I CLAIM:

1. A method for cutting a semiconductor wafer by generating a crack within the wafer, the method comprising:

   - irradiating a pulsed laser beam having a long pulse duration time of 20 μs to 80 μs towards a surface of the wafer; and
   - converging the laser beam to form a focal point so that a focal volume defined by the focal point and a boundary of the laser beam within the wafer is formed;

   wherein energy encompassed within the focal volume causes the wafer located at a periphery of the focal volume to contract faster than the wafer located within the focal volume, thereby generating a crack within the wafer.

2. The method of claim 1, wherein the focal point is formed below the surface of and within the wafer.

3. The method of claim 1, wherein the focal point is formed below and outside the wafer.

4. The method of claim 1, wherein the focal point is formed above the surface of and outside the wafer.

5. The method of claim 2 or 3, wherein energy encompassed within the focal volume causes the wafer located at the periphery of the focal volume to melt slower but to solidify faster and therefore to contract faster than the wafer located within the focal volume.

6. The method of claim 3 or 4, wherein energy encompassed within the focal volume causes the wafer located at the periphery of the focal volume to thermally heat up slower but to cool down faster and therefore to contract faster than the wafer located within the focal volume.

7. The method of any one of the preceding claims, wherein the irradiating comprises irradiating a laser beam having a laser power density lower than a vapourisation threshold of the wafer ablation.

8. The method of any one of the preceding claims, further comprising guiding the laser beam towards the surface of the wafer prior to converging the laser beam to form the focal point.

9. The method of any one of the preceding claims, further comprising expanding the laser beam prior to converging the laser beam.

10. The method of any one of the preceding claims, further comprising shaping and simultaneously converging the laser beam to form a converged laser beam having uniform and concentrated power distribution on the surface of the wafer.

11. The method of any one of the preceding claims, further comprising providing a vacuum suction system to remove vapours and melting droplets produced when the wafer melts.

12. The method of any one of the preceding claims, further comprising providing a shielding plate over the surface of the wafer to maintain a clean surface.

13. The method of any one of the preceding claims, further comprising moving the wafer in a predetermined direction so that the crack generated within the wafer propagates in a direction corresponding to the moving direction of the wafer.

14.

15. The method of any one of the preceding claims, wherein the irradiating comprises irradiating a laser beam having a pulse repetition rate between 5 kHz and 50 kHz.

16. The method of any one of the preceding claims, wherein the irradiating comprises irradiating a laser beam having an infrared wavelength between 1,064 nm and 1,550 nm.

17. The method of any one of the preceding claims, wherein the irradiating comprises irradiating a laser beam having a laser power of at most 400 W.

18. The method of any one of the preceding claims, wherein the wafer is selected from the group consisting of silicon (Si), Si coated with a thin layer of oxide, nitride, carbide, or metal, gallium arsenide (GaAs), silicon carbide (SiC), silicon nitride (SiN), indium phosphide (InP) and a mixture thereof.

19. The method of claim 12, wherein the wafer is silicon.

20. The method of any one of the preceding claims, wherein the wafer has a thickness between 100 µm and 1,500 µm.

21. A system for cutting a semiconductor wafer by generating a crack within the wafer, the system comprising:

- a laser beam source for irradiating a pulsed laser beam having a long pulse duration time of 20 μs to 80 μs towards a surface of the wafer; and
- a converging lens to converge the laser beam to form a focal point so that a focal volume defined by the focal point and a boundary of the laser beam within the wafer is formed;

wherein energy encompassed within the focal volume causes the wafer located at a periphery of the focal volume to contract faster than the wafer located within the focal volume, thereby generating a crack within the wafer.

22. The system of claim 21, wherein the focal point is formed below the surface of and within the wafer.

23. The system of claim 21, wherein the focal point is formed below and outside the wafer.

24. The system of claim 21, wherein the focal point is formed above the surface of and outside the wafer.

25. The system of claim 22 or 23, wherein energy encompassed within the focal volume causes the wafer located at the periphery of the focal volume to melt slower but to solidify faster and therefore to contract faster than the wafer located within the focal volume.

26. The system of claim 23 or 24, wherein energy encompassed within the focal volume causes the wafer located at the periphery of the focal volume to thermally heat up slower but to cool down faster and therefore to contract faster than the wafer located within the focal volume.

27. The system of any one of claims 21 to 26, further comprising a laser beam guide to guide or reflect the laser beam towards the surface of the wafer prior to converging the laser beam to form the focal point.

28. The system of any one of claims 21 to 27, further comprising a beam expander to expand the laser beam prior to converging the laser beam.

29. The system of any one of claims 21 to 28, further comprising a beam shaper to simultaneously shape and converge the laser beam to form a converged laser beam having uniform and concentrated power distribution on the surface of the wafer.

30. The system of any one of claims 21 to 29, further comprising a vacuum suction system to remove vapours and melting droplets produced when the wafer melts.

31. The system of any one of claims 21 to 30, further comprising a shielding plate over the surface of the wafer to maintain a clean surface.

32. The system of any one of claims 21 to 31, further comprising a control device coupled to the wafer so as to move the wafer in a predetermined

direction so that the crack generated within the wafer propagates in a direction corresponding to the moving direction of the wafer.

33. The system of any one of claims 21 to 32, further comprising a laser pulse generator or modulator coupled to the laser beam source to generate or modulate a pulse frequency of the laser beam.

34. A method of claim 1 in which the laser beam has a wavelength of 1064 nanometers to 1550 nanometers and a long pulse duration time of 40 µs and 42 µs.

35. A method of claim 1 further comprising converging the laser beam to form a focal point spaced apart from the surface of the wafer so as to induce thermal heating of the wafer.

36. A method of claim 1 in which the crack generated initially propagates from a surface of the wafer and then spreads to a bottom of the wafer.

37. A system of claim 21 in which the laser beam has a wavelength of 1064 nanometers to 1550 nanometers and a long pulse duration time of 40 µs and 42 µs.

38. A system of claim 21 further comprising converging the laser beam to form a focal point spaced apart from the surface of the wafer so as to induce thermal heating of the wafer.

39. A system of claim 21 in which the crack generated initially propagates from a surface of the wafer and then spreads to a bottom of the wafer.

CLAIMS

1. A method for cutting a semiconductor wafer by generating a crack within the wafer, the method comprising:

irradiating a pulsed laser beam having a long pulse duration time of 20 μs to 80 μs towards a surface of the wafer; and

converging the laser beam to form a focal point so that a focal volume defined by the focal point and a boundary of the laser beam within the wafer is formed;

wherein energy encompassed within the focal volume causes the wafer located at a periphery of the focal volume to contract faster than the wafer located within the focal volume, thereby generating a crack within the wafer extending from said surface of the wafer to another surface of the wafer opposing said surface to cut the wafer.

2. The method of claim 1, wherein the focal point is formed below said surface of and within the wafer.

3. The method of claim 2, wherein energy encompassed within the focal volume causes the wafer located at the periphery of the focal volume to melt slower but to solidify faster and therefore to contract faster than the wafer located within the focal volume.

4. The method of claim 1, wherein the focal point is formed below and outside the wafer.

5. The method of claim 4, wherein energy encompassed within the focal volume causes the wafer located at the periphery of the focal volume to thermally heat up slower but to cool down faster and therefore to contract faster than the wafer located within the focal volume.

6. The method of claim 1, wherein the focal point is formed above said surface of and outside the wafer.

7. The method of claim 1, wherein the irradiating comprises irradiating a laser beam having a laser power density lower than a vapourisation threshold of the wafer ablation.

8. The method of claim 1, further comprising guiding the laser beam towards said surface of the wafer prior to converging the laser beam to form the focal point.

9. The method of claim 1, further comprising expanding the laser beam prior to converging the laser beam.

10. The method of claim 1, further comprising shaping and simultaneously converging the laser beam to form a converged laser beam having uniform and concentrated power distribution on said surface of the wafer.

11. The method of claim 1, further comprising providing a vacuum suction system to remove vapours and melting droplets produced when the wafer melts.

12. The method of claim 1, further comprising providing a shielding plate over said surface of the wafer to maintain said surface of the wafer clean.

13. The method of claim 12, wherein the wafer is silicon.

14. The method of claim 1, further comprising moving the wafer in a predetermined direction so that the crack generated within the wafer propagates in a direction corresponding to the moving direction of the wafer.

15. The method of claim 1, wherein the irradiating comprises irradiating a laser beam having a pulse repetition rate between 5 kHz and 50 kHz.

16. The method of claim 1, wherein the irradiating comprises irradiating a laser beam having an infrared wavelength between 1,064 nm and 1,550 nm.

17. The method of claim 1, wherein the irradiating comprises irradiating a laser beam having a laser power of at most 400 W.

18. The method of claim 1, wherein the wafer is selected from the group consisting of silicon (Si), Si coated with a layer of oxide, nitride, carbide, or metal, gallium arsenide (GaAs), silicon carbide (SiC), silicon nitride (SiN), indium phosphide (InP) and a mixture thereof.

19. The method of claim 1, wherein the wafer has a thickness between 100 μm and 1,500 μm.

20. The method of claim 1 in which the laser beam has a wavelength of 1064 nanometers to 1550 nanometers and a long pulse duration time of 40 μs and 42 μs.

21. The method of claim 1 further comprising converging the laser beam to form a focal point spaced apart from said surface of the wafer so as to induce thermal heating of the wafer.

22. The method of claim 1, wherein said surface is a top surface of the wafer and said another surface is a bottom of the wafer.

23. A system for cutting a semiconductor wafer by generating a crack with in the wafer, the system comprising:
a laser beam source for irradiating a pulsed laser beam having a long pulse duration time of 20 μs to 80 μs towards a surface of the wafer; and
a converging lens to converge the laser beam to form a focal point so that a focal volume defined by the focal point and a boundary of the laser beam within the wafer is formed;
wherein energy encompassed within the focal volume causes the wafer located at a periphery of the focal volume to contract faster than the wafer located within the focal volume, thereby generating a crack within the wafer extending from said surface of the wafer to another surface of the wafer opposing said surface to cut the wafer.

24. The system of claim 23, wherein the focal point is formed below said surface of and within the wafer.

25. The system of claim 24, wherein energy encompassed within the focal volume causes the wafer located at the periphery of the focal volume to melt slower but to solidify faster and therefore to contract faster than the wafer located within the focal volume.

26. The system of claim 23, wherein the focal point is formed below and outside the wafer.

27. The system of claim 26, wherein energy encompassed within the focal volume causes the wafer located at the periphery of the focal volume to thermally heat up slower but to cool down faster and therefore to contract faster than the wafer located within the focal volume.

28. The system of claim 23, wherein the focal point is formed above said surface of and outside the wafer.

29. The system of claim 23, further comprising a laser beam guide to guide or reflect the laser beam towards said surface of the wafer prior to converging the laser beam to form the focal point.

30. The system of claim 23, further comprising a beam expander to expand the laser beam prior to converging the laser beam.

31. The system of claim 23, further comprising a beam shaper to simultaneously shape and converge the laser beam to form a converged laser beam having uniform and concentrated power distribution on said surface of the wafer.

32. The system of claims 23, further comprising a vacuum suction system to remove vapours and melting droplets produced when the wafer melts.

33. The system of claim 23, further comprising a shielding plate over said surface of the wafer to maintain said surface of the wafer clean.

34. The system of claim 23, further comprising a control device coupled to the wafer so as to move the wafer in a predetermined direction so that the crack generated within the wafer propagates in a direction corresponding to the moving direction of the wafer.

35. The system of claim 23, further comprising a laser pulse generator or modulator coupled to the laser beam source to generate or modulate a pulse frequency of the laser beam.

36. The system of claim 23 in which the laser beam has a wavelength of 1064 nanometers to 1550 nanometers and a long pulse duration time of 40 μs and 42 μs.

37. The system of claim 23 further comprising converging the laser beam to form a focal point spaced apart from said surface of the wafer so as to induce thermal heating of the wafer.

38. The system of claim 23, wherein said surface is a top surface of the wafer and said another surface is a bottom of the wafer.