with a lower density in a portion corresponding to the area R2 in FIG. 4 than in a portion corresponding to the area R1 in FIG. 4. In the example in FIG. 4, the equipotential lines 133 extend through the portion of the pipe 130" corresponding to the area R2 in FIG. 4. Thus, the pipe 130" has, in a portion closer to the holder 13d in the area R1 in FIG. 4, equipotential lines 133 with a lower density than in a portion adjacent to the top plate 13b in the area R1 in FIG. 4.

[0037] The pipe 130" in the second reference example has the relationship between the distance from the top plate 13b and the potential as shown in, for example, FIG. 5. The distance is from the surface of the top plate 13b closer to the holder 13d in the direction indicated by the arrow in FIG. 4. In the example in FIG. 5, the holder 13d receives a DC voltage of −1.2 kV, causing a potential difference of 1.2 kV between the top plate 13b and the holder 13d.

[0038] As shown in FIG. 5, a change in the potential with respect to a change in the distance from the holder 13d is larger at a position closer to the holder 13d and is smaller at a position farther from the holder 13d. In other words, the electric field changes by a greater degree at a position closer to the holder 13d and by a lesser degree at a position away from the holder 13d.

[0039] The length of the cross section of the channel 132 in the direction of the arrow in FIG. 4 is plotted with respect to the distance from the top plate 13b as shown in, for example, FIG. 6. The length is set to cause a potential difference to be constant between the wall surface of the channel 132 adjacent to the top plate 13b and the wall surface of the channel 132 adjacent to the holder 13d. As shown in FIG. 6, the length of the cross

section of the channel 132 increases at a position farther from the top plate 13b. The length is set to cause a potential difference to be constant between the wall surface of the channel 132 adjacent to the top plate 13b and the wall surface of the channel 132 adjacent to the holder 13d. In other words, the length of the cross section of the channel 132 in the direction of the arrow in FIG. 4 can be increased at a position farther from the top plate 13b to a degree smaller than or equal to the length of the cross section of the channel 132 shown in FIG. 6 in the second reference example.

[0040] FIG. 7 is a diagram of the pipe 130 according to the present embodiment, illustrating an example distribution of the equipotential lines 133. FIG. 7 simply illustrates a half of the pipe 130 without illustrating the sealing members 131. In the present embodiment, as illustrated in, for example, FIG. 7, the channel 132 has a larger cross section in the direction from the top plate 13b toward the holder 13d (in a direction indicated by the arrows in FIG. 7) at a position farther from the holder 13d. This can increase the cross-sectional area of the channel 132 within a range in which the potential difference between the wall surface of the channel 132 adjacent to the top plate 13b and the wall surface of the channel 132 adjacent to the holder 13d is smaller than or equal to a predetermined value, thus increasing the conductance of the channel 132.

[0041] [Comparison of Conductance of Channel 132]

FIG. 8 is a table showing the comparison of the conductance of the pipes in the first reference example, the second reference example, and the embodiment. For the pipe 130' in the first reference example (refer to FIG. 3), the channel 132 has a cross section of 1 mm in the

direction from the top plate 13b toward the holder 13d independently of the distance from top plate 13b, and receives a maximum voltage of 148 V. For the pipe 130" in the second reference example (refer to FIG. 4), the channel 132 has a cross section of 1.6 mm in the direction from the top plate 13b toward the holder 13d independently of the distance from the holder 13d, and receives a maximum voltage of 144.3 V. For the pipe 130 in the present embodiment (refer to FIGS. 2 and 7), the channel 132 has a cross section with a minimum length of 1.6 mm and a maximum length of 4.0 mm in the direction from the top plate 13b toward the holder 13d, and receives a maximum voltage of 144.3 V. In FIG. 8, the cross section of the channel 132 has the length in the direction from the top plate 13b toward the holder 13d set to provide a potential difference smaller than 178 V, which is a discharge inception voltage of an Ar gas, in each of the first reference example, the second reference example, and the present embodiment.

[0042] As shown in, for example, FIG. 8, the channel 132 in the present embodiment has the highest conductance among the channels 132 in the first reference example, the second reference example, and the present embodiment. The pipe 130 according to the present embodiment can thus increase the conductance of the channel 132 while preventing electric discharge of the gas in the channel 132. The pipe 130 according to the present embodiment has a smaller startup time taken for introducing a gas with a predetermined flow rate into the plasma processing chamber 10 than the pipe 130" in the second reference example. The pipe 130 according to the present embodiment can thus promptly switch the gas in the plasma processing chamber 10 through the pipe 130. To increase the conductance of the channel 132, the length of the cross section of the channel