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Nebulizer

Abstract

A nebulizer includes: a nozzle portion provided with an ejection port through which gas is ejected; and a capillary having a tip end portion disposed to protrude from the ejection port. A plurality of protruding portions protruding inward in a radial direction of the ejection port are arranged side by side in a circumferential direction on a portion of an inner circumferential surface of the nozzle portion, the portion of the inner circumferential surface defining the ejection port. The plurality of protruding portions are provided to define an inscribed circle. The capillary passes through inside the inscribed circle.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This nonprovisional application is based on Japanese Patent Application No. 2024-021685 filed on Feb. 16, 2024 with the Japan Patent Office, the entire contents of which are hereby incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] The present disclosure relates to a nebulizer.

Description of the Background Art

[0003] As a conventional nebulizer for an ion source, US Patent Publication No. 2021/0398789 discloses a configuration in which a nebulizer outlet portion forming an outlet of the nebulizer is attached to a tip end of a hollow cylindrical body through which gas flows.

[0004] By way of example, the nebulizer outlet portion is constituted of a plurality of parts. Specifically, the nebulizer outlet portion includes: an inlet-side member constituting an inlet end; and an outlet-side member constituting an outlet end. The inlet-side member is attached to a tip end of the hollow cylindrical body, and the outlet-side member is attached downstream of the inlet-side member.

[0005] The inlet-side member is provided with a first channel and a second channel extending through the inlet-side member in its axial direction. The first channel is provided along a central axis of the nebulizer outlet portion, and a capillary passes through the first channel. The second channel communicates with the space inside the hollow cylindrical body and serves as a flow path through which the gas introduced into the hollow cylindrical body flows.

[0006] The outlet-side member has a shape tapered toward the outlet. A space communicating with the second channel extends between the inner surface of the outlet-side member and the tip end of the inlet-side member. The outlet-side member has a tip end provided with an outlet opening though which the tip end side of the capillary passes. Also, a gap is provided between the inner circumferential surface of the outlet-side member that defines the outlet opening and the tip end of the capillary. The gas is ejected through the gap.

[0007] As another example, the nebulizer outlet portion is formed of a single member. In this case, in a cross section parallel to the axial direction, on the upstream side of the outlet opening, a substantially V-shaped space is provided, a first channel through which the capillary passes is provided coaxially with the central axis of the outlet opening, and a second channel communicating with the V-shaped space is provided.

SUMMARY OF THE INVENTION

[0008] In the disclosure in US Patent Publication No. 2021/0398789, in the case where the nebulizer outlet portion is constituted of a plurality of parts as described above, the plurality of parts need to be coaxially attached, which requires accuracy in each of the parts and thereby makes it difficult to perform machining. Further, in the case where the nebulizer outlet portion is formed of a single member as described above, the additive manufacturing process needs to be adopted in order to provide the space portion, the first channel, and the second channel, each of which has a complicated shape. This makes it difficult to fabricate a product with general-purpose tools and methods such as an end mill and electric discharge machining.

[0009] Further, in the configuration disclosed in the above-mentioned US Patent Publication No. 2021/0398789, the approximate position of the capillary is determined by the first channel located away from the capillary on the upstream side of the nebulizer outlet portion. This causes a concern that the capillary may be disposed eccentrically from the center of the outlet opening. In this case, the gas blown out from the outlet opening causes unevenness in the spray shape of the droplets

sprayed from the capillary.
[0010] The present disclosure has been made in view of the above-described problems, and an object thereof is to provide a nebulizer that allows a substantially uniform spray to be emitted from an ejection port in a simple configuration.
[0011] A nebulizer according to a first aspect of the present disclosure includes: a nozzle portion provided with an ejection port through which gas is ejected; and a capillary having a tip end portion disposed to protrude from the ejection port. A plurality of protruding portions protruding inward in a radial direction of the ejection port are arranged side by side in a circumferential direction on a portion of an inner circumferential surface of the nozzle portion, the portion of the inner circumferential surface defining the ejection port. The plurality of protruding portions are provided to define an inscribed circle. The capillary passes through inside the inscribed circle.
[0012] According to the above-described configuration, by a simple configuration of the plurality of protruding portions provided on the inner circumferential surface of the nozzle portion, the center of the capillary can be suppressed from being disposed at a position eccentric from the center of the inscribed circle. Further, since the plurality of protruding portions serving to determine the position of the capillary are provided at the ejection port, the displacement of the tip end position of the capillary can be effectively suppressed. This consequently makes it possible to suppress unevenness in the spray shape of the droplets sprayed from the capillary, so that the droplets can be substantially uniformly sprayed from the ejection port.
[0013] A nebulizer according to a second aspect of the present disclosure includes: a nozzle portion provided with an ejection port through which gas is ejected; and a capillary having a tip end portion disposed to protrude from the ejection port. A portion of an inner circumferential surface of the nozzle portion is provided in a circular shape when viewed in an axial direction of the ejection port, the portion of the inner circumferential surface defining the ejection port. The capillary has an outer shape having a plurality of corner portions. The plurality of corner portions are located inside the circular shape when viewed in the axial direction.
[0014] According to the above-described configuration, by a simple configuration in which the ejection port is formed in a circular cylindrical shape and the capillary has an outer shape having a plurality of corner portions, the center of the capillary can be suppressed from being disposed at a position eccentric from the center of the circular ejection port. Further, since the positions of the plurality of corner portions are determined by the ejection port, the displacement of the tip end position of the capillary can be effectively suppressed. This consequently makes it possible to suppress unevenness in the spray shape of the droplets sprayed from the capillary, so that the droplets can be substantially uniformly sprayed from the ejection port.
[0015] The foregoing and other objects, features, aspects, and advantages of the present invention will become apparent from the following detailed description of the present invention when taken in conjunction with the accompanying drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0016] FIG. **1** is a schematic cross-sectional view of a nebulizer according to a first embodiment.
[0017] FIG. **2** is an enlarged perspective view showing an ejection port of the nebulizer according to the first embodiment and the vicinity of the ejection port.
[0018] FIG. **3** is a diagram showing an end surface on a tip end side of a nozzle portion according to the first embodiment as viewed in an axial direction.
[0019] FIG. **4** is a diagram showing an end surface on a tip end side of a nozzle portion according to a first modification as viewed in the axial direction.
[0020] FIG. **5** is a diagram showing an end surface on a tip end side of a nozzle portion according

to a second modification as viewed in the axial direction.
[0021] FIG. **6** is a diagram showing an end surface on a tip end side of a nozzle portion according to a third modification as viewed in the axial direction.
[0022] FIG. **7** is a diagram showing an end surface on a tip end side of a nozzle portion according to a fourth modification as viewed in the axial direction.
[0023] FIG. **8** is an enlarged perspective view showing an ejection port of a nozzle portion according to a second embodiment and the vicinity of the ejection port.
[0024] FIG. **9** is a diagram showing a tip end portion of a capillary according to the second embodiment as viewed in the axial direction.
[0025] FIG. **10** is a diagram showing a tip end portion of a capillary according to a fifth modification as viewed in the axial direction.
[0026] FIG. **11** is a diagram showing a tip end portion of a capillary according to a sixth modification as viewed in the axial direction.
[0027] FIG. **12** is a diagram showing a tip end portion of a capillary according to a seventh modification as viewed in the axial direction.
[0028] FIG. **13** is a diagram showing a tip end portion of a capillary according to an eighth modification as viewed in the axial direction.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0029] Hereinafter, embodiments of the present disclosure will be described in detail with reference to the accompanying drawings. In the embodiments described below, the same or corresponding portions are denoted by the same reference characters in the drawings, and the description thereof will not be repeated.

First Embodiment

[0030] FIG. **1** is a schematic cross-sectional view of a nebulizer according to the first embodiment. The following describes a nebulizer **10** according to the first embodiment with reference to FIG. **1**.
[0031] Nebulizer **10** is used, for example, in an ion analyzer such as a mass spectrometer and an ion mobility spectrometer for performing ionization.
[0032] Nebulizer **10** includes a body portion **20**, a capillary **30**, and a capillary holding portion **40**. Body portion **20** has a substantially hollow cylindrical shape and constitutes a double tube structure together with capillary **30** disposed inside body portion **20**. In other words, body portion **20** is disposed to surround capillary **30** in the circumferential direction. A gas flow path **20***p* through which gas flows is provided inside body portion **20**. A flow path **30***p* through which a liquid such as a sample solution flows is provided in capillary **30**.
[0033] Body portion **20** includes a hollow cylindrical member **21** and a nozzle portion **22**. Hollow cylindrical member **21** has a circular hollow cylindrical shape. Hollow cylindrical member **21** extends in an axial direction. Hollow cylindrical member **21** has one end **21***a* and the other end **21***b*. One end **21***a* is located downstream from the other end **21***b* in the direction in which the above-mentioned gas flows. A gas introduction portion **23** is provided on the other end **21***b* side of hollow cylindrical member **21**. Gas introduction portion **23** extends in the direction intersecting with the axial direction of hollow cylindrical member **21**.
[0034] Nozzle portion **22** is formed such that its tip end side has a substantially conical cylindrical shape and its base end side has a circular hollow cylindrical shape. The tip end of nozzle portion **22** is provided with an ejection port **22***h* through which gas is ejected. The gas introduced from gas introduction portion **23** flows through gas flow path **20***p* and thereafter is ejected from ejection port **22***h*.
[0035] Nozzle portion **22** is fixed to the one end **21***a* side of hollow cylindrical member **21**. The base end portion of nozzle portion **22** is provided with an engagement portion **22***c*. Engagement portion **22***c* engages with the one end **21***a* side of hollow cylindrical member **21**, so that nozzle portion **22** is fixed.
[0036] Capillary **30** has a hollow cylindrical shape that is smaller in outer diameter and inner

diameter than hollow cylindrical member **21**. Capillary **30** has a tip end portion **31** and a base end portion **32**. Capillary **30** is disposed such that tip end portion **31** protrudes from ejection port **22***h*. Capillary **30** is mostly located inside body portion **20**. Base end portion **32** of capillary **30** is held by capillary holding portion **40**.

[0037] Capillary holding portion **40** includes a first member **41** and a second member **42**. First member **41** is fixed to the other end **21***b* of hollow cylindrical member **21**. More specifically, first member **41** is fixed in the state in which its tip end side is partially inserted into the other end **21***b* side of hollow cylindrical member **21**. First member **41** has a through hole **41***h*. The central axis of through hole **41***h* substantially coincides with the central axis of hollow cylindrical member **21**.

[0038] A joint **60** having a pipe **50** inserted thereinto is fixed to the base end side of through hole **41***h*. Second member **42** is fixed to the tip end side of through hole **41***h*. Second member **42** has a hollow cylindrical shape. Base end portion **32** of capillary **30** is inserted into the inside of second member **42**.

[0039] As described above, base end portion **32** of capillary **30** is inserted into the inside of second member **42** inserted into the through hole of first member **41** fixed to the other end **21***b* side of hollow cylindrical member **21**. Thereby, the base end portion **32** side of capillary **30** is held by capillary holding portion **40**.

[0040] Note that capillary **30** is inserted into second member **42** such that flow path **30***p* communicates with the inner space of pipe **50**. A sample solution is supplied to pipe **50**, and thereby, a sample is supplied to capillary **30**.

[0041] The sample supplied to capillary **30** passes through flow path **30***p* and is then sprayed in a mist from the tip end of capillary **30** by the gas ejected from ejection port **22***h*. The gas promotes vaporization of the droplets sprayed from the tip end of capillary **30** to promote ionization.

[0042] FIG. **2** is an enlarged perspective view showing an ejection port of the nebulizer according to the first embodiment and the vicinity of the ejection port. FIG. **3** is a diagram showing an end surface on the tip end side of the nozzle portion according to the first embodiment as viewed in the axial direction.

[0043] As shown in FIGS. **2** and **3**, a plurality of protruding portions **221** protruding inward in the radial direction of ejection port **22***h* are arranged side by side in the circumferential direction on an inner circumferential surface **220** of nozzle portion **22**, inner circumferential surface **220** defining ejection port **22***h*. The plurality of protruding portions **221** are provided so as to define an inscribed circle C. The plurality of protruding portions **221** are provided such that their top surfaces draw an arc shape when viewed in the axial direction of (in the direction of the normal to) ejection port **22***h*. Each of the top surfaces faces the central axis of ejection port **22***h*. The plurality of protruding portions **221** are arranged side by side at prescribed intervals in the circumferential direction. More specifically, the plurality of protruding portions **221** include four protruding portions that are arranged at a 90-degree pitch.

[0044] Further, inner circumferential surface **220** of nozzle portion **22** that defines ejection port **22***h* has a plurality of bulging portions **222**. The plurality of bulging portions **222** bulge outward of inscribed circle C. The plurality of bulging portions **222** are arranged side by side at prescribed intervals in the circumferential direction. The plurality of bulging portions **222** include four bulging portions that are arranged at a 90-degree pitch. By arranging bulging portions **222** at a prescribed pitch, the gas can be ejected substantially uniformly from ejection port **22***h* around capillary **30**. Each bulging portion **222** has a shape obtained by dividing an elongated hole into two parts along the minor axis direction when viewed in the axial direction. Protruding portion **221** is disposed between bulging portions **222** adjacent to each other in the circumferential direction. Bulging portion **222** has an opening opened at inscribed circle C, and the width of this opening is smaller than the outer diameter of capillary **30**. In other words, the interval between protruding portions **221** adjacent to each other in the circumferential direction is smaller than the outer diameter of capillary **30**. This makes it possible to prevent capillary **30** from entering bulging portion **222**.

[0045] Capillary **30** passes through inscribed circle C defined by the plurality of protruding portions **221** as described above. The diameter of inscribed circle C is substantially equal to the outer diameter of capillary **30**.
[0046] Capillary **30** is positioned inside inscribed circle C such that the center of inscribed circle C substantially coincides with the center of capillary **30** by the plurality of protruding portions **221**. Thereby, by the simple configuration of the plurality of protruding portions **221** provided on inner circumferential surface **220** of nozzle portion **22**, the center of capillary **30** can be suppressed from being disposed at a position eccentric from the center of inscribed circle C.
[0047] Further, since the plurality of protruding portions **221** serving to determine the position of capillary **30** are provided at ejection port **22***h*, the displacement of the tip end position of capillary **30** can be effectively suppressed. More specifically, the plurality of protruding portions **221** serving to determine the position of capillary **30** are provided at ejection port **22***h* that is the outlet end of gas flow path **20***p*. Accordingly, the central axis of capillary **30** can be positioned to be substantially coaxial with the central axis of ejection port **22***h* at the outlet end with high accuracy as compared with the configuration in which capillary **30** is aligned at some intermediate position of gas flow path **20***p*. This consequently makes it possible to suppress unevenness in the spray shape of the droplets sprayed from capillary **30**, so that the droplets can be substantially uniformly sprayed from ejection port **22***h*.
[0048] Further, ejection port **22***h* provided at the end surface of nozzle portion **22** located at the tip end has a fixed shape along the axial direction of nozzle portion **22**. Thus, the configuration of nozzle portion **22** can be simplified, and ejection port **22***h* can be fabricated by general-purpose tools and methods such as an end mill and electric discharge machining. This eliminates the need to employ a special manufacturing method such as additive manufacturing, so that nozzle portion **22** and therefore a nebulizer can be manufactured easily and inexpensively.
[0049] In addition, a member (a positioning member) for positioning tip end portion **31** of capillary **30** is formed of a single nozzle portion **22**. Thereby, as compared with the case where the positioning member is formed of a plurality of divided parts, the processing accuracy can be improved, so that the accuracy in positioning capillary **30** can be enhanced.

First Modification

[0050] FIG. **4** is a diagram showing an end surface on a tip end side of a nozzle portion according to the first modification as viewed in the axial direction. The following describes a nebulizer according to the first modification with reference to FIG. **4**.
[0051] The nebulizer according to the first modification is different from the nebulizer according to the first embodiment in the shape of a tip end of a nozzle portion **22**A and the shape of ejection port **22***h*. Other configurations are substantially the same.
[0052] Also in the first modification, a plurality of protruding portions **221** arranged side by side in the circumferential direction on inner circumferential surface **220** of nozzle portion **22** that defines ejection port **22***h* are provided so as to define inscribed circle C, and capillary **30** passes through inscribed circle C. Four protruding portions **221** are provided and arranged at a 90-degree pitch.
[0053] Further, four bulging portions **222** are arranged at a 90-degree pitch in the circumferential direction. Each of four bulging portions **222** has a track shape whose minor axis is substantially in parallel to the radial direction when viewed in the axial direction. Protruding portion **221** is disposed between bulging portions **222** adjacent to each other in the circumferential direction.
[0054] Even in the case of the configuration as described above, the nebulizer according to the first modification can achieve substantially the same effect as that achieved by the nebulizer according to the first embodiment.

Second Modification

[0055] FIG. **5** is a diagram showing an end surface on a tip end side of a nozzle portion according to the second modification as viewed in the axial direction. The following describes a nebulizer according to the second modification with reference to FIG. **5**.

[0056] The nebulizer according to the second modification is different from the nebulizer according to the first embodiment in the shape of a tip end of a nozzle portion **22**B and the shape of ejection port **22***h*. Other configurations are substantially the same.
[0057] Also in the second modification, a plurality of protruding portions **221** arranged side by side in the circumferential direction on inner circumferential surface **220** of nozzle portion **22** that defines ejection port **22***h* are provided so as to define inscribed circle C, and capillary **30** passes through inscribed circle C. Three protruding portions **221** are provided and arranged at a 120-degree pitch.
[0058] Three bulging portions **222** are arranged at a 120-degree pitch in the circumferential direction. Each of three bulging portions **222** has an elongated hole shape extending in a substantially arc shape when viewed in the axial direction. Protruding portion **221** is disposed between bulging portions **222** adjacent to each other in the circumferential direction.
[0059] Even in the case of the configuration as described above, the nebulizer according to the second modification can achieve substantially the same effect as that achieved by the nebulizer according to the first embodiment.

Third Modification

[0060] FIG. **6** is a diagram showing an end surface on a tip end side of a nozzle portion according to the third modification as viewed in the axial direction. The following describes a nebulizer according to the third modification with reference to FIG. **6**.
[0061] The nebulizer according to the third modification is different from the nebulizer according to the first embodiment in the shape of a tip end of a nozzle portion **22**C and the shape of ejection port **22***h*. Other configurations are substantially the same.
[0062] Also in the third modification, a plurality of protruding portions **221** arranged side by side in the circumferential direction on inner circumferential surface **220** of nozzle portion **22** that defines ejection port **22***h* are provided so as to define inscribed circle C, and capillary **30** passes through inscribed circle C. Six protruding portions **221** are provided and arranged at a 60-degree pitch.
[0063] Further, six bulging portions **222** are arranged at a 60-degree pitch in the circumferential direction, and each of six bulging portions **222** has a substantially semicircular shape when viewed in the axial direction. Protruding portion **221** is disposed between bulging portions **222** adjacent to each other in the circumferential direction.
[0064] Even in the case of the configuration as described above, the nebulizer according to the third modification can achieve substantially the same effect as that achieved by the nebulizer according to the first embodiment.

Fourth Modification

[0065] FIG. **7** is a diagram showing an end surface on a tip end side of a nozzle portion according to the fourth modification as viewed in the axial direction. The following describes a nebulizer according to the fourth modification with reference to FIG. **7**.
[0066] The nebulizer according to the fourth modification is different from the nebulizer according to the first embodiment in the shape of a tip end of a nozzle portion **22**D and the shape of ejection port **22***h*. Other configurations are substantially the same.
[0067] Also in the fourth modification, a plurality of protruding portions **221** arranged side by side in the circumferential direction on inner circumferential surface **220** of nozzle portion **22** that defines ejection port **22***h* are provided so as to define inscribed circle C, and capillary **30** passes through inscribed circle C. Six protruding portions **221** are provided and arranged at a 60-degree pitch.
[0068] Further, six bulging portions **222** are arranged at a 60-degree pitch in the circumferential direction, and each of six bulging portions **222** has a substantially circular shape when viewed in the axial direction. Protruding portion **221** is disposed between bulging portions **222** adjacent to each other in the circumferential direction.
[0069] Even in the case of the configuration as described above, the nebulizer according to the

fourth modification can achieve substantially the same effect as that achieved by the nebulizer according to the first embodiment.

Second Embodiment

[0070] FIG. **8** is an enlarged perspective view showing an ejection port of a nozzle portion according to the second embodiment and the vicinity of the ejection port. FIG. **9** is a diagram showing a tip end portion of a capillary according to the second embodiment as viewed in the axial direction. The following describes a nebulizer according to the second embodiment with reference to FIGS. **8** and **9**.

[0071] As shown in FIGS. **8** and **9**, the nebulizer according to the second embodiment is different from the nebulizer according to the first embodiment in the shape of a capillary **30**E, the shape of a tip end of a nozzle portion **22**E, and the shape of ejection port **22***h*. Other configurations are substantially the same.

[0072] In the second embodiment, ejection port **22***h* is provided in a circular shape when viewed in the axial direction of ejection port **22***h*. In other words, when viewed in the axial direction, a portion of the inner circumferential surface of nozzle portion **22** that defines ejection port **22***h* is provided in a circular shape.

[0073] Further, in capillary **30**E having an outer shape having a plurality of corner portions **33**, when viewed in the axial direction, the outer shape of capillary **30**E is similar to the shape of an inner circumferential surface **30***i* of the capillary that defines flow path **30***p*.

[0074] Specifically, capillary **30**E has a polygonal hollow cylindrical shape. More specifically, capillary **30**E has a dodecagonal hollow cylindrical shape whose sides are curved so as to bulge outward. In the illustrated example, the plurality of corner portions **33** are rounded but may not be rounded. The plurality of corner portions **33** are arranged at a prescribed pitch in the circumferential direction. Thereby, the gas can be ejected substantially uniformly from ejection port **22***h* around capillary **30**. When viewed in the axial direction, the plurality of corner portions **33** are disposed inside the above-mentioned circular shape formed by the inner circumferential surface of nozzle portion **22**.

[0075] Capillary **30**E is positioned inside the above-mentioned circular shape by the plurality of corner portions **33** such that the center of the circular shape substantially coincides with the center of capillary **30**E. Thereby, in a simple configuration in which ejection port **22***h* is formed in a circular cylindrical shape and capillary **30** has an outer shape having a plurality of corner portions, the center of capillary **30**E can be suppressed from being disposed at a position eccentric from the center of circular ejection port **22***h*.

[0076] Further, since the positions of the plurality of corner portions **33** are determined by ejection port **22***h*, the displacement of the tip end position of the capillary can be effectively suppressed. This consequently makes it possible to suppress unevenness in the spray shape of the droplets sprayed from the capillary, so that the droplets can be substantially uniformly sprayed from the ejection port.

[0077] As described above, the nebulizer according to the second embodiment can achieve substantially the same effect as that achieved by the nebulizer according to the first embodiment.

Fifth Modification

[0078] FIG. **10** is a diagram showing a tip end portion of a capillary according to the fifth modification as viewed in the axial direction. The following describes a nebulizer according to the fifth modification with reference to FIG. **10**.

[0079] The nebulizer according to the fifth modification is different from the nebulizer according to the second embodiment in the shape of a capillary **30**F. Other configurations are substantially the same.

[0080] Also in the fifth modification, capillary **30**F has an outer shape having a plurality of corner portions **33** and specifically has a hexagonal hollow cylindrical shape. The plurality of corner portions **33** are disposed inside the above-mentioned circular shape formed by the inner

circumferential surface of nozzle portion **22**.
[0081] Even in the case of the configuration as described above, the nebulizer according to the fifth modification can achieve substantially the same effect as that achieved by the nebulizer according to the second embodiment.
Sixth Modification
[0082] FIG. **11** is a diagram showing a tip end portion of a capillary according to the sixth modification as viewed in the axial direction. The following describes a nebulizer according to the sixth modification with reference to FIG. **11**.
[0083] The nebulizer according to the sixth modification is different from the nebulizer according to the second embodiment in the shape of a capillary **30**G. Other configurations are substantially the same.
[0084] Also in the sixth modification, capillary **30**G has an outer shape having a plurality of corner portions **33** and specifically has a quadrangular hollow cylindrical shape. The plurality of corner portions **33** are disposed inside the above-mentioned circular shape formed by the inner circumferential surface of nozzle portion **22**.
[0085] Even in the case of the configuration as described above, the nebulizer according to the sixth modification can achieve substantially the same effect as that achieved by the nebulizer according to the second embodiment.
Seventh Modification
[0086] FIG. **12** is a diagram showing a tip end portion of a capillary according to the seventh modification as viewed in the axial direction. The following describes a nebulizer according to the seventh modification with reference to FIG. **12**.
[0087] The nebulizer according to the seventh modification is different from the nebulizer according to the second embodiment in the shape of a capillary **30**H. Other configurations are substantially the same.
[0088] Also in the seventh modification, capillary **30**H has an outer shape having a plurality of corner portions **33** and specifically has an octagonal hollow cylindrical shape whose sides are curved so as to bulge outward. The plurality of corner portions **33** are disposed inside the above-mentioned circular shape formed by the inner circumferential surface of nozzle portion **22**.
[0089] Even in the case of the configuration as described above, the nebulizer according to the seventh modification can achieve substantially the same effect as that achieved by the nebulizer according to the second embodiment.
Eighth Modification
[0090] FIG. **13** is a diagram showing a tip end portion of a capillary according to the eighth modification as viewed in the axial direction. The following describes a nebulizer according to the eighth modification with reference to FIG. **13**.
[0091] The nebulizer according to the eighth modification is different from the nebulizer according to the second embodiment in the shape of a capillary **30**I. Other configurations are substantially the same.
[0092] Also in the eighth modification, capillary **30**I has an outer shape having a plurality of corner portions **33** and specifically has a triangular hollow cylindrical shape. The plurality of corner portions **33** are disposed inside the above-mentioned circular shape formed by the inner circumferential surface of nozzle portion **22**.
[0093] Even in the case of the configuration as described above, the nebulizer according to the eighth modification can achieve substantially the same effect as that achieved by the nebulizer according to the second embodiment.
Additional Aspects
Configuration 1
[0094] A nebulizer includes: [0095] a nozzle portion provided with an ejection port through which gas is ejected; and [0096] a capillary having a tip end portion disposed to protrude from the

ejection port, wherein [0097] a plurality of protruding portions protruding inward in a radial direction of the ejection port are arranged side by side in a circumferential direction on a portion of an [0098] inner circumferential surface of the nozzle portion, the portion of the inner circumferential surface defining the ejection port, [0099] the plurality of protruding portions are provided to define an inscribed circle, and [0100] the capillary passes through inside the inscribed circle.

Configuration 2

[0101] The nebulizer according to Configuration 1, wherein the plurality of protruding portions are three or more in number.

Configuration 3

[0102] The nebulizer according to Configuration 1 or 2, wherein the plurality of protruding portions are arranged side by side at prescribed intervals in the circumferential direction.

Configuration 4

[0103] The nebulizer according to any one of Configurations 1 to 3, wherein an interval between protruding portions adjacent to each other in the circumferential direction among the plurality of protruding portions is smaller than an outer diameter of the capillary.

Configuration 5

[0104] The nebulizer according to any one of Configurations 1 to 4, wherein [0105] the portion of the inner circumferential surface of the nozzle portion that defines the ejection port has a plurality of bulging portions that bulge outward of the inscribed circle, [0106] the plurality of bulging portions are arranged side by side in the circumferential direction, and [0107] each of the protruding portions is located between bulging portions adjacent to each other in the circumferential direction among the plurality of bulging portions.

Configuration 6

[0108] A nebulizer includes: [0109] a nozzle portion provided with an ejection port through which gas is ejected; and [0110] a capillary having a tip end portion disposed to protrude from the ejection port; wherein [0111] a portion of an inner circumferential surface of the nozzle portion is provided in a circular shape when viewed in an axial direction of the ejection port, the portion of [0112] the inner circumferential surface defining the ejection port, [0113] the capillary has an outer shape having a plurality of corner portions, and the plurality of corner portions are located inside the circular shape when viewed in the axial direction.

Configuration 7

[0114] The nebulizer according to Configuration 6, wherein [0115] the capillary includes a flow path through which a liquid sample flows, and [0116] when viewed in the axial direction, an outer shape of the capillary is similar to a shape of an inner circumferential surface of the capillary, the inner circumferential surface defining the flow path.

[0117] Although the embodiments of the present invention have been described, it should be understood that the embodiments disclosed herein are illustrative and not restrictive in every respect. The scope of the present invention is defined by the terms of the claims, and is intended to include any modifications within the meaning and scope equivalent to the terms of the claims.

Claims

1. A nebulizer comprising: a nozzle portion provided with an ejection port through which gas is ejected; and a capillary having a tip end portion disposed to protrude from the ejection port, wherein a plurality of protruding portions protruding inward in a radial direction of the ejection port are arranged side by side in a circumferential direction on a portion of an inner circumferential surface of the nozzle portion, the portion of the inner circumferential surface defining the ejection port, the plurality of protruding portions are provided to define an inscribed circle, and the capillary passes through inside the inscribed circle.

2. The nebulizer according to claim 1, wherein the plurality of protruding portions are three or more in number.
3. The nebulizer according to claim 1, wherein the plurality of protruding portions are arranged side by side at prescribed intervals in the circumferential direction.
4. The nebulizer according to claim 1, wherein an interval between protruding portions adjacent to each other in the circumferential direction among the plurality of protruding portions is smaller than an outer diameter of the capillary.
5. The nebulizer according to claim 1, wherein the portion of the inner circumferential surface of the nozzle portion that defines the ejection port has a plurality of bulging portions that bulge outward of the inscribed circle, the plurality of bulging portions are arranged side by side in the circumferential direction, and each of the protruding portions is located between bulging portions adjacent to each other in the circumferential direction among the plurality of bulging portions.
6. A nebulizer comprising: a nozzle portion provided with an ejection port through which gas is ejected; and a capillary having a tip end portion disposed to protrude from the ejection port; wherein a portion of an inner circumferential surface of the nozzle portion is provided in a circular shape when viewed in an axial direction of the ejection port, the portion of the inner circumferential surface defining the ejection port, the capillary has an outer shape having a plurality of corner portions, and the plurality of corner portions are located inside the circular shape when viewed in the axial direction.
7. The nebulizer according to claim 6, wherein the capillary includes a flow path through which a liquid sample flows, and when viewed in the axial direction, an outer shape of the capillary is similar to a shape of an inner circumferential surface of the capillary, the inner circumferential surface defining the flow path.