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(54) Coinage material and process for production thereof

(57) A coinage material comprises a ferritic blank, for example of mild steel, which has been surface-treated with an austenite-forming element such as nickel or manganese, and which has chromium diffused into the surface, such that a specific, marked difference, for example in electrical conductivity and/or magnetic permeability, which is electronically detectable exists between the surface and the interior. The coinage material may therefore be validated electronically using suitable detection means.

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Description

This invention relates to a coinage material and production thereof, particularly a coinage material based on a ferritic material, exhibiting electronically detectable characteristics, in particular electrical and/or magnetic properties detectable by electronic validation means.

Coinage has traditionally been produced from homogeneous blanks formed entirely from non-ferrous metals such as copper-based alloys. In many instances worldwide, primarily for reasons of manufacturing economy, such homogeneous coinage is now being replaced by coinage based on more widely available and less costly materials such as mild steel. To afford such coinage materials with adequate protection against tarnish and corrosion, and to provide the desired external appearance, the metal substrate is commonly coated on the surface. Typical coating materials include, copper, brass (Cu-Zn), bronze (Cu-Sn), and nickel, which materials are generally applied by electroplating techniques.

Another type of coating process, known as "chromising", has now been developed for coinage production. In this process, originally disclosed for example in GB 862 282, chromium is deposited onto mild steel blanks by the technique of chemical vapour deposition (CVD) and diffused into the surface to generate a layer which is effectively a ferritic stainless steel. Such chromised coinage material may be offered at a substantial price advantage over conventional homogeneous coinage made entirely from stainless steels, for example AISI 430-type stainless steel, which has hitherto been used in certain countries. Furthermore, it can be struck more easily in a coining press because the interior remains as a soft unalloyed iron.

Electronic coin validators are now widely in use to distinguish valid coinage from coinage which is invalid such as counterfeit, defective or foreign coinage. These validators can exploit differences in the properties between the coating and the substrate materials of conventional electroplated coins. Typically, electronic coin validators are able to detect differences in electrical conductivity and magnetic permeability. However, conventional chromised steel coinage, as with the AISI 430-type stainless steel coinage, does not present special security characteristics which might be exploited in electronic coin validators. Indeed, the two materials may appear equivalent in electronic validators. This is because in a chromised steel blank the stainless steel at the surface and the unalloyed steel in the interior are both of a ferritic character, and consequently show similar electrical and magnetic properties. Therefore, as with the homogeneous stainless steel coinage, no substantial property differences exist between the surface and the interior of chromised steel coinage which might be detected by electronic coin validators.

It has now been found that this limitation which is intrinsic to chromised steel coinage may be overcome by treating the surface of a ferritic blank with an austenite-forming element. Thus, the surface is transformed to a non-ferromagnetic austenitic structure, in contrast to the interior which remains ferritic. Specific, marked differences in properties generated between the surface and the interior as a consequence may then be detected using conventional electronic validation technology.

Accordingly, the present invention provides a coinage material comprising a ferritic blank which has been surface-treated with an austenite-forming element and which has chromium diffused into the surface, such that a specific, marked difference which is electronically detectable exists between the surface and the interior. The invention further provides a process for producing the coinage material, which comprises sequentially or simultaneously treating the surface of a ferritic blank with an austenite-forming element and diffusing chromium into the surface.

The coinage material according to the invention includes struck as well as unstruck coins, coin blanks, tokens, or the like, such as may be used to operate so-called slot machines, for example automatic vending machines and arcade game machines, or any other such machines providing goods or services.

As ferritic material for the blank to be treated in accordance with the invention, preferably mild steel is used, both on account of its low cost and easy availability, and because of its relative softness whereby coin blanks produced from mild steel may be struck without causing undue wear of the striking die or coin press. By "mild steel" is meant steel which has a low carbon content, generally below 0.25 wt%, for example steel conforming to British Standard BS 1449, Pt 1, 1991. Preferably, mild steel having a carbon content of 0.01-0. 1 wt%, in particular 0.03-0.06 wt%, is used. Alternatively, so-called stabilised mild steel is used for the blank, meaning that the steel has been pretreated, usually at the ladle stage, with an element which binds with interstitial elements such as carbon and nitrogen present in the steel, so as to reduce to a negligible amount the content of free interstitial elements remaining in the steel. Thus, the formation of hard carbides or nitrides of chromium during the subsequent chromising treatment according to the invention may be precluded or reduced, thereby advantageously prolonging die life. Suitable stabilising elements include niobium, tantalum and titanium.

According to the invention, the ferritic blank is treated with an element which causes an austenitic layer to form in the surface. Any suitable austenite-forming elements may be used, for example nickel, manganese, or mixtures thereof. Both nickel and manganese are well known austenite-formers for steel; for example manganese is present in austenitic stainless steels AISI 202 and 205 in amounts of 9 wt% and 14.5 wt%, respectively. The austenite-forming treatment may be carried out by any suitable method, such as by electroplating or by CVD, as appropriate to the particular austenite-forming element used. For example, if nickel is used as the austenite-former, it may suitably be applied by electroplating, for example by the plating process disclosed in GB 1 477 981. If manganese is used as the austenite-former, then it may suitably be applied using conventional CVD techniques, or by electroplating. In a preferred embodiment, a mild steel blank is surface-treated with nickel by electroplating. For example, the nickel may be deposited to a thickness up to 50 µm, in particular 2 - 10 µm. Conveniently, nickel-plated coin blanks are now commercially available from a number of producers across the world, and are supplied to a large number of national mints. Suppliers include Westaim, The Royal Mint (GB), IMI Birmingham Mint (GB) and the South African Mint. Such blanks are all fabricated to withstand the high temperatures required in the chromising process and are therefore suitable for use in the present invention.

According to the invention, in addition to the austenite-forming surface treatment the blank is subjected to chromium diffusion, suitably using CVD techniques known in the art. Chromium CVD has been used for example to increase the resistance of substrates such as nickel and nickel alloys to high temperature corrosive attack. The application of chromium coatings in the above manner is particularly useful where any advantageous mechanical properties of the base material need to be preserved. This is especially important for highly stressed components that operate at elevated temperatures such as gas turbine blades. For components that are not highly stressed in service, CVD of chromium may also be advantageous. For example, the machining of components made from alloys containing nickel and chromium is difficult and rapid tool wear can result. Therefore, it is in principle easier to machine the component from nickel and apply the chromium coating at a later stage. There is also an economic advantage in the above route.

The basic principles for the chemical vapour deposition of chromium are as follows:- A precursor chemical which is normally a chromium halide is generated at elevated temperature by the reaction of a hydrogen halide (or halogen) gas with metallic chromium. The halides used are typically chloride, bromide, fluoride or iodide. The volatile chromium halide may be produced by the following reaction, for example:-

$$2Cr\ (metal) + 2HX \rightarrow 2CrX + H_2 \qquad (i)$$

in which X represents Cl, I, Br or F

The chromium halide gas is then allowed to come into contact with the substrate to be coated. Deposition can occur via the following reactions:-

$$2CrX \rightarrow 2Cr\ (metal) + X_2 \qquad (ii)$$

$$2CrX + H_2 \rightarrow 2Cr\ (metal) + 2HX \qquad (iii)$$

Once deposition of chromium has occurred onto the substrate, the elevated temperatures used in the process allow subsequent diffusion of the chromium into the surface. Typically a chromium concentration of 40 wt% is achieved at the surface after a coating operation. The depth of diffusion can be controlled by varying the deposition temperature and the residence time at this temperature.

Where surface treatment to form an austenitic surface layer is carried out by electroplating, for example using nickel or manganese, then the chromium diffusion must take place subsequently. Thus, in accordance with the invention, chromium may for example be diffused into the surface of a mild steel blank that has already been precoated with an electroplate of nickel. The depth of this chromium coating is typically up to 50 µm and preferably from 10 - 40 µm. However, if the surface-treatment is to be effected by CVD of manganese, then the manganese and chromium treatments may be carried out by CVD either simultaneously in one step, or sequentially in two separate steps. Advantageously, the chromising treatment in accordance with the invention provides a coinage material which is resistant to corrosion and discolouration, and of an attractive, lustrous, silver-like appearance.

As a result of the austenite-forming and chromising treatments in accordance with the invention, the ferritic, body-centred cubic crystal structure of the blank is transformed in the surface to an austenitic, face-centred cubic crystal structure, thereby significantly altering the material properties of the blank substrate material. The specific, marked differences in properties thus generated between the surface and the interior may then be detected electronically as a means of validation.

Now, in an electronic validator the coin is made to pass through the magnetic field of one or more electrical coils. A sinusoidally varying magnetic field is set up in each coil; the presence of the coin disturbs the field, and the instrument then detects the change in the resonant frequency, phase or amplitude as a means of validation or rejection. The dimensions and material properties of the coin are the relevant factors that serve to characterise it in such validators.

In practice, most electronic mechanisms use several coils operating at different frequencies. When a coin with a low magnetic permeability and low electrical conductivity passes over a coil operating at a relatively low frequency, the electromagnetic field will induce currents at some distance within the coin itself. By contrast, a high frequency coil will tend to induce currents predominantly in the surface of the coin, especially when the coin is made of a material with a high permeability or high conductivity.

The depth (d) of penetration of the magnetic field in the metal is given by the relationship

$$d = \sqrt{\{\rho/2\pi f\mu_o\mu_r\}}$$

where

ρ is the resistivity of the metal,
f is the frequency of the sinusoidal variation of the magnetic field,
μ_o is the permeability of free space,
μ_r is the relative permeability of the metal, and
d is the penetration depth, being the distance into the magnetic field from the surface at which the magnetic field strength is one half of the field strength at the surface.

Thus, by selecting appropriate frequencies for the various coils it is possible to "read" a coin in a vending machine at various depths and to detect the difference in the metal of the core from that of the coating.

The present invention provides a coinage material in which the interior and surface differ very markedly in their relevant properties (resistivity and permeability), and which can therefore be validated with a higher degree of confidence than has hitherto been possible. In particular, the security of chromised coinage is substantially improved.

This may be demonstrated by considering the actual values for the resistivity and relative permeability of the common coinage metals - with reference to the penetration relationship quoted above.

Thus, for homogeneous coinage made from the various copper-based alloys, the relative permeability is close to unity, since, in every case, these alloys are non-ferromagnetic. Discrimination between these alloys therefore depends principally on their resistivities.

The most conductive of the copper-based coinage alloys are the so-called coinage bronzes, for which the resistivity is typically about 35 nΩ-m.

Stainless steel of the AISI 430 type is also used for homogeneous coinage. The quoted resistivity of this alloy is 620 nΩ-m, but because it is a ferromagnetic alloy its relative permeability will be very large, perhaps 1000 or more. Mild steel will similarly exhibit a high relative magnetic permeability, but is of lower resistivity - typically 120 nΩ-m.

The austenitic or face-centered cubic alloys of iron-chromium-nickel (or iron-chromium-manganese) are of even higher resistivity, probably in excess of 1000 nΩ-m, depending on the exact composition. However, because the alloys in question are non-ferromagnetic, their permeability will again be close to unity.

It can be seen from these figures that the invention offers a coinage material with a low-permeability, high resistivity surface in contrast to the interior which has the opposite properties. These marked differences will greatly assist the task of positive discrimination in coin validators, and thereby offer much increased security.

The surface-treatment of the ferritic blank material with the austenite-forming element and the chromium diffusion results in a complex alloy system in the surface of the coin, comprising the iron, chromium and austenite-forming elements. The composition of this alloy changes continuously across the depth of the surface layer. For example, in a preferred embodiment, if nickel plate is used as austenite-forming element to surface-treat a mild steel blank, followed by chromium CVD and diffusion, then the thickness of the nickel plate may be varied independently of the depth of chromium diffusion. Thus, chromium may be diffused into the nickel plate to a depth which is less than the thickness of the nickel plate, or to a greater depth such that chromium diffuses through the nickel plate completely and into the steel base. Moreover, the solubility of the iron and nickel is such that a solid solution of these elements forms at the original boundary of the electroplate and the steel substrate. Consequently, a complex ternary alloy of iron, nickel and chromium may be created following the chromium diffusion. Similarly, various complex alloys of iron, manganese and chromium can be created by controlling the CVD diffusions of manganese and chromium. Thus, a ternary alloy of iron, chromium and an austenite-forming element may be formed. If more than one austenite-forming element is used, a quaternary alloy of iron, chromium and two austenite-forming elements may be formed. Therefore, by controlling the austenite-forming and chromising treatments, the composition profile of the complex alloy system can be varied. It is thus possible to produce different coin specifications, each exhibiting characteristic properties according to the particular complex composition in the surface. Any suitable remote detection means which is able to measure the characteristic properties in the coin surface can then be used to identify a particular coin specification, and thus distinguish it from other coin specifications as a means of validation, even if dimensionally similar.

Claims

1. A coinage material comprising a ferritic blank which has been surface-treated with an austenite-forming element and which has chromium diffused into the surface, such that a specific, marked difference which is electronically detectable exists between the surface and the interior.

2. A coinage material as claimed in claim 1 wherein the coinage material is a struck or unstruck coin, coin blank or token.

3. A coinage material as claimed in claim 1 or claim 2 wherein the blank consists essentially of mild steel.

4. A coinage material as claimed in claim 3 wherein the steel has a negligible content of free interstitial elements such as carbon or nitrogen, and/or is stabilised for example by the inclusion of carbide- and/or nitride-formers.

5. A coinage material as claimed in any of claims 1 to 4 wherein the austenite-forming element is selected from nickel and manganese.

6. A coinage material as claimed in claim 5 wherein the core has been surface-treated with nickel by electroplating or with manganese by chemical vapour deposition or electroplating.

7. A coinage material as claimed in any of claims 1 to 6 wherein the surface comprises a ternary alloy of iron, chromium and the austenite-forming element.

8. A coinage material as claimed in any of claims 1 to 6 wherein the surface comprises a quaternary alloy of iron, chromium and two austenite-forming elements.

9. A coinage material as claimed in any of claims 1 to 8 wherein the difference is in electrical conductivity and/or magnetic permeability.

10. A process for producing a coinage material as claimed in any of claims 1 to 9, which comprises sequentially or simultaneously treating the surface of a ferritic blank with an austenite-forming element and diffusing chromium into the surface.

11. A process as claimed in claim 10 wherein the surface is treated with nickel or manganese by electroplating and is subsequently subjected to the chromium diffusion.

12. A process as claimed in claim 10 or claim 11 wherein the chromium is deposited onto the surface by chemical vapour deposition and allowed to diffuse therein.

13. A process as claimed in claim 12 wherein the surface is treated with manganese by chemical vapour deposition and is subsequently or simultaneously subjected to the chemical vapour deposition and diffusion of chromium.

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EUROPEAN SEARCH REPORT

Application Number
EP 97 30 6863

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
Y	US 4 973 524 A (ULRICH HUEBNER) * column 1, line 41 - column 2, line 2 * * column 2, line 41 - line 54; claims 1,2 *	1,2	C23C10/02 G07F3/02 G07D5/08
Y,D	GB 862 282 A (THE CHROME-ALLOYING COMPANY) * claims 1-4 *	1,2	
A	US 2 819 208 A (PHILIPPE GALMICHE) * column 4, line 50 - line 53 * * column 5, line 23 - line 26; claims 1,4 *	1,5-7, 10-12	
A	DE 17 74 498 B (VEREINIGTE DEUTSCHE METALLWERKE) * column 1, line 32 - line 35 * * column 2, line 25 - line 32; claims 1,8 *	1,5,6	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)
C23C
G07F
G07D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	11 December 1997	Elsen, D

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
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