CLAIMS

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

a wafer holder for temporary restraining a semiconductor wafer during a cleaning process;

an inlet for delivering a cleaning liquid over a surface of the semiconductor wafer;

a sonic generator configured to alternately operate 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, to impart sonic energy to the cleaning liquid, the first predetermined period of time and the second predetermined period of time consecutively following one another; and

a controller programmed to provide the first and second frequencies, the first and second power levels, the first and second predetermined periods of time, and a number of alternations between the first and second periods of time by the sonic generator, 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, the controller sets 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, the controller sets 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 system 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 system of claim 1, wherein the wafer holder is a rotating chuck.

4. The system of claim 1, wherein the wafer holder is a cassette submerged in a cleaning tank.

5. The system of claim 1, wherein the inlet includes a nozzle.

6. The system of claim 1, further comprising a sonic transducer coupled to the sonic generator.

7. The system of claim 6, wherein the sonic transducer is placed above the semiconductor wafer having a gap therebetween, the gap being filled with the cleaning liquid during a cleaning process.

8. The system of claim 7, wherein the gap varies during the cleaning process.

9. The system of claim 6, wherein the sonic transducer is connected to the inlet and imparts sonic energy to the cleaning liquid flowing through the inlet.

10. The system 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.

11. The system of claim 1, wherein the second power level is zero.

12. The system 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.

13. The system 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.

14. The system 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.

15. The system 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.

16. The system 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.

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

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

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

20. The system 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.

21. The system 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.

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

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

24. The system 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.

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

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

27. The system 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.

28. The system 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.

29. The system 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.

30. The system 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.

31. The system 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.

32. The system 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.

33. The system 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.

34. The system 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.

35. The system of claim 1, further comprising a detection circuit coupled to the sonic generator for detecting output of the sonic generator.

36. The system of claim 35, wherein the detection circuit includes a voltage attenuation circuit for attenuating an input signal.

37. The system of claim 35, wherein the detection circuit includes a shaping circuit for converting a signal from a first waveform to a second waveform.

38. The system of claim 37, wherein the first waveform is sinusoidal wave and the second waveform is a square wave.

39. The system of claim 35, wherein the detection circuit includes an amplitude detection circuit for detecting and comparing amplitude of an input signal with a reference value, and the detection circuit causes an alarm signal to be generated and the sonic generator to be turned off when the detected amplitude exceeds the reference value.

40. The system of claim 39, wherein the reference value is generated by a digital-to-analog converter (DAC).

41. The system of claim 35, wherein the detection circuit detects and compares the first period of time with a predetermined value, and causes an alarm signal to be generated and the sonic generator to be turned off when the first period of time exceeds the predetermined value.

42. The system of claim 35, wherein the detection circuit detects and compares the second period of time with a predetermined value, and causes 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.

43. The system 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.

44. The system 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 system 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.

46. The system of claim 45 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.

47. The system 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.

48. The system of claim 47, wherein the predetermined temperature is substantially close to a room temperature.

49. The system 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.

50. The system 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.

51. The system 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.

52. The system of claim 51, wherein the predetermined temperature is substantially close to a room temperature.

53. The system of claim 1, wherein the number of alternation is empirically determined by inspecting damages to the semiconductor wafer.

54. The system 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.