CLAIMS

1. A method for controlling damages in cleaning a semiconductor wafer comprising features of patterned structures, the method comprising:

delivering a cleaning liquid over a surface of a semiconductor wafer during a cleaning process; and

imparting sonic energy to the cleaning liquid from a sonic transducer during the cleaning process, wherein power is alternately supplied to the sonic transducer at a first frequency and a first power level for a first predetermined period of time and at a second frequency and a second power level for a second predetermined period of time, the first predetermined period of time and the second predetermined period of time consecutively following one another, wherein after a ratio of total bubbles volume to volume inside vias, trenches or recessed areas on the semiconductor wafer increases to a first set value, setting the power at the second frequency and the second power level for the second predetermined period of time, after the ratio of total bubbles volume to volume inside vias, trenches or recessed areas on the semiconductor wafer reduces to a second set value, setting the power at the first frequency and the first power level for the first predetermined period of time;

wherein at least one of the first and second predetermined periods of time, the first and second power levels, and the first and second frequencies is determined such that a percentage of damaged features as a result of the imparting sonic energy is lower than a predetermined threshold, wherein the predetermined threshold is larger than zero.

2. The method of claim 1, wherein bubble sizes in the cleaning liquid increase due to sonic energy during the first predetermined period of time and decreases during the second predetermined period of time.

3. The method of claim 1, further comprising rotating the wafer during the cleaning process.

4. The method of claim 1, further comprising positioning the wafer on a wafer chuck.

5. The method of claim 1, further comprising submerging the semiconductor wafer in a cleaning tank.

6. The method of claim 1, wherein the delivering includes spreading the cleaning liquid through a nozzle.

7. The method of claim 1, wherein the imparting includes transmitting sonic energy to a flowing cleaning liquid.

8. The method of claim 1, further comprising reciprocally altering a distance between the sonic transducer and the wafer.

9. The method of claim 1, wherein the cleaning liquid is selected from a group consisting of a chemical solution, de-ionized water and a combination of the two.

10. The method of claim 1, further comprising repeating the alternation between the first and second periods of time for a predetermined number of times.

11. The method of claim 10, further comprising empirically determining the predetermined number of times of alternation by inspecting damages to the semiconductor wafer.

12. The method of claim 1, wherein the second power level is zero.

13. The method of claim 1, wherein the first frequency is equal to the second frequency and both the frequencies remain constant during the respective operating time period, while the first power level is higher than the second power level and both the power levels remain constant during the respective operating time period.

14. The method of claim 1, wherein the first frequency is higher than the second frequency and both the frequencies remain constant during the respective operating time

period, while the first power level is higher than the second power level and both the power levels remain constant during the respective operating time period.

15. The method of claim 1, wherein the first frequency is lower than the second frequency and both the frequencies remain constant during the respective operating time period, while the first power level is equal to the second power level and both the power levels remain constant during the respective operating time period.

16. The method of claim 1, wherein the first frequency is lower than the second frequency and both the frequencies remain constant during the respective operating time period, while the first power level is higher than the second power level and both the power levels remain constant during the respective operating time period.

17. The method of claim 1, wherein the first frequency is lower than the second frequency and both the frequencies remain constant during the respective operating time period, while the first power lever is lower than the second power level and both the power levels remain constant during the respective operating time period.

18. The method of claim 1, wherein the first power level rises during the first predetermined period of time.

19. The method of claim 1, wherein the first power level falls during the first predetermined period of time.

20. The method of claim 1, wherein the first power level both rises and falls during the first predetermined period of time.

21. The method of claim 1, wherein the second frequency is substantially close to zero and the second power level remains a constant positive value during the second predetermined period of time.

22. The method of claim 1, wherein the second frequency is substantially close to zero and the second power level remains a constant negative value during the second predetermined period of time.

23. The method of claim 1, wherein sonic waves from the sonic transducer in the first and the second periods of time have opposite phases.

24. The method of claim 1, wherein the first predetermined period of time is shorter than 2,000 times of a cycle period of the first frequency.

25. The method of claim 1, wherein the first predetermined period of time is shorter than $((T_i - T_0 - \Delta T)/(\Delta T - \delta T) + 1)/f_1$, where T_i is an implosion temperature, T_0 is a temperature of the cleaning liquid, ΔT is a temperature increase after one time of compression, δT is a temperature decrease after one time of expansion, and f1 is the first frequency.

26. The method of claim 1, wherein the first frequency changes from a higher value to a lower value during the first predetermined period of time.

27. The method of claim 1, wherein the first frequency changes from a lower value to a higher value during the first predetermined period of time.

28. The method of claim 1, wherein the first frequency changes from a lower value to a higher value and then back to the lower value during the first predetermined period of time.

29. The method of claim 1, wherein the first frequency changes from a higher value to a lower value and then back to the higher value during the first predetermined period of time.

30. The method of claim 1, wherein the first frequency is set as f_1 first, f_3 later and f_4 at last during the first predetermined period of time, where f_4 is smaller than f_3, and f_3 is smaller than f_1.

31. The method of claim 1, wherein the first frequency is set as f_4 first, f_3 later and f_1 at last during the first predetermined period of time, where f_4 is smaller than f_3, and f_3 is smaller than f_1.

32. The method of claim 1, wherein the first frequency is set as f_1 first, f_4 later and f_3 at last during the first predetermined period of time, where f_4 is smaller than f_3, and f_3 is smaller than f_1.

33. The method of claim 1, wherein the first frequency is set as f_3 first, f_4 later and f_1 at last during the first predetermined period of time, where f_4 is smaller than f_3, and f_3 is smaller than f_1.

34. The method of claim 1, wherein the first frequency is set as f_3 first, f_1 later and f_4 at last during the first predetermined period of time, where f_4 is smaller than f_3, and f_3 is smaller than f_1.

35. The method of claim 1, wherein the first frequency is set as f_4 first, f_1 later and f_3 at last during the first predetermined period of time, where f_4 is smaller than f_3, and f_3 is smaller than f_1.

36. The method of claim 1, further comprising detecting sonic output from a sonic generator coupled to the sonic transducer.

37. The method of claim 36, wherein the detecting includes detecting and comparing amplitude of an input signal with a reference value, and causing an alarm signal to be generated and the sonic generator to be turned off when the detected amplitude exceeds the reference value.

38. The method of claim 37, wherein the reference value is generated by a digital-to-analog converter (DAC).

39. The method of claim 36, wherein the detecting includes detecting and comparing the first period of time with a predetermined value, and causing an alarm signal to be generated and the sonic generator to be turned off when the first period of time exceeds the predetermined value.

40. The method of claim 36, wherein the detecting includes detecting and comparing the second period of time with a predetermined value, and causing an alarm signal to be generated and the sonic generator to be turned off when the second period of time is less than the predetermined value.

41. The method of claim 1, wherein the first predetermined period of time is empirically determined to avoid bubble implosion in the cleaning liquid by inspecting the semiconductor wafer for damages to patterned structures thereon.

42. The method of claim 41, wherein the empirical determination includes choosing different values for the first predetermined period of time in different cleaning processes while keeping the second predetermined period of time unchanged and significantly longer than the first predetermined period of time, as well as keeping the first and second frequencies and the first and second power levels unchanged.

43. The method of claim 1, wherein the first predetermined period of time is empirically determined to allow limited bubble implosions which do not cause damage to patterned structures on the semiconductor wafer under cleaning.

44. The method of claim 43, wherein the empirical determination includes choosing different values for the first predetermined period of time in different cleaning processes while keeping the second predetermined period of time unchanged and significantly longer than the first predetermined period of time, as well as keeping the first and second frequencies and the first and second power levels unchanged.

45. The method of claim 1, wherein the second predetermined period of time is empirically determined to allow temperature inside bubbles in the cleaning liquid to be cooled down to a predetermined temperature.

46. The method of claim 45, wherein the predetermined temperature is substantially close to a room temperature.

47. The method of claim 1, wherein the first frequency and the first power level are empirically determined to avoid bubble implosion in the cleaning liquid by inspecting the semiconductor wafer for damages to patterned structures thereon.

48. The method of claim 1, wherein the first frequency and the first power level are empirically determined to allow limited bubble implosions which do not cause damage to patterned structures on the semiconductor wafer under cleaning.

49. The method of claim 1, wherein the second frequency and the second power level are empirically determined to allow temperature inside bubbles in the cleaning liquid to be cooled down to a predetermined temperature.

50. The method of claim 49, wherein the predetermined temperature is substantially close to a room temperature.

51. The method of claim 1, wherein a cleaning effect of imparting the sonic energy causes a yield improvement greater than a yield degradation caused by damages as a result of imparting the sonic energy.