We Claim:

1. A ring clamp for separating bonded substrates, said ring clamp having a planar body with a substantially circular shape and a central opening, said body comprising:

an annular interior sidewall;

an annular exterior sidewall;

a top surface extending between the interior sidewall and the exterior sidewall;

a wafer-engaging surface extending outwardly from the interior sidewall, said wafer-engaging surface terminating at a point in the body that is spaced from the exterior sidewall; and

an inwardly extending annular ridge, which slopes inward from said point, and away from the wafer-engaging surface,

wherein said wafer-engaging surface and annular ridge cooperatively form an annular wafer-receiving groove.

2. The ring clamp of claim 1, wherein said body is a unitarily formed split ring clamp having two free ends.

3. The ring clamp of claim 1, said annular ridge terminating in a free edge and having a sloped shoulder surface extending between the free edge and the point where the wafer-engaging surface terminates in the body.

4. The ring clamp of claim 3, wherein said groove has an angle (θ), as measured from the wafer-engaging surface to the shoulder surface of the ridge, of from about 10° to about 90°.

5. The ring clamp of claim 3, where the free edge of the annular ridge does not extend inward past a plane defined by the interior sidewall, such that the annular ridge is outwardly offset from the interior sidewall.

6. The ring clamp of claim 1, wherein said body comprises multiple pieces, each piece being unitarily formed.

7. The ring clamp of claim 1, wherein said body is formed from a material selected from the group consisting of metals, ceramics, polymers, composites, and combinations thereof.

8. The ring clamp of claim 1, wherein said body has a width "*W*," as measured from the interior sidewall to the exterior sidewall, of from about 0.1 to about 50 mm.

9. The ring clamp of claim 1, wherein the interior sidewall has a thickness "t" of from about 0.1 to about 15 mm.

10. The ring clamp of claim 1, wherein the exterior sidewall has a thickness "T" of from about 0.15 to about 16 mm.

11. The combination of:

a clamp having a planar body with a substantially circular shape, said body comprising an annular wafer-receiving groove; and

a planar substrate having an outermost edge defining the periphery of said substrate, at least a portion of said periphery being received in said wafer-receiving groove.

12. The combination of claim 11, said clamp further comprising:

a central opening;

an annular interior sidewall;

an annular exterior sidewall;

a top surface extending between the interior sidewall and the exterior sidewall;

a wafer-engaging surface extending from the interior sidewall outwardly and terminating at a point in the body that is spaced from the exterior sidewall; and

an inwardly extending annular ridge, which slopes inward from said point, and away from the wafer-engaging surface,

wherein said wafer-engaging surface and annular ridge cooperatively form said annular wafer-receiving groove.

13. The combination of claim 12, wherein said substrate further comprises a front surface and a back surface, said front surface comprising a central region and a peripheral region.

14. The combination of claim 13, wherein said annular ridge terminates in a free edge, said annular ridge having a sloped shoulder surface extending between the free edge of the ridge and the point where the wafer-engaging surface terminates in the body, the backside surface of said substrate being engaged by the wafer-engaging surface of the body and the outermost edge and peripheral region of the substrate being engaged by the shoulder and free edge of the ridge.

15. The combination of claim 12, wherein said substrate comprises a material selected from the group consisting of silicon, sapphire, quartz, metal, glass, and ceramics.

16. A temporary bonding method comprising:

providing a stack comprising:

a first substrate having a back surface and a device surface, said device surface having a peripheral region and a central region;

a second substrate bonded to said first substrate, said second substrate having a carrier surface, a backside surface, and an outermost edge defining the periphery of the second substrate, said carrier surface having a peripheral region and a central region; and

separating said first and second substrate using a peeling motion by applying a force to a portion of the periphery of said second substrate causing said second substrate to bend at an angle away from the stack, thereby separating said first substrate and second substrate.

17. The method of claim 16, wherein said stack further comprises an intermediate layer between said first substrate and said second substrate.

18. The method of claim 17, said intermediate layer being bonded to said device surface and to said peripheral region of said carrier surface, wherein said intermediate layer and said central region of said carrier surface comprise a low bonding interface therebetween.

19. The method of claim 18, wherein said low bonding interface comprises surface modification of said central region of said carrier surface.

20. The method of claim 18, wherein said low bonding interface comprises a second layer between said intermediate layer and said central region of said carrier surface.

21. The method of claim 20, wherein said second layer is selected from the group consisting of a low adhesive strength layer and a polymeric layer.

22. The method of claim 17, wherein said intermediate layer comprises a fill material adjacent said central regions and an edge bond adjacent said peripheral regions.

23. The method of claim 17, wherein said intermediate layer comprises a uniform bonding layer.

24. The method of claim 17, further comprising mechanically or chemically disrupting said intermediate layer adjacent said peripheral regions to remove at least a portion of said intermediate layer prior to said separating.

25. The method of claim 17, wherein said carrier surface comprises a patterned surface modification, said intermediate layer being bonded to said device surface and to non-modified portions of said carrier surface, wherein said intermediate layer and said surface-modified portions of said carrier surface comprise a low bonding interface therebetween.

26. The method of claim 16, wherein said device surface comprises an array of devices selected from the group consisting of integrated circuits; MEMS; microsensors; power semiconductors; light-emitting diodes; photonic circuits; interposers; embedded passive devices; and microdevices fabricated on or from silicon, silicon-germanium, gallium arsenide, and gallium nitride.

27. The method of claim 16, said device surface comprising at least one structure selected from the group consisting of: solder bumps; metal posts; metal pillars; and structures formed from a material selected from the group consisting of silicon, polysilicon, silicon dioxide, silicon (oxy)nitride, metal, low k dielectrics, polymer dielectrics, metal nitrides, and metal silicides.

28. The method of claim 16, wherein said second substrate comprises a material selected from the group consisting of silicon, sapphire, quartz, metal, glass, and ceramics.

29. The method of claim 16, further comprising subjecting said stack to processing selected from the group consisting of back-grinding, chemical-mechanical polishing, etching, metal and dielectric deposition, patterning, passivation, annealing, and combinations thereof, prior to separating said first and second substrates.

30. The method of claim 16, wherein said separating is carried out using a ring clamp having a planar body with a substantially circular shape defining the periphery of said ring clamp and a central opening, said ring clamp being secured about the periphery of the second substrate, and wherein said force is applied to only a portion of the periphery of said ring clamp thereby lifting the corresponding portion of the periphery of the second substrate away from the stack in said peeling motion.

31. The method of claim 30, said body comprising:

an annular interior sidewall;

an annular exterior sidewall;

a top surface extending between the interior sidewall and the exterior sidewall;

a wafer-engaging surface extending outwardly from the interior sidewall, said wafer-engaging surface terminating at a point in the body that is spaced from the exterior sidewall; and

an inwardly extending annular ridge, which slopes inward from said point, and away from the wafer-engaging surface,

wherein said wafer-engaging surface and annular ridge cooperatively form an annular wafer-receiving groove, at least a portion of the periphery of said second substrate being received in said groove.

32. The method of claim 31, wherein said body is in the form of a split ring clamp having two free ends.

33. The method of claim 32, wherein said ring clamp is secured about the periphery of said second substrate by:

moving said free ends away from one another, thereby enlarging the central opening of said body;

placing said ring clamp about the periphery of the second substrate; and

drawing said free ends toward one another to compressively engage the second substrate, prior to said separating,

wherein the annular ridge of said ring clamp terminates in a free edge and has a sloped shoulder surface extending between the free edge of the ridge and the point where the wafer-engaging surface terminates in the body, the backside surface of said second substrate being engaged by the wafer-engaging surface of the body and the outermost edge and peripheral region of the second substrate being engaged by the shoulder and free edge of the ridge.

34. The method of claim 33, wherein said ring clamp engages at least about 1° of the periphery of said second substrate.

35. The method of claim 31, wherein said ring clamp does not contact said first substrate.

36. The method of claim 16, wherein the first substrate of said stack is secured to a chuck prior to separating said substrates.

37. The method of claim 36, said first substrate being secured to said chuck via an electrostatic force, a vacuum force, magnetic force, mechanical force, physical restraint, or a layer of adhesive film between said chuck and said first substrate.

38. The method of claim 36, wherein said chuck is moved away from the second substrate during said separating.

39. The method of claim 16, wherein said separating is carried out using a flexible chuck having a periphery, said second substrate being secured to said flexible chuck, said force being applied to only a portion of the periphery of said flexible chuck thereby lifting the corresponding portion of the periphery of said second substrate away from the stack in said peeling motion.

40. The method of claim 16, wherein said separating is carried out using an adhesive film having a periphery, said second substrate being secured to said adhesive film, said force being applied to only a portion of the periphery of said adhesive film thereby lifting the corresponding portion of the periphery of the second substrate away from the stack in said peeling motion.

41. A method of forming a temporary wafer bonding structure, said method comprising:

providing a first substrate having front and back surfaces;

forming a bonding layer on said front surface of said first substrate;

providing a second substrate having front and back surfaces, said front surface having a surface-modified region, a non-modified region, and an optional mask adjacent said non-modified region; and

contacting said front surface of said second substrate with said bonding layer on said first substrate to thereby form said temporary bonding structure, wherein said bonding layer and said surface-modified region of said second substrate comprise a low bonding interface therebetween.

42. The method of claim 41, said surface-modified region comprising a pattern.

43. The method of claim 42, wherein said pattern is selected from the group consisting of grids, lines, and shapes.

44. The method of claim 41, said front surface having a peripheral region and a central region, said central region comprising said surface modified region, wherein said mask is adjacent said peripheral region.

45. The method of claim 44, said surface-modified region comprising a pattern.

46. The method of claim 44, wherein said providing of said second substrate comprises:

forming an mask on said peripheral region;

depositing a surface modifying composition in said central region to yield said surface-modified central region; and

and optionally removing said mask to thereby expose said peripheral region.

47. The method of claim 41, wherein said mask is present, said bonding layer being bonded with said mask.

48. The method of claim 41, wherein said contacting is carried out under heat and pressure, said mask reflowing into said bonding layer to create a uniform bonding layer.

49. The method of claim 41, wherein said mask is not present, said bonding layer being bonded with said non-modified region of said second substrate.

50. A disc-shaped clamp for separating bonded substrates, said clamp having a solid, planar body with a substantially circular shape, said body comprising:

an annular exterior sidewall defining the outer diameter of said body;

a top surface extending the entire diameter between said exterior sidewall;

a wafer-engaging surface extending between a point in the body that is spaced from the exterior sidewall; and

an inwardly extending annular ridge, which slopes inward from said point, and away from the wafer-engaging surface,

wherein said wafer-engaging surface and annular ridge cooperatively form an annular wafer-receiving groove.

Claims

1. A ring clamp for separating bonded substrates, said ring clamp having a planar body with a substantially circular shape and a central opening, said body comprising:

an annular interior sidewall;

an annular exterior sidewall;

a top surface extending between the interior sidewall and the exterior sidewall;

a wafer-engaging surface extending outwardly from the interior sidewall, said wafer-engaging surface terminating at a point in the body that is spaced from the exterior sidewall; and

an inwardly extending annular ridge, which slopes inward from said point, and away from the wafer-engaging surface,

wherein said wafer-engaging surface and annular ridge cooperatively form an annular wafer-receiving groove.

2. The ring clamp of claim 1, wherein said body is a unitarily formed split ring clamp having two free ends.

3. The ring clamp of claim 1, said annular ridge terminating in a free edge and having a sloped shoulder surface extending between the free edge and the point where the wafer-engaging surface terminates in the body.

4. The ring clamp of claim 3, wherein said groove has an angle (θ), as measured from the wafer-engaging surface to the shoulder surface of the ridge, of from 10° to 90°.

5. The ring clamp of claim 3, where the free edge of the annular ridge does not extend inward past a plane defined by the interior sidewall, such that the annular ridge is outwardly offset from the interior sidewall.

6. The ring clamp of claim 1, wherein said body comprises multiple pieces, each piece being unitarily formed.

7. The ring clamp of claim 1, wherein said body is formed from a material selected from the group consisting of metals, ceramics, polymers, composites, and combinations thereof.

8. The ring clamp of claim 1, wherein said body has a width "*W*," as measured from the interior sidewall to the exterior sidewall, of from 0.1 to 50 mm.

9. The ring clamp of claim 1, wherein the interior sidewall has a thickness "t" of from 0.1 to 15 mm.

10. The ring clamp of claim 1, wherein the exterior sidewall has a thickness "T" of from 0.15 to 16 mm.

11. The combination of:

a clamp according to claim 1; and

a planar substrate having an outermost edge defining the periphery of said substrate, at least a portion of said periphery being received in said wafer-receiving groove.

12. The combination of claim 11, wherein said substrate further comprises a front surface and a back surface, said front surface comprising a central region and a peripheral region.

13. The combination of claim 12, wherein said annular ridge terminates in a free edge, said annular ridge having a sloped shoulder surface extending between the free edge of the ridge and the point where the wafer-engaging surface terminates in the body, the backside surface of said substrate being engaged by the wafer-engaging surface of the body and the outermost edge and peripheral region of the substrate being engaged by the shoulder and free edge of the ridge.

14. The combination of claim 11, wherein said substrate comprises a material selected from the group consisting of silicon, sapphire, quartz, metal, glass, and ceramics.

15. A temporary bonding method comprising:

providing a stack comprising:

a first substrate having a back surface and a device surface, said device surface having a peripheral region and a central region;

a second substrate bonded to said first substrate, said second substrate having a carrier surface, a backside surface, and an outermost edge defining the periphery of the second substrate, said carrier surface having a peripheral region and a central region; and

separating said first and second substrate using a peeling motion by applying a force to a portion of the periphery of said second substrate causing said second substrate to bend at an angle away from the stack, thereby separating said first substrate and second substrate, wherein said separating is carried out using a ring clamp having a planar body with a substantially circular shape defining the periphery of said ring clamp and a central opening, said body comprising:

an annular interior sidewall;

an annular exterior sidewall;

a top surface extending between the interior sidewall and the exterior sidewall;

a wafer-engaging surface extending outwardly from the interior sidewall, said wafer-engaging surface terminating at a point in the body that is spaced from the exterior sidewall; and

an inwardly extending annular ridge, which slopes inward from said point, and away from the wafer-engaging surface,

wherein said wafer-engaging surface and annular ridge cooperatively form an annular wafer-receiving groove, said ring clamp being secured about the periphery of the second substrate, at least a portion of the periphery of said second substrate being received in said groove; and

wherein said force is applied to only a portion of the periphery of said ring clamp thereby lifting the corresponding portion of the periphery of the second substrate away from the stack in said peeling motion.

16. The method of claim 15, wherein said stack further comprises an intermediate layer between said first substrate and said second substrate.

17. The method of claim 16, said intermediate layer being bonded to said device surface and to said peripheral region of said carrier surface, wherein said intermediate layer and said central region of said carrier surface comprise a low bonding interface therebetween.

18. The method of claim 17, wherein said low bonding interface comprises surface modification of said central region of said carrier surface.

19. The method of claim 17, wherein said low bonding interface comprises a second layer between said intermediate layer and said central region of said carrier surface.

20. The method of claim 19, wherein said second layer is selected from the group consisting of a low adhesive strength layer and a polymeric layer.

21. The method of claim 16, wherein said intermediate layer comprises a fill material adjacent said central regions and an edge bond adjacent said peripheral regions.

22. The method of claim 16, wherein said intermediate layer comprises a uniform bonding layer.

23. The method of claim 16, further comprising mechanically or chemically disrupting said intermediate layer adjacent said peripheral regions to remove at least a portion of said intermediate layer prior to said separating.

24. The method of claim 16, wherein said carrier surface comprises a patterned surface modification, said intermediate layer being bonded to said device surface and to non-modified portions of said carrier surface, wherein said intermediate layer and said surface-modified portions of said carrier surface comprise a low bonding interface therebetween.

25. The method ofclaims 15,wherein said device surface comprises an array of devices selected from the group consisting of integrated circuits; MEMS; microsensors; power semiconductors; light-emitting diodes; photonic circuits; interposers; embedded passive devices; and microdevices fabricated on or from silicon, silicon-germanium, gallium arsenide, and gallium nitride.

26. The method of claim 15, said device surface comprising at least one structure selected from the group consisting of: solder bumps; metal posts; metal pillars; and structures formed from a material selected from the group consisting of silicon, polysilicon, silicon dioxide, silicon (oxy)nitride, metal, low k dielectrics, polymer dielectrics, metal nitrides, and metal silicides.

27. The method of claim 15, wherein said second substrate comprises a material selected from the group consisting of silicon, sapphire, quartz, metal, glass, and ceramics.

28. The method of claim 15, further comprising subjecting said stack to processing selected from the group consisting of back-grinding, chemical-mechanical polishing, etching, metal and dielectric deposition, patterning, passivation, annealing, and combinations thereof, prior to separating said first and second substrates.

29. The method of claim 15, wherein said body is in the form of a split ring clamp having two free ends.

30. The method of claim 29, wherein said ring clamp is secured about the periphery of said second substrate by:

moving said free ends away from one another, thereby enlarging the central opening of said body;

placing said ring clamp about the periphery of the second substrate; and

drawing said free ends toward one another to compressively engage the second substrate, prior to said separating,

wherein the annular ridge of said ring clamp terminates in a free edge and has a sloped

shoulder surface extending between the free edge of the ridge and the point where the wafer-engaging surface terminates in the body, the backside surface of said second substrate being engaged by the wafer-engaging surface of the body and the outermost edge and peripheral region of the second substrate being engaged by the shoulder and free edge of the ridge.

31. The method of claim 30, wherein said ring clamp engages at least 1° of the periphery of said second substrate.

32. The method of claim 15, wherein said ring clamp does not contact said first substrate.

33. The method of claim 15, wherein the first substrate of said stack is secured to a chuck prior to separating said substrates.

34. The method of claim 33, said first substrate being secured to said chuck via an electrostatic force, a vacuum force, magnetic force, mechanical force, physical restraint, or a layer of adhesive film between said chuck and said first substrate.

35. The method of claim 33, wherein said chuck is moved away from the second substrate during said separating.

36. A method of forming a temporary wafer bonding structure, said method comprising:

providing a first substrate having front and back surfaces;

forming a bonding layer on said front surface of said first substrate;

providing a second substrate having front and back surfaces, said front surface having a surface-modified region, a non-modified region, and an optional mask adjacent said non-modified region; and

contacting said front surface of said second substrate with said bonding layer on said first substrate to thereby form said temporary bonding structure, wherein said bonding layer and said surface-modified region of said second substrate comprise a low

bonding interface therebetween.

37. The method of claim 36, said surface-modified region comprising a pattern.

38. The method of claim 37, wherein said pattern is selected from the group consisting of grids, lines, and shapes.

39. The method of claim 36, said front surface having a peripheral region and a central region, said central region comprising said surface modified region, wherein said mask is adjacent said peripheral region.

40. The method of claim 39, said surface-modified region comprising a pattern.

41. The method of claim 39, wherein said providing of said second substrate comprises:

forming an mask on said peripheral region;

depositing a surface modifying composition in said central region to yield said surface-modified central region; and

and optionally removing said mask to thereby expose said peripheral region.

42. The method of claim 36, wherein said mask is present, said bonding layer being bonded with said mask.

43. The method of claim 36, wherein said contacting is carried out under heat and pressure, said mask reflowing into said bonding layer to create a uniform bonding layer.

44. The method of claim 36, wherein said mask is not present, said bonding layer being bonded with said non-modified region of said second substrate.