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CORROSION RESISTANT COATING

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This invention relates to the formation of a corrosion resistant coating on a metal composition, and more particularly to a corrosion resistant coating for a metal composition wherein the coating is an alloy whose constituents comprise the metal and beryllium. Still more particularly, this invention is concerned with the formation of a beryllide coating on a metal composition where the beryllide coating comprises an alloy of beryllium and the metal, and to the novel compositions obtained thereby.

Attempts have been made to produce a beryllium or beryllide coating on a metal by vapor plating techniques. Although several reports of formation of such coatings have been made, later work showed that such coatings were grossly contaminated with impurities. Using a hot tungsten wire as the source of heat, it is possible to decompose beryllium iodide to beryllium metal as a coarse, granular deposit, but the product is contaminated with corrosion products from the walls of the reaction vessel. In one instance, it was proposed to coat metals such as iron, aluminum and copper with beryllium by electrolysis of a fused salt bath containing a beryllium halide with or without the addition of an alkali metal halide to decrease the melting point of the bath. The electrolysis was carried out at temperatures below the melting point of beryllium under atmospheric conditions while the bath was exposed to air. The metal to be coated with beryllium was used as the cathode in conjunction with an insoluble anode, such as graphite or carbon. It was found to be impossible to use a beryllium anode. Metals whose melting point is far higher than beryllium, such as tungsten, molybdenum, tantalum, niobium, vanadium, etc., could be plated with beryllium only if an intermediate layer such as iron, nickel or copper was first deposited on the surface.

This method has several disadvantages. The beryllium plates out as the metal without diffusing into the surface of the base metal unless the temperature is just below the melting point of the metal being plated. It cannot be used to form beryllium coats directly onto all metals without the use of an intermediate layer for those having high melting points. The process produces only very thin coatings since it is carried out for no longer than a few minutes. Since a beryllium anode cannot be used, the concentration of the beryllium decreases in the bath and must be replenished from time to time with the consequent fluctuations in bath compositions which cause non-uniform plating rates.

Unexpectedly, I have discovered that a uniform, adherent, tough, corrosion resistant beryllide coating can be formed on a specific group of metals without an overlying layer of beryllium by immersing the selected metal and beryllium in a fused bath composed essentially of beryllium fluoride containing from 10 to 66⅔ mole percent of at least one alkali metal fluoride so that at least a portion of the fused salt isolates the metal from the beryllium. I have found that such a combination is an electric cell in which an electric current will be generated when an electrical connection is made, which is external to the fused bath, between the metal and beryllium. Under such conditions, the beryllium dissolves in the fused bath and beryllium ions are discharged at the surface of the metal where they form a deposit of beryllium which immediately diffuses into and reacts with the metal to form a beryllide coating. I have discovered that the rate of dissolution and deposition of the beryllium is self-regulating so that the beryllium is never deposited at a rate faster than it diffuses and alloys with the metal. If a slower rate is desired, it can be easily controlled by means well known in the art, such as by the amount of resistance in the circuit, surface area exposed to the bath, etc. A limited amount of voltage may be impressed upon the electrical circuit to supply additional direct current if a faster rate is desired.

This invention will be easily understood by those skilled in the art from the following detailed description. The metals which may be beryllided by my process are those having atomic numbers 21–29 inclusive, 39–47 inclusive, 57–79 inclusive, and 89–98 inclusive. This range of atomic numbers includes those metals included in the periodic chart of the elements shown on pages 56 and 57 of Lange's Handbook of Chemistry, 9th Edition, Handbook Publishers, Inc., Sandusky, Ohio, 1956, as the group IB metals which are copper, silver, and gold, the group IIIB metals, including the rare earth and actinide series, which are scandium, yttrium, lanthanum, cerium, praseodymium, neodymium, prometheum, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, ytterbium, lutetium, actinium, thorium, protactinium, uranium, neptunium, plutonium, americium, curium, berkelium and californium, the group IVB metals, which are titanium, zirconium, and hafnium, the group VB metals, which are vanadium, niobium, and tantalum, group VIB metals, which are chromium, molybdenum and tungsten, the group VIIB metals, which are manganese, technetium, and rhenium, and the group VIII metals which are iron, cobalt, nickel, ruthenium, rhodium, palladium, osmium, iridium, and platinum. Alloys of these metals with each other, or alloys containing these metals as the major constituent, i.e., over 50 mole percent, but usually over 75 mole percent and preferably at least 90 mole percent, alloyed with other metals as a minor constituent, i.e., less than 50 mole percent, but usually less than 25 mole percent and preferably less than 10 mole percent, can also be beryllided by my process, providing the melting point of the resulting alloy is not lower than 600° C.

The fact that other metals may be minor constituents of an alloy with the metals with which this invention is concerned does not prevent the formation of the desired beryllide coating on the object. These minor constituents may be any of the other metals of the periodic system, i.e., the metals of groups IA, IIA, IIB, IIIA, IVA, VA, and VIA. These metals have atomic numbers 3–4 inclusive, 11–13 inclusive, 19–20 inclusive, 30–32 inclusive, 37–38 inclusive, 48–51 inclusive, 55–56 inclusive, 80–84 inclusive and 87–88 inclusive. In the specification and claims I use the term "beryllide" to designate any solid solution or alloy of beryllium and metal regardless of whether the metal does or does not form an intermetallic compound with beryllium in definite stoichiometric proportions which can be represented by a chemical formula. For example, iron forms a compound with beryllium that can be represented by the formula $FeBe_2$ but silver forms only a solid solution with beryllium.

The alkali metal fluorides which may be used with beryllium fluoride for making the fused bath include the fluorides of lithium, sodium, potassium, rubidium, and cesium. The fused salt bath also may be made by adding beryllium fluoride to at least one alkali metal fluoberyllate, i.e., lithium, sodium, potassium, rubidium or cesium fluoberyllate. Since it is desirable to use as low a temperature as practicable to avoid damaging or distorting the article to be beryllided fused salt mixtures of the

alkali metal fluorides, the alkali metal fluoberyllates, and beryllium fluoride may be used to provide salt baths having lower fusion temperatures than the individual components. Any combination of these materials may be used provided they yield a beryllium content, calculated as beryllium fluoride, corresponding to at least 33⅓ mole percent of the bath composition, the remainder being alkali-metal fluoride. A mixture of 33⅓ mole percent beryllium fluoride and 66⅔ mole percent alkali metal fluoride is believed to form an alkali metal fluoberyllate corresponding to the formula X_2BeF_4 and a mixture of 50 mole percent of each is believed to form the alkali metal fluoberyllate corresponding to the formula $XBeF_3$, where X represents any of the alkali metals. Therefore, a fused salt bath consisting essentially of beryllium fluoride containing from 10 to 66⅔ mole percent alkali metal fluoride can be made from (1) beryllium fluoride with at least one alkali metal fluoride, (2) at least one alkali metal fluoberyllate of the above defined formulae X_2BeF_4 and $XBeF_3$, or (3) a mixture in any proportion of the compounds of (1) and (2), where the molar ratio is at least 1 mole of the beryllium fluoride to 2 moles of the alkali metal fluoride.

In order to produce a reasonably fast plating rate and to insure the fusion of the beryllium into the metal to form the beryllide, I have found it desirable to operate my process at a temperature no lower than about 600° C., even though the bath has a much lower melting temperature. Although lower temperatures may be used, there is some likelihood that the beryllium will plate out onto the surface of the metal without diffusing into the metal. I usually prefer to operate at temperatures of 700°–800° C. and sometimes up to about 900° C. The alkali metal fluorides react with beryllium fluoride to form the alkali metal fluoberyllates. However, this is an equilibrium reaction, so that, at temperatures exceeding 800° C., the vapor pressure of the beryllium fluoride becomes sufficiently high under vacuum that it is readily volatilized from the fused salt bath containing more than 50 mole percent beryllium fluoride. At temperatures of 800–900° C., baths should contain 50–66⅔ mole percent alkali fluorides in order to reduce the vapor pressure of the beryllium fluoride to practical operational limits. I have found that a minimum of 33⅓ mole percent of beryllium fluoride is required to prevent the alkali metal from being formed at the beryllium anode, sometimes with explosive violence. This latter danger is encountered especially when the concentration of the beryllium fluoride is below 10 mole percent and when operating under vacuum.

The chemical composition of the fused salt bath appears to be critical. The starting salts should be as anhydrous and as free of all impurities as possible, or should be easily dried or purified by simply heating during the fusion step. The role of impurities has not been definitely established, but it appears that many things can interfere with the electrode reactions and make for poor berylliding. Because oxygen interferes, the process must be carried out in the substantial absence of oxygen, for example, in an inert gas atmosphere or in a vacuum. Sulfates appear to interfere most drastically, probably to give sulfur which diffuses into the metal and makes it impossible or extremely difficult to obtain good berylliding. Other metal compounds can also cause the formation of poor quality beryllide coatings. Best results are obtained by starting with reagent grade salts and by carrying out the process under vacuum. I have sometimes found that even commercially available, reagent grade salts must be purified further in order to operate satisfactorily in my process. This can easily be done by utilizing scrap articles, preferably of the same metal to be used later, to carry out initial berylliding runs with or without an additional applied voltage thereby plating out and removing from the bath those impurities which interfere with the formation of a high quality beryllide coating. Carrying out the process in a vacuum also aids the process by volatilizing impurities and interfering substances, such as water. It is also desirable to thoroughly clean the metal surfaces before introduction into the fused salt, such as by pickling with or without an abrading treatment.

Although not necessary, I may use a porous conducting container which is inert under process conditions, for example, a graphite basket with holes, to contain the beryllium as small pieces rather than to use a single solid piece of beryllium. To insure a uniform coat the beryllium should be at least 0.25 inch and preferably 1 to 2 inches from the metal article being beryllided. In berylliding extremely large articles, for example, a sheet, in which one side may be shielded from a single beryllium electrode, it may be desirable to use two or more beryllium electrodes, which are judiciously spaced around the article to produce a uniform coating.

When an electrical circuit is formed external to the fused salt bath by joining the beryllium to the metal to be beryllided with a conductor, electric current will flow through the circuit without any applied E.M.F. Apparently, the beryllium acts as an anode by dissolving in the fused bath to produce electrons and beryllium ions. The electrons flow through the external circuit formed by the conductor and the beryllium ions, probably as fluoberyllate ions, migrate through the fused salt bath to the metal to be beryllided acting as the cathode, where the electrons discharge the beryllium ions as a beryllium coating. Because of the combined effect of the temperature of the bath and the fluxing action of the fused salts I use, the beryllium immediately diffuses into the metal and forms a beryllide as a very smooth, adherent, tough, corrosion resistant coating. The amount of current can be measured with an ammeter which enables one to readily calculate the amount of beryllium being deposited on the article and converted to the beryllide layer. Knowing the area of the article being plated, it is possible to calculate the thickness of the beryllide coating deposited, thereby permitting accurate control of the process to obtain any desired thickness of the beryllide layer.

Although my process operates very satisfactorily without the impressing of an additional E.M.F. on the electrical circuit, I have found that it is possible to apply a small voltage when it is desired to increase the deposition rate of the beryllium without exceeding the diffusion rate of beryllium into the article to form the beryllide layer. The impressed E.M.F. should not exceed 0.5 volt, and usually falls between 0.1 and 0.3 volt. Voltages higher than this indicate one or more of the following conditions: (1) high resistance somewhere in the external circuit, (2) impurities in the bath which interfere with the desired chemical reactions with the electrodes, (3) too fast deposition rates, (4) loose or corroded electrical connections, etc. Although my process will operate satisfactorily when such conditions exist, it is desirable that they be corrected for more efficient operation.

When operating as a cell, without any impressed E.M.F., the initial current density is between 0.1 and 1.0 ampere per square decimeter at 700°–800° C. As the beryllide layer increases on the article, the current density drops until, by the time the coating is approximately 1 mil thick, it is usually one-third to one-tenth the initial value.

When it is desirable to apply additional voltage to the circuit in order to shorten the time of operation, the total current density should not exceed 3 amperes per square decimeter. In preparing thick beryllide coatings, the current density preferably should not exceed 1 amphere per square decimeter after the beryllide layer is 1 mil thick. Current densities in excess of these ranges lead to some formation of elemental beryllium in either the form of non-adherent deposits or as a granular or large crystalline deposits which give a rough, undesirable coating which tends to spall on further electrolysis or cooling to room temperature. Such results are desirable for the electro-

winning of beryllium from its compounds but are completely unsatisfactory for the production of smooth, adherent, beryllide coatings on metals.

If an applied E.M.F. is used, the source, for example, a battery or other source of direct current, should be connected in series with the external circuit so that the negative terminal is connected to the external circuit terminating at the metal being beryllided and the positive terminal is connected to the external circuit terminating at the beryllium electrode. In this way, the voltages of both sources are algebraically additive.

As will be readily apparent to those skilled in the art, measuring instruments such as voltmeters, ammeters, resistances, timers, and so forth, may be included in the external circuit to aid in the control of the process.

The following examples are given by way of illustration and not by way of limitation. It is readily apparent that variations from the specific reaction conditions and reactants given may be readily used without departing from the scope of my invention.

EXAMPLE 1

Into a stainless steel vessel (4¾" I.D. x 11" depth) fitted with a Monel liner (4½" I.D. x 10¾" depth) was placed 2800 g. of a mixture of anhydrous reagent grade KF (45 mole percent) LiF (45 mole percent), and NaF (10 mole percent), and 1565 g. of anhydrous BeF_2. The vessel was covered with a glass dome which contained two ports for electrodes and another port for a thermocouple well and vacuum connections. A beryllium anode (½" x ½" x 7") fastened to a ¼" nickel rod by nickel wire and a nickel strip cathode (2 cm. x 10 cm. x 1 cm.) similarly fastened to another ¼" nickel rod were inserted in the electrode ports. The nickel rods of the electrodes were sealed in the ports with rubber tubing which permitted raising and lowering the electrodes in vacuum.

The stainless steel vessel was then placed in a nichrome wound, alumina tube, electric furnace, evacuated and heated to 700° to give a very fluid milky-white melt.

The electrodes were then lowered into the melt and the electrolysis carried out under vacuum (50–25 u), impressing a moderate E.M.F. on the external circuit connecting the anode and cathode. A voltmeter and ammeter were connected in the normal fashion in the external circuit where indicated in the following table:

Time (min.)	Temp. ° C.	Current density, amp./dm.²	
0	700	2.5	No applied E.M.F. external E.M.F. applied.
15	700	4.5	
25	700	2.2	No applied E.M.F. external E.M.F. applied for balance of run.
70	700	4.5	
240	700	4.5	
420 (end)	700	4.5	

During the electrolysis considerable gas was given off, especially at the beryllium anode. This decreased as the electrolysis proceeded and also the milky appearance of the molten salt disappeared and the melt became completely clear.

The electrodes were lifted from the salt and the bath allowed to cool before opening the apparatus. The nickel wire gained 65 mg. of a calculated 325 mg. weight gain of beryllium. The low efficiency is due to small amounts of impurities in the bath which are eliminated in the "clean-up" run, and to too high current density on the cathode. The nickel wire was coated with a smooth, hard 4–5 mil coat of nickel beryllide which on X-ray examination and chemical analysis proved to be Ni_5Be_{21}.

EXAMPLE 2

An yttrium rod (.62 cm. x 10 cm.) was beryllided in the same salt melt and by the same general procedure described in Example 1 with an E.M.F. applied during the entire run.

Time (min.)	Temp., ° C.	Current density, amp./dm.²
0	700	1.2
4	700	1.5
22	700	1.5
100	700	1.5

The yttrium gained 85 mg., the theoretical weight gain for beryllium. The metal rod increased .5 mil in thickness. Metallographic examination showed approximately a ½ mil beryllide coat that was very hard, highly adherent though somewhat brittle, and contained YBe_{13}.

EXAMPLE 3

A copper strip (12 cm. x 2 cm. x .3 cm.) was beryllided in the same apparatus and by the same general procedure described in Example 1.

Time (min.)	Temp.,°C.	Current density, amp./dm.²
0	675	.85
5	675	.50
6	680	1.5
300	700	1.3
780	700	1.2

The copper had gained 1152 mg. of a calculated 1350 mg. weight gain of beryllium. Metallographic examination showed that the copper, which had increased 2.6 mils in thickness, had developed a uniform coating 10 mils thick per side. This coating was actually made up of five different layers. The two outer layers, approximately ½ mil thick each, were silver in appearance and were sufficiently hard to polish a file. The inner layers were decreasingly hard as they progressed inward, but were much harder (625, 525 and 325 Knoop hardness number at 100 g. load) than the substrate copper (75 Knoop hardness number).

EXAMPLE 4

A uranium rod (.155 cm. x 15 cm.) was beryllided in the same salt and by the same general procedure as Example 1.

Time (min.)	Temp.,°C.	Current density, amp./dm.²	
0	630	1.5	No E.M.F. applied.
1	630	.8	Do.
3	630	1.2	External E.M.F. applied.
17	630	1.5	Do.
125	630	1.5	Do.

At this point the uranium rod was removed, weighed and examined. It had gained only 1.5 mg. of a calculated 34 mg. weight gain of beryllium.

The surface appeared to have a thin coating of beryllide. The sample was then returned to the bath and the temperature increased.

Time (min.)	Temp.,°C.	Current density, amp./dm.²	
0	630	.35	No E.M.F. applied.
1	630	.09	Do.
10	660	.09	Do.
30	700	.18	Do.
65	720	.21	Do.
100	730	.18	Do.
101	730	.72	External E.M.F. applied.
266 (end)	730	.72	Do.

The uranium rod had gained 5.5 mg. of a calculated weight gain of 19.1 mg. of beryllium. The rod had gained approximately .5 mil in thickness and metallographic examination showed approximately a .5 mil coating which was very hard.

Another sample of uranium rod which was beryllided by the same procedure as above, was tested for oxidation resistance by heating it in air as an electrical heating element. The untreated rod burst into flame even before it glowed from the electrical heating, whereas the treated sample glowed at dull red heat for several minutes with no signs of burning.

EXAMPLE 5

A piece of 64 titanium alloy (90% Ti, 6% Al, 4% V) (140 cm.² surface area) was beryllided in the same salt mixture and by the same general procedure used in Example 1.

Time (min.)	Temp.,°C.	Current density, amp./dm.²	
0	800	.40	No. E.M.F. applied.
1	800	.20	Do.
2	800	.14	Do.
4	800	.13	Do.
6	800	.40	E.M.F. applied.
66	800	.40	Do.
165	800	.40	Do.

The cathode piece gained 270 mg., the theoretical weight gain of beryllium and increased 1 mil in thickness. A surprising observation was made that most of this thickness gain was due to microscopic irregularities on the surface which were readily removed by slight polishing with 0000 emery. This polishing reduced the thickness gain to 0.1 to 0.2 mil, but only reduced the weight gain by 40 mg. The surface was now extremely smooth, and hard (600–800 Vickers hardness number with 100 g. load) and on microscopic examination was found to have a .5 to 1.0 mil coat. X-ray examination indicated the presence of several titanium beryllides.

Results of berylliding other metals and alloys are shown in Table I. The low efficiencies obtained in some of these runs can be greatly improved by raising the temperatur and/or decreasing the current density. All the coating were uniform and non-porous. In all cases the general procedure and apparatus described in Example 1 were used. All examples had a moderate E.M.F. applied to the external circuit during the entire run except for Example 11 which was run with no applied E.M.F. In this latter case the current densities shown were those at the beginning and end of the run with intermediate values being noted during the run.

Table I

Ex.	Cathode material	Temp., ° C.	Current density, amp./dm.²	Efficiency	Description of coating
6	Platinum	700	3	100	10 mil coat, dark grey, smooth, hard, moderately flexible.
7	Titanium	700	.8	20	.4 mil coat, grey, fine granular surface, hard, flexible.
8	Zirconium	700	3	10	1 mil coat, grey, smooth, hard, flexible.
9	Iron	700	2	40	.3 mil coat, dark grey, smooth, hard, flexible.
10	A 286 (26 % Ni, 2% Co, 15% Cr, 1.25% Mo, 1.5% Mn, 2% Ti, 0.35% Al, balance Fe.	750	.4	70	1 mil coat, blue grey, hard, moderately flexible.
11	Monel	700	1-.2	100	.5 mil coat, light grey, smooth, hard, flexible.

Example 5 was repeated to obtain a titanium alloy (Ti 64) sample in the form of a washer bearing a very smooth beryllide coating. This washer was tested for frictional properties against a rotating cup in a Roxanne wear tester so modified that it could test the plane surfaces of a washer instead of the spherical surfaces of a ball with the following results:

Rotating cup	Washer	Pressure, p.s.i.	Speed, r.p.m.	Lubricant	Wear remarks	μ	Remarks
4140 steel	Titanium alloy	100	2,000	SAE 10 spindle oil	Deep wara track on titanium washer. Cup badly scored and titanium buildup.	Above 0.5	Ran 15-20 sec. and seized.
Do	Beryllided titanium alloy	100	2,000	do	Black polished streaks on cup. Slight polishing of Ti-Be washer.	.092	Ran 2 hrs.

The above examples have illustrated the preferred embodiments of my invention. However, it will be readily apparent to those skilled in the art that other modifications can be made without departing from the scope of the present invention. For example, the beryllide coating can be formed on a metal which is itself a coating on the surface of another metal, for example, an electroplate on a metal base, e.g., chromium on iron.

Because the tough, adherent, corrosion resistant properties of the beryllide coatings are uniform over the entire treated area, the beryllide coated metal compositions prepared by my process have a wide variety of uses. They can be used to fabricate reaction vessels for chemical reactions, to fabricate moderators for nuclear reactors, to make turbine blades for both gas and steam driven turbines to resist the corrosive and erosive effects of the gaseous driving fluid, to make gears, bearings, and other articles requiring hard, wear resistant surfaces. Other uses will be readily apparent to those skilled in the art, as well as other modifications and variations of the present invention in light of the above teachings. It is therefore to be understood that changes may be made in the particular embodiments of the invention described which are within the full intended scope of the invention as defined by the appended claims.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. A method of forming a beryllide coating on a metal composition having a melting point of at least 600° C., at least 50 mol percent of said metal composition being at least one of the metals selected from the group of metals whose atomic numbers are 21–29, 39–47, 57–79, and 89–98, said method comprising (1) forming an electric cell containing said metal composition as the cathode

joined through an external electrical circuit to a beryllium anode and a fused salt electrolyte composed essentially of beryllium fluoride and form 10 to 66⅔ mol percent of at least one alkali metal fluoride, said electrolyte being maintained at a temperature of about 600–900° C., but below the melting point of said metal composition in the substantial absence of oxygen, (2) controlling the current flowing in said electric cell so that the current density of the cathode does not exceed 3 amperes per square decimeter during the formation of the beryllide coating, and (3) interrupting the flow of electrical current after the desired thickness of beryllide coating is formed on the metal composition.

2. The beryllide coated product obtained by the method of claim 1.

3. The process of claim 1 wherein the absence of oxygen is obtained by use of a vacuum.

4. The process of claim 1 wherein all of the electrical energy for the process is self-generated in the electric cell.

5. The process of claim 1 wherein part of the direct current is supplied by an external E.M.F. impressed upon the electrical circuit.

6. A method of forming a beryllide coating on a metal composition having a melting point of at least 600° C., at least 90 mol percent of said metal composition being at least one of the metals selected from the group of metals whose atomic numbers are 21–29, 39–47, 57–79, and 89–98, said method comprising (1) forming an electric cell containing said metal composition as the cathode joined through an external electrical circuit to a beryllium anode and a fused salt electrolyte composed essentially of beryllium fluoride and from 10 to 66⅔ mol percent of at least one alkali metal fluoride, said electrolyte being maintained at a temperature of about 600–900° C., but below the melting point of said metal composition in the substantial absence of oxygen, (2) controlling the current flowing in said electric cell so that the current density of the cathode does not exceed 3 amperes per square decimeter during the formation of the beryllide coating, (3) interrupting the flow of electrical current after the desired thickness of beryllide coating is formed on the metal composition, and (4) removing the metal composition with its integrant beryllide coating from the fused salt electrolyte.

7. The method of claim 6 wherein the metal composition is at least 90 mol percent iron.

8. A method of forming a beryllide coating on an iron-chromium-nickel alloy which comprises (1) forming an electric cell containing said alloy as the cathode joined through an external electrical circuit to a beryllium anode and a fused salt electrolyte composed essentially of beryllium fluoride and from 10 to 66⅔ mol percent of at least one alkali metal fluoride, said electrolyte being maintained at a temperature of about 600°–900° C. in the substantial absence of oxygen, (2) controlling the current flowing in said electric cell so that the current density of the cathode does not exceed 3 amperes per square decimeter during the formation of the beryllide coating, (3) interrupting the flow of electrical current after the desired thickness of beryllide coating is formed on the alloy, and (4) removing the alloy with its integrant beryllide coating from the fused salt electrolyte.

9. A method of forming a beryllide coating on titanium which comprises (1) forming an electric cell containing titanium as the cathode joined through an external electrical circuit to a beryllium anode and a fused salt electrolyte composed essentially of beryllium fluoride and from 10 to 66⅔ mol percent of at least one alkali metal fluoride, said electrolyte being maintained at a temperature of about 600–900° C. in the substantial absence of oxygen, (2) controlling the current flowing in the said electric cell so that the current density of the cathode does not exceed 3 amperes per square decimeter during the formation of the beryllide coating, (3) intterrupting the flow of electrical current after the desired thickness of beryllide coating is formed on the titanium, and (4) removing the titanium with its integrant beryllide coating from the fused salt electrolyte.

10. A method of forming a beryllide coating on copper which comprises (1) forming an electric cell containing copper as the cathode joined through an external electrical circuit to a beryllium anode and a fused salt electrolyte composed essentially of beryllium fluoride and from 10 to 66⅔ mol percent of at least one alkali metal fluoride, said electrolyte being maintained at a temperature of about 600–900° C. in the substantial absence of oxygen, (2) controlling the current flowing in said electric cell so that the current density of the cathode does not exceed 3 amperes per square decimeter during the formation of the beryllide coating, (3) interrupting the flow of electrical current after the desired thickness of beryllide coating is formed on the copper, and (4) removing the copper with its integrant beryllide coating from the fused salt electrolyte.

11. A method of forming a beryllide coating on yttrium which comprises (1) forming an electric cell containing yttrium as the cathode joined through an external electrical circuit to a beryllium anode and a fused salt electrolyte composed essentially of beryllium fluoride and from 10 to 66⅔ mol percent of at least one alkali metal fluoride, said electrolyte being maintained at a temperature of about 600–900° C. in the substantial absence of oxygen, (2) controlling the current flowing in said electric cell so that the current density of the cathode does not exceed 3 amperes per square decimeter during the formation of the beryllide coating, (3) interrupting the flow of electrical current after the desired thickness of beryllide coating is formed on the yttrium, and (4) removing the yttrium with its integrant beryllide coating from the fused salt electrolyte.

12. A method of forming a beryllide coating on uranium which comprises (1) forming an electric cell containing uranium as the cathode joined through an external electrical circuit to a beryllium anode and a fused salt electrolyte composed essentially of beryllium fluoride and from 10 to 66⅔ mol percent of at least one alkali metal fluoride, said electrolyte being maintained at a temperature of about 600–900° C. in the substantial absence of oxygen, (2) controlling the current flowing in said electric cell so that the current density of the cathode does not exceed 3 amperes per square decimeter during the formation of the beryllide coating, (3) interrupting the flow of electrical current after the desired thickness of beryllide coating is formed on the uranium, and (4) removing the uranium with its integrant beryllide coating from the fused salt electrolyte.

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