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METAL ALLOY

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This invention relates to certain improvements in alloys and is particularly directed to a metal alloy which is adapted for casting dentures.

The principal objects of the invention are directed to the provision of an alloy which has greater qualities of castability in plaster of Paris than known prior art alloys which has a high resistance to corrosion, and which has a low melting point.

The novel features of my invention are attained by the new and unique combination of certain specific elements in predetermined proportions, the elements themselves being selected for their individual characteristics and for their ability to combine with other elements so as to produce an end result possessing properties for the casting of dentures superior to any known prior art alloys.

A prime requisite in alloys of the type herein referred to is castability. It must form a liquid of low viscosity when heated to the casting temperature so as to permit an easy and rapid flow into the mold.

A minimum amount of heat between the melting point and the casting temperature is a desideratum. With such minimum attained, oxidation is minimized and the chances for interaction with the mold surfaces are likewise lessened.

Such objectives are easily attained by means of the alloy of my invention. That is to say, the alloy is adapted to form castings which are homogeneous, dense, and free from pits or blowholes.

Another requisite in alloys of this type is a freedom from change in strength or hardness upon cooling. Shrinkage must be negligible for obvious reasons. The degree of corrosion resistance must be high, also for obvious reasons.

Other objects and advantages of my invention will be readily apparent by reference to the following specification and it is to be understood that any modifications may be made in the exact details herein described, within the scope of the appended claim, without departing from or exceeding the spirit of the invention.

The alloy described and explained herein is to be considered as consisting of a plurality of elements namely carbon, manganese, silicon, chromium, molybdenum, nickel, cobalt, columbium, copper, aluminum, and iron.

As to the various elements employed in my invention, I deem it important to explain why each is used.

Carbon

Carbon is primarily an impurity and is necessarily tolerated in my alloy.

Manganese

Manganese serves as a deoxidizer. It serves as an aid to the melting of the alloy.

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Furthermore, it is used to "clean up" a melt prior to tapping.

It increases the fluidity of the alloy permitting lighter sections to be cast successfully.

Silicon

Silicon serves as an aid to the melting of the alloy. As with manganese, it is also used to "clean up" a melt prior to tapping. That is to say, it helps to reduce the surface film. Too, it increases the corrosion resistance of the alloy since it is a powerful deoxidizer. It also serves to increase the fluidity of the alloy.

Chromium

Chromium imparts strength and hardness to the alloy and serves to increase its corrosion resistance.

Molybdenum

The molybdenum serves to increase corrosion resistance in reducing media such as is so frequently encountered in the human mouth. It also increases the elevated temperature strength of the alloy, thereby minimizing hot cracks.

Tungsten is interchangeable with molybdenum, and like molybdenum, serves to increase corrosion resistance in reducing media. It also increases the elevated temperature strength, minimizing hot tearing.

Nickel

Nickel serves as a very excellent base to which the alloying additions may be made.

It possesses fair corrosion resistance properties and it has a reasonably low melting point.

It will be observed that the other alloying additions may be added to the nickel base since all are readily soluble in both molten and solid nickel.

Nickel imparts toughness and ductility to the alloy.

Cobalt

Cobalt, like nickel, serves as a base in which the other elements are soluble in the liquid and solid states.

If desired, cobalt may be substituted for a like quantity of nickel. That is to say, these elements may be used interchangeably or in combination with each other within the scope of the invention inasmuch as cobalt behaves similarly to nickel although cobalt bearing alloys are more difficult to machine.

Cobalt offers strength to the alloy. It increases the resistance to "hot tearing," and it forms an oxide film.

Columbium

Columbium is not employed only as a carbide stabilizer. In my alloy, it also serves to increase resistance to hot tearing and to increase fluidity

by altering the copper-aluminum rich oxide film which forms during the melting.

Columbium gives sufficient fluidity to run in the thin areas of the dental castings such as saddles.

It is an all important alloy addition without which the requisite fluidity would not be obtained.

Tantalum

Tantalum is interchangeable with columbium, and, like columbium, serves as a carbide stabilizer. In my alloy, it serves to increase resistance to hot tearing and to increase fluidity by altering the copper-aluminum rich oxide film which forms during the melting. Whenever tantalum is referred to in this specification, it will be understood that it may be used interchangeably with columbium.

With columbium and/or tantalum, sections as thin as 0.008" can be run. Sections thinner than 0.025" cannot be run without columbium and/or tantalum. The average dental casting has sections as thin as 0.010".

Copper

Copper serves to aid in the forming of the protective skin in the molten alloy which permits same to be cast in plaster of Paris bound investments. If this skin is not formed, the alloy reacts vigorously with the sulphur in the investment and is valueless. Copper reduces the melting point of the alloy.

Aluminum

Aluminum together with copper serves to form the protective skin in the molten alloy.

The copper and aluminum must be added in the proper ratio in order to obtain this protective skin.

I have found that the combination of aluminum and copper permits higher copper additions to be made without the precipitation of free copper.

The copper and aluminum must be added in the form of a master alloy as I have found that additions of metallic copper and aluminum will not result in the desired alloy.

What is all important in my invention is not the indiscriminate addition of aluminum but the maintenance of the all important copper aluminum ratio.

Iron

A minimum of iron is desired as it reacts unfavorably with any sulphur present in the investment in which the alloy is cast and it further tends to raise the melting point.

Further, it is desirable to keep its amount to a minimum so as to attain as high a degree of corrosion resistance as possible.

Following is a table giving the elements that go to make up the alloy:

Element	Minimum	Maximum	Preferred Range
	<i>Percent</i>	<i>Percent</i>	<i>Percent</i>
Carbon	0.05	2.00	0.05-0.15
Manganese	0.70	2.00	0.70-0.90
Silicon	1.00	3.00	1.20-1.60
Chromium	10.00	30.00	17.5-19.5
Molybdenum or Tungsten	3.00	12.00	9.0-10.0
Nickel	20.0	40.0	29.0-31.0
Cobalt	20.0	40.0	23.0-25.0
Columbium or Tantalum	.40	2.00	0.6-0.7
Copper	5	20.0	10.0-12.0
Aluminum	0.6	2.0	0.8-1.0
Iron		10.0	Approx. 4.0

It will be appreciated that this table gives minimum and maximum percentages by weight of each element.

The absolute minimum of each element is to be avoided except, of course, in the case of iron.

The ranges of carbon, manganese, silicon, chromium, molybdenum, nickel, cobalt, columbium, copper, aluminum, and iron have been coordinated with each other only as a result of considerable experimentation on my part.

The minimum claimed amounts of the elements have not been arbitrarily selected and, in each instance, same has been established only as a result of my experimentation.

As to the criticalness of the proportions, I have determined, after considerable experimentation as follows:

Carbon (C)

Carbon in quantities less than 0.05% is primarily an impurity. Within the range 0.05%-0.15%, carbon increases in strength at a slight decrease in ductility and corrosion resistance. For certain dental, surgical, and jewelry applications, it is sometimes desirable to take advantage of the strengthening effect of an increase in the carbon content to within the range 0.15%-2.0%. I have found, however, that when the carbon content exceeds 2.0% the alloy becomes objectionably brittle. The hardness is increased whereas the ductility and corrosion resistance is decreased.

The physical properties of the alloy containing within the range of 0.05%-0.15% of carbon have been found to be suited ideally for most dental applications.

Manganese (Mn)

As the manganese is increased in quantity, the fluidity of the alloy is proportionately increased, within certain limits.

I have found that the best results are obtained when manganese is used within the range 0.70%-0.90%.

If maximum fluidity is desired, the manganese content may be raised to as much as 2.0%. Under no conditions, however, should the manganese content exceed 2.0% since the resultant alloy is then subject to "hot tearing."

Silicon (Si)

I have found that at least as a very minimum 1.0% is required for adequate fluidity and that at the very most a maximum of 3.0% must not be exceeded. To exceed 3.0% will produce an objectionably brittle alloy.

Chromium (Cr)

A minimum of 10.0% is required to insure adequate corrosion resistance in the human mouth. When the content is less than 10.0%, the resultant product is not corrosion resistant and a maximum of any more than 30.0% must not be exceeded or the melting point of the alloy will be too high and the ductility will be too low. Furthermore, if the content is more than 30.0%, the chromium will combine with the sulphur in the plaster of Paris investments, and will tend to harden the alloy and to render it less ductile.

I have found from experiment that chromium contents greater than 20.0% make the alloy coarse grained and brittle.

I have found that chromium within a range of 17.5%-19.5% is ideal for adequate corrosion resistance with a reasonable safety factor.

If the carbon content is greater than 0.15%,

the chromium content must be accordingly increased in order to compensate for that portion of the chromium which combines with the carbon so as to render itself unavailable for corrosion resistance functions.

Molybdenum (Mo)

A minimum of 3.0% is required in order to obtain the desired effects relative to resistance to pitting, corrosion, and increase in hot strength.

I have also found that a content of molybdenum amounting to more than 12.0% will result in an alloy which is objectionably brittle.

A content within the range 9.0%-10.0% insures that even the most delicate of dental castings will be crack free.

Nickel (Ni)

Nickel serves as one of the bases in which the other elements are soluble in the liquid and solid states.

Cobalt (Co)

At least 20.0% of cobalt must be used in order to insure freedom from hot tearing.

Because cobalt costs roughly 400% more than nickel, it is obviously desirable to maintain the cobalt content as low as possible.

The preferred range is within 23.0%-25.0%.

Columbium (Cb)

Columbium serves to increase the corrosion resistance as a carbide stabilizer and also to increase fluidity.

I have found that 0.40% as a minimum must be used in order to obtain the desired effect. A maximum of 2.0% must not be exceeded or the alloy will become too brittle.

In lieu of columbium, tantalum may be used with equally effective results.

Copper (Cu)

In my alloy, I provide a minimum of 5.0% copper.

If the pouring temperature of the alloy is high, optimum results are obtained when the copper content is 10.0%.

I do not exceed a maximum of 20.0% as I have found that an excessive amount makes the alloy brittle.

Other alloys in the art employ a maximum of 10.0% of copper. In such prior art disclosures, the copper content is held below 10.0% in order to prevent free copper from being thrown out from the solution when it solidifies.

Aluminum (Al)

Likewise, in my alloy, I provide a minimum of 0.6% of aluminum in order to obtain the desired result. If the pouring temperature of the alloy is high, best results are obtained when the aluminum content is 0.8%.

Other alloys in the art known to me employ no aluminum.

I have found that the aluminum content should never exceed 2.0%. If used in any greater quantity, the alloy is embrittled and rendered subject to "hot tearing."

Optimum results are obtained when the copper-aluminum ratio is 8-12:1. This is all important in my invention. The addition of copper and aluminum may not be indiscriminate. The ratio is the important factor.

Iron (Fe)

Iron is an impurity not intentionally added.

I have found that the iron content should not exceed 10.0% or the alloy is subject to hot tearing and loses much of its ductility and corrosion resistance.

Particularly desirable results have been obtained where the proportions are as follows:

	Per cent
Carbon	0.05
10 Manganese	0.70
Silicon	1.20
Chromium	17.5
Molybdenum	9.0
Nickel	29.0
15 Cobalt	23.0
Columbium	0.6
Copper	10.0
Aluminum	0.8
Iron	Balance

The alloy is high in copper and aluminum and has very marked resistance to the action of sulphur which is present in the usual investments in which castings are made. Plaster of Paris is an ordinary material used for investments.

Also, the alloy is very low in iron which is necessary to overcome corrosion and hold the melting point below a range where expensive and complicated equipment must be used.

Castings made from the alloy when taken from the mold have a pleasingly bright and clean appearance, are ductile, and possess good machineability.

The combination of elements provide a casting having an outer layer or skin which is rich in copper and aluminum, which is desired for its resistance to sulphur attack in the mold. This skin is only a few millionths of an inch thick and is subsequently polished off.

Were manganese not used in my alloy, the alloy would be "wild" when melted in the casting machine crucible. The correct proportion of manganese as set forth above is critical to my resultant product.

If silicon was not added to my alloy, same would lack fluidity and would be "wild" when melted in the casting machine crucible. Silicon is a critical element in my alloy.

Were chromium not added to my alloy in the production thereof, the alloy would corrode rapidly in the human mouth, both in the areas exposed to the air and in those areas in close contact with tissue or with teeth. Chromium is a critical element in my alloy.

If molybdenum was not added thereto, the alloy would pit in areas in close contact with the tissue or the teeth. The hot strength of the alloy would be too low to permit obtaining a hot tear-free casting in a plaster of Paris bound investment. The correct proportion of molybdenum as set forth herein is critical to my resulting alloy.

If cobalt was not incorporated as a part of my alloy, same would "tear" badly when cast in plaster of Paris bound investments. It is a critical element in my alloy.

Columbium is a critical element in the sense that were it not used, the alloy would lack fluidity and would be subject to hot tearing.

Copper is critical since were it not added, and in the proper quantity, it would not be possible to cast the alloy in plaster of Paris bound investments due to the sulphur reaction.

Aluminum is likewise critical and for the same reason as given for copper, namely, that were it

not added, the alloy could not be cast in plaster of Paris bound investments.

It should be added here that neither copper nor aluminum is effective when used alone and the ratio of copper and aluminum as set forth above must be maintained. It is this ratio which is all important.

The elements in the specific proportions above set forth provide an alloy which has a low melting point of about 2300° F. to facilitate ready and easy casting in ordinary investments, presents a brilliant appearance, has marked resistance to corrosion, and possesses a very desirable ductility and machinability.

The base composition used for producing the alloy comprises:

	Per cent
Carbon	0.05-0.15
Manganese	0.80- 1.0
Silicon	1.40-1.60
Chromium	20.5-22.5
Molybdenum	10.0-11.0
Nickel	30.0-32.0
Cobalt	24.0-26.0
Columbium	0.7- 0.8
Iron	approx. 4.0

The "as cast" tensile properties of this base composition are as follows:

Tensile strength, 100,000-120,000 p. s. i.
Yield strength, 70,000-90,000 p. s. i.
Elongation, 10-15 per cent
Reduction of area, 25-35 per cent
Hardness, Rockwell "C"—18-25

The copper and aluminum must be added in the form of a master alloy addition of the following composition:

	Per cent.
Aluminum	6.0-12.0
Iron	0.6- 2.0
Copper	Balance

If the copper addition is not made in this manner, there is a marked change in the properties of the resultant alloy. Additions of metallic copper and aluminum will not result in the desired alloy. An alloy, having the same nominal composition, but with the copper and aluminum additions of each separate metal will be hard and brittle. Furthermore, free copper will be thrown out of solution in the form of small nodules of copper.

The hardness and strength may also be further increased by the addition of more aluminum either by itself or in the form of a master alloy such as nickel-aluminum.

The control of hardness and strength may also be effected by the use of a so-called "hardener" melt having nominally the same composition as the "base" melt except that the aluminum and copper are added separately. Suitable combinations of "hardener" and "base" melts may then be made to procure any desired hardness.

The numerical amounts of the claimed ranges of the elements of my alloy involve more than a mere departure from the disclosures of the prior art which are known to me and effort is made herein to set forth the patentable differences.

For example, I am aware of a prior art alloy which employs proportions of elements as follows:

	Per cent
Carbon	between 0.1 and 1.0
Manganese	between 0.1 and 1.0
Silicon	between 0.2 and 1.0
Chromium	between 18.0 and 28.0
Molybdenum	between 4.0 and 12.0
Nickel	between 19.0 and 40.0
Cobalt	between 18.0 and 40.0
Copper	between 1.0 and 10.0
Columbium and aluminum are not used in this alloy.	

The normal investment used in work of the type contemplated with this and similar alloys is a plaster of Paris bound silica investment. The value of the alloy of this prior art disclosure is minimized due to the sulphur reaction. This alloy is not castable due to this objectionable sulphur reaction. Since the alloy contains copper alone, the copper does not prevent the sulphur reaction, even if and when the alloy is made with the maximum of copper, namely 10%.

Also, I am aware of another prior art alloy which employs other proportions of elements. This alloy comprises 63 parts nickel, 5 parts copper, 15 parts chromium, 10 parts molybdenum-chromium alloy in equal percentages, 2 parts tungsten, 1½ parts aluminum, 1½ parts manganese-titanium alloy (70 parts manganese and 30 parts titanium), 1 part manganese-boron alloy (70 parts manganese and 30 parts boron), 1 part copper-silicon alloy (80 parts copper and 20 parts silicon) and ½ part boron suboxid.

In this alloy the chromium content may be varied between 15.0 and 21.0%. The nickel may be varied between 55.0 and 65.0%, the copper may be varied between 5.0 and 11.0%, and the aluminum may be varied between 0.5 and 1.5%.

Cobalt and columbium are not even used in this alloy.

Taking this disclosure to the top side of the chemistry where the quantities of copper and aluminum are the highest, the desired castability might be obtained but the alloy would lack the all-important quality of fluidity. The alloy lacks sufficient silicon to increase the fluidity and is subject to the most severe form of hot tearing due to the insufficient hot strength.

The use of titanium in this alloy seriously alters the oxide film, reduces the fluidity, reduces the hot strength, and increases the rate of the sulphur reaction.

The use of boron in this alloy rapidly accelerates the sulphur reaction which I avoid in my alloy and reduces the hot strength markedly.

In neither of the above referred to alloys is columbium and/or tantalum used.

While there are several cobalt and nickel base alloys available that counteract the faults of the cast gold dental alloys, they too have serious drawbacks, viz. (1) high melting points necessitate costly melting equipment; (2) high melting points coupled with low resistance to sulphur attack prohibit the use of the plaster of Paris (calcium sulphate) type of investments. The more complex investments required zirconite, sillimanite, bauxite, etc., necessitating complicated investing techniques; (3) relatively low ductilities prohibit an appreciable manipulation of delicate clasps, etc., due to the possibility of breakage.

My extensive independent research program has been designed to develop thoroughly, by the most modern and extensive metallurgical means, an alloy to meet the needs of a more modern simplified prosthetic dentistry. Sixty different

alloys were investigated in my research program that led to the development of the herein claimed invention.

Specifically, the advantages of my alloy are:

(1) the low melting point permits the use of gas-air furnaces, platinum wound resistor type furnaces, etc. to melt the alloy in the dental laboratory; (2) the "nobility" or high corrosion resistance of the alloy insures that the alloy will not stain in the human mouth; (3) the unique resistance of the alloy to attack by sulphur permits the use of plaster of Paris type investments; (4) the relatively high ductility of certain grades of the alloy permits mechanical adjustments of clasps, and the like; (5) the low melting point, and resistance to attack by sulphur of the alloy simplifies the equipment required in the dental laboratory. This simplification of equipment results in a lower first cost of equipment, a lower operating cost, and the elimination of cumbersome and space consuming apparatus; (6) the pleasing, warm, platinum-like color of the alloy is attractive to both patient and dentist.

The invention may be embodied in other specific forms without departing from the essential characteristics thereof. Hence, the present embodiments are therefore to be considered in all respects merely as being illustrative and not as being restrictive, the scope of the invention being indicated by the appended claim rather than by the foregoing description, and all modifications

and variations as fall within the meaning and purview and range of equivalency of the appended claim are therefore intended to be embraced therein.

What it is desired to claim and secure by Letters Patent of the United States is:

A casting alloy for dentures consisting of, between 0.05% and 0.15% carbon, between 0.70% and 0.90% manganese, between 1.20% and 1.60% silicon, between 17.5% and 19.5% chromium, between 9.0% and 10.0% tungsten, between 29.0% and 31.0% nickel, between 23.0% and 25.0% cobalt, between 0.6% and 0.7% tantalum, between 10.0% and 12.0% copper, between 0.8% and 1.0% aluminum, and a balance of iron.

SIDNEY LOW.

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