CLAIMS

1. A method for forming a silicon nitride film, comprising:

disposing a substrate including a surface in a chamber;

flowing a silicon-containing gas and a first nitrogen-containing gas into the chamber at a first total flow rate;

depositing a silicon and nitrogen containing layer on the surface of the substrate by applying a first radio frequency (RF) power at a first power level to the silicon-containing gas and the first nitrogen-containing gas;

discontinuing the flow of the silicon-containing gas and the first nitrogen-containing gas and flowing a second nitrogen-containing gas into the chamber, wherein a flow rate of the second nitrogen-containing gas is higher than the first total flow rate;

treating the silicon and nitrogen containing layer by applying a second RF power to the second nitrogen-containing gas at a second power level higher than the first power level; and

repeating the flowing the silicon-containing gas and the first nitrogen-containing gas, the depositing the silicon and nitrogen containing layer, the discontinuing the flow of the silicon-containing gas and the first nitrogen-containing gas and the flowing the second nitrogen-containing gas, and the treating the silicon and nitrogen containing layer until a film with a predetermined thickness is formed.

2. The method of claim 1, wherein

the silicon-containing gas comprises silane (SiH_4);

the silicon-containing gas is flowed at a flow rate of about 10 standard cubic centimeters per minute (sccm) to about 50 sccm;

the first nitrogen-containing gas comprises at least one of ammonia (NH_3) and diatomic nitrogen gas (N_2);

the ammonia of the first nitrogen-containing gas is flowed at a flow rate of about 30 sccm to about 1500 sccm;

the diatomic nitrogen gas of the first nitrogen-containing gas is flowed at a flow rate of about 500 sccm to about 3000 sccm;

the second nitrogen-containing gas comprises diatomic nitrogen gas (N_2); and

the second nitrogen-containing gas is flowed at a flow rate about 10000 sccm to about 20000 sccm.

3. The method of claim 1, wherein a pressure of the chamber is not greater than 6 torr, and wherein the pressure in chamber during the treating of the silicon and nitrogen containing layer is higher than the pressure in the chamber during the depositing of the silicon and nitrogen containing layer.

4. The method of claim 1, wherein

the first power level is about 50 Watts (W) to about 100 W;

the first RF power is applied for a duration of about 1 second to about 5 seconds;

the second power level is about 80 W to about 120 W; and

the second RF power is applied for a duration of about 5 seconds to 15 seconds.

5. The method of claim 4, further comprising:

flowing an oxygen-containing gas into the chamber; and

applying the second RF power to the oxygen-containing gas during the treating the silicon and nitrogen containing layer or applying the second RF power to the oxygen-containing gas after the treating the silicon and nitrogen containing layer, wherein the second RF power after the treating the silicon and nitrogen containing layer is applied for a duration of about 2 seconds to about 10 seconds at the second power level.

6. A method for forming a silicon nitride film, comprising:

disposing a substrate including a surface in a chamber;

flowing a first process gas set comprising a silicon-containing gas and a first nitrogen-containing gas into the chamber, wherein the first process gas set is diatomic hydrogen gas-free;

depositing an initiation layer on the surface of the substrate by applying a third radio frequency (RF) power to the first process gas set at a second frequency and a third power level;

discontinuing the flowing the first nitrogen-containing gas of the first process gas set and flowing a second process gas set comprising the silicon-containing gas, a second nitrogen-containing gas, and a hydrogen-containing gas into the chamber, wherein the second process gas set is diatomic nitrogen gas-free; and

depositing a bulk silicon nitride layer on the initiation layer by applying a first RF power to the second process gas set at a first frequency higher than the second frequency and a first power level higher than the third power level.

7. The method of claim 6, wherein

the silicon-containing gas comprises silane (SiH_4);

while flowing the first process gas set, the silicon-containing gas is flowed at a flow rate of about 10 standard cubic centimeters per minute (sccm) to about 50 sccm;

the first nitrogen-containing gas comprises ammonia (NH_3) and diatomic nitrogen gas (N_2);

while flowing the first process gas set, the ammonia is flowed at a flow rate of about 100 sccm to about 200 sccm and the diatomic nitrogen gas (N_2) is flowed at a flow rate of about 1000 to about 3000 sccm;

the second nitrogen-containing gas comprises ammonia (NH_3);

while flowing the second process gas set, the second nitrogen-containing gas is flowed at a flow rate about 100 sccm to about 200 sccm;

the hydrogen-containing gas comprises diatomic hydrogen gas (H_2); and

while flowing the second process gas set, the hydrogen-containing gas is flowed at a flow rate of about 3000 sccm to 4000 sccm.

8. The method of claim 6, wherein a pressure of the chamber is not greater than 8 torr, and wherein the pressure in chamber during the depositing of the initiation layer is the same as the pressure in the chamber during the depositing of the bulk silicon nitride layer.

9. The method of claim 6, wherein

the third power level is about 50 Watts (W) to about 100 W;

the second frequency is less than 500 kilohertz (kHz);

the third RF power is applied for a duration of about 10 seconds to 20 seconds;

the first power level is about 50 W to about 100 W;

the first frequency is about 10 megahertz (MHz) to about 20 MHz; and

the first RF power is applied for a duration of about 200 seconds to 300 seconds.

10. The method of claim 6, further comprising flowing about 200 sccm to about 600 sccm of NH_3 prior to the flowing the first process gas set.

11. The method of claim 6, further comprising flowing an oxygen-containing gas into the chamber and applying the third RF power to the oxygen-containing gas, wherein the third RF power is applied to the oxygen-containing gas during the depositing the initiation layer.

12. The method of claim 11, further comprising flowing the oxygen-containing gas into the chamber and applying the first RF power to the oxygen-containing gas, wherein the first RF power is applied to the oxygen-containing gas during the depositing of the bulk silicon nitride layer.

13. The method of claim 6, further comprising:

transitioning from the depositing the initiation layer by applying a fourth RF power at the first frequency and a fourth power level of about 25 W to about 75 W and the third RF power at the first frequency and the third power level to the first process gas set for a duration of about 1 second to about 3 seconds, wherein the third power level is higher than the fourth power level; and

transitioning to the depositing the bulk silicon nitride layer by applying the first RF at the first frequency and the first power level and a fifth RF power at the first frequency and a fifth power level of about 15 W to about 45 W to the first process gas set for a duration of about 1 second to about 3 seconds, wherein a flow rate of the first nitrogen-containing gas during the transitioning from the depositing the initiation layer is higher than a flow rate of the first nitrogen-containing gas at the transitioning to the depositing of the bulk silicon nitride layer.

14. A method for forming a silicon nitride film, comprising:

disposing a substrate including a surface in a chamber;

flowing a first process gas set comprising a silicon-containing gas and a first nitrogen-containing gas into the chamber at a first total flow rate;

depositing a silicon and nitride containing layer on the surface of the substrate by applying a first radio frequency (RF) power to the first process gas set at a first frequency of 10 megahertz (MHz) and 20 MHz and a first power level of about 50 Watts (W) to about 100 W for a duration of about 1 second to about 5 seconds at a first pressure of the chamber less than 8 torr;

discontinuing the flow of the first process gas set;

flowing a second process gas set comprising a second nitrogen-containing gas into the chamber at a second total flow rate, wherein the second total flow rate is higher than the first total flow rate;

treating the silicon and nitrogen containing layer by applying a second RF power at the first frequency and a second power level of about 80 W to about 120 W to the second process gas set for a duration of about 5 second to 15 seconds at a second pressure of the chamber, wherein the second power level is higher than

the first power level, and wherein the first pressure of the chamber is higher than the second pressure of the chamber;

repeating the flowing the first process gas set, the depositing the silicon and nitride containing layer, the discontinuing the flow of the first process gas set, the flowing the second process gas set, and the treating of the silicon and nitrogen containing layer until a first initiation layer with a predetermined thickness is formed;

discontinuing the flow of the second process gas set and flowing a third process gas set comprising the silicon-containing gas, a third nitrogen-containing gas, and a hydrogen-containing gas into the chamber, wherein the third process gas set is diatomic nitrogen gas-free; and

depositing a bulk silicon nitride layer on the first initiation layer by applying the first RF power to the third process gas set at the first frequency and the first power level for a duration of about 200 to about 300 seconds at a third pressure of the chamber, wherein the second pressure of the chamber is higher than the third pressure of the chamber.

15. The method of claim 14, wherein

the silicon-containing gas comprises silane (SiH_4);

while flowing the first process gas set, the silicon-containing gas is flowed at a flow rate of about 10 standard cubic centimeters per minute (sccm) to about 50 sccm;

the first nitrogen-containing gas comprises ammonia (NH_3) and diatomic nitrogen gas (N_2);

while flowing the first process gas set, the ammonia is flowed at a flow rate of about 750 sccm to about 1500 sccm and the diatomic nitrogen gas (N_2) is flowed at a flow rate of about 1000 to about 3000 sccm;

the second nitrogen-containing gas comprises diatomic nitrogen gas (N_2);

while flowing the second process gas set, the second nitrogen-containing gas is flowed at a flow rate about 10000 sccm to about 20000 sccm;

the third nitrogen-containing gas comprises ammonia (NH_3);

while flowing the third process gas set, the second nitrogen-containing gas is flowed at a flow rate about 100 sccm to about 200 sccm;

the hydrogen-containing gas comprises diatomic hydrogen gas (H_2); and

while flowing the third process gas set, the hydrogen-containing gas is flowed at a flow rate of about 3000 sccm to 4000 sccm.

16. The method of claim 14, further comprising:

flowing a fourth process gas set comprising the silicon-containing gas and the first nitrogen-containing gas into the chamber;

depositing a second initiation layer by applying a third RF power to the fourth process gas set at a second frequency less than 500 kilohertz (kHz) and a third power level of about 50 W to about 100 W, wherein the first power level is higher than the third power level and the first frequency is higher than the second frequency;

transitioning from the depositing the second initiation layer by applying a fourth RF power at the first frequency and a fourth power level of about 25 W to about 75 W and the third RF power at the first frequency and the third power level to the fourth process gas set for a duration of about 1 second to about 3 seconds, wherein the third power level is higher than the fourth power level;

transitioning to the depositing the bulk silicon nitride layer by applying the first RF at the first frequency and the first power level and a fifth RF power at the first frequency and a fifth power level of about 15 W to about 45 W to the fourth process gas set for a duration of about 1 second to about 3 seconds, wherein a flow rate of the first nitrogen-containing gas during the transition from the depositing the second initiation layer is higher than a flow rate of the first nitrogen-containing gas at the transitioning to the depositing of the bulk silicon nitride layer; and

discontinuing the flow of the fourth process gas set.

17. The method of claim 14, further comprising flowing about 200 sccm to about 600 sccm of ammonia (NH_3) prior to the flowing the first process gas set;

18. The method of claim 14, further comprising:

flowing an oxygen-containing gas into the chamber; and

applying the second RF power to the oxygen-containing gas during the treating the silicon and nitrogen containing layer or applying the second RF power to the oxygen-containing gas after the treating the silicon and nitrogen containing layer, wherein the second RF power is applied for a duration of about 2 seconds to about 10 seconds at the second power level.

19. The method of claim 16, further comprising flowing an oxygen-containing gas into the chamber and applying the third RF power to the oxygen-containing gas, wherein the third RF power is applied to the oxygen-containing gas during the depositing of the second initiation layer.

20. The method of claim 18, further comprising flowing the oxygen-containing gas into the chamber and applying the first RF power to the oxygen-containing gas, wherein the first RF power is applied to the oxygen-containing gas during the depositing of the bulk silicon nitride layer.