What is claimed is:

[Claim 1] A quartz glass crucible for pulling up a silicon single crystal, comprising:

a high-aluminum-content layer which is made of quartz glass having a relatively high average aluminum concentration and is provided to form an outer surface of the quartz glass crucible; and

a low-aluminum-content layer which is made of quartz glass having a lower average aluminum concentration than that in the high-aluminum-content layer and is provided on an inner side of the high-aluminum-content layer,

wherein the low-aluminum-content layer includes an opaque layer made of quartz glass containing a large number of minute bubbles, and

the high-aluminum-content layer is made of transparent or translucent quartz glass having a lower bubble content than does the opaque layer,

wherein an average aluminum concentration in the high-aluminum-content layer is 20 ppm or more, and

an average aluminum concentration in the low-aluminum-content layer is less than 20 ppm.

[Claim 2] The quartz glass crucible according to claim 1, further comprising:

an inner transparent layer which is provided on an inner side of the opaque layer to form an inner surface of the quartz glass crucible and contains substantially no bubbles; and

an outer transparent layer which is provided on an outer side of the opaque layer to form an outer surface of the quartz glass crucible and contains substantially no bubbles,

wherein a thickness of the high-aluminum-content layer is thinner than that of the outer transparent layer.

[Claim 3] The quartz glass crucible according to claim 1, further comprising:

a cylindrical straight body portion;

a curved bottom portion; and

a corner portion which connects the straight body portion to the bottom portion, wherein the high-aluminum-content layer is provided in at least the straight body portion.

[Claim 4] The quartz glass crucible according to claim 2,

wherein a bubble content in the outer transparent layer is 2.1% or less.

[Claim 5] The quartz glass crucible according to claim 1,

wherein an aluminum concentration distribution in the high-aluminum-content layer is microscopically unevenly distributed.

[Claim 6] The quartz glass crucible according to claim 5,

wherein a part with a high aluminum concentration is present in a mesh form within a region of 1 mm^3 in the high-aluminum-content layer.

[Claim 7] The quartz glass crucible according to claim 6,

wherein a high-aluminum-concentration region having an aluminum concentration of 60 ppm or more and a low-aluminum-concentration region having an aluminum concentration of less than 25 ppm coexist within a region of 1 mm^2.

[Claim 8] The quartz glass crucible according to claim 7,

wherein an aluminum concentration gradient in a vicinity of a boundary between the high concentration region and the low concentration region is 1 ppm/μm or more and 100 ppm/μm or less.

[Claim 9] The quartz glass crucible according to claim 1,

wherein an average concentration of each of carbon and sulfur in the high-aluminum-content layer is 5 ppm or less.

[Claim 10] The quartz glass crucible according to claim 9,

wherein the bubble content in the high-aluminum-content layer is less than 0.5%.

[Claim 11] A manufacturing method of a quartz glass crucible according to a rotating mold method, the manufacturing method comprising:

a step of forming a deposition layer of raw material quartz powder by depositing aluminum-added quartz powder and natural quartz powder in this order on an inner surface of a rotating mold; and

a step of subjecting the deposition layer of the raw material quartz powder to arc melting from an inner side of the mold,

wherein the step of subjecting the deposition layer of the raw material quartz powder to the arc melting includes

a step of forming an inner transparent layer made of quartz glass with substantially no bubbles contained therein by strengthening a degree of decompression through a large number of vent holes provided in the inner surface of the mold at the time of start of the arc melting,

a step of forming an opaque layer made of quartz glass containing a large number of minute bubbles by weakening the degree of decompression after forming the inner transparent layer, and

a step of forming an outer transparent layer made of quartz glass with substantially no bubbles contained therein by strengthening the degree of decompression again after forming the opaque layer, and

in the step of forming the outer transparent layer, a high-aluminum-content layer is formed by melting the aluminum-added quartz powder, and a timing at which the degree of decompression is strengthened again is controlled to form the outer transparent layer so as to cause a thickness of the outer transparent layer to be thicker than that of the high-aluminum-content layer,

wherein a low-aluminum-content layer which is made of quartz glass having a lower average aluminum concentration than that in the high-aluminum-content layer is provided on an inner side of the high-aluminum-content layer,

an average aluminum concentration in the high-aluminum-content layer is 20 ppm or more, and

an average aluminum concentration in the low-aluminum-content layer is less than 20 ppm.

[Claim 12] The manufacturing method of a quartz glass crucible according to claim 11,

wherein a thickness of the high-aluminum-content layer is 200 μm or more.

[Claim 13] The manufacturing method of a quartz glass crucible according to claim 11,

wherein an average particle size of the aluminum-added quartz powder is 100 to 400 μm,

an aluminum concentration of a top surface of the aluminum-added quartz powder is 60 ppm or more, and

an aluminum concentration of a center portion of the aluminum-added quartz powder is less than 25 ppm.

[Claim 14] The manufacturing method of a quartz glass crucible according to claim 13, further comprising:

a step of preparing the aluminum-added quartz powder before filling the mold with the aluminum-added quartz powder,

wherein the step of preparing the aluminum-added quartz powder includes

a fixing step of fixing aluminum to the natural quartz powder by mixing a solution containing an aluminum compound in the natural quartz powder and thereafter dehydrating and drying the mixture, and

a first heat treatment step of allowing the aluminum to penetrate into a surface layer portion of the natural quartz powder by heating the natural quartz powder to which the aluminum is fixed at a temperature of 1000° C. or higher and 1200° C. or lower, at which temperature the natural quartz powder is not sintered.

[Claim 15] The manufacturing method of a quartz glass crucible according to claim 14,

wherein a heating time in the first heat treatment step is two hours or longer and 20 hours or shorter.

[Claim 16] The manufacturing method of a quartz glass crucible according to claim 14,

wherein an aluminum concentration distribution in the high-aluminum-content layer of the quartz glass crucible is measured by secondary ion mass spectrometry, and on the basis of measurement results of the aluminum concentration distribution, a concentration of the solution containing the aluminum compound used for manufacturing a subsequent quartz glass crucible, or a heat treatment time or a heat treatment temperature for the aluminum-added quartz powder is adjusted.

[Claim 17] The manufacturing method of a quartz glass crucible according to claim 11, further comprising:

a step of removing impurities derived from carbon and sulfur adhered to the aluminum-added quartz powder and other manufacturing processes before filling the mold with the aluminum-added quartz powder.

[Claim 18] The manufacturing method of a quartz glass crucible according to claim 17,

wherein the step of removing the impurities includes

a second heat treatment step of heating the aluminum-added quartz powder in a chamber in an air atmosphere at normal pressure at 1000° C. or higher and 1200° C. or lower,

a first holding step of evacuating an inside of the chamber and holding the aluminum-added quartz powder in a vacuum for a predetermined time, and

a second holding step of changing the inside of the chamber to a helium atmosphere at normal pressure and holding the aluminum-added quartz powder in the helium atmosphere at normal pressure for a predetermined time.

[Claim 19] The manufacturing method of a quartz glass crucible according to claim 18,

wherein a heating time in the second heat treatment step is two hours or longer and 20 hours or shorter.

[Claim 20] A quartz glass crucible for pulling up a silicon single crystal, comprising:

a high-aluminum-content layer which is made of quartz glass having a relatively high average aluminum concentration and is provided to form an outer surface of the quartz glass crucible; and

a low-aluminum-content layer which is made of quartz glass having a lower average aluminum concentration than that in the high-aluminum-content layer and is provided on an inner side of the high-aluminum-content layer,

wherein a part with a high aluminum concentration is present in a mesh form within a region of 1 mm^3 in the high-aluminum-content layer, and

a high-aluminum-concentration region having an aluminum concentration of 60 ppm or more and a low-aluminum-concentration region having an aluminum concentration of less than 25 ppm coexist within a region of 1 mm^2.

[Claim 21] The quartz glass crucible according to claim 20,

wherein the low-aluminum-content layer includes an opaque layer made of quartz glass containing a large number of minute bubbles, and

the high-aluminum-content layer is made of transparent or translucent quartz glass having a lower bubble content than does the opaque layer.

[Claim 22] The quartz glass crucible according to claim 21, further comprising:

an inner transparent layer which is provided on an inner side of the opaque layer to form an inner surface of the quartz glass crucible and contains substantially no bubbles; and

an outer transparent layer which is provided on an outer side of the opaque layer to form an outer surface of the quartz glass crucible and contains substantially no bubbles,

wherein a thickness of the high-aluminum-content layer is thinner than that of the outer transparent layer.

[Claim 23] The quartz glass crucible according to claim 20, further comprising:

a cylindrical straight body portion;

a curved bottom portion; and

a corner portion which connects the straight body portion to the bottom portion,

wherein the high-aluminum-content layer is provided in at least the straight body portion.

[Claim 24] The quartz glass crucible according to claim 22,

wherein a bubble content in the outer transparent layer is 2.1% or less.

[Claim 25] The quartz glass crucible according to claim 20,

wherein an aluminum concentration gradient in a vicinity of a boundary between the high concentration region and the low concentration region is 1 ppm/μm or more and 100 ppm/μm or less.

[Claim 26] The quartz glass crucible according to claim 20,

wherein an average concentration of each of carbon and sulfur in the high-aluminum-content layer is 5 ppm or less.

[Claim 27] The quartz glass crucible according to claim 26,

wherein the bubble content in the high-aluminum-content layer is less than 0.5%.