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ALLOY ADAPTED FOR PROSTHETIC ARTICLES

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Our invention relates to alloys and particularly to alloys suitable for making prosthetic articles.

It has heretofore been suggested that alloys containing chromium, nickel, cobalt, beryllium and molybdenum are especially adapted for the casting of prosthetic articles such as dentures and the like, and while such alloys are highly resistant to corrosion they do exhibit a definite loss of lustre when highly polished specimens thereof are exposed to very dilute lactic acid solutions. Thus, a denture formed of such an alloy and which, initially, is highly polished, loses its high lustre when exposed to lactic acid in concentrations of the order encountered in the human mouth. The surface corrosion which effects this loss of lustre does not in any way weaken or otherwise affect the function of the denture but it is highly objectionable from an aesthetic viewpoint.

We have investigated the reason for this loss of lustre and find that it is due to the fact that the beryllium forms an inter-metallic phase in the alloy which darkens when exposed to lactic acid. These darkened areas throughout the matrix cause the loss of reflection or lustre. While this inter-metallic phase persists to a certain degree as long as there is any beryllium present in the alloy, and beryllium is an essential element which endows the alloy with the fluidity at casting temperatures necessary to cause the metal to flow into the smaller mold cavities, we have found that by reducing the beryllium to a comparatively low percentage the detrimental effect thereof on the retention of a high surface lustre is so reduced that it is no longer objectionable.

However, when the beryllium content is lowered to the extent necessary to avoid loss of lustre other difficulties are encountered such as a reduction in yield strength and a raising of the melting point.

Where the alloy is to be used in the casting of partial dentures, such as those which are provided with clasps for engagement with the natural teeth, the minimum yield strength should not be less than 65,000 to 70,000 p. s. i. although the yield point for full dentures, or those without clasps, may be somewhat lower than this.

Furthermore, it is desirable to produce an alloy which may be cast in a plaster bound silica type investment, and to accomplish this the melting point of the alloy cannot exceed about 2450° to 2500° F.

The principal object, therefore, of our invention is to provide an alloy of the character described which will retain its surface lustre when a highly polished section thereof is exposed to lactic acid in concentrations of the order encountered in the human mouth; which will have a yield point sufficiently high to permit dentures, for example, having attenuated portions, such as clasps thereon, to be cast therefrom; and which will have a melting point sufficiently low to permit it to be cast in investments of the plaster bound silica type. More specifically the object of our invention is to provide a balanced alloy of the character described in which the reduction in the yield strength and the increase in the melting point, which occur when the beryllium content is reduced to a point where it does not affect the retention of lustre, are offset by the addition of other elements.

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A further object of our invention is to provide an alloy which can be processed to produce a casting characterized by a relatively fine grain size.

It is well known that, at room temperature, the common metals and alloys are harder and stronger in the fine grain condition than in the coarse grain condition. In small cross-sections, such as those present in a prosthetic article where coarse grains may limit the total number of grains in the cross-section to 10 or less, the production of the desired physical properties is much more difficult than is the case with a fine grain material. One factor having a pronounced effect on grain size, is the rate at which the casting is cooled during the solidification thereof.

In order to obtain a rapid cooling rate during the solidification of the metal in the mold, it is desirable that the temperature of the molds at the time the molten metal is introduced therein, be as low as possible. Those familiar with the art of casting prosthetic articles will realize that the permissible mold temperature is governed by the amount of thermal expansion which can be obtained by heating the mold to that temperature and, by the ability of the alloy being cast to flow freely and register the fine details present in the mold. Plaster bound silica investment provides adequate thermal expansion to compensate for metal shrinkage at much lower temperatures than the highly refractory investment material used with alloys having high melting points. Therefore, more specifically, a further object of our invention is to provide an alloy having a melting range which is low enough to permit its being cast in a plaster bound silica type investment and fluid enough to permit its flowing in relatively thin sections when the mold

temperature is in the range of about 900° to 1300° F.

The essential ingredients of our alloy and their percentages, by weight, of the total composition are:

	Percent
Chromium	15 to 27
Beryllium	0.2 to 1.2
Manganese	2 to 8
Molybdenum	3 to 12
Copper	2 to 10

the balance being nickel and cobalt, each between about 5% and about 50% with the combined nickel-cobalt content being from 42% to about 77%.

The preferred ranges of the essential ingredients of our alloy are:

	Percent
Chromium	20 to 25
Molybdenum	5 to 10
Beryllium	0.5 to 1.0
Manganese	3 to 6
Copper	3 to 6

the balance being nickel and cobalt; the nickel being present in quantities from about 18% to about 40% and the cobalt being present in quantities from about 20% to about 50%; the combined nickel-cobalt content being from about 52% to about 68%.

A consideration of the alloys set forth in the following table will be helpful in understanding our invention.

Alloy No.	Percentage by Weight							Hardness, Rc
	Ni	Co	Cr	Mo	Be	Mn	Cu	
19	26	30	25	12	1		6	38
20	26	30	25	12	1	6		28
24	20	30	25	12	1	6	6	40
25	30	20	25	12	1	6	6	35
30	30.5	20	25	12	0.5	6	6	25
31	33.5	20	25	12	0.7	6	3	25
60	20	45.2	28	6	0.8			19
138	20	45.2	25	6	0.8		3	24
139	20	41.2	25	6	0.8	4	3	24
142	20	41.2	22	8	0.8	4	4	27
142A	19.8	41.2	22	8	1.0	4	4	32

It has been found that both the yield strength and hardness of the base alloy decrease and the melting point rises when the beryllium content is lowered. Alloy 60, for example, will not lose its lustre in dilute lactic acid but it has a hardness value of only C 19 (corresponding to a yield strength of about 60,000 p. s. i.) and therefore would not have sufficient strength for all applications. Furthermore, the melting point is too high to permit its use in a plaster bound investment. However, by adding copper, as in alloy 138, the hardness value is increased to C 24 and the yield strength is raised to 78,000 p. s. i. The addition of copper does not substantially affect the melting which is about 2475° F. If 4% of manganese is added, as in alloy 139 the melting point is reduced to about 2325° F. which is low enough to permit the casting of the alloy in a plaster bound investment. It will also be noted that the manganese addition does not affect the hardness.

Alloys 19, 20, and 24 further illustrate the effectiveness of copper as a hardener and manganese as a means of reducing the melting point. Thus, alloy 20, which has no copper therein, has a hardness of C 28 and a melting point of 2300° F. By substituting 6% of copper for the 6% of manganese, as in alloy 19, the hardness is increased to C 38 and the melting point is raised to about 2375° F. Alloy 24 which contains both manganese and copper retains the high hardness of alloy 19 and has substantially the same melting point (2300° F.) as alloy 20.

A comparison of alloy 24 with alloy 25 indicates how the hardness and melting point may be controlled by manipulating the ratio of nickel to cobalt while keeping the combined content of these two elements constant. Thus alloy 24 with a nickel-cobalt ratio of 1 to 1.5 has a hardness of C 40 and a melting point of about 2300° F. By changing the nickel-cobalt ratio to 1.5 to 1, as in alloy 25, the hardness is decreased to C 35 and the melting point to 2250° F.

In general, it has been found that if the chromium content falls appreciably below 15% there is a marked reduction in the corrosion resistance of the alloy. On the other hand, if it exceeds 30%, an additional chromium rich phase begins to appear in the microstructure and the alloy becomes quite brittle.

Alloys having a molybdenum content as high as 18% have been melted and investigated, but these high molybdenum alloys have a rather high specific gravity which is undesirable in a prosthetic article, and, in remelting, the molybdenum seems to oxidize excessively, even though the beryllium content of the alloy does afford some protection. Therefore, while the upper limit of the molybdenum range is not critical, it has been found that more desirable alloys are obtained when the maximum molybdenum content is limited to 12%. The molybdenum contributes to both the corrosion resistance and the fluidity of the alloy and, while the lower limit of the molybdenum range is not critical it has been found to be approximately 3%.

The beryllium content while small, has a very pronounced effect on the physical properties, the melting point, and the casting characteristics of the alloy. If the beryllium content exceeds 1.2% the concentration of the beryllium intermetallic phase becomes so great that it is visible on the surface of polished specimens of the alloy when they are subjected to the action of a dilute lactic acid solution. By maintaining the beryllium content below this level, loss of lustre is avoided.

The manganese addition required to offset the rise in the melting point caused by lowering the beryllium content tends to make the alloy react with the silica of the investment. Unles a certain minimum beryllium content is maintained, the surface condition of the casting becomes so poor that it cannot be used. This minimum is approximately 0.2%.

Manganese in excess of about 8% causes a reaction with the investment, even when the maximum beryllium content is employed, and, for this reason, should be avoided. Furthermore, since the manganese is used partially to offset the rise in the melting point associated with a lowering of the beryllium content, the manganese, as a rule, should be present in the lower portion of its range when the beryllium is present in the upper portion of its range, and vice versa.

The copper is added as a hardening agent to offset the drop in yield strength associated with the reduction in beryllium. Therefore, the copper should ordinarily be present in the lower portion in its range when the beryllium is present in the upper portion of its range. Nickel and cobalt are more or less interchangeable in order to vary

the yield strength and ductility of the resulting alloy. Thus, a high cobalt content tends to raise the yield strength and usually the melting point, while high nickel, on the other hand, tends to give a softer, lower melting point alloy. For general applications the preferred ratio of nickel to cobalt has been found to be from 1 to 2, to 1 to 1½.

What we claim is:

1. An alloy adapted for use in the manufacture of prosthetic articles and characterized by its retention of a bright surface lustre when highly polished and subjected to the action of dilute lactic acid in concentrations of the order encountered in the human mouth; said alloy comprising a plurality of elements of which the following, in the proportions, by weight, set forth below are the only necessary elements to attain said characteristics:

	Percent
Chromium	20 to 25
Molybdenum	5 to 10
Beryllium	0.5 to 1.0
Manganese	3 to 6
Copper	3 to 6

and the balance being nickel from 18% to 40% and cobalt from 20% to 50% with a combined nickel and cobalt content from about 52% to about 68%.

2. An alloy adapted for use in the manufacture of prosthetic articles and characterized by its retention of a bright surface lustre when highly polished and subjected to the action of dilute

lactic acid in concentrations of the order encountered in the human mouth; said alloy comprising a plurality of elements of which the following, in the proportions, by weight, set forth below are the only necessary elements to attain said characteristics:

	Percent
Chromium	15 to 27
Molybdenum	3 to 12
Beryllium	0.2 to 1.2
Manganese	2 to 8
Copper	2 to 10

the balance being nickel and cobalt, each between about 5% and about 50%, with a combined nickel and cobalt content of at least 42%.

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