % en poids
Zinc	de 8 à 9 % en poids
Cuivre	de 38 à 40 % en poids

et facultativement

Silicium	de 0,01 à 0,5 % en poids
Bore	de 0,001 à 0,15 % en poids

la somme représentant 100 % en poids, conjointement avec des impuretés inévitables.

13. Alliage d'or jaune de 9 carats durcissable par vieillissement consistant en :

Or	environ 37,5 % en poids
Argent	environ 15,0 % en poids
Zinc	environ 8,3 % en poids
Cuivre	environ 39,2 % en poids

la somme représentant 100 % en poids, conjointement avec des impuretés inévitables.

14. Article de joaillerie, objet d'art, verre à pied, coupe, médaille ou médaillon dans lequel au moins une partie de celui-ci est formé d'un alliage comme défini dans l'une quelconque des revendications précédentes.

15. Procédé pour la fabrication d'un alliage d'or jaune de 9 carats adapté pour utilisation dans la fabrication de joaillerie, ledit procédé comprenant les étapes consistant à :

(a) procurer une composition d'alliage consistant en

Or	environ 37,5 % en poids
Argent	de 13 à 20 % en poids
Zinc	de 4 à 10 % en poids

et facultativement

Silicium	de 0,01 à 0,5 % en poids
Bore	de 0,001 à 0,15 % en poids

et le complément en cuivre, conjointement avec des impuretés inévitables,

(b) traiter en solution la composition d'alliage à une température allant jusqu'à la température de solidus ;

(c) refroidir l'alliage traité en solution de l'étape (b) à température ambiante ; et

(d) durcir par vieillissement l'alliage refroidi de l'étape (c) à une température dans la plage de 200 à 400°C, suivi par un refroidissement à température ambiante, dans lequel le durcissement par vieillissement est effectué pendant une durée suffisante pour obtenir une dureté Vickers (Hv) ≥ 200 dans l'alliage final.

16. procédé selon la revendication 15, dans lequel le traitement en solution dans l'étape (b) est effectué à une température dans la plage de 500 à 860°C.

17. Procédé selon la revendication 16, dans lequel le traitement en solution dans l'étape (b) est effectué à une température dans la plage de 700 à 800°C.

18. Procédé selon l'une quelconque des revendications 15 à 17, dans lequel le traitement en solution dans l'étape (b) est effectué pendant au moins 1 minute, et dans lequel le durcissement par vieillissement dans l'étape (d) est effectué pendant 5 à 60 minutes.

19. Procédé selon la revendication 18, dans lequel le traitement en solution dans l'étape (b) est effectué pendant 5 à 60 minutes, et dans lequel le durcissement par vieillissement dans l'étape (d) est effectué pendant 10 à 60 minutes.

20. Procédé selon la revendication 19, dans lequel le traitement en solution dans l'étape (b) est effectué pendant 10 à 60 minutes, et dans lequel le durcissement par vieillissement dans l'étape (d) est effectué pendant 30 à 60 minutes.

21. Procédé selon l'une quelconque des revendications 15 à 20, dans lequel la composition d'alliage est formée en un article de joaillerie avant le traitement en solution dans l'étape (b).

Hardness vs Temperature

FIG. 1.

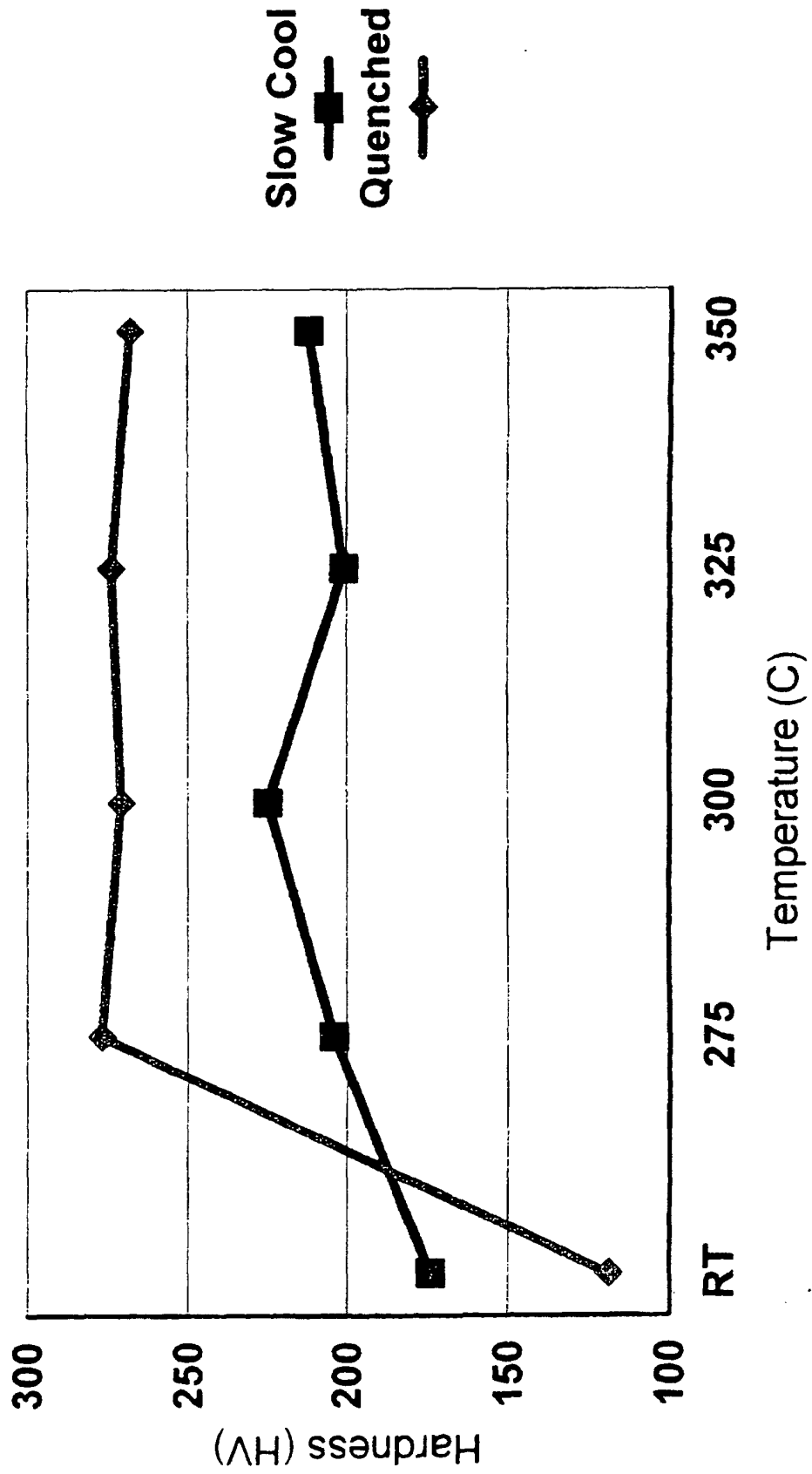


FIG. 2.



FIG. 3.



FIG. 4.

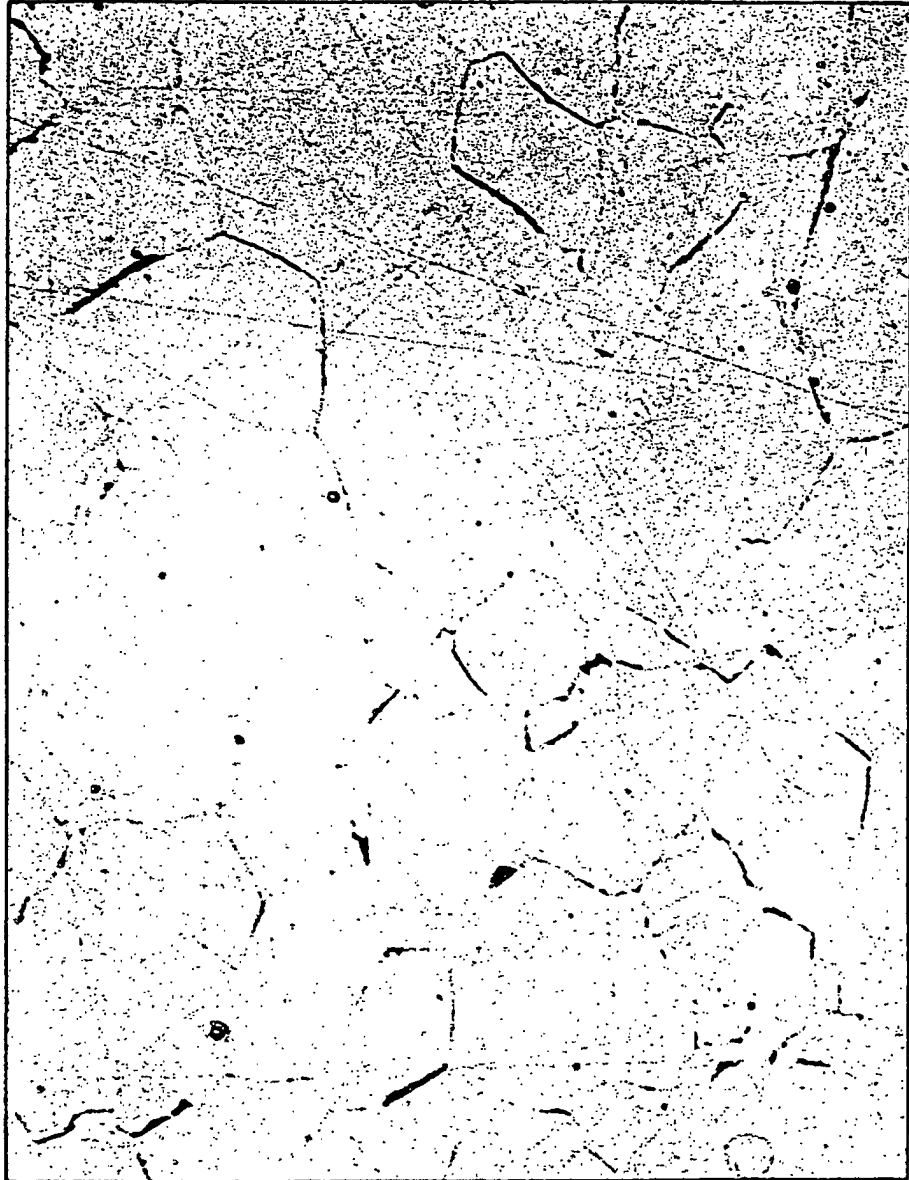


FIG. 5.



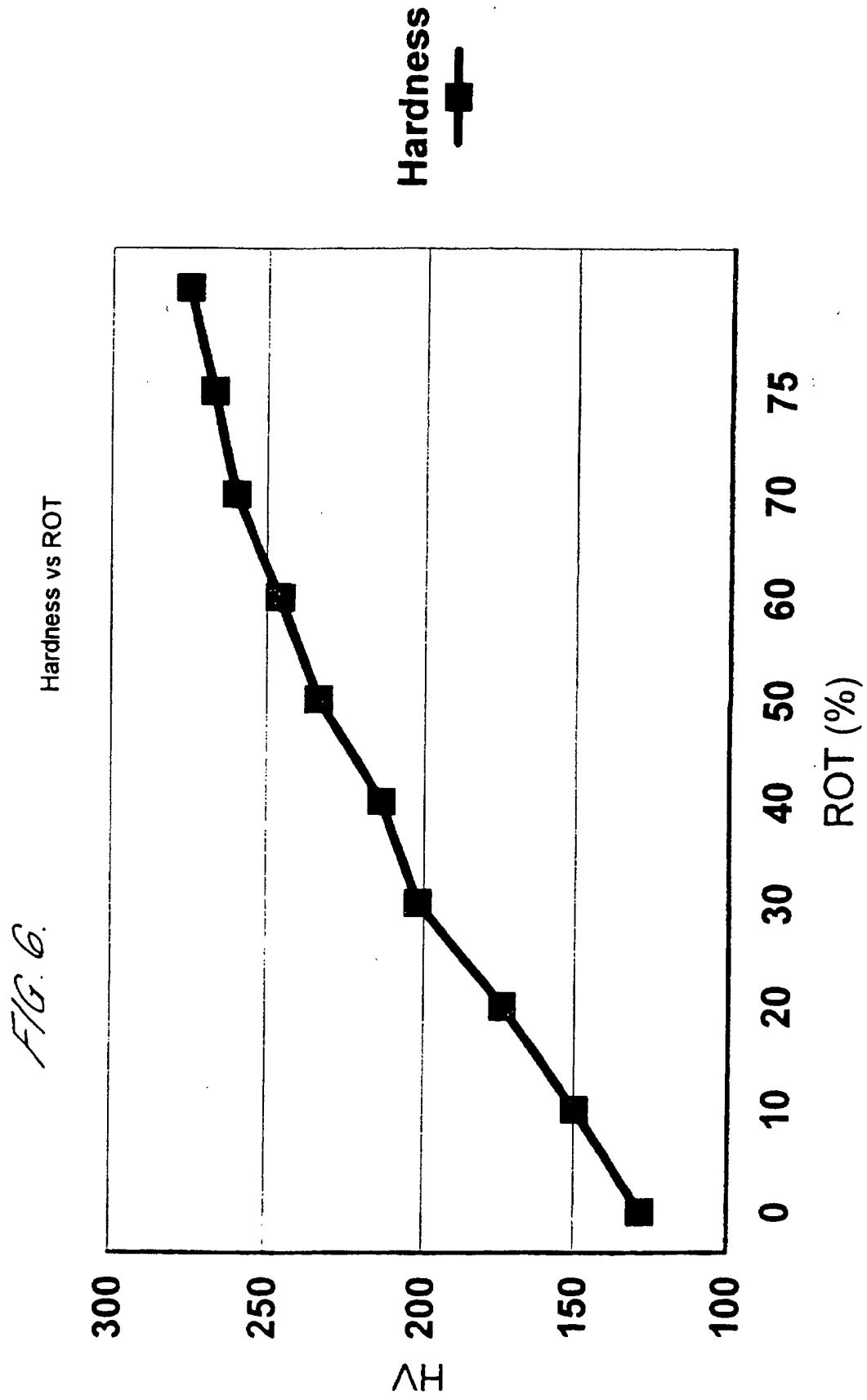


FIG. 7.

UTS/0.2% Proof Stress vs ROA

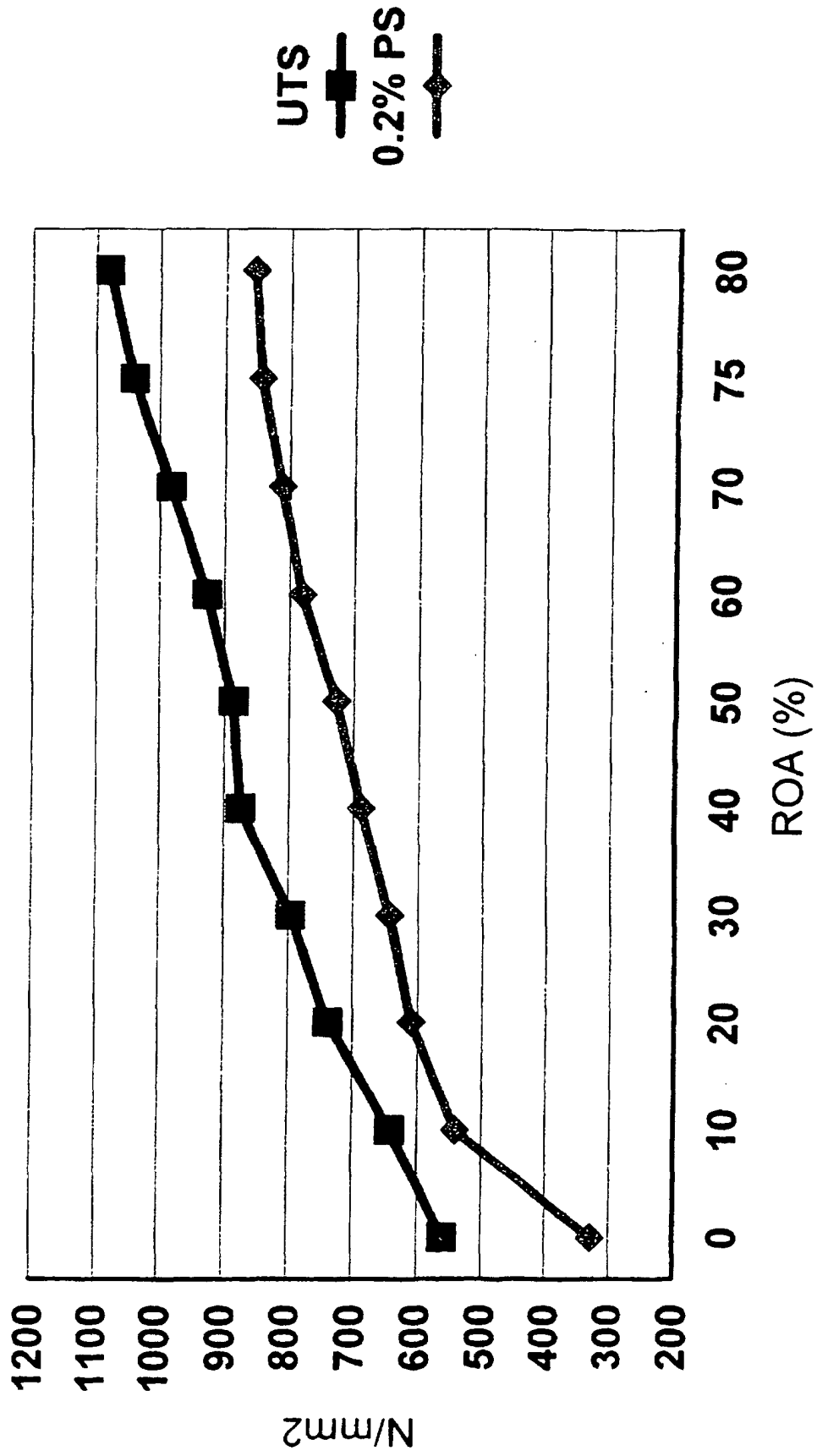


FIG. 8.

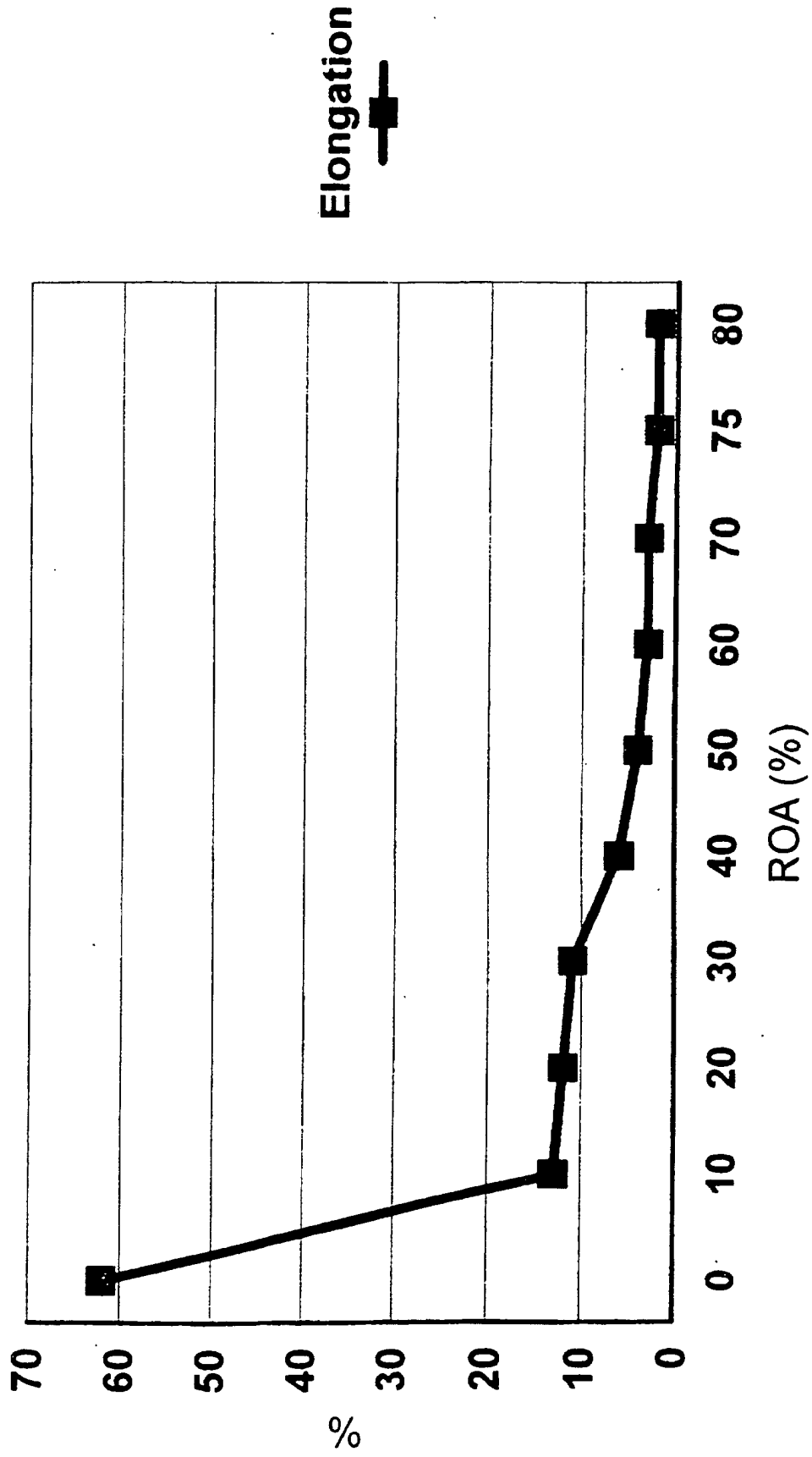


FIG. 9.

Youngs Modulus vs ROA

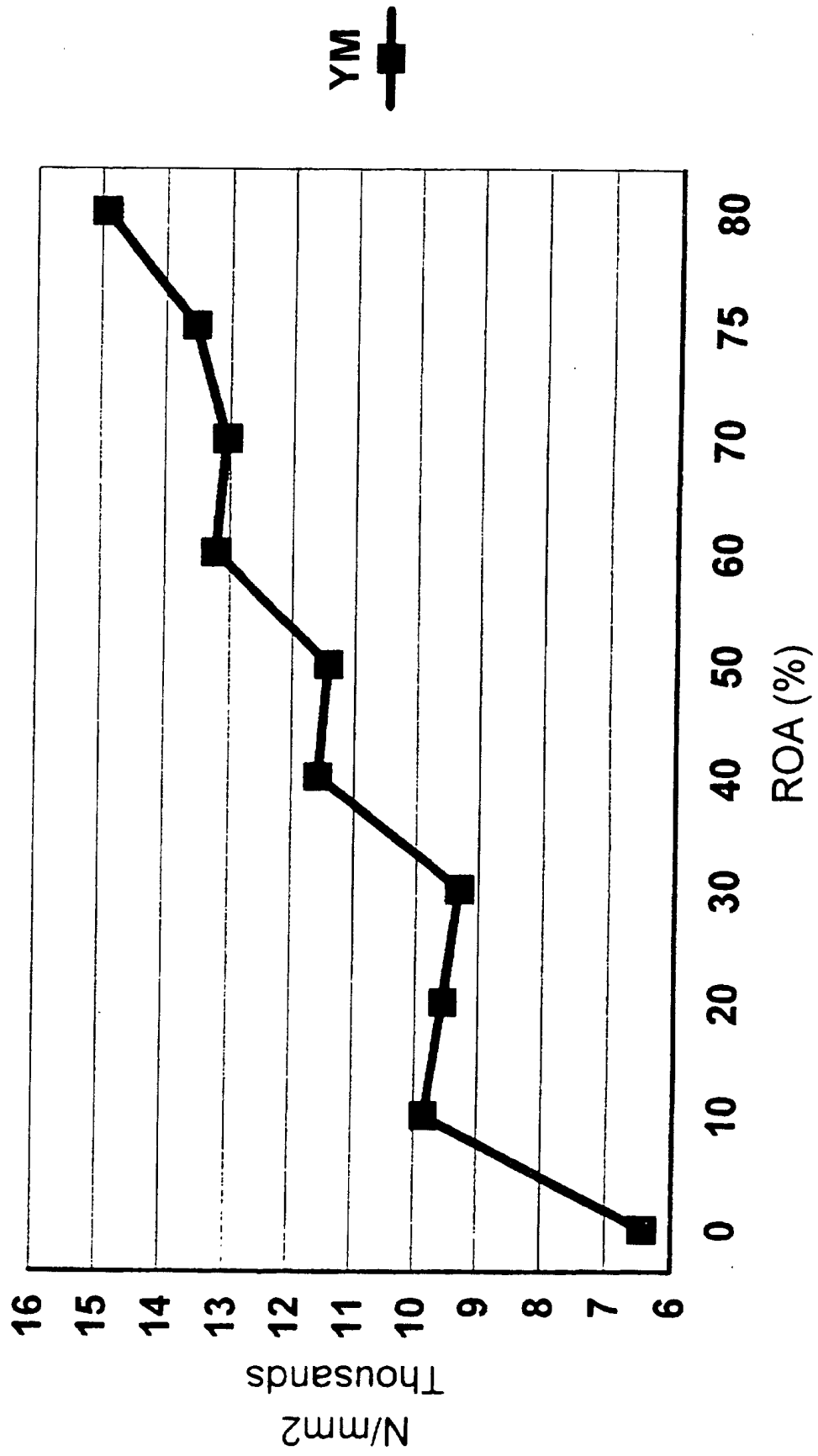


FIG. 10.

