CLAIMS

What is claimed is:

1. A vacuum pump for pumping a gas, comprising:

an outer enclosure that is substantially gas impermeable, wherein the outer enclosure defines an interior space with an interior surface;

a rotatable disk or ring in the interior space, wherein the rotatable disk or ring has a first surface, a second surface opposite of the first surface, and a peripheral edge between the first surface and the second surface, and wherein the first surface and the second surface are substantially flat;

wherein the rotatable disk or ring is arranged to separate the interior space into a low pressure portion and a high pressure portion with the first surface facing the low pressure portion and the second surface facing the high pressure portion;

wherein the outer enclosure has a first apex that is spaced from the first surface and the interior surface slopes substantially continuously outward from at or near the first apex around substantially the entire peripheral edge of the rotatable disk or ring in the low pressure portion of the interior space;

wherein the peripheral edge of the rotatable disk or ring and the interior surface of the outer enclosure define a first gap, wherein the gas is able to flow between the low pressure portion and the high pressure portion through the first gap while the vacuum pump is pumping the gas, and there is no seal to prevent the gas from flowing between the high pressure portion and the low pressure portion through the first gap, wherein the first gap has a first dimension, that is related to the length of the mean free path of the gas at a predetermined target minimum pressure in the low pressure portion so that the first gap is able to conduct a net outflow of the gas from the low pressure portion to the high pressure portion while the vacuum pump is pumping the gas until the pressure in the low pressure portion reaches the target minimum pressure;

a drive coupled to the rotatable disk or ring, wherein the drive is operable to rotate the rotatable disk or ring with at least a portion of the first surface and the second having tangential velocity in the range of approximately 1 to 6 times the most probable velocity of the molecules of the gas over a range of pressures in the low pressure portion from a starting pressure to the target minimum pressure to cause the molecules of the gas impinging on the rotatable disk or ring to flow outwardly from the peripheral edge of the rotatable disk or ring

through the first gap to reduce the pressure in the low pressure portion from the starting pressure to the predetermined target minimum pressure in a single pumping stage, wherein the target minimum pressure in a single pumping stage;

a second enclosure in the high pressure portion, wherein the second enclosure is substantially gas impermeable, defines a second interior space that is adjacent to the second surface of the rotatable disk or ring, has a second apex that is spaced from the second surface, and has a surface that slopes outwardly from the second apex toward the peripheral edge of the rotatable disk or ring in the high pressure portion and terminates just inwardly of the peripheral edge around substantially the entire peripheral edge;

wherein the peripheral edge of the rotatable disk or ring and the surface of the second enclosure define a second gap having a second dimension wherein the second interior space and the high pressure portion are in gaseous communication via the second gap;

wherein the second dimension of the second gap slightly less than the first dimension of the first gap to reduce a pressure differential between the first surface and the second surface while the pump is pumping the gas.

2. The vacuum pump of claim 1, wherein the starting pressure is about 1 atm and the target minimum pressure is in the range of approximately 10^{-4} to 10^{-6} atm.

3. The vacuum pump of claim 1, wherein the outer enclosure comprises an inlet in gaseous communication with the low pressure portion and an outlet in gaseous communication with the high pressure portion.

4. The vacuum pump of claim 1, wherein the first dimension of the first gap is in the range of approximately 0.5 mm to approximately 100 mm.

5. The vacuum pump of claim 1, wherein the rotatable ring comprises a substantially circular ring with a central opening, a radius dimension between the central opening and the peripheral edge, an interior open portion and a peripheral surface portion with a dimension in the range of approximately 0.05 to less than 0.5 times the radius dimension.

6. The vacuum pump of claim 1, comprising a plurality of substantially parallel planar rotatable disks or rings arranged in a stacked configuration.

7. The vacuum pump of claim 1, wherein the drive is operable to rotate the rotatable disk or ring with at least a portion of the first and second rotatable surfaces having a tangential velocity having a first velocity value when the pressure in the low pressure portion is approximately the starting pressure and having one or more second velocity values that are progressively greater than the first velocity value as the pressure in the low pressure portion is reduced toward the target minimum pressure.

8. A vacuum pump for pumping a gas, comprising:

an outer enclosure that is substantially gas impermeable, wherein the outer enclosure defines an interior space with an interior surface;

a rotatable surface in the interior space, wherein the rotatable surface has a first surface, a second surface opposite of the first surface, and a peripheral edge between the first surface and the second surface, and wherein the first surface and the second surface are substantially flat;

wherein the rotatable surface is arranged to separate the interior space into a low pressure portion and a high pressure portion with the first surface facing the low pressure portion and the second surface facing the high pressure portion;

wherein the outer enclosure has an apex that is spaced from the first surface and the interior surface slopes substantially continuously outward from at or near the first apex around the peripheral edge of the rotatable surface in the low pressure portion of the interior space;

wherein the peripheral edge of the rotatable surface and the interior surface of the outer enclosure define a first gap, wherein the gas is able to flow between the low pressure portion and the high pressure portion through the first gap while the vacuum pump is pumping the gas, and there is no seal to prevent the gas from flowing between the high pressure portion and the low pressure portion through the first gap, wherein the first gap has a first dimension that is related to the length of the mean free path of the gas at a predetermined target minimum pressure in the low pressure portion so that the first gap is able to conduct a net outflow of the gas from the low pressure portion to the high pressure portion while the vacuum pump is pumping the gas until the pressure in the low pressure portion reaches the target minimum pressure;

a drive coupled to the rotatable surface, wherein the drive is operable while the pump is pumping gas to rotate the rotatable surface with at least a portion of the rotatable surface having a tangential velocity in the range of approximately 1 to 6 times the most probable

velocity of the molecules of the gas over a range of pressures in the low pressure portion from a starting pressure of when the pump begins pumping the gas to the target minimum pressure to cause the molecules of the gas impinging on the rotatable surface to flow outwardly from the peripheral edge of the rotatable surface through the first gap to reduce the pressure in the low pressure portion from the starting pressure to the predetermined target minimum pressure in a single pumping stage.

9. The vacuum pump of claim 8, wherein the starting pressure is about 1 atm and the target minimum pressure is in the range of approximately 10^{-4} to 10^{-6} atm.

10. The vacuum pump of claim 8, wherein the first dimension of the first gap is in the range of approximately 0.5 mm to approximately 100 mm.

11. The vacuum pump of claim 8, wherein the rotatable surface comprises a substantially circular ring with a central opening, a radius dimension between the central opening and the peripheral edge, an interior open portion and a peripheral surface portion with a dimension in the range of approximately 0.05 to less than 0.5 times the radius dimension.

12. The vacuum pump of claim 8, comprising a plurality of substantially parallel planar rotatable surfaces arranged in a stacked configuration.

13. The vacuum pump of claim 8, wherein the drive is operable to rotate the rotatable surface with at least a portion of the rotatable surface having a tangential velocity having a first velocity value when the pressure in the low pressure portion is approximately the starting pressure and having one or more second velocity values that are progressively greater than the first velocity value as the pressure in the low pressure portion is reduced toward the target minimum pressure.

14. A vacuum pump for pumping a gas, comprising:

an outer enclosure that is substantially gas impermeable, wherein the outer enclosure defines an interior space with an interior surface;

a plurality of rotatable rings arranged in a stack in the interior space, wherein the stack has a top ring and a bottom ring, wherein each ring of the plurality of rings is substantially

circular and has an interior open portion, an axis of rotation, a peripheral edge, a first peripheral surface around the peripheral edge, and a second peripheral surface around the peripheral edge opposite of the first peripheral surface, wherein the first peripheral surface and the second peripheral surface are substantially flat;

wherein the stack of rotatable rings separates the interior space into a low pressure portion and a high pressure portion with the first peripheral surface of the top ring facing the low pressure portion and the second peripheral surface of the bottom ring facing the high pressure portion;

wherein the outer enclosure has an apex that is spaced from the first surface of the top ring and the interior surface slopes substantially continuously outward from at or near the apex around the peripheral edges of the stack of rotatable rings in the low pressure portion of the interior space;

wherein the peripheral edge of the top ring and the interior surface of the outer enclosure define a first gap, wherein the gas is able to between from the low pressure portion and the high pressure portion through the first gap while the vacuum pump is pumping the gas, and there is no seal to prevent the gas from flowing between the high pressure portion and the low pressure portion through the first gap, wherein the first gap has a first dimension, that is related to the length of the mean free path of the gas at a predetermined target minimum pressure in the low pressure portion so that the first gap is able to conduct a net outflow of the gas from the low pressure portion to the high pressure portion while the vacuum pump is pumping the gas until the pressure in the low pressure portion reaches the target minimum pressure;

a drive coupled to the stack of rotatable rings, wherein the drive is operable while the vacuum pump is pumping the gas to rotate the stack of rotatable rings with at least a portion of the first peripheral surface and the second peripheral surface of at least the top ring having a tangential velocity in the range of approximately 1 to 6 times the most probable velocity of the molecules of the gas to cause the molecules of the gas in the low pressure portion to flow outwardly through the first gap to reduce the pressure in the low pressure portion.

15. The vacuum pump of claim 14, wherein the target minimum pressure is at least as low as approximately 0.5 atm.

16. The vacuum pump of claim 15, wherein the drive is operable when the vacuum pump is pumping the gas to rotate the stack of rotatable rings with at least a portion of the

first peripheral surface and the second peripheral surface of each ring having a tangential velocity in the range of approximately 1 to 6 times the most probable velocity of the molecules of the gas over a range of pressures in the low pressure portion from a starting pressure when the pump begins pumping the gas to the target minimum pressure.

17. The vacuum pump of claim 36, wherein the starting pressure is about 1 atm and the target minimum pressure is in the range of approximately 10^{-4} to 10^{-6} atm.

18. The vacuum pump of claim 14, wherein the drive is operable while the vacuum pump is pumping the gas to rotate the stack of rotatable rings with at least a portion of the first peripheral surface and the second peripheral surface of each ring having a tangential velocity with a first velocity value when the pressure in the low pressure portion has a predetermined starting value and with one or more second velocity values that are progressively greater than the first velocity value as the pressure in the low pressure portion is reduced toward the target minimum pressure.

19. A vacuum pump for pumping a gas, comprising:

an outer enclosure that is substantially gas impermeable, wherein the outer enclosure defines an interior space with an interior surface;

a rotatable surface in the interior space, wherein the rotatable surface has a first surface, a second surface opposite of the first surface, and a peripheral edge between the first surface and the second surface, and wherein the first surface and the second surface are substantially flat and featureless;

wherein the rotatable surface is arranged to separate the interior space into a low pressure portion and a high pressure portion with the first surface facing the low pressure portion and the second surface facing the high pressure portion;

wherein the outer enclosure has an apex that is spaced from the first surface and the interior surface slopes substantially continuously from at or near the first apex toward the peripheral edge of the rotatable surface and extends around the peripheral edge;

wherein the peripheral edge and the interior surface define a first gap, wherein the gas is able to flow between the low pressure portion and the high pressure portion through the first gap while the vacuum pump is pumping the gas and there is no seal to prevent the gas from flowing between the high pressure portion and the low pressure portion through the first gap, wherein the first gap has a first dimension that is related to the length of the mean free

path of the gas at a predetermined target minimum pressure in the low pressure portion so that the first gap is able to conduct a net outflow of the gas from the low pressure portion to the high pressure portion while the vacuum pump is pumping the gas until the pressure in the low pressure portion reaches the target minimum pressure; and

a drive coupled to the rotatable surface and operable to cause the rotatable surface to rotate with at least a portion of the surface having a tangential velocity that is sufficient to cause molecules of the gas in the space between the apex and the rotatable surface that impinge on the surface to be directed toward the peripheral edge and through the gap into the high pressure portion to reduce the pressure of the gas in the low pressure portion.

20. A method of operating the vacuum pump of claim 19, comprising:

introducing the gas into the space between the apex and the rotatable surface in the low pressure portion; and

operating the drive to rotate the rotatable surface with at least a portion of the rotatable surface having a tangential velocity in the range of approximately 1 to 6 times the most probable velocity of the molecules of the gas until the pressure of the gas in the low pressure portion is reduced from a starting pressure when the pump begins pumping the gas to the target minimum pressure in a single pumping stage.

21. The method of claim 19 wherein the starting pressure is about 1 atm and the minimum target pressure is at least as low as approximately .5 atm.

22. The method of claim 19 wherein the starting pressure is about 1 atm and the minimum target pressure is in a range of approximately 10^{-4} to 10^{-6} atm.