



(11) **EP 1 600 515 B1**

(12) **EUROPEAN PATENT SPECIFICATION**

(45) Date of publication and mention of the grant of the patent:
30.07.2008 Bulletin 2008/31

(51) Int Cl.:
C22C 9/04^(2006.01) C22F 1/08^(2006.01)

(21) Application number: **05017189.1**

(22) Date of filing: **16.11.1998**

(54) **Lead-free, free-cutting copper alloys**

Bleifreie Automatenkupferlegierung

Alliage de cuivre de décolletage sans plomb

(84) Designated Contracting States:
BE DE FI FR GB IT SE

(30) Priority: **12.10.1998 JP 28859098**

(43) Date of publication of application:
30.11.2005 Bulletin 2005/48

(62) Document number(s) of the earlier application(s) in accordance with Art. 76 EPC:
98953071.2 / 1 045 041

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- **PATENT ABSTRACTS OF JAPAN vol. 1998, no. 04, 31 March 1998 (1998-03-31) -& JP 09 316570 A (CHUETSU GOKIN CHUKO KK), 9 December 1997 (1997-12-09)**
- **PATENT ABSTRACTS OF JAPAN vol. 015, no. 227 (C-0839), 10 June 1991 (1991-06-10) -& JP 03 068731 A (NIPPON MINING CO LTD), 25 March 1991 (1991-03-25)**
- **PATENT ABSTRACTS OF JAPAN vol. 1997, no. 10, 31 October 1997 (1997-10-31) -& JP 09 143598 A (CHUETSU GOKIN CHUKO KK), 3 June 1997 (1997-06-03)**

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Description

BACKGROUND OF THE INVENTION

5 1. Field of The Invention

[0001] The present invention relates to lead-free, free-cutting copper alloys.

10 2. Prior Art

[0002] Among the copper alloys with a good machinability are bronze alloys such as the one under JIS designation H5111 BC6 and brass alloys such as the ones under JIS designations H3250-C3604 and C3771. Those alloys are enhanced in machinability by the addition of 1.0 to 6.0 percent, by weight, of lead and provide an industrially satisfactory machinability. Because of their excellent machinability, those lead-contained copper alloys have been an important basic material for a variety of articles such as city water faucets, water supply/drainage metal fittings and valves.

[0003] However, the application of those lead-mixed alloys has been greatly limited in recent years, because lead contained therein is an environment pollutant harmful to humans. That is, the lead-containing alloys pose a threat to human health and environmental hygiene because lead is contained in metallic vapor that is generated in the steps of processing those alloys at high temperatures such as melting and casting and there is also concern that the lead contained in the water system metal fittings, valves and others made of those alloys will dissolve out into drinking water.

[0004] On that ground, the United States and other advanced countries have been moving to tighten the standards for lead-contained copper alloys to drastically limit the permissible level of lead in copper alloys in recent years. In Japan, too, the use of lead-contained alloys has been increasingly restricted, and there has been a growing call for development of free-cutting copper alloys with a low lead content.

[0005] JP-A-9-316570 discloses an end bearing for a one way clutch having high wear resistance having manganese silicide type high strength brass having $\leq 30\%$ beta phase in its metallic structure. The brass has a chemical composition comprising (1) by weight 15-37% Zn, 0.3-5.0% Mn, 0.3-3.0% Si, and the balance Cu. In addition the composition may composition one or more elements selected from the group consisting of 0.1-5% Al, 0.1-4% Ni, Co, Pb or Bi, 0.1-3% Sn or Fe, 0.05-2% Cr, Ti, V, Zr, Nb or Mo.

30 SUMMARY OF THE INVENTION

[0006] It is an object of the present invention to provide a lead-free copper alloy which does not contain the machinability-improving element lead yet is quite excellent in machinability and can be used as safe substitute for the conventional free cutting copper alloy with a large content of lead presenting environmental hygienic problems and which permits recycling of chips without problems, thus a timely answer to the mounting call for restriction of lead-contained products.

[0007] It is another object of the present invention to provide a lead-free copper alloy which has a high corrosion resistance as well as an excellent machinability and is suitable as basic material for cutting works, forgings, castings and others, thus having a very high practical value. The cutting works, forgings, castings and others include city water faucets, water supply/drainage metal fittings, valves, stems, hot water supply pipe fittings, shaft and heat exchanger parts.

[0008] It is yet another object of the present invention to provide a lead-free copper alloy with a high strength and wear resistance as well as machinability which is suitable as basic material for the manufacture of cutting works, forgings, castings and other uses requiring a high strength and wear resistance such as, for example, bearings, bolts, nuts, bushes, gears, sewing machine parts and hydraulic system parts, hence has a very high practical value.

[0009] It is a further object of the present invention to provide a lead-free copper alloy with an excellent high-temperature oxidation resistance as well as machinability which is suitable as basic material for the manufacture of cutting works, forgings, castings and other uses where a high thermal oxidation resistance is essential, e.g. nozzles for kerosene oil and gas heaters, burner heads and gas nozzles for hot-water dispensers, hence has a very high practical value.

[0010] The objects of the present inventions are achieved by provision of the following copper alloy:

50 The present invention provides a lead-free free-cutting copper alloy also with an excellent machinability and with an excellent high strength feature and high corrosion resistance which is composed of 62 to 78 percent, by weight, of copper; 2.5 to 4.5 percent, by weight, of silicon; at least one element selected from among 0.3 to 3.0 percent, by weight, of tin, 0.2 to 2.5 percent, by weight, of aluminium, and 0.02 to 0.25 percent, by weight, of phosphorus; at least one element selected from among 0.7 to 3.5 percent, by weight, of manganese and 0.7 to 3.5 percent, by weight, of nickel; optionally at least one element selected from among 0.02 to 0.4 percent, by weight, of bismuth, 0.02 to 0.4 percent, by weight, of tellurium, and 0.02 to 0.4 percent, by weight, of selenium; and the remaining percent, by weight, of zinc.

The present invention also provides a method of forming a lead-free, free cutting alloy which comprises having a metal structure which has at least one phase selected from the γ (gamma) phase and the κ (kappa) phase which comprises alloying copper and silicon in an amount of 62 to 78 percent, by weight, of copper; 2.5 to 4.5 percent, by weight, of silicon; at least one element selected from tin, aluminium and phosphorous in an amount of 0.3 to 3.0 percent, by weight, of tin, 0.2 to 2.5 percent, by weight, of aluminium and 0.02 to 0.25 percent, by weight, of phosphorous; at least one element selected from manganese and nickel in an amount of 0.7 to 3.5 percent, by weight, of manganese and 0.7 to 3.5 percent, by weight, of nickel; optionally at least one element selected from bismuth, tellurium and selenium in an amount of 0.02 to 0.4 percent, by weight, of bismuth, 0.02 to 0.4 percent, by weight, of tellurium and 0.02 to 0.4 percent, by weight, of selenium; and the remaining percent, by weight, of zinc. Manganese and nickel combine with silicon to form intermetallic compounds represented by Mn_xSi_y or Ni_xSi_y which are evenly precipitated in the matrix, thereby raising the wear resistance and strength. Therefore, the addition of manganese and/or nickel would improve the high strength feature and wear resistance. Such effects will be exhibited if manganese and nickel are added in an amount not smaller than 0.7 percent by weight respectively. But the saturation state is reached at 3.5 percent by weight, and even if the addition is increased beyond that, no proportional results will be obtained. The addition of silicon is set at 2.5 to 4.5 percent by weight to match the addition of manganese or nickel, taking into consideration the consumption to form intermetallic compounds with those elements.

[0011] It is also noted that tin, aluminum and phosphorus help to reinforce the alpha phase in the matrix, thereby improving strength, wear resistance, and also machinability. Tin and phosphorus disperse the alpha and gamma phases, by which the strength, wear resistance and also machinability are improved. Tin in an amount of 0.3 or more percent by weight is effective in improving the strength and machinability. But if the addition exceeds 3.0 percent by weight, the ductility will fall. For this reason, the addition of tin is set at 0.3 to 3.0 percent by weight to raise the high strength feature and wear resistance in the alloy of the present invention to enhance the machinability. Aluminium also contributes to improving the wear resistance and exhibits its effect of reinforcing the matrix when added in 0.2 or more percent by weight. But if the addition exceeds 2.5 percent by weight, there will be a fall in ductility. Therefore, the addition of aluminium is set at 0.2 to 2.5 in consideration of improvement of machinability. Also, the addition of phosphorus disperses the gamma phase and at the same time refines the crystal grains in the alpha phase in the matrix, thereby improving the hot workability and also the strength and wear resistance. Furthermore, it is very effective in improving the flow of molten metal in casting. Such results will be produced when phosphorus is added in the range of 0.02 to 0.25 percent by weight. The content of copper is set at 62 to 78 percent by weight in the light of the addition of silicon and bonding of silicon with manganese and nickel.

[0012] The alloy of the present invention contains at least one element selected from among 0.02 to 0.4 percent, by weight, of bismuth, 0.02 to 0.4 percent, by weight, of tellurium, and 0.02 to 0.4 percent, by weight, of selenium. Addition of these elements causes an improvement in machinability by adding at least one element selected among bismuth and other elements which are effective in raising the machinability through a mechanism different from that exhibited by silicon.

[0013] Bismuth, tellurium and selenium as well as lead do not form a solid solution in the matrix but disperse in granular form to enhance the machinability and that through a mechanism different from that of silicon. Hence, the addition of those elements along with silicon could further improve the machinability beyond the level obtained by the addition of silicon alone. From this finding, the alloy of the present invention is provided in which at least one element selected from bismuth, tellurium and selenium is mixed to improve further the machinability of the alloy of the present invention. The addition of bismuth, tellurium or selenium in addition to silicon produces a high machinability such that complicated forms could be freely cut at a high speed. But no improvement in machinability can be realized from the addition of bismuth, tellurium or selenium in an amount less than 0.02 percent, by weight. Meanwhile, those elements are expensive as compared with copper. Even if the addition exceeds 0.4 percent by weight, the proportional improvement in machinability is so small that the addition beyond that does not pay economically. What is more, if the addition is more than 0.4 percent by weight, the alloy will deteriorate in hot workability such as forgeability and cold workability such as ductility. While it might be feared that heavy metals like bismuth would cause problems similar to those of lead, an addition in a very small amount of less than 0.4 percent by weight is negligible and would present no particular problems. From those considerations, the second invention alloy is prepared with the addition of bismuth, tellurium or selenium kept to 0.02 to 0.4 percent by weight. The addition of those elements, would not effect the proper contents of copper and silicon.

[0014] The alloy of the present invention may have further improved machinability obtained by subjecting it to a heat treatment for 30 minutes to 5 hours at 400°C to 600°C.

[0015] The alloys of the present invention contain machinability improving elements such as silicon and have an excellent machinability because of the addition of such elements. Of the invention alloys, the alloys with a high copper content which have great amounts of other phases, mainly kappa phase, than alpha, beta, gamma and delta phases can further improve in machinability in a heat treatment. In the heat treatment, the kappa phase turns to a gamma phase. The gamma phase finely disperses and precipitates to further enhance the machinability. The alloys with a high content of copper are high in ductility of the matrix and low in absolute quantity of gamma phase, and therefore are excellent in

cold workability. But in case cold working such as caulking and cutting are required, the aforesaid heat treatment is very useful. In other words, among the alloys of the present invention, those which are high in copper content with gamma phase in small quantities and kappa phase in large quantities (hereinafter referred to as the "high copper content alloy") undergo a change in phase from the kappa phase to the gamma phase in a heat treatment. As a result, the gamma phase is finely dispersed and precipitated, and the machinability is improved. In the manufacturing process of castings, expanded metals and hot forgings in practice, the materials are often force-air-cooled or water cooled depending on the forging conditions, productivity after hot working (hot extrusion, hot forging etc.), working environment and other factors. In such cases, among the alloys of the present invention, those with low content of copper (hereinafter called the low copper content alloy") are rather low in the content of the gamma phase and contain beta phase. In a heat treatment, the beta phase changes into gamma phase, and the gamma phase is finely dispersed and precipitated, whereby the machinability is improved. Experiments showed that heat treatment is especially effective with high copper content alloys where mixing ratio of copper and silicon to other added elements (except for zinc) A is given as $67 \leq \text{Cu} - 3\text{Si} + a\text{A}$ or low copper content alloys with such a composition with $64 \geq \text{Cu} - 3\text{Si} + a\text{A}$. It is noted that a is a coefficient. The coefficient is different depending on the added element A. For example, with tin a is - 0.5; aluminium, -2; phosphorus, -3; antimony, 0; arsenic, 0; manganese, +2.5; and nickel, +2.5.

[0016] But a heat treatment temperature at less than 400°C is not economical and practical, because the aforesaid phase change will proceed slowly and much time will be needed. At temperatures over 600°C, on the other hand, the kappa phase will grow or the beta phase will appear, bringing about no improvement in machinability. From the practical viewpoint, therefore, it is desired to perform the heat treatment for 30 minutes to 5 hours at 400 to 600°C.

BRIEF DESCRIPTION OF THE DRAWING

[0017]

Fig. 1 shows perspective views of cuttings formed in cutting a round bar of copper alloy by lathe.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Example 1

[0018] As the first series of examples of the present invention, cylindrical ingots with compositions given in Tables 1 to 18, each 100 mm in outside diameter and 150 mm in length, were hot extruded into a round bar 15 mm in outside diameter at 750°C to produce the following test pieces: alloys Nos. 7001 to 7030 and 8001 to 8147.

[0019] As comparative examples, cylindrical ingots with the compositions as shown in Table 19, each 100 mm in outside diameter and 150 mm in length, were hot extruded into a round bar 15 mm in outside diameter at 750°C to obtain the following round extruded test pieces: Nos. 14001 to 14006 (hereinafter referred to as the "conventional alloys"). No. 14001 corresponds to the alloy "JIS C 3604", No. 14002 to the alloy "CDA C 36000", No. 14003 to the alloy "JIS C 3771", and No. 14004 to the alloy "CDA C 69800", No. 14005 corresponds to the alloy "JIS C 6191". This aluminium bronze is the most excellent of the expanded copper alloys under the JIS designations with regard to strength and wear resistance. No. 14006 corresponds to the naval brass alloy "JIS C 4622" and is the most excellent of the expanded copper alloys under the JIS designations with regard to corrosion resistance.

[0020] To study the machinability of the alloys of the present invention alloys in comparison with the conventional alloys, cutting tests were carried out. In the tests, evaluations were made on the basis of cutting force; condition of chips cut surface condition.

[0021] The tests were conducted this ways: The extruded test pieces obtained, as mentioned above, were cut on the circumferential surface by a lathe mounted with a point nose straight tool at a rake angle of - 8 degrees and at a cutting rate of 50 meters/minute, a cutting depth of 1.5 mm, a feed of 0.11 mm/rev. Signals from a three-component dynamometer mounted on the tool were converted into electric voltage signals and recorded on a recorder. From the signals were then calculated the cutting resistance. It is noted that while, to be perfectly exact, an amount of the cutting resistance should be judged by three component forces - cutting force, feed force and thrust force, the judgement was made on the basis of the cutting force (N) of the three component forces in the present example. The results are shown in Table 20 to Table 29.

[0022] Furthermore, the chips from the cutting work were examined and classified into four forms (A) to (D) as shown in Fig. 1. The results are enumerated in Table 20 to Table 29. In this regard, the chips in the form of a spiral with three or more windings as (D) in Fig. 1 are difficult to process, that is, recover or recycle, and could cause trouble in cutting work as, for example, getting tangled with the tool and damaging the cut metal surface. Chips in the form of an arc with a half winding to a spiral with two about windings as shown in (C), Fig. 1 do not cause such serious trouble as the chips in the form of a spiral with three or more windings yet are not easy to remove and could get tangled with the tool or

damage the cut metal surface. In contrast, chips in the form of a fine needle as (A) in Fig. 1 or in the form of an arc as (B) will not present such problems as mentioned above and are not bulky as the chips in (C) and (D) and easy to process. But fine chips as (A) still could creep into the sliding surfaces of a machine tool such as a lathe and cause mechanical trouble, or could be dangerous because they could stick into the worker's finger, eye or other body parts. Those taken into account, it is appropriate to consider that the chips in (B) are the best, and the second best are the chips in (A). Those in (C) and (D) are not good. In Table 20 to Table 29, the chips judged to be shown in (B), (A), (C) and (D) are indicated by the symbols "●", "○", "△" and "×" respectively.

[0023] In addition, the surface condition of the cut metal surface was checked after cutting work. The results are shown in Table 20 to Table 29. In this regard, the commonly used basis for indication of the surface roughness is the maximum roughness (R_{max}). While requirements are different depending on the application field of brass articles, the alloys with R_{max} < 10 microns are generally considered excellent in machinability. The alloys with 10 microns ≤ R_{max} < 15 microns are judged as industrially acceptable, while those with R_{max} ≥ 15 microns are taken as poor in machinability. In Table 20 to Table 29, the alloys with R_{max} < 10 microns are marked "o", those with 10 microns ≤ R_{max} < 15 microns are indicated as "△" and those with R_{max} ≥ 15 microns are represented by symbol "x".

[0024] As is evident from the results of the cutting tests shown in Table 20 to Table 29, the following invention alloys are all equal to the conventional lead- contained alloys Nos 14001 to 14003 in machinability: alloy Nos. 7001 to 7030 and 8001 to 8147. Especially with regard to formation of the chips, those invention alloys are favourably compared not only with the conventional alloys Nos. 14004 to 14006 with a lead content of not higher than 0.1 percent by weight but also Nos. 14001 to 14003 which contain large quantities of lead.

[0025] In another series of tests, the alloys of the present invention were examined in comparison with the conventional alloys in hot workability and mechanical properties. For the purpose, hot compression and tensile tests were conducted the following way.

[0026] First, two test pieces, first and second test pieces, in the same shape 15 mm in outside diameter and 25 mm in length were cut out of each extruded test piece obtained as described above. In the hot compression tests, the first test piece was held for 30 minutes at 700°C, and then compressed 70 percent in the direction of axis to reduce the length from 25 mm to 7.5 mm. The surface condition after the compression (700°C deformability) was visually evaluated. The results are given in Table 20 to Table 29. The evaluation of deformability was made by visually checking for cracks on the side of the test piece. In Table 20 to Table 29, the test pieces with no cracks found are marked "o", those with small cracks are indicated in "△" and those with large cracks are represented by a symbol "x".

[0027] The second test pieces were put to a tensile test by the commonly practised test method to determine the tensile strength, N/mm² and elongation, %.

[0028] As the test results of the hot compression and tensile tests in Table 20 to Table 29 indicate, it was confirmed that the alloys of the present invention are equal to or superior to the conventional alloys Nos. 14001 to 14004 and No. 14006 in hot workability and mechanical properties and are suitable for industrial use. The alloys of the present invention in particular have the same level of mechanical properties as the conventional alloy No. 14005, the aluminium bronze which is the most excellent in strength of the expanded copper alloys under the JIS designations, and thus have understandably a prominent high strength feature.

Example 2

[0029] As the second series of examples of the present invention, cylindrical ingots with compositions given in Tables 1-18, each 100 mm in outside diameter and 200 mm in length, were hot extruded into a round bar 35 mm in outside diameter at 700°C to produce the following test pieces: alloy Nos. 7001a to 7030a and alloys Nos. 8001a to 8147a. In parallel, cylindrical ingots with compositions given in Table 19 each 100 mm in outside diameter and 200 mm in length, were hot extruded into a round bar 35 mm in outside diameter at 700 C to produce the following alloy test pieces: Nos. 14001a to 14006a as second comparative examples (hereinafter referred to as the "conventional alloys"). It is noted that the alloys Nos. 7001a to 7030a, Nos. 8001a to 8147a and Nos. 14001a to 14006a are identical in composition with the aforesaid copper alloys Nos. 7001 to 7030, Nos. 8001 to 8147 and Nos. 14001 to No. 14006 respectively.

[0030] Those alloys Nos. 7001a to 7030a and alloys Nos. 8001a to 8147a were put to wear resistance tests in comparison with the conventional alloys Nos. 14001a to 14006a.

[0031] The tests were carried out in this procedure. Each extruded test piece thus obtained was cut on the circumferential surface, holed and cut down into a ringshaped test piece 32 mm in outside diameter and 10 mm in thickness (that is, the length in the axial direction). The test piece was then fitted around a free-rotating shaft, and a roll 48 mm in outside diameter placed in parallel with the axis of the shaft was urged against the test piece under a load of 50 kg. The roll was made of stainless steel under the JIS designation SUS 304. Then, the SUS 304 roll and the test piece put in rotational sliding contact with the roll were rotated at the same rate of revolutions/minute - 209 r.p.m., with multipurpose gear oil being dropped onto the circumferential surface of the test piece. When the number of revolutions reached 100,000, the SUS 304 roll and the test piece were stopped, and the weight difference between the start and the end of

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rotation, that is, the loss of weight by wear, mg, was determined. It can be said that the alloys which are smaller in the loss of weight by wear are higher in wear resistance. The results are given in Tables 30 to 40.

[0032] As is clear from the wear resistance test results shown in Tables 30 to 40, the tests showed that those alloys Nos. 7001a to 7030a and eighth Nos. 8001a to 8147a were excellent in wear resistance as compared with not only the conventional alloys Nos. 14001a to 14004a and 14006a but also No. 14005a, which is an aluminium bronze having a highest wear resistance of the expanded copper alloys under the JIS designations. From comprehensive considerations of the test results including the tensile test results, it may safely be said that the seventh and eighth invention alloys are excellent in machinability and also possess a higher strength feature and wear resistance than the aluminum bronze which is the highest in wear resistance of all the expanded copper alloys under the JIS designations.

Table 1

No.	alloy composition (wt%)							
	Cu	Si	Sn	Al	P	Mn	Ni	Zn
7001	62.9	2.7	2.6			2.2		remainder
7001a								
7002	64.8	3.4	1.8				3.1	remainder
7002a								
7003	68.2	4.1	0.6			1.9	1.5	remainder
7003a								
7004	66.5	3.5	1.9	0.9		1.9		remainder
7004a								
7005	71.3	3.7	0.4	1.8			2.3	remainder
7005a								
7006	73.6	2.9	0.7	2.1		1.3	0.8	remainder
7006a								
7007	70.1	3.2	0.5	1.4	0.11	1.8		remainder
7007a								
7008	77.1	4.2	0.8	2.3	0.03		1.8	remainder
7008a								
7009	67.3	3.7	2.6	0.2	0.08	0.9	1.8	remainder
7009a								
7010	75.5	3.9		2.3		0.8		remainder
7010a								

Table 2

No.	alloy composition (wt%)							
	Cu	Si	Sn	Al P		Mn	Ni	Zn
7011	69.8	3.4		0.3			1.3	remainder
7011a								
7012	71.2	4.0		1.4		2.1	1.2	remainder
7012a								
7013	73.3	3.9		2.0	0.03	3.2		remainder
7013a								

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(continued)

No.	alloy composition (wt%)							
	Cu	Si	Sn	Al	P	Mn	Ni	Zn
7014	65.9	2.9		0.3	0.21		1.3	remainder
7014a								
7015	68.8	3.9		1.1	0.05	0.9	2.0	remainder
7015a								
7016	68.1	4.0	0.4		0.04	2.8		remainder
7016a								
7017	63.8	2.6	2.7		0.19		0.9	remainder
7017a								
7018	66.7	3.4	1.3		0.07	1.2	0.8	remainder
7018a								
7019	67.2	3.6			0.21	1.9		remainder
7019a								
7020	69.1	3.8			0.06		2.2	remainder
7020a								

Table 3

No.	alloy composition (wt%)							
	Cu	Si	Sn	Al	P	Mn	Ni	Zn
7021	72.1	4.3			0.07	2.0	0.8	remainder
7021a								
7022	71.3	3.9		1.1		3.1		remainder
7022a								
7023a	70.5	3.5		1.6		2.3		remainder
7023a								
7024	70.0	3.6		1.5			3.2	remainder
7024a								
7025	69.3	2.7		2.1		0.9		remainder
7025a								
7026	70.2	3.5		1.4			2.1	remainder
7026a								
7027	65.0	2.8	2.6	2.3		0.8		remainder
7027a								
7028	69.8	3.6	1.5	1.7		2.4		remainder
7028a								
7029	71.0	3.6	0.4	0.3		2.2		remainder
7029a								

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(continued)

No.	alloy composition (wt%)							
	Cu	Si	Sn	Al	P	Mn	Ni	Zn
7030	68.4	4.2	2.6			3.3		remainder
7030a								

Table 4

No.	alloy composition (wt%)								
	Cu	Si	Sn	Al	Bi	Te	Se	Mn	Zn
8001	62.6	2.6	2.6		0.31			1.9	remainder
8001a									
8002	65.3	3.4	1.8		0.11	0.02		2.5	remainder
8002a									
8003	66.4	4.2	0.5		0.05		0.03	3.4	remainder
8003a									
8004	72.1	4.4	0.4		0.06	0.05	0.02	2.8	remainder
8004a									
8005	67.4	3.3	2.3			0.31		0.9	remainder
8005a									
8006	63.8	2.8	2.9			0.06	0.07	2.1	remainder
8006a									
8007	71.5	3.9	1.5				0.20	1.4	remainder
8007a									
8008	64.2	2.9	2.4	0.3	0.28			2.1	remainder
8008a									
8009	68.8	3.4	1.0	1.5	0.07	0.20		1.7	remainder
8009a									
8010	65.3	3.6	2.8	0.2	0.05		0.13	2.2	remainder
8010a									

Table 5

No.	alloy composition (wt%)									
	Cu	Si	Sn	Al	Bi	Te	Se	P	Mn	Zn
8011	66.8	3.3	1.9	2.1	0.04	0.05	0.05		2.3	remainder
8011a										
8012	75.1	4.1	0.4	2.4		0.03			1.8	remainder
8012a										
8013	74.2	3.9	0.5	1.8		0.10	0.04		1.7	remainder
8013a										

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(continued)

No.	alloy composition (wt%)									
	Cu	Si	Sn	Al	Bi	Te	Se	P	Mn	Zn
8014	77.1	4.2	0.4	2.1			0.32		2.0	remainder
8014a										
8015	62.8	2.6	2.9		0.12			0.03	1.2	remainder
8015a										
8016	64.4	2.9	2.7		0.23	0.09		0.13	1.8	remainder
8016a										
8017	68.3	3.6	0.4		0.05		0.05	104	2.2	remainder
8017a										
8018	73.2	4.3	0.5		0.06	0.02	0.11	0.02	3.1	remainder
8018a										
8019	72.4	4.1	0.7			0.14		0.21	2.1	remainder
8019a										
8020	69.5	3.7	0.7			0.06	0.04	0.05	1.9	remainder
8020a										

Table 6

No.	alloy composition (wt%)									
	Cu	Si	Sn	Al	Bi	Te	Se	P	Mn	Zn
8021	64.2	3.4	2.5				0.31	0.03	1.9	remainder
8021a										
8022	65.6	3.7	2.3	0.2	0.06			0.03	1.4	remainder
8022a										
8023	67.1	3.6	0.4	0.5	0.04	0.05		0.05	2.0	remainder
8023a										
8024	73.2	4.0	0.5	2.1	0.03		0.05	0.12	2.4	remainder
8024a										
8025	68.8	3.5	0.4	1.8	0.12	0.03	0.03	0.04	1.8	remainder
8025a										
8026	66.5	3.4	1.2	0.3		0.24		0.21	1.7	remainder
8026a										
8027	64.8	3.0	1.3	1.2		0.16	0.10	0.06	1.5	remainder
8027a										
8028	71.2	3.9	0.4	1.0			0.14	0.03	2.6	remainder
8028a										
8029	68.1	3.6		0.2	0.05				2.0	remainder
8029a										

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(continued)

No.	alloy composition (wt%)									
	Cu	Si	Sn	Al	Bi	Te	Se	P	Mn	Zn
8030	64.9	2.9		0.3	0.28	0.08			1.0	remainder
8030a										

Table 7

No.	alloy composition (wt%)									
	Cu	Si	Al	Bi	Te	Se	P	Mn	Zn	
8031	75.3	3.9	2.1	0.07		0.04		0.8	remainder	
8031a										
8032	77.2	4.3	2.3	0.03	0.25	0.04		2.8	remainder	
8032a										
8033	64.7	2.8	2.2		0.33			0.9	remainder	
8033a										
8034	69.3	3.5	1.6		0.03	0.03		1.8	remainder	
8034a										
8035	71.2	3.8	1.5			0.21		2.0	remainder	
8035a										
8036	70.6	3.7	0.3	0.04			0.13	1.7	remainder	
8036a										
8037	69.7	3.8	1.4	0.12	0.04		0.04	1.8	remainder	
8037a										
8038	70.7	4.2	1.5	0.03		0.16	0.03	3.3	remainder	
8038a										
8039	70.4	3.9	0.2	0.15	0.10	0.02	0.04	2.2	remainder	
8039a										
8040	68.8	3.7	0.4		0.05		0.12	1.9	remainder	
8040a										

Table 8

No.	alloy composition (wt%)										
	Cu	Si	Sn	Al	Bi	Te	Se	P	Mn	Ni	Zn
8041	70.3	3.9		0.2		0.20	0.03	0.22	2.1		remainder
8041a											
8042	74.6	4.3		2.1			0.12	0.03	2.4		remainder
8042a											
8043	77.0	4.5			0.03			0.12	1.7		remainder
8043a											

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(continued)

No.	alloy composition (wt%)										
	Cu	Si	Sn	Al	Bi	Te	Se	P	Mn	Ni	Zn
8044	70.6	3.9			0.10	0.06		0.04	2.6		remainder
8044a											
8045	74.2	4.3			0.11		0.21	0.16	2.8		remainder
8045a											
8046	69.9	3.8			0.06	0.11	0.03	0.08	1.2		remainder
8046a											
8047	66.8	3.4				0.09		0.06	2.2		remainder
8047a											
8048	71.3	4.2				0.04	0.05	0.05	1.4		remainder
8048a											
8049	72.4	4.1					0.12	0.09	2.7		remainder
8049a											
8050	62.9	2.8	2.8		0.12					1.5	remainder
8050a											

Table 9

No.	alloy composition (wt%)									
	Cu	Si	Sn	Al	Bi	Te	Se	Ni Zn		
8051	64.8	3.1	2.4		0.08	0.03		2.0	remainder	
8051a										
8052	68.9	3.9	0.3		0.03		0.06	1.8	remainder	
8052a										
8053	67.3	3.7	0.7		0.05	0.04	0.04	2.1	remainder	
8053a										
8054	66.5	3.8	0.9			0.31		2.2	remainder	
8054a										
8055	73.8	4.3	2.1			0.03	0.05	3.3	remainder	
8055a										
8056	74.2	4.4	1.3				0.03	2.7	remainder	
8056a										
8057	70.1	3.8	1.5	1.9	0.06			1.8	remainder	
8057a										
8058	67.9	2.9	0.88	2.3	0.16	0.06		0.9	remainder	
8058a										
8059	68.2	3.6	2.0	0.6	0.04		0.09	1.7	remainder	
8059a										

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(continued)

No.	alloy composition (wt%)									
	Cu	Si	Sn	Al	Bi	Te	Se	Ni Zn		
8060	66.6	3.5	1.8	0.2	0.10	0.05	0.05	1.2	remainder	
8060a										

Table 10

No.	alloy composition (wt%)										
	Cu	Si	Sn	Al	Bi	Te	Se	P	Ni	Zn	
8061	67.6	3.6	0.44	0.6		0.30			1.8	remainder	
8061a											
8062	68.8	3.0	0.6	2.1		0.08	0.03		1.1	remainder	
8062a											
8063	71.2	4.1	2.4	0.8			0.31		2.2	remainder	
8063a											
8064	68.2	3.6	2.6		0.04			0.05	1.5	remainder	
8064a											
8065	63.9	2.9	2.3		0.32	0.02		0.08	0.8	remainder	
8065a											
8066	70.5	3.9	1.1		0.05		0.05	0.05	2.2	remainder	
8066a											
8067	67.7	3.7	1.2		0.09	0.03	0.02	0.04	2.0	remainder	
8067a											
8068	66.6	3.5	1.4			0.06		0.04	2.6	remainder	
8068a											
8069	72.3	4.1	0.6			0.05	0.04	0.10	3.0	remainder	
8069a											
8070	70.6	4.0	0.4				0.16	0.05	3.2	remainder	
8070a											

Table 11

No.	alloy composition (wt%)										
	Cu	Si	Sn	Al	Bi	Te	Se	P	Ni	Zn	
8071	75.6	3.9	0.5	2.2	0.21			0.21	1.4	remainder	
8071a											
8072	71.2	3.4	0.7	1.5	0.18	0.10		0.14	1.3	remainder	
8072a											
8073	68.5	3.7	0.7	1.2	0.03		0.08	0.03	1.9	remainder	
8073a											

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(continued)

No.	alloy opposition (wt%)									
	Cu	Si	Sn	Al	Bi	Te	Se	P	Ni	Zn
8074	64.9	3.2	0.8	0.4	0.12	0.03	0.04	0.04	1.8	remainder
8074a										
8075	65.3	3.3	2.8	0.2		0.06		0.05	1.5	remainder
8075a										
8076	68.8	4.0	2.5	0.6		0.05	0.13	0.03	2.7	remainder
8076a										
8077	67.3	3.4	1.6	0.5			0.06	0.12	2.4	remainder
8077a										
8078	77.0	4.1		2.2	0.13				2.1	remainder
8078a										
8079a	71.2	3.8		1.4	0.05	0.20			2.0	remainder
8079a										
8080	68.2	3.8		1.3	0.04		0.05		2.8	remainder
8080a										

Table 12

No.	alloy composition(wt%)									
	Cu	Si	Al	Bi	Te	Se	P	Ni	Zn	
8081	67.3	3.4	0.8	0.05	0.06	0.03			1.7	remainder
8081a										
8082	70.4	3.9	1.2		0.05			2.2	remainder	
8082a										
8083	73.6	3.9	1.3		0.21	0.06		3.1	remainder	
8083a										
8084	68.8	3.8	1.2			0.18		2.6	remainder	
8084a										
8085	67.5	3.5	1.2	0.04			0.16	1.8	remainder	
8085a										
8086	64.9	2.9	1.6	0.08	0.04		0.05	1.5	remainder	
8086a										
8087	76.3	4.3	1.5	0.29		0.05	0.10	2.8	remainder	
8087a										
8088	65.8	2.8	2.3	0.16	0.06	0.03	0.05	1.3	remainder	
8088a										
8089	66.7 7	3.3	2.1		0.32		0.03	1.8	remainder	
8089a										

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(continued)

No.	alloy composition(wt%)								
	Cu	Si	Al	Bi	Te	Se	P	Ni	Zn
8090	69.2	4.0	1.2		0.11	0.02	0.10	2.5	remainder
8090a									

Table 13

No.	alloy composition (wt%)										
	Cu	Si	Sn	Al	Bi	Te	Se	P	Mn	Ni	Zn
8091	70.6	3.8		1.3			0.14	0.05		1.7	remainder
8091a											
8092	67.2	3.4			0.05			0.04		2.0	remainder
8092a											
8093	65.8	3.2			0.15	0.03		0.06		1.2	remainder
8093a											
8094	67.7	3.7			0.06		0.10	0.08		2.1	remainder
8094a											
8095	64.7	2.9			0.31	0.04	0.05	0.09		1.5	remainder
8095a											
8096	66.5	3.6				0.18		0.21		2.3	remainder
8096a											
8097	67.3	3.8				0.08	0.05	0.12		2.2	remainder
8097a											
8098	65.9	3.6					0.21	0.20		2.5	remainder
8098a											
8099	64.9	3.6	0.4		0.18				0.8	2.6	remainder
8099a											
8100	67.3	3.8	1.8		0.03	0.06			1.9	1.0	remainder
8100a											

Table 14

No.	alloy composition (wt%)									
	Cu	Si	Sn	Al	Bi	Te	Se	Mn	Ni	Zn
8101	62.9	2.9	2.4		0.20		0.16	1.3	0.9	remainder
8101a										
8102	68.3	3.4	0.5		0.04	0.04	0.05	1.5	0.8	remainder
8102a										
8103	65.8	3.8	2.6			0.03		1.4	1.2	remainder
8103a										

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(continued)

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No.	alloy composition (wt%)									
	Cu	Si	Sn	Al	Bi	Te	Se	Mn	Ni	Zn
8104	64.7	3.6	2.7			0.25	0.03	1.3	1.6	remainder
8104a										
8105	70.4	3.9	1.8				0.07	1.0	2.0	remainder
8105a										
8106	70.3	3.8	0.4	1.8	0.05			2.3	0.7	remainder
8106a										
8107	72.1	3.7	0.4	2.1	0.03	0.05		1.3	1.2	remainder
8107a										
8108	69.8	3.8	0.6	1.5	0.05		0.05	1.5	2.1	remainder
8108a										
8109	75.4	4.2	0.6	1.8	0.05	0.04	0.04	2.3	1.1	remainder
8109a										
8110	66.4	3.5	2.5	0.2		0.12		1.6	0.9	remainder
8110a										

Table 15

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No.	alloy composition (wt%)										
	Cu	Si	Sn	Al	Bi	Te	Se	P	Mn	Ni	Zn
8111	64.9	3.3	2.5	0.3		0.08	0.05		1.2	1.3	remainder
8111a											
8112	70.0	3.8	1.2	0.5			0.03		1.5	0.8	remainder
8112a											
8113	72.0	3.9	1.1		0.25			0.20	2.4	0.9	remainder
8113a											
8114	66.5	3.6	1.2		0.06	0.04		0.05	1.3	1.1	remainder
8114a											
8115	67.0	3.5	1.3		0.12		0.04	0.08	0.9	1.2	remainder
8115a											
8116	64.0	2.8	2.6		0.30	0.08	0.03	0.05	0.8	1.0	remainder
8116a											
8117	67.3	3.7	2.3			0.03		0.03	1.2	1.3	remainder
8117a											
8118	66.4	3.8	2.4			0.05	0.15	0.03	1.0	1.6	remainder
8118a											
8119	70.2	3.9	0.5				0.30	0.07	1.7	0.9	remainder
8119a											

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(continued)

No.	alloy composition (wt%)										
	Cu	Si	Sn	Al	Bi	Te	Se	P	Mn	Ni	Zn
8120	73.1	4.2	0.5	2.3	0.04			4.14	2.00	1.1	remainder
8120a											

Table 16

No.	alloy composition (wt%)										
	Cu	Si	Sn	Al	Bi	Te	Se	P	Mn	Ni	Zn
8121	71.0	3.6	0.6	2.3	0.03	0.12		0.20	1.8	1.3	remainder
8121a											
8122	70.0	3.5	0.5	1.8	0.06		0.03	0.10	1.2	1.3	remainder
8122a											
8123	68.5	3.4	0.5	0.7	0.30	0.03	0.02	0.03	1.0	1.5	remainder
8123a											
8124	68.8	3.9	1.2	0.2		0.06		0.05	1.0	1.2	remainder
8124a											
8125	64.9	3.0	1.8	0.5		0.25	0.05	0.05	1.1	0.8	remainder
8125a											
8126	63.7	2.9	2.7	1.0			0.31	0.03	1.2	0.8	remainder
8126a											
8127	70.4	3.9		0.2	0.04				1.6	1.3	remainder
8127a											
8128	66.5	3.6		0.3	0.02	0.04			1.2	1.1	remainder
8128a											
8129	67.3	3.7		0.7	0.03		0.08		1.3	1.2	remainder
8129a											
8130	66.0	3.4		0.7	0.22	0.08	0.04		1.3	1.0	remainder
8130a											

Table 17

No.	alloy composition (wt%)										
	Cu	Si	Al	Bi	Te	Se	P	Mn	Ni	Zn	
8131	68.0	3.8	0.8		0.05			1.1	1.4	remainder	
8131a											
8132	70.0	3.4	2.1		0.03	0.22		0.9	1.1	remainder	
8132a											
8133	75.5	4.2	2.2			0.05		1.2	1.9	remainder	
8133a											

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(continued)

No.	alloy composition (wt%)									
	Cu	Si	Al	Bi	Te	Se	P	Mn	Ni	Zn
8134	68.5	3.8	1.8	0.10			0.04	1.4	1.6	remainder
8134a										
8135	78.5	4.3	2.1	0.03	0.10		0.15	1.8	1.3	remainder
8135a										
8136	66.5	3.6	1.2	0.05		0.16	0.05	1.2	1.3	remainder
8136a										
8137	72.0	4.1	1.0	0.04	0.03	0.02	0.07	1.3	2.2	remainder
8137a										
8138	70.2	4.0	1.0		0.04		0.03	2.1	1.4	remainder
8138a										
8139	66.8	3.8	0.5		0.32	0.03	0.03	1.2	1.6	remainder
8139a										
8140	67.3	3.9	0.4			0.05	0.03	1.8	1.0	remainder
8140a										

Table 18

No.	alloy composition (wt%)									
	Cu	Si	Bi	Te	Se	P	Mn	Ni	Zn	
8141	66.5	3.6	0.05			0.05	1.5	1.2	remainder	
8141a										
8142	63.9	2.9	0.30	0.03		0.04	1.2	0.9	remainder	
8142a										
8143	68.4	3.8	0.03		0.05	0.12	0.9	2.5	remainder	
8143a										
8144	65.8	3.4	0.10	0.05	0.02	0.03	1.0	1.4	remainder	
8144a										
8145	70.5	3.9		0.12		0.05	2.6	0.8	remainder	
8145a										
8146	72.0	4.2		0.04	0.05	0.18	1.0	2.4	remainder	
8146a										
8147	68.0	3.7			0.20	0.06	1.5	1.0	remainder	
8147a										

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Table 19

No.	alloy composition (wt%)								
	Cu	Si	Sn	Al	Mn	Pb	Fe	Ni	Zn
14001	58.8		0.2			3.1	0.2		remainder
14001a									
14002	61.4		0.2			3.0	0.2		remainder
14002a									
14003	59.1		0.2			2.0	0.2		remainder
14003a									
14004	69.2	1.2				0.1			remainder
14004a									
14005	remainder			9.8	1.1		3.9	1.2	
14005a									
14006	61.8		1.0			0.1			remainder
14006a									

Table 20

No.	machinability			hot workability	mechanical properties	
	form of chippings	condition of cut surface	cutting force (N)	700°C deformability	tensile strength (N/mm ²)	elongation (%)
7001	⊙	Δ	138	○	670	18
7002	⊙	Δ	136	○	712	20
7003	⊙	○	132	○	783	23
7004	⊙	○	138	○	736	21
7005	⊙	○	136	○	785	23
7006	⊙	Δ	139	○	700	24
7007	Δ	○	138	○	707	23
7008	⊙	○	131	○	805	22
7009	⊙	○	136	○	768	19
7010	⊙	○	135	○	718	23
7011	Δ	○	137	○	677	23
7012	⊙	○	134	○	800	21
7013	⊙	○	133	○	819	22
7014	Δ	○	138	○	641	21
7015	⊙	○	134	○	764	23
7010	⊙	○	129	○	759	20
7017	Δ	○	139	○	638	18
7018	⊙	○	135	○	717	20
7019	⊙	○	136	○	694	24
7020	Δ	○	138	○	712	25

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Table 21

No.	machinability			hot workability	mechanical properties	
	form of chippings	condition of cut surface	cutting force (N)	700 °C deformability	tensile strength (N/mm ²)	elongation (%)
7021	⊙	○	130	○	754	24
7022	⊙	Δ	134	○	780	23
7023	⊙	○	133	○	765	22
7024	⊙	○	135	○	772	23
7025	Δ	○	138	○	687	24
7026	⊙	○	135	○	718	24
7027	⊙	Δ	136	○	742	18
7028	Δ	○	138	○	785	20
7029	⊙	○	134	○	703	23
7030	⊙	○	135	○	820	18

Table 22

No.	machinability			hot workability	mechanical properties	
	form of chippings	condition of cut surface	cutting force (N)	700 °C deformability	tensile strength (N/mm ²)	elongation (%)
8001	⊙	○	132	○	655	15
8002	⊙	○	129	○	708	17
8003	⊙	○	127	○	768	20
8004	⊙	○	128	○	785	18
8005	⊙	○	131	○	714	16
8006	⊙	○	134	○	680	16
8007	⊙	○	132	○	764	17
8008	⊙	○	130	○	673	16
8009	⊙	○	132	○	759	18
8010	⊙	○	132	○	751	15
8011	⊙	○	134	○	767	17
8012	⊙	○	128	○	796	18
8013	⊙	○	129	○	784	18
8014	⊙	○	129	○	802	17
8015	⊙	○	133	○	679	15
8016	⊙	○	130	○	706	16
8017	⊙	○	129	○	707	18
8018	⊙	○	131	○	780	16
8019	⊙	○	128	○	768	16
8020	⊙	○	132	○	723	19

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Table 23

No.	machinability			hot workability	mechanical properties	
	form of chippings	condition of cut surface	cutting force (N)	700°C deformability	tensile strength (N/mm ²)	elongation (%)
8021	⊙	○	134	○	765	16
8022	⊙	○	132	○	770	16
8023	⊙	○	131	○	746	18
8024	⊙	○	132	○	816	19
8025	⊙	○	129	○	159	18
8026	⊙	○	130	○	726	17
8027	⊙	○	133	○	703	17
8028	⊙	○	132	○	737	18
8029	⊙	○	129	○	719	20
8030	⊙	○	133	○	645	23
8031	⊙	○	129	○	764	22
8032	⊙	○	131	○	790	19
8033	⊙	○	133	○	674	20
8034	⊙	○	131	○	748	23
8035	⊙	○	129	○	777	22
8036	⊙	○	131	○	725	23
8037	⊙	○	128	○	770	21
8038	⊙	○	131	○	815	18
8039	⊙	○	127	○	739	24
8040	⊙	○	130	○	721	22

Table 24

No.	machinability			hot workability	mechanical properties	
	form of chippings	condition of cut surface	cutting force (N)	700°C deformability	tensile strength (N/mm ²)	elongation (%)
8041	⊙	○	128	○	735	23
8042	⊙	○	127	○	822	18
8043	⊙	○	131	○	780	18
8044	⊙	○	126	○	726	21
8045	⊙	○	128	○	766	22
8046	⊙	○	127	○	712	23
8047	⊙	○	128	○	674	21
8048	⊙	○	129	○	753	24
8049	⊙	○	127	○	768	22
8050	⊙	○	132	○	691	17

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(continued)

No.	machinability			hot workability	mechanical properties	
	form of chippings	condition of cut surface	cutting force (N)	700°C deformability	tensile strength (N/mm ²)	elongation (%)
8051	⊙	○	131	○	717	17
8052	⊙	○	128	○	739	21
8053	⊙	○	128	○	730	22
8054	⊙	○	127	○	735	20
8055	⊙	○	134	○	818	15
8056	⊙	○	132	○	812	16
8057	⊙	○	131	○	755	18
8058	⊙	○	133	○	659	20
8059	⊙	○	132	○	740	17
8060	⊙	○	130	○	714	19

Table 25

No.	machinability			hot workability	mechanical properties	
	form of chippings	condition of cut surface	cutting force (N)	700°C deformability	tensile strength (N/mm ²)	elongation (%)
8061	⊙	○	129	○	705	21
8062	⊙	○	131	○	690	22
8063	⊙	○	133	○	811	18
8064	⊙	○	131	○	746	17
8065	⊙	○	133	○	652	19
8066	⊙	○	130	○	758	19
8067	⊙	○	129	○	734	19
8068	⊙	○	131	○	710	17
8069	⊙	○	131	○	767	20
8070	⊙	○	131	○	753	18
8071	⊙	○	129	○	792	19
8072	⊙	○	131	○	736	21
8073	⊙	○	130	○	767	22
8074	⊙	○	132	○	679	19
8075	⊙	○	134	○	728	17
8076	⊙	○	133	○	795	16
8077	⊙	○	133	○	716	18
8078	⊙	○	132	○	809	18
8079	⊙	○	129	○	758	22
8080	⊙	○	130	○	724	21

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Table 26

No.	machinability			hot workability	mechanical properties	
	form of chippings	condition of cut surface	cutting force (N)	700°C deformability	tensile strength (N/mm ²)	elongation (%)
8081	⊙	○	132	○	706	23
8082	⊙	○	130	○	768	23
8083	⊙	○	128	○	774	25
8084	⊙	○	129	○	765	22
8085	⊙	○	130	○	729	23
8086	⊙	○	133	○	687	24
8087	⊙	○	131	○	798	20
8088	⊙	○	132	○	699	23
8089	⊙	○	130	○	740	21
8090	⊙	○	132	○	782	18
8091	⊙	○	129	○	763	22
8092	⊙	○	130	○	680	22
8093	⊙	○	131	○	655	23
8094	⊙	○	128	○	714	21
8095	⊙	○	132	○	638	24
8096	⊙	○	128	○	889	22
8097	⊙	○	129	○	711	21
8098	⊙	○	130	○	893	20
8099	⊙	○	127	○	702	21
8100	⊙	○	129	○	724	18

Table 27

No.	machinability			hot workability	mechanical properties	
	form of chippings	condition of cut surface	cutting force (N)	700°C deformability	tensile strength (N/mm ²)	elongation (%)
8101	⊙	○	131	○	685	18
8102	⊙	○	132	○	690	21
8103	⊙	○	133	○	744	17
8104	⊙	○	130	○	726	17
8105	⊙	○	133	○	751	19
8106	⊙	○	130	○	752	21
8107	⊙	○	131	○	760	21
8108	⊙	○	132	○	748	22
8109	⊙	○	130	○	807	18
8110	⊙	○	133	○	739	16

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(continued)

No.	machinability			hot workability	mechanical properties	
	form of chippings	condition of cut surface	cutting force (N)	700°C deformability	tensile strength (N/mm ²)	elongation (%)
8111	⊙	○	132	○	717	17
8112	⊙	○	134	○	763	20
8113	⊙	○	129	○	745	22
8114	⊙	○	132	○	722	20
8115	⊙	○	130	○	706	17
8116	⊙	○	133	○	684	19
8117	⊙	○	132	○	740	18
8118	⊙	○	133	○	765	16
8119	⊙	○	128	○	733	22
8120	⊙	○	131	○	819	19

Table 28

No.	machinability			hot workability	mechanical properties	
	form of chippings	condition of cut surface	cutting force (N)	700°C deformability	tensile strength (N/mm ²)	elongation (%)
8121	⊙	○	130	○	788	20
8122	⊙	○	131	○	755	22
8123	⊙	○	127	○	711	21
8124	⊙	○	130	○	763	20
8125	⊙	○	131	○	687	18
8126	⊙	○	134	○	706	17
8127	⊙	○	128	○	730	22
8128	⊙	○	130	○	702	23
8129	⊙	○	132	○	727	21
8130	⊙	○	130	○	701	24
8131	⊙	○	129	○	745	22
8132	⊙	○	132	○	749	21
8133	⊙	○	130	○	826	18
8134	⊙	○	128	○	770	20
8135	⊙	○	129	○	828	17
8136	⊙	○	129	○	746	20
8137	⊙	○	130	○	784	23
8138	⊙	○	131	○	779	21
8139	⊙	○	128	○	710	22
8140	⊙	○	131	○	717	22

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Table 29

No.	machinability			hot workability	mechanical properties	
	form of chippings	condition of cut surface	cutting force (N)	700°C deformability	tensile strength (N/mm ²)	elongation (%)
8141	⊙	○	131	○	687	22
8142	⊙	○	130	○	635	20
8143	⊙	○	129	○	710	23
8144	⊙	○	130	○	662	24
8145	⊙	○	128	○	728	23
8146	⊙	○	129	○	753	21
8147	⊙	○	130	○	709	24

Table 30

No.	wear resistance	
	weight loss by wear (mg/100000rot.)	
7001a	1.3	
7002a	0.8	
7003a	0.9	
7004a	1.4	
7005a	1.3	
7006a	1.7	
7007a	1.8	
7008a	1.2	
7009a	0.8	
7010a	2.4	
7011a	1.9	
7012a	1.2	
7013a	1.1	
7014a	2.7	
7015a	1.4	
7016a	1.3	
7017a	1.6	
7018a	1.4	
7019a	1.9	
7020a	1.5	

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Table 31

No.	wear resistance
	weight loss by wear (mg/100000rot)
7021a	1.3
7022a	0.9
7023a	1.2
7024a	1.0
7025a	2.3
7026a	1.7
7027a	1.8
7028a	1.1
7029a	1.5
7030a	1.4

Table 32

No.	wear resistance
	weight loss by rear (ng/100000rot.)
8001a	1.4
8002a	1.1
8003a	0.9
8004a	1.2
8005a	1.8
8006a	1.3
8007a	1.5
8008a	1.0
8009a	1.2
8010a	0.7
8011a	1.0
8012a	1.3
8013a	1.4
8014a	1.3
8015a	1.5
8016a	0.9
8017a	1.4
8018a	0.9
8019a	1.0
8020a	1.5

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Table 33

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No.	wear resistance	
	weight loss by wear (mg/100000rot.)	
8021a	1.0	
8022a	1.4	
8023a	1.4	
8024a	0.8	
8025a	1.2	
8028a	1.4	
8027a	1.9	
8028a	0.9	
8029a	1.4	
8130a	2.2	
8131a	2.1	
8132a	1.0	
8133a	2.4	
8134a	1.4	
8135a	1.2	
8136a	1.5	
8137a	1.3	
8138a	0.8	
8139a	1.4	
8140a	1.5	

Table 34

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No.	wear resistance	
	weight loss by wear (mg/100000rot.)	
8041a	1.5	
8042a	1.3	
8043a	1.6	
8044a	1.2	
8045a	1.0	
8046a	2.0	
8047a	1.6	
8048a	1.7	
8049a	1.3	
8050a	1.5	
8051a	1.0	
8052a	1.5	
8053a	1.3	

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(continued)

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No.	wear resistance
	weight loss by wear (mg/100000rot.)
8054a	1.2
8055a	0.7
8056a	0.9
8057a	1.6
8058a	2.4
8059a	1.6
8060a	1.9

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Table 35

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No.	wear resistance
	weight loss by wear (mg/100000rot.)
8061a	1.6
8062a	1.9
8063a	1.2
8064a	1.7
8065a	2.0
8068a	1.4
8067a	1.5
8068a	1.2
8069a	0.9
8070a	1.0
8071a	1.7
8072a	1.9
8073a	1.6
8014a	1.6
8075a	1.8
8076a	0.8
8077a	1.3
8078a	1.2
8079a	1.4
8080a	1.3

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Table 36

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No.	wear resistance
	weight loss by wear (mg/100000rot.)
8081a	1.6

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(continued)

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No.	wear resistance
	weight loss by wear (mg/100000rot)
8082a	1.3
8083a	1.0
8084a	1.2
8085a	1.5
8086a	1.6
8087a	1.1
8088a	2.0
8089a	1.4
8090a	1.2
8091a	1.5
8092a	1.6
8093a	2.1
8094a	1.5
8095a	1.9
8096a	1.5
8097a	1.5
8098a	1.4
8099a	1.1
8100a	0.9

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Table 37

No.	wear resistance
	weight loss by wear (mg/100000rot.)
8101	1.4
8102	1.3
8103	0.8
8104	0.8
8105	0.7
8106	0.9
8107	1.2
8108	1.1
8109	1.0
8110	0.7
8111	0.8
8112	1.2
8113	0.9
8114	1.2

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(continued)

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No.	wear resistance
	weight loss by wear (mg/100000rot.)
8115	1.1
8116	1.4
8117	1.1
8118	0.9
8119	1.
8120	0.9

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Table 38

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No.	wear resistance
	weight loss by wear (mg/100000rot.)
8121a	1.0
8122a	1.0
8123a	1.2
8124a	0.8
8125a	1.1
8126a	0.9
8127a	1.3
8128a	1.4
8129a	1.3
8130a	1.5
8131a	1.2
8132a	1.3
8133a	0.8
8134a	1.0
8135a	0.8
8136a	1.3
8137a	1.1
8138a	0.9
8139a	1.2
8140a	1.0

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Table 39

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No.	wear resistance
	weight loss by wear (ng/100000rot)
8141a	1.4
8142a	1.8

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(continued)

No.	wear resistance
	weight loss by wear (ng/100000rot)
8143a	1.6
8144a	1.9
8145a	1.1
8146a	1.2
8147a	1.4

Table 40

No.	rear resistance
	weight loss by wear (ng/100000rot.)
14001a	500
14002a	620
14003a	520
14004a	450
14005a	25
14006a	600

Claims

1. A lead-free, free cutting copper alloy which comprises 62 to 78 percent, by weight, of copper; 2.5 to 4.5 percent, by weight, of silicon; at least one element selected from among 0.3 to 3.0 percent, by weight, of tin, 0.2 to 2.5 percent, by weight, aluminium, and 0.02 to 0.25 percent, by weight, of phosphorous; at least one element selected from among 0.7 to 3.5 percent, by weight, manganese, and 0.7 to 3.5 percent, by weight, nickel; optionally at least one element selected from among 0.02 to 0.4 percent, by weight, of bismuth, 0.02 to 0.4 percent, by weight, of tellurium and 0.02 to 0.4 percent, by weight, selenium; and the remaining percent, by weight, of zinc and wherein the metal structure of the free cutting copper alloy has at least one phase selected from the γ (gamma) phase and the κ (kappa) phase.
2. A lead free, free-cutting copper alloy according to claim 1 wherein when cut on a circumferential surface by a lathe provided with a point nose straight tool at a rake angle of -8 (minus 8) and at a cutting rate of 50m/min, a cutting depth of 1.5 mm, a feed rate of 0.11 mm/rev yields a chips having one or more shapes selected from the group consisting of an arch shape and a fine needle shape.
3. A lead free, free-cutting copper alloy according to any one of the preceding claims which is subjected to a heat treatment for 30 minutes to 5 hours at 400 to 600°C.
4. A method of forming a lead-free, free cutting alloy having a metal structure which has at least one phase selected from the γ (gamma) phase and the κ (kappa) phase which comprises alloying copper and silicon in an amount of 62 to 78 percent, by weight, of copper; 2.5 to 4.5 percent, by weight, of silicon; at least one element selected from tin, aluminium and phosphorous in an amount of 0.3 to 3.0 percent, by weight, of tin, 0.2 to 2.5 percent, by weight, of aluminium and 0.02 to 0.25 percent, by weight, of phosphorous; at least one element selected from manganese and nickel in an amount of 0.7 to 3.5 percent, by weight, of manganese and 0.7 to 3.5 percent, by weight, of nickel; optionally at least one element selected from bismuth, tellurium and selenium in an amount of 0.02 to 0.4 percent, by weight, of bismuth, 0.02 to 0.4 percent, by weight, of tellurium and 0.02 to 0.4 percent, by weight, of selenium; and the remaining percent, by weight, of zinc.

5. The method of claim 4 wherein said silicon is provided as a Cu-Si alloy.
6. The method of any one of claims 4 to 5 wherein said lead-free, free cutting alloy is subjected to a heat treatment for 30 minutes to 5 hours at 400 to 600°C.

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Patentansprüche

1. Bleifreie, schnittige Kupferlegierung, enthaltend:

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62 bis 78 Gew.-% Kupfer, 2,5 bis 4,5 Gew.-% Silizium; wenigstens ein Element ausgewählt aus [der Gruppe] 0,3 bis 3,0 Gew.-% Zinn, 0,2 bis 2,5 Gew.-% Aluminium, und 0,02 bis 0,25 Gew.-% Phosphor; wenigstens ein Element ausgewählt aus [der Gruppe] 0,7 bis 3,5 Gew.-% Mangan und 0,7 bis 3,5 Gew.-% Nickel; optional wenigstens ein Element ausgewählt aus [der Gruppe] 0,02 bis 0,4 Gew.-% Bismut, 0,02 bis 0,4 Gew.-% Tellur und 0,02 bis 0,4 Gew.-% Selen;

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wobei der restliche Gew.-%-Gehalt Zink ist und worin die Metall-Struktur der schnittigen Kupferlegierung wenigstens eine Phase gewählt aus γ (gamma)-Phase und κ (kappa)-Phase besitzt.

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2. Bleifreie, schnittige Kupferlegierung nach Anspruch 1, wobei dann, wenn diese auf einer ringförmigen Oberfläche mit einer Drehmaschine, die mit einem geraden Drehspitzmeißel ausgestattet ist, mit einem Spanwinkel von -8 (minus 8) und einer Zerspangeschwindigkeit von 50m/min, einer Schneidtiefe von 1,5 mm, einem Vorschub von 0,11 mm/Umdrehung spanabhebend bearbeitet wird, Späne ergibt, die eine oder mehrere Formen ausgewählt aus der Gruppe Bogenform oder feine Nadelform haben.

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3. Bleifreie, schnittige Kupferlegierung nach einem der vorhergehenden Ansprüche, die einer Wärmebehandlung von 30 Minuten bis 5 Stunden bei 400 bis 600° C ausgesetzt wird.

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4. Verfahren zur Herstellung einer bleifreien, schnittigen Kupferlegierung, die eine Metall-Struktur hat, die wenigstens eine Phase, gewählt aus γ (gamma)-Phase und κ (kappa)-Phase besitzt, wobei das Verfahren das Legieren von Kupfer und Silizium in einer Menge von 62 bis 78 Gew.-% Kupfer; 2,5 bis 4,5 Gew.-% Silizium umfasst; sowie von wenigstens einem Element ausgewählt aus Zinn, Aluminium und Phosphor in einer Menge von 0,3 bis 3,0 Gew.-% Zinn, 0,2 bis 2,5 Gew.-% Aluminium und 0,02 bis 0,25 Gew.-% Phosphor; von wenigstens einem Element ausgewählt aus Mangan und Nickel in einer Menge von 0,7 bis 3,5 Gew.-% Mangan, und 0,7 bis 3,5 Gew.-% Nickel; optional von wenigstens einem Element ausgewählt aus Bismut, Tellur und Selen in einer Menge von 0,02 bis 0,4 Gew.-% Bismut, 0,02 bis 0,4 Gew.-% Tellur und 0,02 bis 0,4 Gew.-% Selen; wobei der restliche Gew.-%-Gehalt Zink ist.

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5. Verfahren nach Anspruch 4, wobei das Silizium als eine Cu-Si-Legierung beigefügt wird.

6. Verfahren nach einem der Ansprüche 4 oder 5, wobei die genannte bleifreie, schnittige Legierung einer Wärmebehandlung von 30 Minuten bis 5 Stunden bei 400 bis 600° C ausgesetzt wird.

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Revendications

1. Alliage de cuivre de décolletage sans plomb qui comprend 62 à 78 pour cent, en poids, de cuivre ; 2,5 à 4,5 pour cent, en poids, de silicium ; au moins un élément choisi parmi 0,3 à 3,0 pour cent, en poids, d'étain, 0,2 à 2,5 pour cent, en poids, d'aluminium et 0,02 à 0,25 pour cent, en poids, de phosphore ; au moins un élément choisi parmi 0,7 à 3,5 pour cent, en poids, de manganèse et 0,7 à 3,5 pour cent, en poids, de nickel ; facultativement au moins un élément choisi parmi 0,02 à 0,4 pour cent, en poids, de bismuth, 0,02 à 0,4 pour cent, en poids, de tellure et 0,02 à 0,4 pour cent, en poids, de sélénium ; et le pourcentage restant, en poids, de zinc et dans lequel la structure métallique de l'alliage de cuivre de décolletage comporte au moins une phase choisie parmi la phase γ (gamma) et la phase κ (kappa).

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2. Alliage de cuivre de décolletage sans plomb selon la revendication 1, qui, lorsqu'il est découpé sur une surface circonférentielle par un tour muni d'un outil droit à nez en pointe selon un angle de coupe de -8 (moins 8) et à une

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vitesse de coupe de 50 m/min, une profondeur de coupe de 1,5 mm, une vitesse d'alimentation de 0,11 mm/tour, donne des copeaux ayant une ou plusieurs formes choisies dans le groupe constitué par une forme en arcade et une forme en aiguille fine.

- 5 **3.** Alliage de cuivre de décolletage sans plomb selon l'une quelconque des revendications précédentes, qui est soumis à un traitement de chaleur pendant 30 minutes à 5 heures à 400 à 600 °C.
- 10 **4.** Procédé de formation d'un alliage de décolletage sans plomb présentant une structure métallique qui comporte au moins une phase choisie parmi la phase γ (gamma) et la phase κ (kappa) qui comprend la formation d'un alliage de cuivre et de silicium à une quantité de 62 à 78 pour cent, en poids, de cuivre ; 2,5 à 4,5 pour cent, en poids, de silicium ; au moins un élément choisi parmi l'étain, l'aluminium et le phosphore à une quantité de 0,3 à 3,0 pour cent, en poids, d'étain, 0,2 à 2,5 pour cent, en poids, d'aluminium et 0,02 à 0,25 pour cent, en poids, de phosphore ; au moins un élément choisi parmi le manganèse et le nickel à une quantité de 0,7 à 3,5 pour cent, en poids, de manganèse et 0,7 à 3,5 pour cent, en poids, de nickel ; facultativement au moins un élément choisi parmi le bismuth, le tellure et le sélénium à une quantité de 0,02 à 0,4 pour cent, en poids, de bismuth, 0,02 à 0,4 pour cent, en poids, de tellure et 0,02 à 0,4 pour cent, en poids, de sélénium ; et le pourcentage restant, en poids, de zinc.
- 15 **5.** Procédé selon la revendication 4, dans lequel ledit silicium est fourni sous la forme d'un alliage de Cu-Si.
- 20 **6.** Procédé selon l'une quelconque des revendications 4 à 5, dans lequel ledit alliage de décolletage sans plomb est soumis à un traitement de chaleur pendant 30 minutes à 5 heures à 400 à 600 °C.

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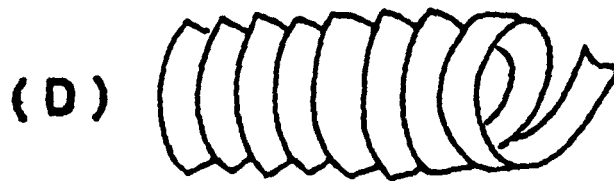
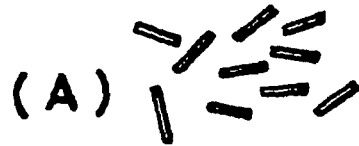
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FIGURE 1



REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

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