

What is Claimed is:

1. A TiON film forming method comprising:

accommodating a target substrate in a processing chamber;

maintaining an inside of the processing chamber in a depressurized state;

and

repeating multiple times a cycle of forming a unit TiN film at a predetermined processing temperature by alternately supplying a Ti-containing gas and a nitriding gas into the processing chamber and oxidizing the unit TiN film by supplying an oxidizing agent into the processing chamber,

wherein in an initial stage of the film formation, a cycle of supplying the oxidizing agent after repeating the alternate supply of the Ti-containing gas and the nitriding gas X1 times is repeated Y1 times,

wherein in a later stage of the film formation, a cycle of supplying the oxidizing agent after repeating the alternate supply of the Ti-containing gas and the nitriding gas X2 times is repeated Y2 times until a desired film thickness is obtained,

wherein the number of repetition X1 in the initial stage of the film formation is set to be greater than the number of repetition X2 in the later stage of the film formation, and

wherein the Y1 is within a range of $1 \leq Y1 \leq 5$, wherein a relation between X1 and X2 is selected based on a desired film surface smoothness.

2. The TiON film forming method of claim 1, wherein the X1 is within a

range of $10 \leq X1 \leq 60$ and the $X2$ is within a range of $1 \leq X2 \leq 25$.

3. The TiON film forming method of claim 1, wherein the $X1$ is at least three times greater than the $X2$.

4. The TiON film forming method of claim 1, further comprising:

after the forming of the unit TiN film and before the oxidizing of the unit TiN film, performing a post flow process of supplying the nitriding gas into the processing chamber.

5. The TiON film forming method of claim 4, wherein the post flow process is performed by repeating supply of the nitriding gas and supply of a purge gas multiple times.

6. The TiON film forming method of claim 4, wherein the oxidizing agent is supplied intermittently multiple times.

7. The TiON film forming method of claim 1, further comprising:

after the film formation. performing Ar ion treatment on the surface of the film.

8. The TiON film forming method of claim 7, wherein the Ar ion treatment is performed by generating an Ar plasma and attracting Ar ions in the Ar plasma to the

target substrate.

9. The TiON film forming method of claim 7, wherein the Ar ion treatment is performed on the surface of the film by bombardment effect of the Ar ions.

10. The TiON film forming method of claim 7, wherein the film formation and the Ar ion treatment are performed by separate apparatuses.

11. The TiON film forming method of claim 10, wherein the apparatus for performing the film formation and the apparatus for performing the Ar ion treatment are installed in a processing system including a transfer system for transferring the target substrate in a vacuum state and consecutively perform the film formation and the Ar ion treatment while maintaining a vacuum state.

12. The TiON film forming method of claim 7, wherein the film formation and the Ar ion treatment are performed in a same processing chamber.

13. The TiON film forming method of claim 1, wherein:

the oxidizing of the unit TiN film is performed by intermittently supplying the oxidizing agent into the processing chamber.

14. The TiON film forming method of claim 1, wherein the Ti-containing gas is TiCl_4 gas and the nitriding gas is NH_3 gas.

15. The TiON film forming method of claim 1, wherein the oxidizing agent is an oxygen-containing gas selected from a group consisting of O₂ gas, O₃ gas, H₂O and NO₂ or a plasma of the oxygen-containing gas.

16. The TiON film forming method of claim 1, wherein the processing temperature ranges from 300°C to 500°C.

17. The TiON film forming method of claim 13, wherein the oxidizing agent is supplied in a pulsed manner.

18. The TiON film forming method of claim 13, wherein the oxidizing of the unit TiN film is performed by repeating multiple times a cycle of supplying the oxidizing agent into the processing chamber and purging the processing chamber.