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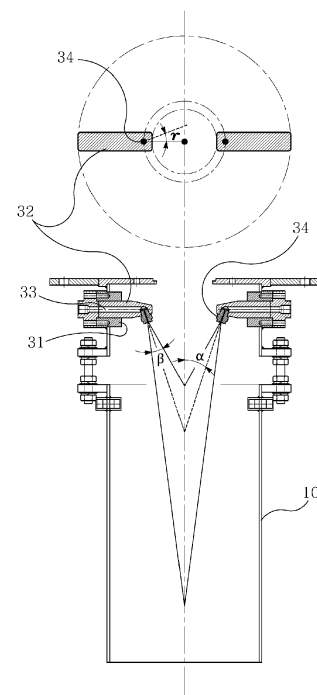
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(54) **SPRAY NOZZLE AND METAL POWDER MANUFACTURING APPARATUS INCLUDING SAME**

(57) A spray nozzle according to the present disclosure includes a spray nozzle holder protruding toward the inside of a chamber and a spray nozzle tip coupled to the spray nozzle holder, wherein the spray nozzle tip is oriented toward a direction lower than the spray nozzle holder, so that the pressure of cooling water can be efficiently transmitted to molten metal droplets that are atomized and scattered, resulting in a fast cooling rate. Thus, the present disclosure is advantageous in the manufacture of metal powders with a high amorphous phase ratio. In addition, by controlling a spray angle and a spray coverage angle of the spray nozzle tip, it is possible to consistently manufacture metal powder under various cooling conditions, thereby obtaining favorable conditions for the manufacture of amorphous metal powder, and thus increasing the ratio of the amorphous phase of the manufactured metal powder.

[FIG. 1]



Description

CROSS REFERENCE TO RELATED APPLICATION

- 5 **[0001]** The present application claims priority to Korean Patent Application No. 10-2020-0021220, filed February 20, 2020, the entire contents of which is incorporated herein for all purposes by this reference.

BACKGROUND OF THE INVENTION

10 Field of the Invention

[0002] One aspect of the present disclosure relates to a spray nozzle for spraying cooling water to cool metal powder in an apparatus for manufacturing metal powder, and to a metal powder manufacturing apparatus.

15 Description of the Related Art

[0003] In order to derive miniaturization, high functionality, diversification, and precision of high-density electronic circuit elements for the recent rapid development of electronics industry, increased spread of electronic devices, and the improvement of processing speed, it is necessary to preferentially establish a technology for manufacturing fine metal powders that are chemically stable and have excellent conductivity.

20 **[0004]** As a representative method of such metal powder manufacturing technology, a rapid solidification process is used. The rapid solidification process is a process for manufacturing spherical powders for not only functional alloy materials such as hard magnetic materials, soft magnetic materials, hydrogen storage alloy materials, and thermoelectric materials, but also materials of various mechanical parts used for structural purposes, such as aluminum-based alloys, copper-based alloys, and stainless steels.

[0005] In general, the following processes are mainly used for the rapid solidification process: water atomization in which a metal melt stream is atomized by shear force generated by blowing fluid or gas into the molten metal stream at high speed when manufacturing metal powder from molten metal, gas atomization, and centrifugal atomization in which a metal melt stream is atomized by centrifugal force of a cup or disk rotating at high speed.

30 **[0006]** In the case of a conventional cooling system for powder manufacturing, because the system simply performs a primary cooling action by gas spraying or centrifugal atomization, the cooling rate ($\leq 103^{\circ}\text{C}$) of the metal powder is limited and thus the rapid cooling effect is insufficient. In order to solve this problem and obtain a high cooling rate, a spinning water atomization process (SWAP) has been developed that can simultaneously implement spraying of powder by fluid and cooling by water.

35 **[0007]** However, during cooling of molten metal powder, on the surface of the powder, vaporized cooling water generates bubbles or a water vapor layer is formed, so that it is difficult to achieve a cooling rate above a certain level.

[0008] In particular, in order to manufacture amorphous metal powder, a cooling rate higher than that obtained in a conventional metal powder manufacturing apparatus is essential.

40 **[0009]** Amorphous is a term that refers to the state of a non-crystalline material having an unordered and irregular atomic arrangement, and a representative example of amorphous material is glass. Amorphous metals have characteristics such as high strength and excellent ductility due to lack of crystal orientation, no magnetic anisotropy, and low electrical resistance and thus can be used for various purposes, and their demand has recently been increasing.

[0010] In the manufacturing of such amorphous metal powder, the cooling rate acts as an important factor. This is because if the rate at which a molten metal stream is cooled is not sufficiently high, metal atoms in the molten metal form stable crystals as they cool down, thereby forming a crystalline metal powder.

45 **[0011]** Conventional metal powder manufacturing apparatuses including SWAP have attempted to perform cooling using cooling water after atomization of a stream of molten metal. However, there is a problem in that the cooling rate is too low to form an amorphous metal powder, or even if an amorphous powder is obtained because the cooling rate is sufficient, the size of particles is irregular and the powder is manufactured in a non-spherical shape. There is a further problem in that production cost is high because a large amount of gas or cooling water is consumed to atomize and cool the molten metal stream.

[0012] The foregoing is intended merely to aid in the understanding of the background of the present disclosure, and is not intended to mean that the present disclosure falls within the purview of the related art that is already known to those skilled in the art.

55 Documents of Related Art

[0013] (Patent document 1) Korean Patent No. 10-1334156

SUMMARY OF THE INVENTION

[0014] Accordingly, the present disclosure has been made keeping in mind the above problems occurring in the related art, and an objective of the present disclosure is to provide a spray nozzle capable of manufacturing a metal powder having a high amorphous phase ratio by cooling atomized molten metal droplets at a high cooling rate, and suitable for manufacturing amorphous metal powder under various cooling conditions.

[0015] In order to achieve the above objective, according to one aspect of the present disclosure, there is provided a spray nozzle that sprays cooling water by being fixed by a fixing means inside a chamber where pulverized molten metal droplets are cooled, the spray nozzle including: a spray nozzle holder including a base portion connected to the fixing means, a front end portion protruding in a first direction toward an inside of the chamber, and a hollow flow path formed internally through the base portion and the front end portion and allowing the cooling water to flow therethrough in the first direction; and a spray nozzle tip including a fastening portion coupled to the front end portion, and a spray portion having a nozzle hole receiving the cooling water from the front end portion and spraying the cooling water into the chamber, wherein the spray nozzle tip may spray the cooling water in a second direction lower than the first direction.

[0016] The flow path may be formed in the first direction in the base portion and formed in a direction lower than the first direction in the front end portion.

[0017] The spray nozzle tip may include a guide member for guiding a spray coverage angle within a predetermined range, the spray coverage angle at which a stream of the cooling water sprayed from the nozzle hole spreads.

[0018] The spray nozzle tip may be rotated at the front end portion of the spray nozzle holder so that a spray direction may be adjusted.

[0019] A length of the spray nozzle holder may be 0.1 to 0.7 times an inner diameter of the chamber.

[0020] A difference between a spray direction of the spray nozzle tip and the first direction may be in a range of 35 to 50°.

[0021] A diameter of the flow path may be 10 to 50 times a diameter of the nozzle hole.

[0022] The spray nozzle may further include: a vertical spray angle controller controlling a vertical spray angle which is a smaller angle among angles formed between a central axis of the fixing means and a spray direction; and a circumferential spray angle controller controlling a circumferential spray angle which is an angle that the spray direction deviates from a direction of the central axis when observed along the central axis.

[0023] The vertical spray angle may be in a range of 10 to 70°.

[0024] The circumferential spray angle may be in a range of 0 to 90°.

[0025] The guide member may have a slit shape protruding from each of opposite sides of the nozzle hole in a spray direction.

[0026] The cooling water may flow from the base portion in the first direction to flow to the front end portion, and may be sprayed from the nozzle hole into the chamber through the spray nozzle tip formed in the second direction at the front end portion.

[0027] According to another aspect of the present disclosure, there is provided a metal powder manufacturing apparatus that pulverizes molten metal into droplets and cools the molten metal droplets, the metal powder manufacturing apparatus including: a chamber in which the molten metal droplets are cooled; a molten metal supply part supplying molten metal into the chamber; an atomizer spraying a fluid into a molten metal stream sprayed from the molten metal supply part to break up the molten metal stream; and a spray nozzle fixed by a fixing means inside the chamber, and spraying cooling water, wherein the spray nozzle may include: a spray nozzle holder including a base portion connected to the fixing means, a front end portion protruding in a first direction toward an inside of the chamber, and a hollow flow path formed internally through the base portion and the front end portion; and a spray nozzle tip including a fastening portion coupled to the front end portion, and a spray portion having a nozzle hole spraying the cooling water into the chamber, wherein the spray nozzle holder may extend and protrude in the first direction, and the spray nozzle tip may be configured so that a spray direction is oriented toward a direction lower than the first direction.

[0028] The number of spray nozzles may be in a range of 2 to 16, and a spray pressure of the cooling water may be in a range of 30 to 500 bar.

[0029] A flow rate of the cooling water may be in a range of 20 to 200 l/min.

[0030] The spray nozzle according to the aspect of the present disclosure can destroy a vapor layer formed on the surface of scattered molten metal droplets by spraying cooling water onto the scattered molten metal droplets by the gas atomizer, and cool down powder at a faster rate, thereby manufacturing a metal powder having a high amorphous phase ratio.

[0031] In the spray nozzle, since the spray nozzle holder of the chamber protrudes in the first direction oriented toward the inside of the chamber and thereby the collision point of the molten metal droplets is formed close from the spray position of the cooling water, the spray pressure of the cooling water can be effectively transmitted. In addition, since the spray nozzle tip is formed in a direction lower than the first direction, it is easy to adjust the spray angle, and it a wide spray angle can be advantageously formed.

[0032] In addition, since the guide member formed on each of the opposite sides of the nozzle hole of the spray nozzle

can guide the spray coverage angle to a desired range, a cooling environment created by cooling water can be stably provided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] The above and other objectives, features, and other advantages of the present disclosure will be more clearly understood from the following detailed description when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a view illustrating a front view and a sectional view schematically illustrating a coupled state of a spray nozzle according to an embodiment of the present disclosure;

FIG. 2 is a view illustrating an example of a spray nozzle tip;

FIGS. 3A, 3B, 3C, and 3D are views illustrating values of crystallization enthalpy according to powder particle size in Experimental Examples 1 to 4; and

FIGS. 4A, 4B, 4C, and 4D are views illustrating the results of analyzing metal powder prepared in Experimental Examples 1 to 4 with an X-ray diffraction (XRD) analyzer.

DETAILED DESCRIPTION OF THE INVENTION

[0034] Prior to describing the present disclosure in detail below, it is understood that the terminology used herein is for the purpose of describing particular embodiments only and is not construed to limit the scope of the present disclosure, which is limited only by the appended claims. Unless otherwise defined, all terms including technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which the present disclosure belongs.

1) As shapes, sizes, percentages, angles, numbers, etc. are roughly illustrated in the accompanying drawings, some variations thereof are allowed. 2) As the drawings are drafted from the observer's perspective, any direction or position to describe the drawings may be available for various modifications according to the observer's position.

3) The same reference numerals will be used on the same portions even in different drawings.

4) The terms "comprise", "comprises", "comprising", "have", "composed of", etc. may be interpreted to mean "any other portion can be added" unless "only" is used therewith. 5) Any element used in a singular form may also be interpreted to indicate plural forms. 6) Although shapes, comparisons in size, position relations, etc. are not described with "about", "substantially", etc., they may be interpreted to cover a general scope of tolerance.

7) Although the terms "after ~", "before ~", "subsequently", "following", "this time", etc., are used, they may not be used as a meaning to limit a temporal point. 8) The terms "first", "second", "third", etc., are used selectively, exchangeably, or repeatedly, and they are not interpreted as a limited meaning.

9) Where a position relation between two portions is described with "on ~" "above ~" "below ~" "beside ~" "on a side ~", "between ~", etc., there may be at least one other portion between the two portions unless they are used with "directly". 10) Where parts are electrically connected by using "or" between them, the parts may be interpreted to cover any combination thereof as well as respectively. Where the parts are electrically connected "~ or, one of ~", they are interpreted to mean the parts respectively.

[0035] Hereinafter, the components of the present disclosure will be described in detail with reference to the drawings.

[0036] FIG. 1 is a view schematically illustrating a sectional view of a spray nozzle for manufacturing metal powder according to an aspect of the present disclosure. The spray nozzle for manufacturing the metal powder includes a spray nozzle holder 32 and a spray nozzle tip 34, and may be provided on an inner wall of a chamber 10 of a metal powder manufacturing apparatus by a fixing means 31.

[0037] The fixing means 31 is a means for fixing the spray nozzle inside a reactor for manufacturing metal powder, and the spray nozzle holder 32 may be coupled to the fixing means 31. The fixing means 31 is not limited in size or shape, but is preferably configured in a cylindrical shape having a central axis.

[0038] The fixing means 31 may be installed to fix the spray nozzle to the chamber 10, and is preferably installed close to an upper portion of the chamber 10.

[0039] A molten metal melting furnace may be disposed on the chamber 10, and in order to allow the melting furnace to be fixed and to stably spray a stream of molten metal, an upper plate on which the molten metal melting furnace is mounted or fixedly coupled may be further included between the upper portion of the chamber 10 and the melting furnace.

[0040] The upper plate may support the melting furnace, and includes a fastening hole for fastening a screw to the melting furnace therethrough so that the melting furnace can be fixed. The upper plate includes a concentric upper hole formed at a center portion thereof, and the molten metal stream may be sprayed into the chamber 10 through the upper hole. The upper hole is preferably smaller in inner diameter than the chamber 10.

[0041] In a case where the fixing means 31 has a cylindrical shape, for example, one or more spray nozzles may be installed along a circumferential surface thereof. The spray nozzle may be installed in a fixed position, and after installation, may shift its position or a gap between the spray nozzles may be changed.

[0042] The position of a coupling portion to which the spray nozzle holder 32 is coupled may be changed so that the spray nozzle coupled to the fixing means 31 can be installed by changing its number and position. In a case where the fixing means 31 has a cylindrical shape, the coupling portion to which the spray nozzle holder 32 is coupled may be formed along an inner circumferential surface of the fixing means 31, and the coupling portion may be formed in the form of a rail or groove.

[0043] The spray nozzle holder 32 is connected to the fixing means 31 to fix the spray nozzle to the chamber 10, and serves to uniformly provide cooling water supplied from outside to the spray nozzle.

[0044] The spray nozzle holder 32 is configured in the form of a hollow tubular body having a hollow hole therein, and allows the cooling water to flow through the inner hollow hole as a flow path 33. The spray nozzle holder 32 includes a base portion fixed to the fixing means 31 and a front end portion to which a spray nozzle tip 34 is coupled, and the front end portion may be formed in a form in which an outer diameter thereof gradually decreases toward an end thereof.

[0045] The spray nozzle holder 32 has a length of about 100 to 120 mm, and the length of the spray nozzle holder 32 is 0.1 to 0.7 times the inner diameter of the chamber 10, preferably 0.15 to 0.5 times.

[0046] When the length of the spray nozzle holder 32 is shorter than the above range, a spray position of the cooling water is farther than a scattering point of molten metal droplets, so that pressure transmission efficiency and cooling rate may be decreased, and distribution of powders having a large particle size may be increased. On the other hand, when the length thereof is longer than the above range, a gap between spray nozzle holders 32 becomes narrow, so that the molten metal droplets may directly collide with the nozzle during atomization of the molten metal droplets, causing a problem in manufacturing spherical powder.

[0047] The spray nozzle holder 32 is formed to protrude from the inner wall of the chamber 10 in an inward direction, and thus, a distance at which the pressurized and sprayed cooling water collides with the scattered molten metal droplets, and a time therefor are reduced. In this case, during the collision of the molten metal droplets and the cooling water, transmission of pressure is efficient, so that a water vapor layer formed on the surface of the metal droplets is easily destroyed, thereby increasing the cooling rate.

[0048] The base portion of the spray nozzle holder 32 is fixed to the coupling portion of the fixing means 31, and a rotary shaft that enables rotation of the spray nozzle holder 32 in a horizontal direction perpendicular to a central axis may be provided in the fixing means 31 and the base portion of the spray nozzle holder 32. The spray nozzle holder 32 may rotate with respect to the rotary shaft of the base portion to adjust the direction of the spray nozzle holder 32.

[0049] In another embodiment of the present disclosure, the coupling portion of the fixing means 31 may be formed in the form of a rail having a height equal to that of the fixing means 31, and the spray nozzle holder 32 may be configured in a form that is provided in the coupling portion of the fixing means 31 and is coupled to the coupling portion to be movable therealong so that the base portion of the spray nozzle holder 32 is movable along the coupling portion of the circumferential surface of the fixing means 31 and can be fixed and operated at a desired position.

[0050] The spray nozzle holder 32 is provided by extending from the base portion toward a first direction. The first direction may be a direction oriented toward the inside of the chamber 10, preferably toward a central axis of the chamber 10, and the flow path 33 formed inside the spray nozzle holder 32 is formed in the first direction in the base portion.

[0051] The flow path 33 may be formed in a second direction lower than the first direction in the front end portion of the spray nozzle holder 32. The flow path 33 may be formed inside the spray nozzle holder 32 in a curved shape or a bent shape bent at one or more points.

[0052] In this case, a portion of the flow path 33 formed in the first direction in the spray nozzle holder 32 is preferably longer in length than a remaining portion thereof formed in the second direction.

[0053] FIG. 2 is a view schematically illustrating the structure of the spray nozzle tip 34. The spray nozzle tip 34 serves to cool the molten metal droplets by spraying the cooling water supplied to the flow path 33 of the spray nozzle holder 32 into the metal powder manufacturing apparatus. The spray nozzle tip 34 is configured in the form of a hollow body in which a hollow hole is formed, and has a discharge port formed at a front side thereof with respect to a spray direction of fluid and an inlet port formed at a rear side thereof with respect thereto.

[0054] The spray nozzle tip 34 is fastened to the spray nozzle holder 32. A fastening portion is formed at the rear side of the spray nozzle tip 34, and a spray portion for spraying the cooling water is formed at the front side thereof. The fastening portion includes the inlet port for allowing inflow of the cooling water by being connected to the flow path 33 of the spray nozzle holder 32, and may include a means for fastening to the spray nozzle holder 32 on a circumferential surface thereof, for example, a screw thread.

[0055] In a case where the fastening portion of the spray nozzle tip 34 has the screw thread on an outer surface thereof, the spray nozzle tip 34 is fastened to a screw thread formed on an inner surface of the flow path 44 located in the front end portion of the spray nozzle holder 32. Since the flow path of the spray nozzle holder 32 is formed in a shape bent at an end of the front end portion, a spray direction of the spray nozzle tip 34 may be formed to be oriented toward

the second direction, which is a direction lower than the first direction.

[0056] A fastening portion of the spray nozzle may be fastened by a screw thread to the spray nozzle tip 34 in the flow path 33 formed in the first direction in the front end portion of the spray nozzle holder 32, and fastened to the spray nozzle tip 34 in the flow path 33 formed in the second direction.

[0057] The first direction is not limited, but is preferably formed in a direction perpendicular to the central axis of the chamber 10 or perpendicular to the inner wall thereof, and preferably, the angle formed by the first direction with respect to the central axis or the inner wall of the chamber 10 is 80 to 100°.

[0058] The second direction in which the flow path 33 formed in the front end portion of the spray nozzle holder 32 is different from the first direction in which the flow path 33 is formed in the base portion thereof, and the difference between the first direction and the second direction may be in the range of 35 to 50°, preferably in the range of 35 to 45°.

[0059] In a case where the flow path 33 is a straight flow path, the spray nozzle holder 32 may be directly rotated to adjust the spray direction thereof. However, in this case, the rotation radius of the spray nozzle holder 32 is large due to its protruding structure, and thus, it is difficult to change the spray direction while avoiding collision with atomized molten metal droplets. In addition, when the spray direction of the spray nozzle tip 34 is changed and adjusted, the cooling water is generally sprayed in a downward direction, and thus, a spray angle is required to be largely displaced in only one direction in order to change the spray direction in the first direction to the downward direction.

[0060] Under the condition that the spray nozzle holder 32 is provided in a direction lower than the first direction as described above, the spray angle can be adjusted both in upward and downward directions, so that even with a small angular displacement, the spray angle can be implemented over a wide range in upward and downward directions, which provides an advantage in implementation and operation of equipment.

[0061] The spray nozzle tip 34 is adjusted in the spray direction by a spray angle controller. The spray angle controller may control the spray direction of the spray nozzle tip 34 coupled to the front end portion of the spray nozzle holder 32 in a vertical direction and a circumferential direction.

[0062] The spray direction of the spray nozzle may be divided into a vertical spray angle and a circumferential spray angle, and these spray angles are illustrated in FIG. 1. The vertical spray angle α refers to a smaller angle among angles formed by the spray direction with respect to the central axis of the fixing means 31 or the chamber 10. The vertical spray angle may be in the range of 10 to 70°, preferably in the range of 30 to 60°, and more preferably in the range of 35 to 45°.

[0063] The circumferential spray angle g refers to an angle that the spray direction deviates from a direction of the central axis when observed along the central axis, and may be expressed as an angle between an orthogonal projection of a cooling water spray direction onto a cross section perpendicular to the central axis and a virtual plane passing through the central axis and a spray hole of the nozzle. The circumferential spray angle may be in the range of 0 to 90°, preferably in the range of 0 to 65°, and more preferably in the range of 15 to 45°.

[0064] The spray nozzle tip 34 may be configured as a nozzle tip having a structure in which a spray portion and a fastening portion are rotatable independently of each other. The fastening portion coupled to the front end portion of the spray nozzle holder 32 may be fixed to the spray nozzle holder 32 by a screw thread, and the spray portion of the spray nozzle tip 34 may be rotatable to be adjusted to a desired spray direction by the spray angle controller, so that the cooling water spray direction may be controlled.

[0065] The control of the spray direction of the spray nozzle tip 34 is performed by adjusting the vertical spray angle along the central axis while the spray direction of the spray nozzle tip 34 is oriented toward the central axis, and then rotating the spray direction horizontally to adjust the circumferential spray angle.

[0066] A nozzle hole 35 formed in the discharge port of the spray nozzle tip 34 may have a diameter of 0.1 to 5.0 mm, preferably 0.3 to 3.0 mm. A spray cross-sectional area varies according to the diameter of the nozzle hole 35 of the spray nozzle tip 34, and thus, a flow rate of the sprayed cooling water may vary.

[0067] When the diameter of the nozzle hole 35 is smaller than the above range, the flow rate increases, so that the molten metal stream may be further broken up or it may be difficult to form spherical powder. On the other hand, when the diameter thereof is larger than the above range, there is a problem in that the flow rate decreases, which reduces the cooling effect, so that the ratio of an amorphous phase contained in the manufactured metal powder is low.

[0068] The hollow hole of the spray nozzle tip 34 may have a diameter equal to that of the nozzle hole 35, and may have a diameter smaller than that of the flow path 33 of the spray nozzle holder 32. In this case, the ratio of the diameter of the hollow hole of the spray nozzle tip 34 to the diameter of the flow path 33 of the spray nozzle holder 32 is in the range of 1 to 10 to 1 to 50, preferably in the range of 1 to 15 to 1 to 30. When the diameter ratio is out of the above range, the ratio between the flow rate of the sprayed cooling water and the flow rate of the supplied cooling water decreases. Therefore, there is a difficulty reducing a spraying speed of the cooling water or having to pressurize the supplied cooling water under high pressure, and there is a problem in that resistance increases according to a diameter difference, which is inefficient.

[0069] A spray coverage angle β refers to a spreading angle of the sprayed cooling water with respect to the spray direction, and is illustrated in FIG. 1. The spray coverage angle β refers to a central angle of a conical or sectoral spray

shape. The spray coverage angle β may be adjusted by the diameter of the nozzle hole 35 and a gap between slits.

[0070] When a depth from a protruding surface of the spray nozzle tip 34 where the slits are formed to the nozzle hole 35 of the discharge port is referred to as d , a slit gap is referred to as $D2$, and the diameter of the nozzle hole 35 is referred to as $D1$, the following inequality holds for the spray coverage angle β .

$$\tan^{-1} \frac{D2 - D1}{2h} \geq \frac{\beta}{2}$$

[0071] The spray coverage angle β may be controlled in the range of 15 to 150°, preferably in the range of 25 to 90°, and more preferably in the range of 25 to 65°.

[0072] The spray portion of the spray nozzle tip 34 includes a guide member 36 capable of guiding or controlling a stream of cooling water sprayed from the spray nozzle tip 34 within a predetermined angular range.

[0073] The guide member 36 allows the spray angle or the spray coverage angle β of the cooling water to be sprayed from the spray nozzle tip 34 in a conical shape or sectoral shape to be formed within a predetermined range.

[0074] In an embodiment, the present disclosure may include a slit structure protruding from opposite sides of the discharge port of the spray nozzle tip 34. The spray nozzle tip 34 may include slits protruding from the opposite sides of the discharge port thereof and may adjust the spray shape and coverage angle β of the sprayed cooling water. The cooling water sprayed from the discharge port of the spray nozzle tip 34 may be sprayed in cone shapes symmetrical with respect to the circular nozzle hole 35, and the angle of the spray shape, i.e., the coverage angle β , may vary according to the pressure and flow rate conditions of the cooling water.

[0075] In order to set and maintain the spray coverage angle β at a desired angle, the protruding slit structure of the spray nozzle tip 34 may be used. Since the slits of the spray nozzle tip 34 protrude from opposite sides of the nozzle hole 35, the spray shape of the cooling water that is sprayed while spreading is determined by the slit gap.

[0076] When the angle of the cooling water sprayed from the nozzle hole 35 is smaller than that formed between the nozzle hole 35 and ends of the slits, the sprayed cooling water is sprayed through the gap of the slits. On the other hand, when the angle of the cooling water sprayed from the nozzle hole 35 is greater than that formed between the nozzle hole 35 and the ends of the slits, the sprayed cooling water collides with inner surfaces of the slits, and the cooling water is sprayed within an angular range determined by the gap of the slits, so that a uniform coverage angle can be obtained.

[0077] In addition, due to the presence of the slits, the cooling water may be sprayed in a conical shape and a flat sectoral shape, so that there is an advantage in that an appropriate spray shape can be used according to the cooling area and the requirements for intensive cooling.

[0078] The slit gap of the spray nozzle tip 34 may be in the range of 0.3 to 5.0 mm, preferably in the range of 0.8 to 4.5 mm, and more preferably in the range of 1 to 2.5 mm, and may be three to six times the diameter of the nozzle hole 35, preferably three to four times.

[0079] The guide member 36 is not limited in shape, and may have a slit shape protruding from each of the opposite sides of the nozzle hole 35 as described above, or a hollow cylindrical shape protruding from the periphery of the nozzle hole 35 to surround the periphery.

[0080] In a case where the spray nozzle for manufacturing the metal powder is used in the metal powder manufacturing apparatus, the number and arrangement of nozzles are not limited. However, the number of the nozzles is preferably in the range of 2 to 16, and a gap between the nozzles is preferably in the range of 10 to 100 mm.

[0081] When the number of the nozzles is 1, it is difficult to uniformly cool the entire molten metal droplets because the cooling water is sprayed only on one surface of the falling molten metal droplets. On the other hand, when the number thereof is equal to or greater than 17, a chamber 10 having a large diameter is required. In addition, as the number of the nozzles increases, it is necessary to change a spray angle of each of the nozzles in order to prevent water splashing upward, and there is a problem in that the flow rate of the sprayed cooling water increases, which increases production cost.

[0082] When the gap between the nozzles is out of the above range, there is a problem in the manufacture of metal powder, which requires controlling a crystal structure at a fast cooling rate. There is a further problem in that the droplets are not sufficiently cooled while being scattered and thus collide with the chamber 10, thereby manufacturing a plate-shaped defective powder instead of spherical powder.

[0083] When two or more spray nozzles for manufacturing the metal powder are provided, the spray nozzles may be arranged in a symmetrical shape with respect to the central axis, and each of the spray nozzles is preferably provided at a position corresponding to each vertex of a regular polygon so that the spray nozzles have a rotationally symmetrical shape.

[0084] The supplied cooling water is supplied by a pressurizing device to each of a plurality of spray nozzles along the flow path 33 of the spray nozzle holder 32, and the flow rate of the supplied cooling water is preferably in the range of 20 to 200 l/min, and the pressure of the pressurized cooling water is preferably in the range of 30 to 500 bar.

[0085] Another embodiment of the present disclosure is a metal powder manufacturing apparatus including the above-described spray nozzle for manufacturing the metal powder.

[0086] The metal powder manufacturing apparatus includes the spray nozzle for manufacturing the metal powder, a chamber 10 to which a fixing means 31 is coupled, a molten metal supply part for spraying a molten metal stream at a position on the chamber 10, and an atomizer 20 or a fluid spray nozzle for spraying a fluid into the molten metal stream to break up the molten metal stream into droplets. In the present specification, the fluid spray nozzle is used in the same meaning as the atomizer 20. The fluid spray nozzle is a concept that is distinguished from the above-described spray nozzle, and is a means for forming droplets by spraying the fluid directly into a melt stream, but there is a difference in difficulty manufacturing spherical metal powder due to insufficient cooling effect.

[0087] As the spray nozzle for manufacturing the metal powder, a nozzle including the above-described features may be used, and the description of the configuration of the spray nozzle remains the same as that of the above description and thus is omitted.

[0088] The chamber 10 has a tub shape including a space in which atomized molten metal droplets are cooled. The chamber 10 is not limited in shape, but preferably has a cylindrical shape or a tub shape whose diameter is changed. The chamber 10 has an airtight structure that prevents inflow of external air into the chamber 10 by separating the outside and the inside thereof, with an inner wall on which a fixing means 31 for coupling the spray nozzle for manufacturing the metal powder is provided.

[0089] The chamber 10 may be composed of an upper chamber and a lower chamber, and the upper and lower chambers may be used by being connected to each other. The chamber 10 has cooled metal powder and sprayed cooling water in a lower portion thereof, and may have a separating portion for separating the metal powder and the cooling water from each other. The separated metal powder may be dried, and the separated cooling water may be treated and then pressurized again to be circulated into the inside of the chamber 10 through the spray nozzle for manufacturing the metal powder.

[0090] The ratio of the inner diameter of the chamber 10 to the length thereof is in the range of 1 to 3 to 1 to 10, preferably in the range of 1 to 6 to 1 to 7.

[0091] When the inner diameter-to-length ratio is out of the above range, the flow of air inside the chamber 10, which is generated along the flow of water sprayed at high pressure from the nozzle, cannot sufficiently escape, so that there is a problem in that the flow of air flows back upward and cools down the temperature of a metal liquid phase that has melted and passed through an orifice, thereby clogging the orifice.

[0092] The molten metal supply part is located on the chamber 10, serves to supply molten metal into the chamber 10, and may be coupled to an upper portion of the chamber 10 so that inflow of external air into the chamber 10 is not allowed.

[0093] The molten metal stream may be sprayed through the molten metal supply part or fall down by gravity. The molten metal is not limited in composition, but the composition may be predetermined according to the composition of the metal powder to be manufactured, and may be adjusted so that the ratio of an amorphous phase is high during cooling of the powder.

[0094] The molten metal is not limited in temperature, but the temperature is formed higher than a melting temperature of an alloy according to the composition of the molten metal, and may be adjusted to obtain a desirable cooling rate and to manufacture a metal powder having a high amorphous phase ratio.

[0095] Melting and heating of the metal is performed in a melting furnace. The melting furnace is not limited in type, and a reverberatory furnace, a crucible furnace, a cupola furnace, or an electric furnace may be used.

[0096] The atomizer 20 sprays a fluid into the molten metal stream or the melt stream sprayed or falling down from the molten metal supply part to break up the molten metal stream or the melt stream into fine droplets. The sprayed fluid is not limited. A liquid atomization method for spraying a liquid and a gas atomization method for injecting a gas may be used, but among these, the gas atomization method is preferred.

[0097] The gas used for gas atomization is not limited in type, but a gas that does not oxidize or react with a hot molten metal may be used, preferably, an inert gas such as helium, neon, or argon, or a gas with low reactivity such as nitrogen is used.

[0098] The atomizer 20 is located below the melting furnace for spraying the molten metal stream, and may be coupled to an upper hole of an upper plate of the fixing means 31 to break up the molten metal stream sprayed into the chamber 10.

[0099] The fluid spray nozzle used for atomization may be configured in various shapes and numbers, and any nozzle can be used as long as it has a shape and number that can break up the molten metal stream into molten metal droplets in the particle size range of the metal powder to be manufactured.

[0100] The fluid spray nozzle of the atomizer 20 may be variously adjusted in position and spray angle. The molten metal droplets sprayed downward may vary in cooling area according to the spray angle of the fluid spray nozzle, and may vary in cooling rate and cooling area according to the position and height of the fluid spray nozzle.

[0101] In another embodiment of the present disclosure, the fluid spray nozzle may be coupled to the upper hole of the upper plate. The fluid spray nozzle is coupled to the upper hole, includes a through-hole for allowing the molten

metal stream to be sprayed therethrough, and may include an annular slit-shaped nozzle or spray hole surrounding the periphery of the through-hole.

[0102] The fluid supplied from outside may be gas or cooling water, and is filled in a supply pipe provided around the fluid spray nozzle and then sprayed through the annular fluid spray nozzle. The fluid is sprayed in a conical shape, and directly breaks up the molten metal stream sprayed from the melting furnace and rapidly cools the same to form amorphous metal powder.

[0103] In order to cool the sprayed molten metal droplets at a high rate and form a uniform cooling condition, when the angle formed by a spray direction of the fluid spray nozzle with respect to the molten metal stream is referred to as a fluid spray angle α , the value of $h \cdot \tan \alpha / D$ (wherein, h is the distance or height difference between the spray nozzle for manufacturing the metal powder and the fluid spray nozzle of the atomizer 20, α is the fluid spray angle, and D is the inner diameter of the chamber 10) is in the range of 0.1 to 0.5.

[0104] When the value thereof is out of the above range, a scattering angle of the molten metal droplets becomes too large, so that the molten metal droplets fall into an area outside the cooling area created by the spray nozzle for manufacturing the metal powder, with the result that the properties of the manufactured metal powder may be non-uniform or the ratio of the amorphous phase may be low.

Example

Example 1

[0105] A gas atomizer with a spray direction of 5° was used for atomization, a vertical spray angle was set to 30° and a circumferential spray angle was set to 20° for droplet cooling, a spray coverage angle was set to 65° , and four spray nozzles each having a nozzle tip with a hole diameter of 1.0 mm were arranged.

Comparative Example 1

[0106] A metal powder manufacturing apparatus was prepared that was composed of a gas atomizer and cooling water in a static state, without including a spray nozzle.

Experimental example

Experimental Examples 1 to 4: Manufacturing of metal powder

[0107] For Examples 1 to 3 and Comparative Example 1, pressures of atomizing gas were set to 65, 75, 75, and 60 bar, respectively, flow rates of cooling water were set to 35, 40, 40 and 0 l/min, respectively, pressures of cooling water were set to 110, 180, and 180 bar, respectively, and temperatures of molten metal were set to 1500, 1420, 1400, and 1550°C , respectively, to manufacture metal powders.

[0108] The results of Examples 1 to 3 and Comparative Example 1 are summarized in Table 1 below.

Table 1

No.	Gas Atomization		cooling / 2 nd Water Atomization							Molten metal temperature [°C]
	Angle (°)	Pressure [bar]	Vertical spray angle, α (°)	Spray coverage angle, β (°)	Circumferential spray angle, γ (°)	Nozzle tip number	Nozzle tip diameter [mm]	Flow rate [l/min]	Pressure [bar]	
Example 1	5	65	30	65	20	4	1.0	35	110	1500
Example 2	5	75	30	65	20	4	1.0	40	180	1420
Example 3	5	75	30	65	20	4	1.0	40	180	1400
Comparative Example	5	60								1550

Experimental Examples 5 to 8

[0109] Values of crystallization enthalpy according to powder particle size in Experimental Examples 1 to 4 were measured with a differential scanning calorimeter (DSC). The results are summarized in Table 2 below, and a measurement graph is illustrated in FIGS. 3A to 3D.

Table 2

No.	Powder particle size	ΔH [J/g]			
		-25 μm	25 ~ 32 μm	32 ~ 45 μm	45 ~ 63 μm
Example 1		58.86	50.41	58.9	56.28
Example 2		72.73	77.47	76.06	65.12
Example 3		74.30	66.18	75.61	77.14
Comparative Example		70.89	73.3	66	55.7

Experimental Examples 9 to 12

[0110] The metal powders manufactured in Experimental Examples 1 to 4 were analyzed with an X-ray diffraction (XRD) analyzer. The results are illustrated in FIGS. 4A to 4D.

[0111] The features, structures, effects, etc. described in the embodiments provided in each embodiment can be combined or modified in other embodiments by those skilled in the art to which the embodiments belong. Therefore, contents related to the combination and modification should be construed to be included in the scope of the present disclosure.

Claims

1. A spray nozzle that sprays cooling water by being fixed by a fixing means inside a chamber where pulverized molten metal droplets are cooled, the spray nozzle comprising:

a spray nozzle holder including a base portion connected to the fixing means, a front end portion protruding in a first direction toward an inside of the chamber, and a hollow flow path formed internally through the base portion and the front end portion and allowing the cooling water to flow therethrough in the first direction; and a spray nozzle tip including a fastening portion coupled to the front end portion, and a spray portion having a nozzle hole receiving the cooling water from the front end portion and spraying the cooling water into the chamber, wherein the spray nozzle tip sprays the cooling water in a second direction lower than the first direction.

2. The spray nozzle of claim 1, wherein the flow path is formed in the first direction in the base portion and formed in a direction lower than the first direction in the front end portion.

3. The spray nozzle of claim 1 and/or claim 2, wherein the spray nozzle tip comprises a guide member for guiding a spray coverage angle within a predetermined range, the spray coverage angle at which a stream of the cooling water sprayed from the nozzle hole spreads.

4. The spray nozzle of any one of claims 1 to 3, wherein the spray nozzle tip is rotated at the front end portion of the spray nozzle holder so that a spray direction is adjusted.

5. The spray nozzle of any one of claims 1 to 4, wherein a length of the spray nozzle holder is 0.1 to 0.7 times an inner diameter of the chamber.

6. The spray nozzle of any one of claims 1 to 5, wherein a difference between a spray direction of the spray nozzle tip and the first direction is in a range of 35 to 50°.

7. The spray nozzle of any one of claims 1 to 6, wherein a diameter of the flow path is 10 to 50 times a diameter of the nozzle hole.

8. The spray nozzle of any one of claims 1 to 7, further comprising:

a vertical spray angle controller controlling a vertical spray angle which is a smaller angle among angles formed between a central axis of the fixing means and a spray direction; and
a circumferential spray angle controller controlling a circumferential spray angle which is an angle that the spray direction deviates from a direction of the central axis when observed along the central axis.

9. The spray nozzle of claim 8, wherein the vertical spray angle is in a range of 10 to 70°.

10. The spray nozzle of claim 8 and/or claim 9, wherein the circumferential spray angle is in a range of 0 to 90°.

11. The spray nozzle of any one of claims 3 to 10, wherein the guide member has a slit shape protruding from each of opposite sides of the nozzle hole in a spray direction.

12. The spray nozzle of any one of claims 1 to 11, wherein the cooling water flows from the base portion in the first direction to flow to the front end portion, and is sprayed from the nozzle hole into the chamber through the spray nozzle tip formed in the second direction at the front end portion.

13. A metal powder manufacturing apparatus that pulverizes molten metal into droplets and cools the molten metal droplets, the metal powder manufacturing apparatus comprising:

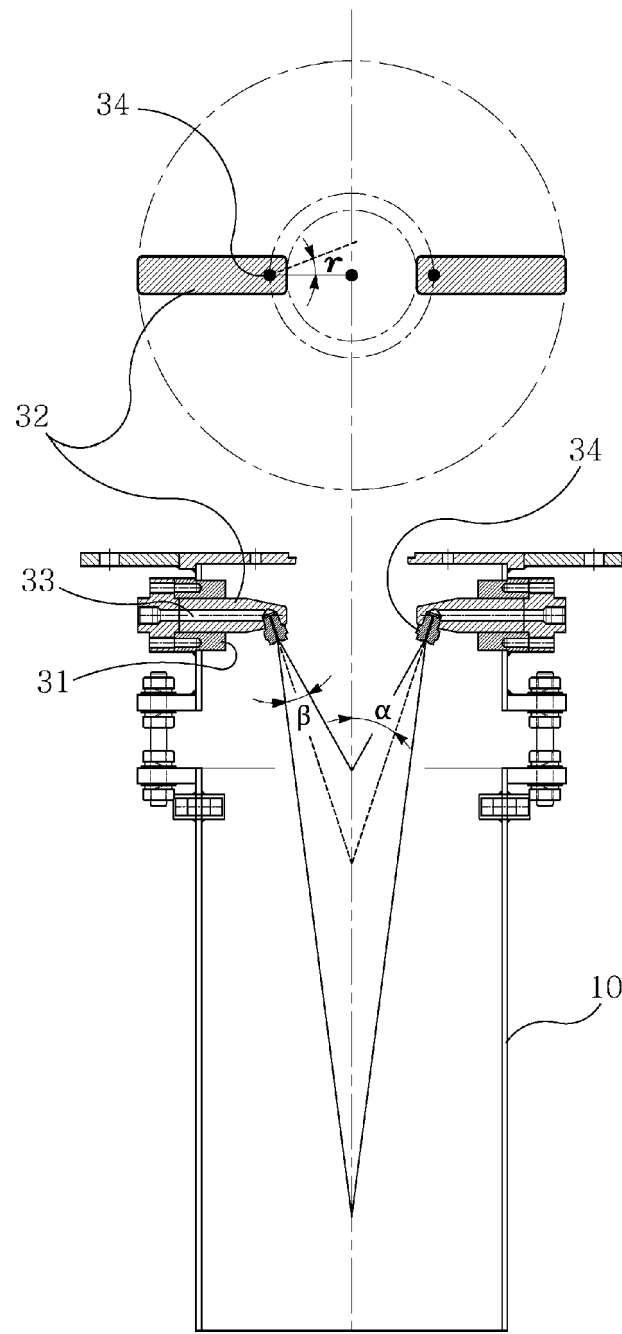
a chamber in which the molten metal droplets are cooled;
a molten metal supply part supplying molten metal into the chamber;
an atomizer spraying a fluid into a molten metal stream sprayed from the molten metal supply part to break up the molten metal stream; and
a spray nozzle fixed by a fixing means inside the chamber, and spraying cooling water,
wherein the spray nozzle comprises:

a spray nozzle holder including a base portion connected to the fixing means, a front end portion protruding in a first direction toward an inside of the chamber, and a hollow flow path formed internally through the base portion and the front end portion; and
a spray nozzle tip including a fastening portion coupled to the front end portion, and a spray portion having a nozzle hole spraying the cooling water into the chamber,
wherein the spray nozzle holder extends and protrudes in the first direction, and the spray nozzle tip is configured so that a spray direction is oriented toward a direction lower than the first direction.

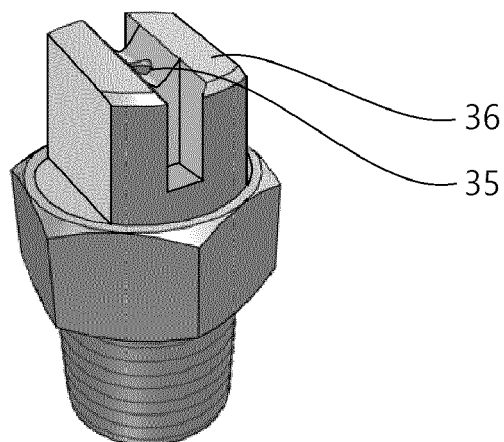
14. The metal powder manufacturing apparatus of claim 13, wherein a spray pressure of the cooling water is in a range of 30 to 500 bar.

15. The metal powder manufacturing apparatus of claim 13 and/or claim 14, wherein a flow rate of the cooling water is in a range of 20 to 200 l/min.

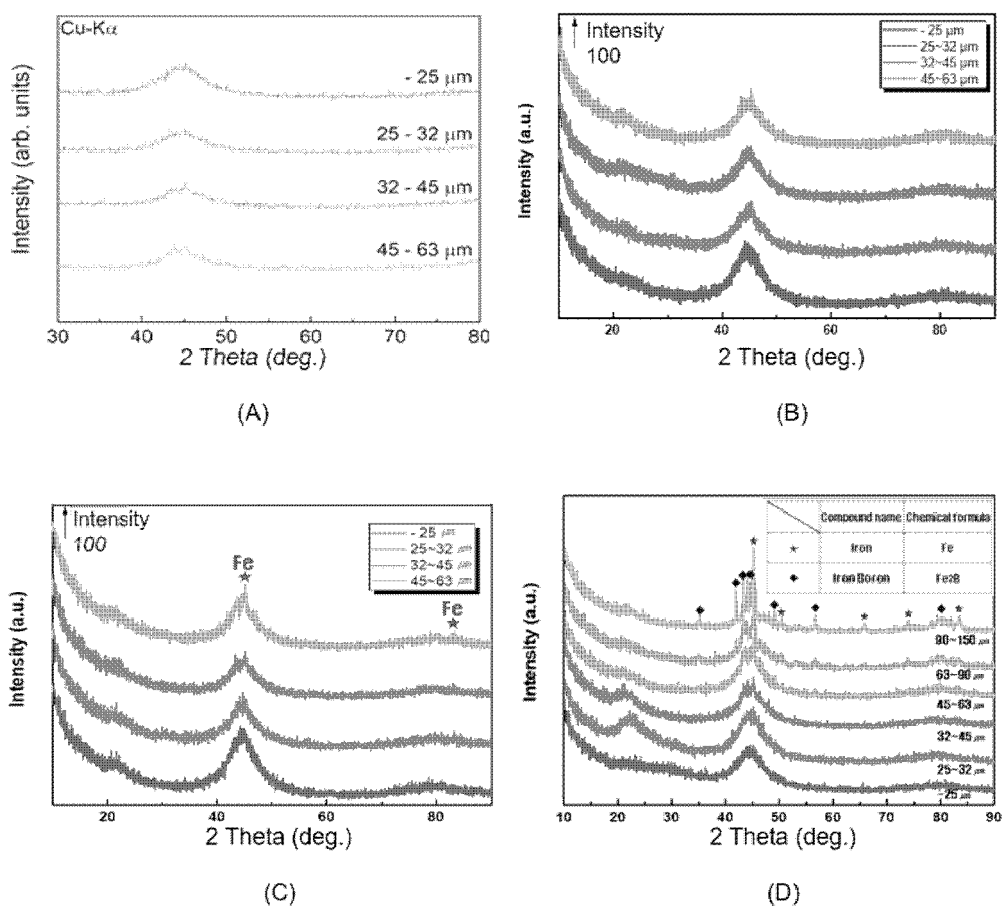
[FIG. 1]



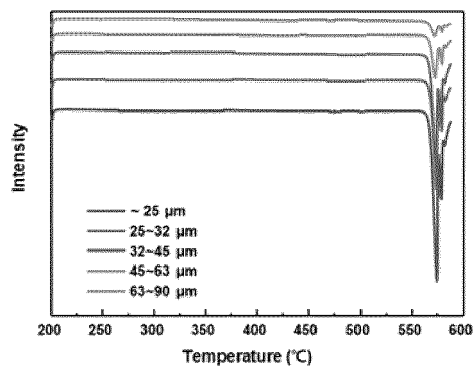
[FIG. 2]



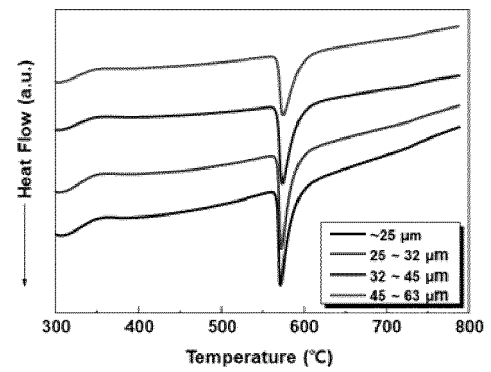
[FIG. 3]



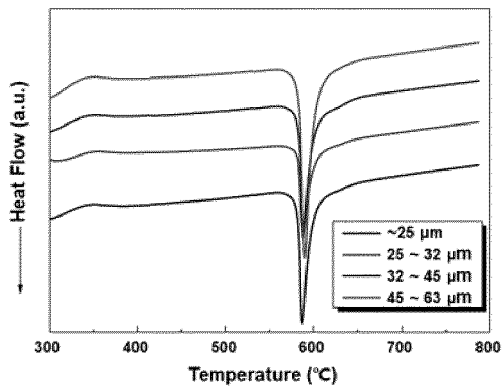
[FIG. 4]



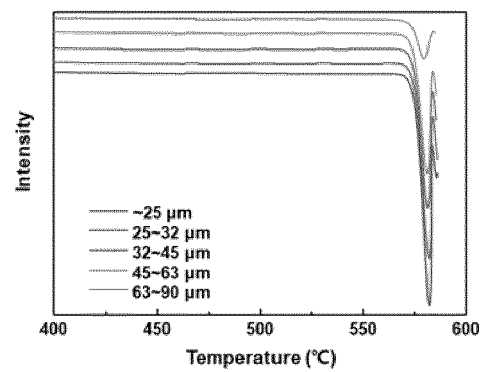
(A)



(B)



(C)



(D)



EUROPEAN SEARCH REPORT

Application Number
EP 21 15 8018

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