(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 350 019 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
10.04.2024 Bulletin 2024/15

(21) Application number: **23200983.7**

(22) Date of filing: **29.09.2023**

(51) International Patent Classification (IPC):
C22C 1/04 (2023.01) ***C22C 30/02*** (2006.01)
C22F 1/02 (2006.01)

(52) Cooperative Patent Classification (CPC):
C22C 1/0433; C22C 30/02; C22F 1/02

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(30) Priority: **04.10.2022 KR 20220126332**

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(54) HIGH-ENTROPY ALLOY AND MANUFACTURING METHOD THEREFOR

(57) The present disclosure relates to a high-entropy alloy and a manufacturing method therefor, and in particular, a high-entropy alloy and a manufacturing method therefor that comprises a multi-element alloy matrix and Cu, and comprises an alloy having a face-centered cubic (FCC)-based phase, such that the high-entropy alloy may have greater hardness and strength than an existing transition metal alloy while maintaining a FCC-based single phase, and has high lubricity.

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Description

TECHNICAL FIELD

[0001] Disclosed herein are a high-entropy alloy and a manufacturing method therefor, and in particular, a high-entropy alloy having high strength, hardness and lubricity and a manufacturing method therefor.

BACKGROUND

[0002] High-entropy alloys (HEAs) are multi-element alloys that are obtained by alloying 5 or more elements at a similar ratio, rather than a major element constituting alloys. Intermetallic compounds or interphases are not formed in HEAs since the entropy of mixing in the alloys is high, and HEAs are metallic materials having a single phase tissue such as a face-centered cubic (FCC) or a body-centered cubic (BCC).

[0003] In designing a high-entropy alloy, two important factors include composition ratios of elements constituting an alloy and configurational entropy of an alloy group.

[0004] As mentioned above, the first important factor is a composition ratio of a high-entropy alloy. A high-entropy alloy needs to be comprised of at least 5 or more elements, and a composition ratio of each element constituting the alloy is defined as 5 to 35 at%. Additionally, in the case where another element is added in addition to a major element constituting a high-entropy alloy at a time of manufacturing the high-entropy alloy, another element needs to be added at 5 at% or less.

[0005] Alloys are ordinarily categorized into high-entropy alloys, medium-entropy alloys (MEAs) and low-entropy alloys (LEAs), depending on configurational entropy (Sconf) based on the composition of alloy elements.

[0006] However, alloy elements included in an alloy group that is being studied currently are very expensive, and heavy alloy elements are mainly used for high-entropy and medium-entropy alloys, making it hard to commercialize high-entropy and medium-entropy alloys. In recent years, research has been performed into a lightweight high-entropy alloy that is manufactured based on a combination of lightweight alloy elements. However, solid solubility among light-weight alloy elements is low, and in a case where an alloy element is added in almost the same proportion, based on the definition of a high-entropy alloy, an intermetallic compound is formed in a high-entropy alloy, limiting plastic deformation of the alloy, degrading workability and making it hard to commercialize the alloy.

[0007] To commercialize high-entropy and medium-entropy alloys, price competitiveness and excellent mechanical properties need to be realized based on an adjustment of alloy elements.

[0008] High-entropy and medium-entropy alloys described above are used for parts of a superprecision machine such as a micro gear as well as turbines, compressors, gear boxes and the like used in the aerospace, aviation, vehicle, vessel and heavy equipment areas.

[0009] Importantly, the surfaces of portions affected by a friction and wear among the parts need to ensure high hardness and lubricity. To this end, a new material needs to be developed to ensure basic mechanical properties such as hardness, fracture toughness and the like of an existing material applied to the parts and to adjust high functionality property in accordance with a usage environment.

[0010] Further, the surface of a bearing of a compressor to which a mater alloy for coating is mainly applied needs to have basic properties such as high rigidity and high hardness, and low friction coefficient and high lubricity that conceptually conflict with the basic properties.

[0011] To ensure the above-described properties, composite materials and composite structuralization are ordinarily used, and a metallic material is developed to include a crystalline strengthened phase **as/in** a high hardness-high corrosion resistance non-crystalline matrix. However, manufacturing conditions for forming non-crystals are not appropriate for ordinary mass production, and a forming process for a complex part is hardly performed.

SUMMARY

Technical Problems

[0012] The objective of the present disclosure is to provide a novel high-entropy alloy exhibiting high strength, high hardness and high lubricity.

[0013] The objective of the present disclosure is to provide a novel high-entropy alloy to which Cu is added, ensuring low friction coefficient and high lubricity.

[0014] The objective of the present disclosure is to provide a manufacturing method of a high-entropy alloy.

[0015] Aspects according to the present disclosure are not limited to the above ones, and other aspects and advantages that are not mentioned above can be clearly understood from the following description and can be more clearly understood from the embodiments set forth herein. Additionally, understandably, the aspects and advantages in the present disclosure are embodied via means and combinations thereof that are described in the appended claims.

Technical Solutions

[0016] In a high-entropy alloy according to the present disclosure, Cu is added to a multi-element alloy matrix to maintain a face-centered cubic (FCC)-based single phase and ensure high hardness, strength and lubricity.
[0017] Specifically, the high-entropy alloy according to the present disclosure comprises a multi-element alloy matrix and Cu, and the multi-element alloy matrix comprises three or more sorts among Cr, Co, Ni and Mo, and comprises an alloy having a face-centered cubic (FCC)-based single phase.
[0018] Preferably, the high-entropy alloy in one embodiment may be expressed as chemical formula 1 described hereafter.

[Chemical formula 1] $Cr_aCo_bNi_cCu_x$

(In chemical formula 1, a+b+c+x=1, and $0<x\leq0.2$are satisfied.)
[0019] Preferably, x above may satisfy $0.02\leq x\leq0.2$.
[0020] Further, the high-entropy alloy in one embodiment may be expressed as chemical formula 2 described hereafter.

[Chemical formula 2] $Mo_aCo_bNi_cCu_x$

(In chemical formula 2 described above, a+b+c+x=1, and $0<x\leq0.2$are satisfied.)
[0021] Preferably, x above may satisfy $0.1\leq x\leq0.2$.
[0022] A manufacturing method for a high-entropy alloy in one embodiment comprises manufacturing a mixture powder in which alloy matrix elements and a Cu powder are mixed; heating and dissolving the mixture power, and casting the mixture powder in a predetermined form; rolling the cast alloy and manufacturing an alloy material; and thermally treating the alloy material and manufacturing an alloy, wherein the alloy matrix elements comprise three or more sorts among Cr, Co, Ni and Mo, and the alloy has a face-centered cubic (FCC)-based single phase.

Advantageous Effects

[0023] According to the present disclosure, a novel high-entropy alloy ensuring improvement in mechanical properties at room temperature and high temperature may be provided.
[0024] The high-entropy alloy in the present disclosure has greater strength than an existing transition metal alloy, while maintaining a FCC-based single phase.
[0025] Additionally, the high-entropy alloy in the present disclosure has high strength, hardness and lubricity.
[0026] Further, the high-entropy alloy in the present disclosure ensures low friction coefficient and high lubricity.
[0027] Furthermore, the manufacturing method of a high-entropy alloy in the present disclosure may involve changing the microstructure of the high-entropy alloy, in a homogenization process based on thermal treatment, to maximize the strength, hardness and lubricity of the high-entropy alloy.
[0028] Specific effects are described along with the above-described effects in the section of detailed description.

DETAILED DESCRIPTION

[0029] The above-described aspects, features, and advantages are specifically described hereinafter with reference to accompanying drawings such that one having ordinary skill in the art to which embodiments pertain can embody the technical spirit easily. Hereinafter, *description* of known technologies in relation to the subject matter *is* omitted if it is deemed to *make* the *gist* unnecessarily *vague*. Hereinafter, the embodiments are specifically described with reference to the accompanying drawings.
[0030] Throughout the disclosure, each component can be provided a single one or a plurality of ones, unless stated to the contrary.
[0031] The singular forms "a", "an" and "the" are intended to include the plural forms as well, unless explicitly indicated otherwise. It is to be further understood that the terms "comprise" or "include" and the like, set forth herein, are not interpreted as necessarily including all the stated components or steps but can be interpreted as excluding some of the stated components or steps or can be interpreted as including additional components or steps.
[0032] Hereinafter, a high-entropy alloy and a manufacturing method therefor according to the present disclosure are described.

High-entropy alloy

[0033] Provided is a novel alloy having high lubricity as well as high hardness and high strength, by doping Cu to an existing alloy and adjusting a doping amount, to improve the low strength of an FCC-based high-entropy alloy and provide high lubricity to the FCC-based high-entropy alloy.

[0034] The high-entropy alloy according to the present disclosure comprises a multi-element alloy matrix and Cu, and the multi-element alloy matrix comprises three or more sorts among Cr, Co, Ni and Mo, and an alloy having a face-centered cubic (FCC)-based single phase.

[0035] Like an existing high-entropy alloy, the high-entropy alloy according to the present disclosure comprises a multi-element alloy base, and the alloy matrix comprises three or more sorts among Cr, Co, Ni and Mo. Additionally, the alloy according to the present disclosure comprises Cu as well as the alloy base. Accordingly, the alloy in the present disclosure experiences a severe lattice distortion, maintains a FCC-based single phase, and has increased hardness and strength. Further, the alloy in the present disclosure exhibits low friction and high lubricity.

[0036] In particular, the component Cu performs a lubrication operation, in a soft phase that is a typical metal lubrication phase, even at high temperature. In an alloy, the component Cu exhibits its properties, based on precipitation. Mostly, the element Cu has low solid solubility in an alloy, and is precipitated in a Cu-rich phase of the matrix and another composition/component. However, the element Cu may decrease the hardness and strength of an alloy and not be ordinarily applied to a high-entropy alloy.

[0037] For the high-entropy alloy in the present disclosure, Cu is applied to the multi-element alloy base comprising three or more sorts among Cr, Co, Ni and Mo, such that the high-entropy alloy exhibits excellent hardness, strength and lubricity.

[0038] Specifically, the high-entropy alloy in an embodiment may be expressed as chemical formula 1 described hereafter, and comprise an alloy having a face-centered cubic (FCC)-based single phase.

[Chemical formula 1] $Cr_aCo_bNi_cCu_x$

(In chemical formula 1 described above, a+b+c+x=1, and O<x≤0.2 are satisfied.)

[0039] Additionally, x described above may satisfy $0.02 \le x \le 0.2$, preferably.

[0040] Further, the high-entropy alloy in one embodiment may be expressed as chemical formula 2 described hereafter and comprise an alloy having a face-centered cubic (FCC)-based single phase.

[Chemical formula 2] $Mo_aCo_bNi_cCu_x$

(In chemical formula 2 described above, a+b+c+x=1, and O<x≤0.2 are satisfied.)

[0041] Preferably, x described above may satisfy $0.1 \le x \le 0.2$.

Manufacturing method for high-entropy alloy

[0042] The manufacturing method for a high-entropy alloy according to the present disclosure comprises manufacturing a mixture powder in which an alloy matrix element and a Cu powder are mixed; heating and dissolving the mixture power, and casting the mixture powder in a predetermined form; rolling the cast alloy and manufacturing an alloy material; and thermally treating the alloy material and manufacturing an alloy, wherein the alloy matrix element comprises three or more sorts among Cr, Co, Ni and Mo, and the alloy has a face-centered cubic (FCC)-based single phase.

[0043] The manufacturing method for a high-entropy alloy according to the present disclosure comprises manufacturing a mixture powder in which an alloy matrix element and a Cu powder are mixed.

[0044] The multi-element alloy matrix comprises three or more sorts among Cr, Co, Ni and Mo. A preferable atomic % of the alloy is described above.

[0045] Then the manufacturing method for a high-entropy alloy according to the present disclosure comprises heating and dissolving the mixture power, and casting the mixture powder in a predetermined form. The casting method is not limited, and the casting process may be performed in a way that a melting pot is charged with a material.

[0046] Further, the manufacturing method for a high-entropy alloy according to the present disclosure may comprise milling and mechanically alloying the mixture powder and forming a mechanically alloyed powder, before the casting process.

[0047] Then the manufacturing method for a high-entropy alloy according to the present disclosure comprises rolling the cast alloy and manufacturing an alloy material. Preferably, the rolling process may comprise hot rolling and cold rolling. Preferably, the cast alloy may be rolled such that a reduction ratio may be 60 to 80 %.

[0048] Then the manufacturing method for a high-entropy alloy according to the present disclosure comprises thermally treating the alloy material and manufacturing an alloy. Herein, the quality of the alloy may become homogeneous, based on the thermal treatment.

[0049] The thermally treating process may be performed in a vacuum atmosphere, an inert gas atmosphere, an oxygen atmosphere, or an atmosphere including at least any one of nitrogen, boron and carbon.

[0050] Further, the thermally treating process may be performed at 200 °C to 1300 °C for 1 to 24 hours, preferably, at 900 °C to 1000 °C for 6 hours or greater.

[0051] The high-entropy alloy manufactured based on the manufacturing method in the present disclosure may comprise the above-described alloy.

[0052] Hereinafter, the subject matter of the present disclosure is described more specifically, with reference to preferred embodiments.

<Embodiment>

1. Manufacturing of embodiments and comparative example

[0053] An alloy matrix element and a Cu powder were mixed at ratios in the following table, to manufacture a mixture powder. Each pure element was prepared in the form of a pellet of 10 mm or less and of purity of 99.5 % or greater.

[0054] A melting pot was charged with the pure element, and the pure element was heated and dissolved at 1550 °C, and then a dissolved alloy was manufactured as an ingot, in a zirconia melting pot. Pressure in the solidification process was maintained at about 2.5 bar. The ingot was hot-rolled at 900 to 1100°C, at a reduction ratio of 60 %, and then air-cooled (air quenched). Then a cold-rolled plate was thermally treated. All the above-described thermally treating processes were performed at 1100°C for 6 hours in an inert gas (Ar) atmosphere.

[Table 1]

	Cr (at%)	Mo (at%)	Fe (at%)	Co (at%)	Ni (at%)	Cu (at%)
Comparative example 1	33.33	0	0	33.33	33.33	0
Embodiment 1	10	0	0	34	54	2
Embodiment 2	10	0	0	32.5	52.5	5
Embodiment 3	10	0	0	30	50	10
Embodiment 4	10	0	0	10	60	20
Embodiment 5	0	5	0	42.5	42.5	10
Embodiment 6	0	5	0	37.5	37.5	10

2. Evaluation test

[0055] Test results of the HV hardness and tensile strength of the manufactured alloys are shown in the following table.

[Table 2]

	HV hardness	YS(MPa)	UTS(MPa)	EL(%)	Friction coefficient
Comparative example 1	153.0±3.0	275.0	630.0	83.8	0.671
Embodiment 1	122.0±5.0	174.0	509.0	51.0	0.381
Embodiment 2	136.0±5.0	196.0	522.0	52.3	0.379
Embodiment 3	141.3±5.5	217.0	521.0	46.4	0.372
Embodiment 4	149.8±5.2	242.0	562.0	25.8	0.383
Embodiment 5	160.0±5.2	249.0	702.0	41.8	0.422
Embodiment 6	211.0±5.2	563.0	707.0	25.1	0.402

[0056] Referring to table 2, the hardness and strength of embodiments 1 to 4 including Cu are slightly less than those of an alloy including no Cu (comparative example 1), but the friction coefficient of embodiments 1 to 4 is much less than that of comparative example 1. However, the hardness and strength of embodiments 5 and 6 including Mo are greater than those of comparative example 1, and the friction coefficient of embodiments 1 to 4 is less than that of comparative example 1.

[0057] As described above, the high-entropy alloy according to the present disclosure has excellent hardness and strength like an existing alloy, and has high lubricity unlike an existing alloy.

[0058] The embodiments are described above with reference to a number of illustrative embodiments thereof. However, embodiments are not limited to the embodiments and drawings set forth herein, and numerous other modifications and embodiments can be drawn by one skilled in the art within the technical scope of the disclosure. Further, the effects and predictable effects based on the configurations in the disclosure are to be included within the range of the disclosure.

Claims

1. A high-entropy alloy, comprising:

a multi-element alloy matrix and Cu,
wherein the multi-element alloy matrix comprises three or more sorts among Cr, Co, Ni and Mo, and
the multi-element alloy matrix has a face-centered cubic (FCC)-based single phase.

2. The high-entropy alloy according to claim 1, wherein the alloy is expressed as chemical formula 1:

$$Cr_aCo_bNi_cCu_x \qquad \text{[Chemical formula 1]},$$

wherein a+b+c+x=1, and $0<x\leq0.2$ are satisfied.

3. The high-entropy alloy according to claim 2, wherein x satisfies $0.02\leq x\leq0.2$.

4. The high-entropy alloy according to claim 1, wherein the alloy is expressed as chemical formula 2:

$$Mo_aCo_bNi_cCu_x \qquad \text{[Chemical formula 2]},$$

wherein a+b+c+x=1, and $0<x\leq0.2$ are satisfied.

5. The high-entropy alloy according to claim 4, wherein x satisfies $0.1\leq x\leq0.2$.

6. A manufacturing method for a high-entropy alloy, comprising:

manufacturing a mixture powder in which alloy matrix elements and a Cu powder are mixed;
heating and dissolving the mixture power, and casting the mixture powder in a predetermined form;
rolling the cast alloy and manufacturing an alloy material; and
thermally treating the alloy material and manufacturing an alloy,
wherein the alloy matrix elements comprise three or more sorts among Cr, Co, Ni and Mo, and the alloy has a face-centered cubic (FCC)-based single phase.

7. The manufacturing method according to claim 6, wherein the thermal treating step may be performed in a vacuum atmosphere, an inert gas atmosphere, an oxygen atmosphere, or an atmosphere including at least any one of nitrogen, boron and carbon.

8. The manufacturing method according to claim 6 or 7, wherein the thermal treating step is performed at 200 °C to 1300 °C for 1 to 24 hours.

9. The manufacturing method according to any of claims 6 to 8, wherein the alloy is expressed as chemical formula 1:

$$Cr_aCo_bNi_cCu_x \qquad \text{[Chemical formula 1]},$$

wherein a+b+c+x=1, and $0<x\leq0.2$ are satisfied.

10. The manufacturing method according to claim 9, wherein x above satisfies $0.02\leq x\leq0.2$.

11. The manufacturing method according to any of claims 6 to 8, wherein the alloy is expressed as chemical formula 2:

$Mo_aCo_bNi_cCu_x$ [Chemical formula 2],

wherein a+b+c+x=1, and $0<x\leq 0.2$ are satisfied.

12. The manufacturing method according to claim 11, wherein x above satisfies $0.1\leq x\leq 0.2$.

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EUROPEAN SEARCH REPORT

Application Number
EP 23 20 0983

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	JODI DENNIS EDGARD ET AL: "Phase separation and its effect on atomic interactions in CoCrNiCux medium-entropy alloys", MATERIALS LETTERS, ELSEVIER, AMSTERDAM, NL, vol. 255, 9 August 2019 (2019-08-09), XP085837292, ISSN: 0167-577X, DOI: 10.1016/J.MATLET.2019.126528 [retrieved on 2019-08-09]	1-3	INV. C22C1/04 C22C30/02 C22F1/02
Y	* 2. Experimental procedures *	6-12	
A	* 3. Results and discussions * -----	4,5	
X	CN 102 796 936 A (SHAANXI TIANYUAN MATERIALS PROT TECHNOLOGY CO LTD) 28 November 2012 (2012-11-28)	1,4,5	
Y	* claims * -----	6-8,11, 12	
Y	ALSHATAIF YASER A ET AL: "Manufacturing Methods, Microstructural and Mechanical Properties Evolutions of High-Entropy Alloys: A Review", METALS AND MATERIALS INTERNATIONAL, THE KOREAN INSTITUTE OF METALS AND MATERIALS, SEOUL, vol. 26, no. 8, 6 December 2019 (2019-12-06), pages 1099-1133, XP037192600, ISSN: 1598-9623, DOI: 10.1007/S12540-019-00565-Z [retrieved on 2019-12-06]	6-12	TECHNICAL FIELDS SEARCHED (IPC) C22C C22F
A	* 3.1 Arc melting process * -----	1-5	

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	9 February 2024	Morra, Valentina

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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09-02-2024

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