[0024] Subsequently, a processing operation in the etching apparatus 1 and a phenomenon considered to occur during the processing of the wafer W will be described with reference to explanatory views of FIGS. 2 to 6 schematically illustrating the etching apparatus 1, a time chart of FIG. 7, and a schematic longitudinal cross-sectional view of the wafer W of FIG. 8. In FIGS. 2 to 6, a flow path in which an exhaust flow is formed in the exhauster 5 is illustrated thicker than a flow path in which no exhaust flow is formed, and open and closed states of the valves V1 and V2 in the exhauster 5 are distinguished and illustrated according to angles of valve bodies. The time chart illustrates changes in the pressure within the processing container 21 and timings of the supply and stop of each gas into the processing container 21. The timings of the supply and stop of each gas may also be regarded as opening and closing timings of a valve constituting the flow rate adjusters 35.

[0025] First, the wafer W is loaded into the processing container 21 by the transfer mechanism (not shown). As shown at an upper part of FIG. 8, the thermal oxide film 11 and the non-thermal oxide film 12 are formed on an underlying film 13, and the thermal oxide film 11 and the non-thermal oxide film 12 form a surface of the wafer W. The wafer W is placed on the stage 24, the gate valve 23 of the processing container 21 is closed, and inert gases (Ar gas and N_2 gas) are respectively supplied from the gas supply paths 31 and 32 of a gas supply mechanism. The exhauster 5 is set to a state of the first operation which uses the TMP 52, and the pressure within the processing container 21 is set to a relatively low pressure P0, for example, 10 Torr (1,333 Pa).

[0026] Thereafter, since supply of the HF gas into the processing container 21 from the gas supply path 31 is started, both the HF gas and the Ar gas are supplied from the gas supply path 31, and a degree of opening of the valve V1 is changed so that the pressure within the processing container 21 starts to increase (time t1 in the chart). Subsequently, the valve V1 is closed, and the valve V2 is opened, so that the exhauster 5 is switched to a state of the second operation, and by adjusting a degree of opening of the valve V2, the pressure within the processing container 21 is further increased (FIG. 2). In parallel with the increase in pressure, the temperature of the wafer W reaches the above-described set temperature.

period and is also a common supply period overlapping the first period. A process of supplying the NH_3 gas during the period from time t2 to t3 is a second gas supply process. In the period from time t2 to t3 during which both the HF gas and the NH_3 gas are supplied, an exhaust process of the processing container 21 performed by the exhauster 5 is a first exhaust process.

[0034] Further, an exhaust process performed by the exhauster 5 during a period from time t4 to t6 when the vacuum step is performed is a second exhaust process. In the second exhaust process, an exhaust process performed by the exhauster 5 in the second operation during a period from time t4 to t5 is a pre-exhaust process, and an exhaust process performed by the exhauster 5 in the first operation during a period from time t5 to t6 is a post-exhaust process. Further, the purge step corresponds to a continuous etching process of continuing etching even after the supply of the HF gas and the NH_3 gas is stopped.

[0035] When a required etching amount for the thermal oxide film 11 is relatively large, the pressure adjustment step, the main etching step, the purge step, and the vacuum step may be regarded as one cycle, and the cycle may be repeatedly performed. That is, after the vacuum step is terminated at time t6 and before the wafer W is unloaded from the processing container 21, the operations of the apparatus during a period from time t1 to t6 may be performed again. The number of cycle repetitions may be arbitrarily set according to a desired etching amount. In addition, regarding the pressure adjustment step, it has been described that the temperature of the wafer W is adjusted in addition to the adjustment of the pressure within the processing container 21. However, since the temperature adjustment of the wafer W is completed during the pressure adjustment step in a first cycle, only the pressure within the processing container 21 is adjusted in the pressure adjustment steps in second and subsequent cycles.

[0036] However, respective supply start timings and supply stop timings of the HF gas and the NH_3 gas supplied into the processing container 21 may be made to coincide with each other. That is, in the process shown in the above chart, the HF gas may not be supplied into the processing container 21 during the period from time t1 to t2, and the supply of the HF gas into the processing container 21 may be started from time t2, so that the supply timings of the HF gas and the NH_3 gas may become same.

However, in that case, it was confirmed that the etching rate of the thermal oxide film 11 could not be made sufficiently higher than the etching rate of the non-thermal oxide film 12, and thus an effectiveness of performing the purge step is demonstrated. The reason that the etching rate of the thermal oxide film 11 did not increase sufficiently is presumed to be that a progress of a reaction of Equation 1 was enhanced relative to Equation 2, so that etching, in which AFS described in the background art is generated, proceeded relatively well, whereas etching due to an action of HF_2^- was less likely to proceed. In addition, in Evaluation Test 2, while etching was performed on the thermal oxide film 11 and the non-thermal oxide film 12 formed on the underlying film 13 having no concave-convex pattern, it is considered that a reactivity of each film does not change depending on the presence or absence of the concave-convex pattern. That is, etching may be performed on the thermal oxide film 11 and the non-thermal oxide film 12 formed on the concave-convex pattern. In that case as well, it is considered that etching selectivity having same tendency as the etching selectivity shown in Evaluation Test 2 is obtained with respect to the thermal oxide film 11 and the non-thermal oxide film 12.

EXPLANATION OF REFERENCE NUMERALS

[0061] W: wafer, 11: thermal oxide film, 21: processing container