

SUMMARY

[0006] In view of the foregoing, exemplary embodiments provide a plasma etching method capable of forming a hole having a required opening diameter in a silicon nitride layer, while suppressing a tip end portion of the hole from being narrowed.

[0007] In one exemplary embodiment, a plasma etching method of etching a processing target object, which includes a silicon nitride layer and a first mask formed on the silicon nitride layer, placed in a plasma processing apparatus includes a first process of supplying a processing gas containing oxygen and fluorocarbon into the plasma processing apparatus; and a second process of etching the silicon nitride layer of the processing target object with the first mask by exciting the processing gas into plasma. Further, the second process is performed in a state where an organic film generated from the processing gas is formed on an inner wall of an opening of the first mask by reducing a temperature of the processing target object from a first temperature T1 of about $80^{\circ}\text{C} \pm 10^{\circ}\text{C}$ to a second temperature T2 of about $40^{\circ}\text{C} \pm 10^{\circ}\text{C}$. The temperature of the processing target object is reduced through multiple stages from the first temperature to the second temperature during a predetermined time period from an initiation of the second process

[0008] In this case, at near the first temperature T1 as a high temperature, the organic film is formed on the inner wall of the opening of the first mask. Accordingly, it is possible to suppress the diameter of the opening of the first mask from being increased. Further, as the temperature approaches the second temperature T2, the formation of the organic film is suppressed, and the etching in which the tip end portion of the hole becomes narrowed is suppressed. Thus, the hole having a required opening diameter can be formed in the silicon nitride layer, while suppressing the tip end portion of the hole from being narrowed.

[0009] Moreover, the processing target object may further include an etching target layer under the silicon nitride layer, and the plasma etching method may further include a third

process of etching the etching target layer with the silicon nitride layer, which is etched in the second process, as a second mask.

[0010] The hole formed in the second mask has the required opening diameter, and the tip end portion thereof is suppressed from being narrowed, as stated above. Thus, when performing the etching process with this second mask, ions in the plasma can etch the etching target layer based on the shape of the second mask. Therefore, the etching target layer can be etched to have a hole of a required opening diameter, while suppressing the tip end portion of the hole from being narrowed.

[0011]

[0012] In this temperature range, the above-described effects can be appropriately achieved.

[0013] For the reason why the temperatures are set to 80°C and 40°C, if a temperature higher than 80°C is set, the etching process is performed very slowly, whereas if a temperature lower than 40°C is set, it may be difficult to suppress the diameter of the hole from being increased.

[0014] Furthermore, the reason for allowing the error range is because an appropriate temperature may vary depending on the kind and the thickness of the silicon nitride layer.

[0015] In the second process, a time period Time taken to reduce the first temperature T1 to the second temperature T2 satisfies a relationship of $\Delta T = \delta T \times \text{Time}$, when a temperature variation per a unit time (sec) is δT (°C/sec) and a temperature variation width is $(T2 - T1) = \Delta T$ (°C). Accordingly, there is established a relationship of $\text{Time (sec)} = (\text{temperature variation } \delta T)^{-1} (\text{sec/}^\circ\text{C}) \times \text{temperature variation width } \Delta T (^\circ\text{C})$. If the $\delta T^{-1} (\text{sec/}^\circ\text{C})$ is set as a slowness coefficient, when the δT^{-1} is a negative value, the temperature declines slowly as an absolute value of the δT^{-1} .

WE CLAIM

1. A plasma etching method of etching a processing target object, which includes a silicon nitride layer and a first mask formed on the silicon nitride layer, placed in a plasma processing apparatus, the plasma etching method comprising:

a first process of supplying a processing gas containing oxygen and fluorocarbon into the plasma processing apparatus; and

a second process of etching the silicon nitride layer of the processing target object with the first mask by exciting the processing gas into plasma,

wherein the second process is performed in a state where an organic film generated from the processing gas is formed on an inner wall of an opening of the first mask by reducing a temperature of the processing target object from a first temperature of about $80^{\circ}\text{C} \pm 10^{\circ}\text{C}$, to a second temperature of about $40^{\circ}\text{C} \pm 10^{\circ}\text{C}$, and

the temperature of the processing target object is reduced through multiple stages from the first temperature to the second temperature during a predetermined time period from an initiation of the second process.

2. The plasma etching method of Claim 1,

wherein the processing target object further includes an etching target layer under the silicon nitride layer, and

the plasma etching method further comprises:

a third process of etching the etching target layer with the silicon nitride layer, which is etched in the second process, as a second mask.

3. The plasma etching method of Claim 1 or 2,