Claims

1. A method of forming a piezoelectric film, comprising:

(a) depositing a first piezoelectric film layer on a surface of a substrate by a first physical vapor deposition (PVD) process;

(b) depositing a second piezoelectric film layer, on top of and in contact with the first piezoelectric film layer, by a second physical vapor deposition (PVD) process;

(c) reducing a temperature of the substrate after forming the first piezoelectric film layer and before forming the second piezoelectric film layer, wherein the temperature is reduced by performing a process for a first period of time; and

additionally performing processes (a), (b) and (c) one or more times, wherein process (c) in the additionally performed processes (a), (b) and (c) is performed for a second period of time, and the second period of time being different than the first period of time, wherein the first piezoelectric film layer and the second piezoelectric film layer comprise a same material combination, wherein the first PVD process and the second PVD process each comprise sputtering a material from a target that comprises an aluminum.

2. The method of claim 1, wherein process of depositing the first piezoelectric film layer and the process of depositing a second piezoelectric film layer have at least one process parameter that is different, and the at least one process parameter is selected from a group consisting of deposition process pressure, bias power and deposition process time.

3. The method of claim 1, wherein the first PVD process and the second PVD process each comprise:

sputtering a material from a target that comprises scandium,

while flowing a process gas that includes argon and nitrogen at a ratio of between about 1 to 1 and about 5 to 1.

4. The method of claim 1, wherein the first PVD process and the second PVD process each comprise:

sputtering a material from a target that comprises aluminum,

while flowing a process gas that includes argon and nitrogen at a ratio of between about 1 to 1 and about 5 to 1.

5. The method of claim 1, wherein the first piezoelectric film layer and the second piezoelectric film layer comprise a same material combination, and a time to form of the first piezoelectric film layer and the second piezoelectric film layer in less than about 40 seconds.

6. The method of claim 1, further comprising:

forming a third piezoelectric film layer, by use of a third PVD process, on the substrate at a first bias power for a third period of time; and

cooling the first piezoelectric film layer and the second piezoelectric film layer before the forming of the third piezoelectric film layer,

wherein the first piezoelectric film layer, the second piezoelectric film layer, and the third piezoelectric film layer comprise the same material combination.

7. The method of claim 1, wherein the first period of time and the second period of time is each between about 6 seconds and about 60 seconds, wherein an XRD inspection of an interface between the first piezoelectric film layer and the second piezoelectric film layer generates a rocking curve substantially having a single peak.

8. The method of claim 1, further comprising flowing a process gas that comprises argon (Ar) and nitrogen (N) while depositing the first piezoelectric film layer on the surface of the substrate.

9. A method of forming a piezoelectric film, comprising:

(a) depositing, in a first processing chamber, a first piezoelectric film layer on a surface of a substrate by a first physical vapor deposition (PVD) process;

(b) depositing, in the first processing chamber, a second piezoelectric film layer, on top of and in contact with the first piezoelectric film layer, by a second PVD process;

(c) reducing a temperature of a substrate after forming the first piezoelectric film layer and before forming the second piezoelectric film layer, wherein the temperature is reduced by performing a process for a first period of time; and

additionally performing processes (a), (b) and (c) one or more additional times, wherein the additionally performed process (c) is performed for a second period of time, and the second period of time being different than the first period of time,

wherein the first piezoelectric film layer and the second piezoelectric film layer comprise a same material combination, wherein the first PVD process and the second PVD process each comprise sputtering a material from a target that comprises an aluminum.

10. The method of claim 9, further comprising pausing the deposition process for a pausing period of time after process (a) and before process (b), the pausing period of time being from about 3 seconds to about 50 seconds, and the first period of time is between about 10 seconds and about 60 seconds, and the second period of time is between about 10 seconds and about 50 seconds.

11. The method of claim 9, wherein process of depositing the first piezoelectric film layer and the process of depositing a second piezoelectric film layer have at least one process parameter that is different, and the at least one process parameter is selected from a group consisting of deposition process pressure, bias power and deposition process time.

12. The method of claim 9, wherein the first PVD process and the second PVD process each comprise:

sputtering a material from a target that comprises scandium,

while flowing a process gas that includes argon and nitrogen at a ratio of between about 1 to 1 and about 5 to 1.

13. The method of claim 9, wherein the first PVD process and the second PVD process each comprise:

sputtering a material from a target that comprises aluminum,

while flowing a process gas that includes argon and nitrogen at a ratio of between about 1 to 1 and about 5 to 1.

14. The method of claim 9, wherein reducing the temperature of the substrate after forming the first piezoelectric film layer and before forming the second piezoelectric film layer further comprises:

actively cooling the first piezoelectric film layer before depositing the second piezoelectric film layer, and

wherein depositing each of the first piezoelectric film layer and the second piezoelectric film layer in less than about 60 seconds.

15. The method of claim 9, further comprising:

depositing a third piezoelectric film layer on the substrate at a first bias power for a third period of time; and

cooling the first piezoelectric film layer and the second piezoelectric film layer before depositing the third piezoelectric film,

wherein the first piezoelectric film layer, the second piezoelectric film layer, and the third piezoelectric film layer comprise the same material combination.

16. The method of claim 15, further comprising cooling the first piezoelectric film layer and the second piezoelectric film layer before depositing a third piezoelectric film layer over the first piezoelectric film layer and the second piezoelectric film layer.

17. An apparatus for processing a substrate, comprising:

a processor coupled to at least one non-transitory computer readable medium, wherein the at least one non-transitory computer readable medium includes instructions which when executed by the processor are configured to perform a method comprising:

(a) depositing a first piezoelectric film layer on a surface of a substrate by a first physical vapor deposition (PVD) process;

(b) depositing a second piezoelectric film layer, on top of and in contact with the first piezoelectric film, by a second physical vapor deposition (PVD) process;

(c) reducing a temperature of the substrate after forming the first piezoelectric film layer and before forming the second piezoelectric film

layer, wherein the temperature is reduced by performing a process for a first period of time; and

additionally performing processes (a), (b) and (c) one or more times, wherein process (c) in the additionally performed processes (a), (b) and (c) is performed for a second period of time, and the second period of time being different than the first period of time,

wherein the first piezoelectric film layer and the second piezoelectric film layer comprise a same material combination, wherein the first PVD process and the second PVD process each comprise sputtering a material from a target that comprises an aluminum.

18. The apparatus of claim 17, wherein the instructions executed by the processor are further configured to cause:

the first piezoelectric film layer to be actively cooled before depositing the second piezoelectric film layer, and

the first piezoelectric film layer and the second piezoelectric film layer to be deposited in less than about 60 seconds.

19. The apparatus of claim 17, wherein the instructions executed by the processor are further configured to cause:

the second piezoelectric film layer to be deposited on the substrate using a first bias power that is different than a bias power generated during the deposition of the first piezoelectric film layer; and

the first piezoelectric film layer and the second piezoelectric film layer to be cooled from a first temperature to a second temperature before depositing a third piezoelectric film layer,

wherein the first piezoelectric film layer, the second piezoelectric film layer, and the third piezoelectric film layer comprise the same material combination.

20. The apparatus of claim 19, wherein the instructions executed by the processor are further configured to cause the first piezoelectric film layer and the second piezoelectric film layer to be formed by:

sputtering a material from a target that comprises aluminum, or aluminum and scandium,

while flowing a process gas that includes argon and nitrogen at a ratio of between about 1 to 1 and about 5 to 1.

21. The method of claim 1 wherein the first PVD process and the second PVD process each comprise sputtering the material from the target that further comprises scandium, and wherein the target has between 1at% and 40at% of scandium.

22. The method of claim 9 wherein the first PVD process and the second PVD process each comprise sputtering the material from the target that further comprises scandium, and wherein the target has between 1at% and 40at% of scandium.

23. The apparatus of claim 17 wherein the first PVD process and the second PVD process each comprise sputtering the material from the target that further comprises scandium, and wherein the target has between 1at% and 40at% of scandium.