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(54) **A METHOD FOR PRODUCING ULTRA-HIGH-SILICON ALUMINIUM ALLOY**

(57) The present invention discloses a method for producing ultra-high-silicon aluminum alloy, which comprises the following steps: S1. Use metal spray forming technology to make the aluminum-silicon alloy melt into an aluminum-silicon alloy ingot (100); S2. Heat the aluminum-silicon alloy ingot to a semi-solid temperature; S3. Use die pressing to form the aluminum-silicon alloy ingot with a semi-solid temperature into an ultra-high-silicon aluminum alloy. The method of the present invention firstly uses metal spray forming to produce a silicon-aluminum alloy with a lower silicon content (e.g.: silicon content is 50%), which then goes through semi-solid forming with overflow. In this way, an appropriate amount of liquid eutectic aluminum-silicon liquid phase is pressed into an overflow groove (211), then the overall volume becomes smaller and the content of free silicon is enriched, so as to obtain an ultra-high-silicon aluminum alloy with a higher silicon content, and the silicon content can be increased to over 60%. The method of the present invention can also realize gradient or local enrichment of free silicon content through the asymmetric or partial arrangement of the overflow groove according to the functional requirements of materials.

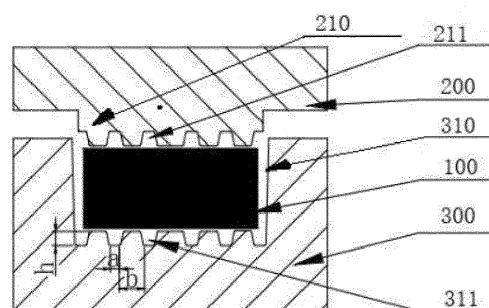


Fig. 1

Description

TECHNICAL FIELD

[0001] The present invention belongs to the field of preparation technology of high-silicon aluminum alloy, and particularly relates to a method for producing ultra-high-silicon aluminum alloy.

BACKGROUND

[0002] Ultra-high-silicon aluminum alloy (mass content of silicon $\geq 50\%$) is an important raw material for the production of lightweight noise-free bearings due to its high abrasive resistance, noise reduction performance, and light weight. Moreover, with the increase of silicon content, its coefficient of linear expansion is reduced to $(4-7) \times 10^{-6}/K$. It is largely used as electronic packaging parts and plays a wide and important role in industrial fields.

[0003] Powder metallurgy and spray forming are the most commonly used processes for producing ultra-high-silicon aluminum alloys. Spray forming directly atomizes the spray forming liquid and makes spray deposition into blanks with uniform structure and excellent primary silicon morphology, so the flow of production is short, having the advantage of higher cost efficiency. However, when the silicon content is greater than or equal to 50%, the melting point of ultra-high-silicon aluminum alloys increases greatly, and the fluidity of the molten metal is drastically reduced. The spray forming process performance of ultra-high-silicon aluminum alloy is deteriorated, making it difficult to produce ultra-high-silicon aluminum alloy with a silicon content above 60% by spray forming. Therefore, how to produce ultra-high-silicon aluminum alloy with a silicon content above 60% is an urgent problem to be solved.

SUMMARY

[0004] The purpose of the present invention is to provide a method for producing ultra-high-silicon aluminum alloy to solve one or more technical problems existing in the available technology, or at least provide one beneficial choice or create conditions.

[0005] Technical solution used to solve the above technical problems:

A method for producing ultra-high-silicon aluminum alloy, comprising the following steps:

- S1. Use metal spray forming technology to make an aluminum-silicon alloy melt into an aluminum-silicon alloy ingot;
- S2. Heat the aluminum-silicon alloy ingot to a semi-solid temperature;
- S3. Use die-pressing to form the aluminum-silicon alloy ingot at a semi-solid temperature into an ultra-high-silicon aluminum alloy.

[0006] As a further improvement of the above-mentioned technical solution, in said S2, an electromagnetic inductor is used to heat the aluminum-silicon alloy ingot.

[0007] As a further improvement of the above-mentioned technical solution, in said S2, the aluminum-silicon alloy ingot is made into an appropriate shape by cold and hot processing such as cutting and then heating to semi-solid temperature.

[0008] As a further improvement of the above-mentioned technical solution, in said S2, the aluminum-silicon alloy ingot is heated to the semi-solid temperature and then held there for 1-60 minutes.

[0009] As a further improvement of the above-mentioned technical solution, in said S3, the specific forming process of ultra-high-silicon aluminum alloy is as follows: the die used is a forging die, comprising an upper mold and a lower mold, and the upper mold and/or lower mold are/is provided with an overflow groove. The aluminum-silicon alloy ingot with a semi-solid temperature is placed between the upper mold and the lower mold, and then the die forging equipment closes the upper and lower molds.

[0010] As a further improvement of the above-mentioned technical solution, the bottom surface of said upper mold is provided with a projection, and several first overflow grooves are evenly arranged on the bottom surface of said projection.

[0011] As a further improvement of the above-mentioned technical solution, said lower mold is provided with a first groove matching said projection, and the bottom surface of said first groove is provided with a second overflow groove corresponding to the first overflow groove.

[0012] As a further improvement of the above-mentioned technical solution, the bottom surface of said upper mold is provided with a second groove.

[0013] As a further improvement of the above-mentioned technical solution, said lower mold is provided with a third groove corresponding to said second groove, and several third overflow grooves are evenly arranged on the bottom surface of the third groove.

[0014] An ultra-high-silicon aluminum alloy prepared by the above-mentioned method, and the mass content of silicon in the ultra-high-silicon aluminum alloy is greater than or equal to 60%.

[0015] Semi-solid forming technology is a new metal forming technology invented in the 1970s. Through various technological means, the dendrites generated during the process of solidification of metal are transformed into nodules with semi-solid thixotropic behavior and the rheological mold-filling capacity under pressure. Compared with traditional die-casting, semi-solid forming products have the advantages of high strength and great density, low shrinkage rate, thus enabling more precise sizes and shapes of parts. Moreover, the lower forming temperature helps to prolong the service life of mold. The semi-solid temperature refers to the temperature in the solid-liquid temperature interval.

[0016] Compared with existing technology, the present invention has the following beneficial effects:

The method of the present invention firstly uses metal spray forming to produce a silicon-aluminum alloy with a lower silicon content (e.g.: mass content of silicon is 50%), which is then heated to semi-solid temperature to go through die pressing with overflow. In this way, an appropriate amount of liquid eutectic aluminum-silicon liquid phase is pressed into the overflow groove, then the overall volume becomes smaller, which enriches the content of free silicon, so as to produce the ultra-high-silicon aluminum alloy with a higher silicon content, and the mass content of silicon can be increased to above 60%. The present invention can realize a gradient change or local enrichment of free silicon content through the asymmetric or partial arrangement of the overflow groove according to the functional requirements of material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] A further explanation of the present invention is given below in combination with the attached figures and embodiments.

Fig.1 is the structural schematic diagram of Embodiment 1 of the present invention before die pressing;

Fig. 2 is the metallographic picture of the silicon-aluminum alloy of Embodiment 1 of the present invention before die pressing;

Fig.3 is the structural schematic diagram of Embodiment 1 of the present invention after die pressing;

Fig. 4 is the metallographic picture of the silicon-aluminum alloy of Embodiment 1 of the present invention after die pressing;

Fig.5 is the structural schematic diagram of Embodiment 2 of the present invention before die pressing;

Fig.6 is the structural schematic diagram of Embodiment 2 of the present invention after die pressing;

Fig. 7 is the metallographic picture of the top of the silicon-aluminum alloy of Embodiment 2 of the present invention after die pressing;

Fig. 8 is the metallographic picture of the bottom of the silicon-aluminum alloy of Embodiment 2 of the present invention after die pressing;

[0018] In the figure, 100-aluminum-silicon alloy ingot, 200-upper mold, 210-projection, 211-the first overflow groove, 220-the second groove, 300-lower mold, 310-the first groove, 311-the second overflow groove, 320-the third groove, 321-the third overflow groove.

DETAILED DESCRIPTION

[0019] This part will describe the specific embodiments of the present invention in detail. The preferred embodiments of the present invention are shown in the attached figures. The function of the attached figures is to supplement the text description in the Specifications with graphics, so that each technical feature and the overall technical solution of the present invention can be understood intuitively and vividly. However, it shall not be construed as a limitation of the scope of protection of the present invention.

[0020] In the description of the present invention, it needs to be understood that, as for description of orientation, the orientation or location relationship indicated by words such as upper, lower, front, back, left and right is orientation or location relationship based on those shown in the attached figures, which are only for the sake of description of the present invention and simplification of description, and don't indicate or imply that the device or component referred to must have the specific orientation, be constructed and operated in a specific orientation, and therefore cannot be understood as a limitation to the present invention.

[0021] In the description of the present invention, if there are descriptions using the word such as "several", it means one or more; more means more than two; more than, less than, exceeding, etc. should be understood as not including the number itself; above, below and within should be understood as including the number itself.

[0022] In the description of the present invention, unless otherwise expressly defined, terms such as arrangement, installation, and connection should be understood in a broad sense. Those skilled in the field of technology can reasonably determine the specific meaning of the above terms in the present invention based on the specific content of the technical solution.

Embodiment 1

[0023] Referring to Fig. 1-4, in the Embodiment 1 of the present invention, a method for producing ultra-high-silicon aluminum alloy, comprising the following steps:

S1. Use metal spray forming technology to make an aluminum-silicon alloy melt into an aluminum-silicon alloy ingot;

S2. Heat the aluminum-silicon alloy ingot to a semi-solid temperature;

S3. Use die-pressing to form the aluminum-silicon alloy ingot into an ultra-high-silicon aluminum alloy at a semi-solid temperature.

[0024] In S2, an electromagnetic inductor is used to heat the aluminum-silicon alloy ingot. In this way, the entire aluminum-silicon alloy ingot can be heated simul-

taneously by adjusting the frequency and power to prevent the traditional outside heating method from heating or even melting the outside of the aluminum-silicon alloy ingot before the inside reaches the semi-solid temperature, which can effectively reduce the heating time and achieve better control of overall temperature.

[0025] In S2, the aluminum-silicon alloy ingot is made into an appropriate shape by cold and hot processing methods such as cutting and heated to the semi-solid temperature. For example, the processing methods can be used to make it into rods, cuboids or cubes, and the specific shapes are processed according to requirements.

[0026] In S2, the aluminum-silicon alloy ingot is heated to a semi-solid temperature and then held there for 1-60 minutes. The specific holding time depends on the temperature, the type of alloy and the size of aluminum-silicon alloy ingot. In this way, the internal and external temperature of the aluminum-silicon alloy ingot can be consistent.

[0027] In S3, the formation process of ultra-high-silicon aluminum alloy is as follows: the die used is a forging die, comprising an upper mold and a lower mold, and the bottom surface of the upper mold is provided with projection, on the bottom surface of which several first overflow grooves are evenly arranged. The lower mold is provided with the first groove matching the projection, and the bottom surface of the first groove is provided with the second overflow groove corresponding to the first overflow groove. Preheat the mold to 250°C to 350°C, place the aluminum-silicon alloy ingot of semi-solid temperature in the first groove of the lower mold, and use the forging equipment to put the upper mold and the lower mold together to produce the ultra-high-silicon aluminum alloy.

[0028] It can be seen from comparison of Fig. 2 and Fig. 4 that the present invention firstly uses metal spray forming to produce silicon-aluminum alloy with a silicon content of 50%, which is then heated to semi-solid temperature to go through die pressing with overflow. In this way, an appropriate amount of liquid eutectic aluminum-silicon liquid phase is extruded into the overflow grooves of upper and lower mold to reduce the overall volume compression and enrich the free silicon content, thus producing the ultra-high-silicon aluminum alloy with silicon content over 60%.

Embodiment 2

[0029] Referring to Fig. 5-8, in the Embodiment 2 of the present invention, a method for producing ultra-high-silicon aluminum alloy, comprising the following steps:

S1. Use the metal spray forming technology to make an aluminum-silicon alloy melt into an aluminum-silicon alloy ingot;

S2. Heat the aluminum-silicon alloy ingot to a semi-

solid temperature;

S3. Use die pressing to form the aluminum-silicon alloy ingot at a semi-solid temperature into an ultra-high-silicon aluminum alloy.

[0030] In S2, an electromagnetic inductor is used to heat the aluminum-silicon alloy ingot. In this way, the entire aluminum-silicon alloy ingot can be heated simultaneously by adjusting the frequency and power to prevent the traditional surface heating method from heating or even melting the outside of the aluminum-silicon alloy ingot before the inside reach the semi-solid temperature, which can effectively reduce heating time and achieve better control of overall temperature.

[0031] In S2, the aluminum-silicon alloy ingot is made into an appropriate shape by cold and hot processing methods such as cutting and heated to semi-solid temperature. For example, cold or hot machining cutting can be used to make it into rods, cuboids or cubes, and the specific shapes are processed according to processing requirements.

[0032] In S2, the aluminum-silicon alloy ingot is heated to a semi-solid temperature and then held for 1-60 minutes. The specific holding time depends on the temperature, the type of alloy and the size of aluminum-silicon alloy ingot. In this way, the internal and external temperature of the aluminum-silicon alloy ingot can be consistent.

[0033] In S3, the formation process of ultra-high-silicon aluminum alloy is as follows: the die used is a forging die, comprising an upper mold and a lower mold, and the bottom surface of the upper mold is provided with the second groove. The lower mold is provided with the third groove corresponding to the second groove. The bottom surface of the third groove is evenly placed with several third overflow grooves. Preheat the mold to 300°C to 400°C, place the aluminum-silicon alloy ingot of semi-solid temperature between the second groove of upper mold and the third groove of the lower groove, and then use the forging equipment to put the upper mold and the lower mold together to produce the ultra-high-silicon aluminum alloy.

[0034] The present invention firstly uses metal spray forming to produce silicon-aluminum alloy with a silicon content of 50%, which is then heated to semi-solid temperature to go through die pressing with overflow. In this way, an appropriate amount of eutectic aluminum-silicon liquid phase is pressed into the overflow groove of the lower mold. It can realize a gradient change or local enrichment of free silicon content through the asymmetric or partial arrangement of the overflow groove. As shown in Fig. 5 and Fig.6, the overflow groove is only placed on the lower mold, in this way, the top of the silicon-aluminum alloy formed through extrusion still retains a free silicon content of 50%, while the free silicon content adjacent to the bottom of the overflow groove is up to over 60%, forming a functional structural material with a gra-

dient change of free silicon content from top to bottom, as shown in Fig. 7 and Fig. 8. The top has greater strength and weldability, while the bottom has greater abrasive resistance and dimensional stability caused by dramatic reduction in thermal expansion coefficient at different temperatures.

[0035] The size (a, h) and spacing (b) of the overflow groove of the present invention can be set according to actual needs.

[0036] The preferred embodiments of the present invention are described in detail above, but the present invention is not limited to said embodiments. Those skilled in the field of technology can work out equivalent modifications or substitutions without being against the principle of the present invention. These equivalent modifications or substitutions should be included in the scope defined by the claims of this application.

Claims

1. A method for producing ultra-high-silicon aluminum alloy, **characterized in that**, it comprises the following steps:

S1. Use metal spray forming technology to make an aluminum-silicon alloy melt into an aluminum-silicon alloy ingot (100);
 S2. Heat the aluminum-silicon alloy ingot (100) to a semi-solid temperature;
 S3. Form the aluminum-silicon alloy ingot (100) at a semi-solid temperature into an ultra-high-silicon aluminum alloy by the die-pressing method.

2. The method for producing ultra-high-silicon aluminum alloy according to claim 1, **characterized in that**, in said S2, an electromagnetic inductor is used to heat the aluminum-silicon alloy ingot (100).

3. The method for producing ultra-high-silicon alloy according to claim 1, **characterized in that**, in said S2, the aluminum-silicon alloy ingot (100) is made into an appropriate shape by cold and hot processing methods such as cutting, and heated to semi-solid temperature.

4. The method for producing ultra-high-silicon aluminum alloy according to claim 1, **characterized in that**, in said S2, the aluminum-silicon alloy ingot (100) is heated to a semi-solid temperature and held for 1-60 minutes.

5. The method for producing ultra-high-silicon aluminum alloy according to claim 1, **characterized in that**, in said S3, the processes of the ultra-high-silicon aluminum alloy is as follows: the die used is a forging die, comprising an upper mold (200) and a

lower mold (300), and the upper mold and/or lower mold are/is provided with overflow groove (211; 310) and the aluminum-silicon alloy ingot at the semi-solid temperature is placed between the upper mold and the lower mold, and then the die forging equipment closes the molds.

6. The method for producing ultra-high-silicon aluminum alloy according to claim 5, **characterized in that**, the bottom surface of said upper mold (200) is provided with a projection, and the bottom surface of said projection (210) is provided with several first overflow grooves (211) at regular intervals.

7. The method for producing ultra-high-silicon aluminum alloy according to claim 6, **characterized in that**, said lower mold is provided with the first groove (310) matching said projection (210), and the bottom surface of said first groove (310) is provided with the second overflow groove (311) corresponding to said first overflow groove.

8. The method for producing ultra-high-silicon aluminum alloy according to claim 5, **characterized in that**, the bottom surface of said upper mold (200) is provided with the second groove (220), said lower mold is provided with the third groove (320) corresponding to the second groove (220), and the bottom surface of said third groove (320) is evenly provided with several third overflow grooves (321).

9. The method for producing ultra-high-silicon aluminum alloy according to claim 5, **characterized in that** an appropriate amount of liquid eutectic aluminum-silicon liquid phase is pressed into the overflow groove, which enriches the content of free silicon, so as to produce the ultra-high-silicon aluminum alloy with a higher silicon content.

10. An ultra-high-silicon aluminum alloy, **characterized in that**, it is prepared by the method described in any of Claims 1-9, and the mass content of silicon in said ultra-high-silicon aluminum alloy is greater than or equal to 60%.

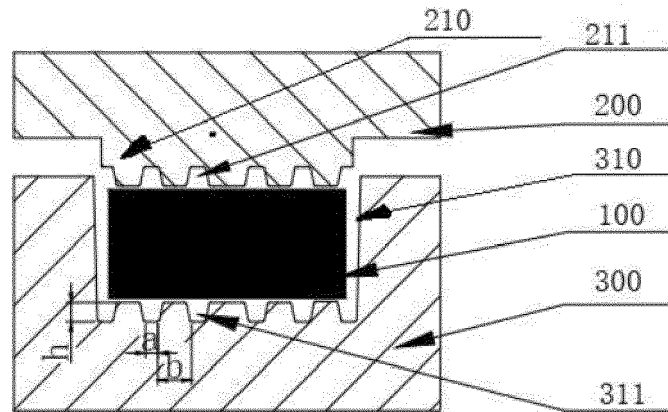


Fig. 1

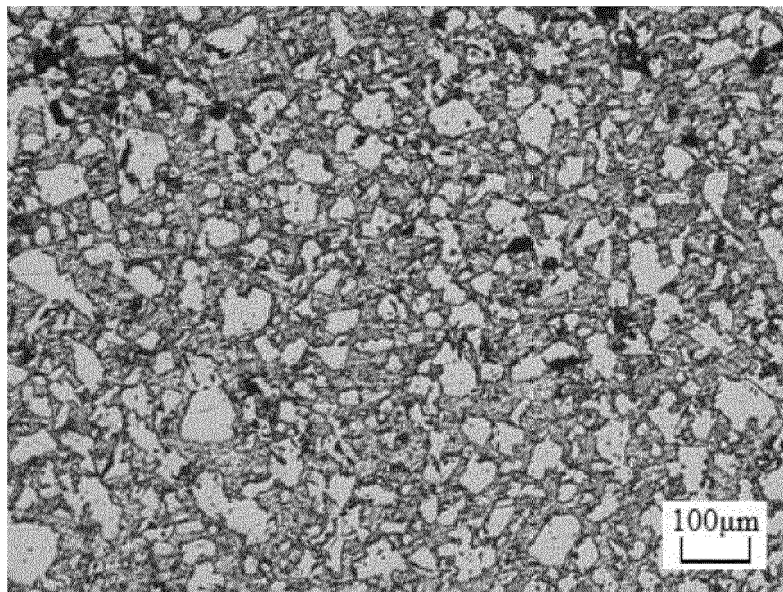


Fig. 2

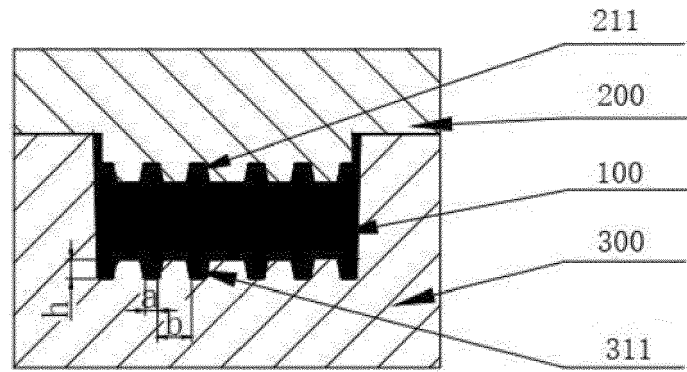


Fig. 3

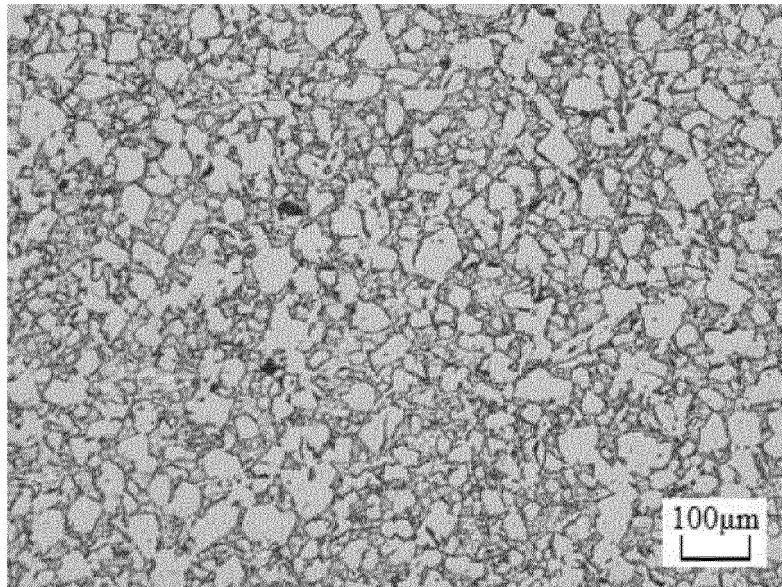


Fig. 4

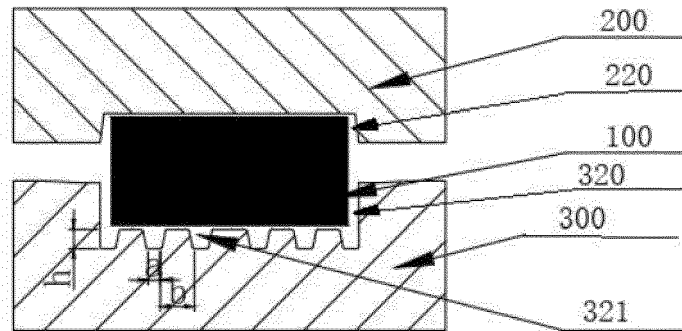


Fig. 5

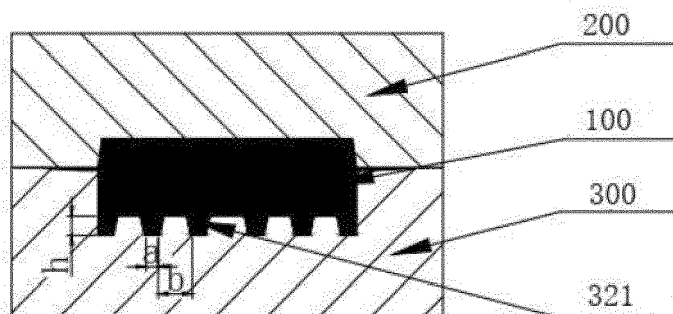


Fig. 6

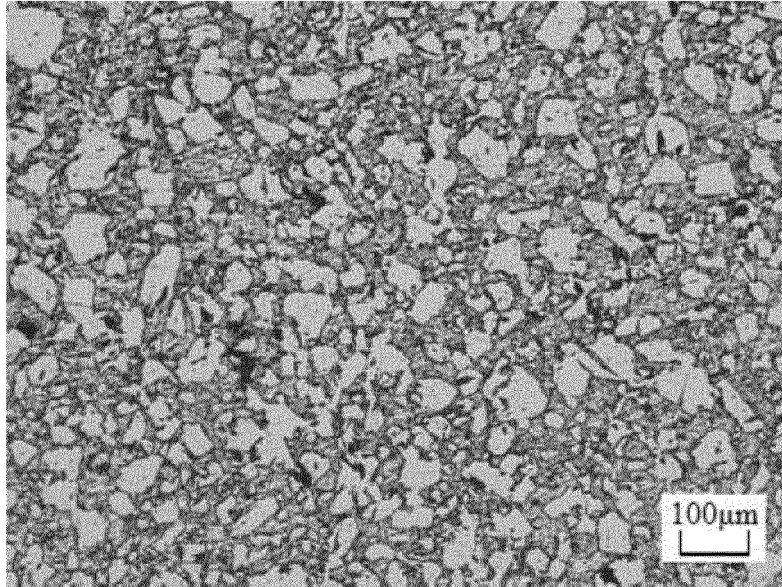


Fig. 7

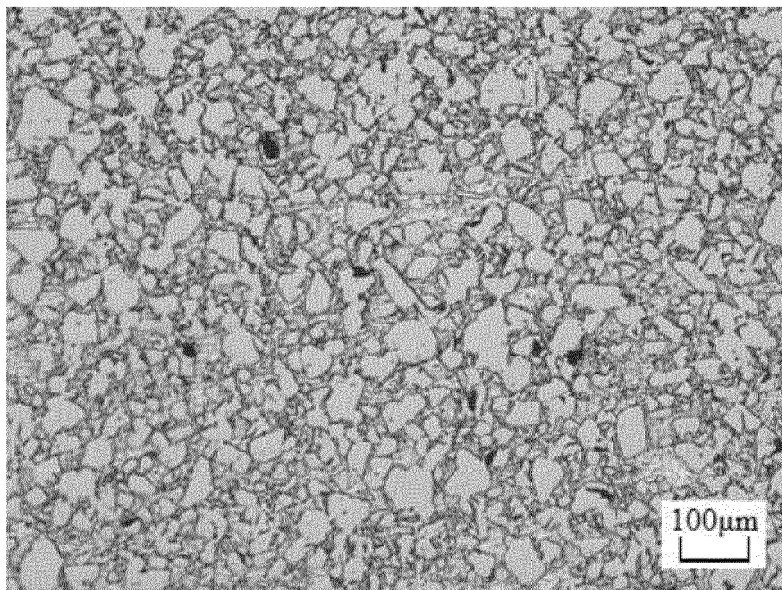


Fig. 8



EUROPEAN SEARCH REPORT

Application Number

EP 21 18 8931

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	WO 2020/052528 A1 (FOSHAN FENGHE PSF TECH LIMITED [CN]) 19 March 2020 (2020-03-19)	1-4	INV.
A	* claims *	5-10	B22F3/115
	-----		B21J5/00
X	CN 101 713 057 B (BEIJING NONFERROUS METAL) 15 June 2011 (2011-06-15)	1-4, 10	B21J13/00
A	* claims *	5-9	B21J13/02
	-----		B22D17/00
X	CN 109 371 305 A (TIANJIN BAIENWEI NEW MATERIAL TECH CO LTD) 22 February 2019 (2019-02-22)	10	B22D17/22
A	* examples 2, 3, 5 *	1-9	C22C1/04
	-----		C22C21/02
X	CN 106 947 893 A (HUANGPING COUNTY SUNLIGHT TECH DEVELOPMENT CO LTD) 14 July 2017 (2017-07-14)	10	C22F1/043
A	* example 8 *	1-9	

The present search report has been drawn up for all claims			TECHNICAL FIELDS SEARCHED (IPC)
			B22F
			B22D
			B21L
			C22F
			C22C
			B21J
1	The present search report has been drawn up for all claims		Examiner
	Place of search The Hague	Date of completion of the search 13 January 2022	Morra, Valentina
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 O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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ON EUROPEAN PATENT APPLICATION NO.**

EP 21 18 8931

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2020052528 A1	19-03-2020	CN 109290543 A	01-02-2019
		WO 2020052528 A1	19-03-2020

CN 101713057 B	15-06-2011	NONE	

CN 109371305 A	22-02-2019	NONE	

CN 106947893 A	14-07-2017	NONE	

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