CLAIMS:

1. A method for cleaning a substrate comprising features of patterned structures, the method comprising:

placing the substrate on a substrate holder configured to rotate the substrate;

applying cleaning liquid on the substrate;

rotating the substrate by the substrate holder at a first rate when acoustic energy is being applied to the cleaning liquid by a transducer; and

rotating the substrate by the substrate holder at a second rate higher than the first rate when acoustic energy is not being applied to the cleaning liquid by the transducer;

wherein the method further comprises performing pretreatment on the substrate to remove defects that attract bubbles before applying the cleaning liquid on the substrate.

2. The method of claim 1, wherein the steps of rotating the substrate at a first rate when acoustic energy is being applied and rotating the substrate at a second rate when acoustic energy is not being applied are alternately applied one after another for a number of cycles.

3. The method of claim 1, wherein the first rate is from 10 revolutions per minute to 200 revolutions per minute.

4. The method of claim 1, wherein the second rate is from 100 revolutions per minute to 1500 revolutions per minute.

5. The method of claim 1, wherein rotating the substrate at a first rate when acoustic energy is being applied comprises:

controlling, based on a timer, a power supply of the transducer to deliver acoustic energy to the cleaning liquid at a first frequency and a first power level for a predetermined first time period; and

controlling, based on the timer, the power supply of the transducer to deliver acoustic energy to the cleaning liquid at a second frequency and a second power level for a predetermined second time period.

6. The method of claim 5, wherein the first and second time periods, the first and second power levels, and the first and second frequencies are determined such that a percentage of damaged features as a result of delivering the acoustic energy is lower than a predetermined threshold.

7. The method of claim 1, wherein a device manufacturing node of the substrate is 45 nanometers or smaller than 45 nanometers.

8. The method of claim 1, wherein a line width of the features of patterned structures is 60 nanometers or smaller than 60 nanometers.

9. The method of claim 1, wherein a depth to width aspect ratio of the features of patterned structures is 3 or larger than 3.

10. The method of claim 1, further comprising moving the transducer away from the cleaning liquid after rotating the substrate at a first rate when acoustic energy is being applied and before rotating the substrate at a second rate when acoustic energy is not being applied.

11. The method of claim 1, further comprising performing pretreatment on the cleaning liquid to remove at least a part of bubbles within the cleaning liquid before applying cleaning liquid on the substrate.

12. A method for cleaning a substrate comprising features of patterned structures, the method comprising:

performing pretreatment on the substrate to remove defects that attract bubbles;

after the pretreatment step, applying cleaning liquid on the substrate;

controlling, based on a timer, a power supply of a transducer to deliver acoustic energy to the cleaning liquid at a first frequency and a first power level for a predetermined first time period; and

controlling, based on the timer, the power supply of the transducer to deliver acoustic energy to the cleaning liquid at a second frequency and a second power level for a predetermined second time period,

wherein the first and second time periods are alternately applied one after another for a predetermined number of cycles.

13. The method of claim 12, wherein the first and second time periods, the first and second power levels, and the first and second frequencies are determined such that a percentage of damaged features as a result of delivering the acoustic energy is lower than a predetermined threshold.

14. The method of claim 12, wherein the pretreatment comprises applying plasma energy on the substrate.

15. The method of claim 12, wherein the pretreatment comprises applying one or more pretreatment liquids on the substrate.

16. The method of claim 15, wherein applying one or more pretreatment liquids on the substrate comprises applying SC1 liquid.

17. The method of claim 15, wherein applying one or more pretreatment liquids on the substrate comprises:

applying ozone liquid on the substrate;

applying deionized water on the substrate; and

applying diluted hydrogen fluoride on the substrate.

18. An apparatus for cleaning a substrate comprising features of patterned structures, the apparatus comprising:

a substrate holder configured to hold the substrate and configured to rotate the substrate;

an inlet configured to apply cleaning liquid on the substrate;

a transducer configured to deliver acoustic energy to the liquid;

a pretreatment device; and

one or more controllers configured to:

control the substrate holder to rotate the substrate at a first rate while controlling the transducer to deliver acoustic energy to the cleaning liquid;

control the substrate holder to rotate the substrate at a second rate higher than the first rate while controlling the transducer not to deliver acoustic energy to the cleaning liquid; and

control the pretreatment device to perform pretreatment on the substrate to remove defects that attract bubbles before the cleaning liquid is applied on the substrate.

19. The apparatus of claim 18, wherein the substrate holder comprises a rotating chuck.

20. The apparatus of claim 18, wherein the inlet comprises a nozzle configured to spray the cleaning liquid on the substrate.

21. The apparatus of claim 18, wherein the one or more controllers are further configured to alternately rotate the substrate at a first rate when acoustic energy is being applied and rotate the substrate at a second rate when acoustic energy is not being applied for a number of cycles.

22. The apparatus of claim 18, wherein the first rate is from 10 revolutions per minute to 200 revolutions per minute.

23. The apparatus of claim 18, wherein the second rate is from 100 revolutions per minute to 1500 revolutions per minute.

24. The apparatus of claim 18, wherein:

the transducer comprises a power supply;

the one or more controllers comprise a timer; and

the one or more controllers are further configured to, when rotating the substrate at a first rate:

control, based on the timer, the power supply of the transducer to deliver acoustic energy to the cleaning liquid at a first frequency and a first power level for a predetermined first time period, and

control, based on the timer, the power supply of the transducer to deliver acoustic energy to the cleaning liquid at a second frequency and a second power level for a predetermined second time period after the first time period.

25. The apparatus of claim 18, wherein a device manufacturing node of the substrate is 45 nanometers or smaller than 45 nanometers.

26. The apparatus of claim 18, wherein a line width of the features of patterned structures is 60 nanometers or smaller than 60 nanometers.

27. The apparatus of claim 18, wherein a depth to width aspect ratio of the features of patterned structures is 3 or larger than 3.

28. The apparatus of claim 18, wherein the one or more controllers are further configured to move the transducer away from the cleaning liquid after rotating the substrate at a first rate when acoustic energy is being applied and before rotating the substrate at a second rate when acoustic energy is not being applied.

29. The apparatus of claim 18, wherein the device for performing pretreatment comprises a plasma source configured to apply plasma energy on the substrate before applying the cleaning liquid on the substrate.

30. The apparatus of claim 18, wherein the device for performing pretreatment comprises the inlet which is further configured to apply one or more pretreatment liquids on the substrate before applying the cleaning liquid on the substrate.

31. The apparatus of claim 30, wherein the one or more pretreatment liquids comprise SC1 liquid.

32. The apparatus of claim 30, wherein the one or more pretreatment liquids comprise ozone liquid, deionized water, and diluted hydrogen fluoride.

33. The apparatus of claim 18, further comprising a debubbler coupled to the inlet configured to remove at least a part of bubbles within the cleaning liquid.

34. The apparatus of claim 33, wherein the debubbler is further configured to substantially remove bubbles larger than a threshold size.