## CLAIMS

1. A method of establishing a thermal joint for conducting heat between a heat spreader and a heat source of an electronic device, the method comprising positioning a thermal interface material (TIM1) between the heat spreader and the heat source, wherein the TIM1 comprises:

a phase change thermal interface material having a softening temperature that is below or within a normal operating temperature range of the heat source; and/or

a thermoplastic thermal interface material having a softening or melting temperature above a normal operating temperature range of the heat source;

and heating the TIM1 to a temperature above the normal operating temperature range, such that the TIM1 is flowable under pressure; and

allowing the TIM1 to return to a temperature below or within the normal operating temperature range, whereby the TIM1 establishes a thermal joint between the heat spreader and the heat source.

2. The method of claim 1, wherein the TIM1 is operable for establishing a restorable thermal joint between the heat spreader and the heat source, such that if delamination of the TIM1 occurs during thermal cycling then interfacial contact resistance and thermal resistance of the thermal joint will increase whereby heat from the heat source will cause the TIM1 to soften, reduce contact resistance, and reestablish the thermal joint.

3. The method of claim 1 or claim 2, further comprising heating the TIM1 to a phase change temperature while under pressure such that the TIM1 flows to form a thin bond line between the heat spreader and the heat source; and allowing the TIM1 to return to a solid state, whereby the TIM1 establishes a thermal joint between the heat spreader and the heat source.

4. The method of claim 1 or claim 2, further comprising:

applying the TIM1 to the heat spreader or to the heat source before positioning the TIM1 between the heat spreader and the heat source; and/or

wherein the method includes curing an adhesive for attaching the heat spreader to the electronic device, which curing process also heats the TIM1 to at least the softening temperature.

5. The method of any one of claims 1 to 4, wherein:

the softening temperature of the TIM1 is below or within the normal operating temperature range of the heat source; and/or

the TIM1 comprises a phase change material having a softening temperature range from 45 °C to 70 °C; and/or

the TIM1 has a phase change temperature below or within the normal operating temperature range of the heat source; and/or

the TIM1 is shear thinning and thixotropic such that the thermal interface material is not flowable at the phase change temperature except under pressure; and/or

the TIM1 has a phase change temperature above the normal operating temperature range of the heat source, such that the TIM1 softens, without melting, within the normal operating temperature range of the heat source.

6. The method of any one of claims 1 to 5, wherein:

the electronic device comprises a semiconductor device having the heat source;

the heat spreader comprises a lid of the electronic device;

the TIM1 comprises a first thermal interface material between the semiconductor device and the lid; and

the method further comprises positioning a second thermal interface material (TIM2) between a heat sink and the lid spreader, whereby the semiconductor device is in effective thermal communication with the heat sink via the first thermal interface material, the lid, and the second thermal interface material.

7. The method of any one of claims 1 to 5, wherein:

the heat spreader comprises an integrated heat spreader or lid of the electronic device;

the heat source comprises one or more heat generating components of the electronic device;

the TIM1 comprises a thermoplastic thermal interface material having a softening or melting temperature above a normal operating temperature of the one or more heat generating components; and wherein the method comprises:

positioning the thermoplastic thermal interface material between the integrated heat spreader or lid and the one or more heat generating components;

heating the thermoplastic thermal interface material to at least the softening or melting temperature while under pressure such that the thermoplastic thermal interface material flows to form a thin bond line between the integrated heat spreader or lid and the one or more heat generating components; and

allowing the thermoplastic thermal interface material to return to a solid state, whereby the thermoplastic thermal interface material establishes a thermal joint between the integrated heat spreader or lid and the one or more heat generating components.

8. The method of claim 7, wherein:

the electronic device comprises a central processing unit having the one or more heat generating components; and

the heating of the thermoplastic thermal interface material to at least the softening or melting temperature while under pressure occurs during a curing process of an adhesive that attaches the integrated heat spreader or lid to the central processing unit.

9. The method of claim 7 or claim 8, wherein:

heating the thermoplastic thermal interface material comprising heating the thermoplastic thermal interface material to a temperature within a range from 100 °C to 200 °C or from 125 °C to 175 °C while under a pressure within a range from a range

from 5 pounds per square inch (psi) 34474 $N/m^2$ to 100 psi 689476 $N/m^2$ or from 10 psi 68947.6 $N/m^2$ to 50 psi 344740 $N/m^2$; and/or

the thermoplastic thermal interface material is sandwiched between the integrated heat spreader or lid and the one or more heat generating components with the thermoplastic thermal interface material compressed against the one or more heat generating components; and/or

the thermoplastic thermal interface material comprises a thermally conductive thermal plastic or a thermally conductive temperature reversible gel; and/or

positioning the thermoplastic thermal interface material comprises positioning a multilayered thermal interface material including a heat spreader and one or more layers of the thermoplastic thermal interface material along one or both sides of the heat spreader.

10. The method of any one of claims 7 to 9, wherein:

the normal operating temperature of the one or more heat generating components is within a range from 60 °C to 100 °C;

the softening or melting temperature of the thermoplastic thermal interface material is within a range from 100 °C to 200 °C; and

heating the thermoplastic thermal interface material comprises heating the thermoplastic thermal interface material to a temperature of at least 100 °C or more.

11. The method of any one of claims 7 to 10, wherein operation of the one or more heat generating components heats the thermoplastic thermal interface material to no more than the normal operating temperature due to the presence of the thermal joint, whereby the thermoplastic thermal interface material remains below the softening or melting temperature in the solid state thereby retaining the thermal joint.

12. A method of establishing a thermal joint for conducting heat between a heat spreader and a heat source of an electronic device, the method comprising positioning a thermal interface material (TIM1) between the heat spreader and the heat source, wherein:

the TIM1 establishes a restorable thermal joint between the heat spreader and the heat source; and/or

the method comprises positioning the TIM1 prior to curing an adhesive for attaching the heat spreader to the electronic device

and heating the TIM1 to a temperature above the normal operating temperature range, such that the TIM1 is flowable under pressure; and

allowing the TIM1 to return to a temperature below or within the normal operating temperature range, whereby the TIM1 establishes a thermal joint between the heat spreader and the heat source.

13. The method of claim 12, wherein the TIM1 establishes the restorable thermal joint between the heat spreader and the heat source such that if delamination of the TIM1 occurs during thermal cycling then interfacial contact resistance and thermal resistance of the thermal joint will increase whereby heat from the heat source will cause the TIM1 to soften, reduce contact resistance, and reestablish the thermal joint.

14. The method of claim 12 or claim 13, wherein the method comprises positioning the TIM1 between the heat spreader and the heat source prior to curing an adhesive for attaching the heat spreader to the electronic device.

15. The method of claim 14, further comprising attaching the heat spreader to the electronic device by curing the adhesive.

16. The method of claim 14, further comprising:

attaching the heat spreader to the electronic device by curing the adhesive, and wherein during the curing, the TIM1 is heated under pressure such that the TIM1 flows to form a thin bond line between the heat spreader and the heat source; and

allowing the TIM1 to return to a solid state, whereby the TIM1 establishes a thermal joint having low thermal resistance between the heat spreader and the heat source.

17. The method of any one of claims 12 to 16, wherein the TIM1 has a softening or melting temperature higher than a normal operating temperature of the heat source, whereby the TIM1 will flow to form a thin bond line when heated to at least the softening or melting temperature while under pressure.

18. The method of claim 17, wherein:

the electronic device comprises a central processing unit having one or more heat generating components;

the heat spreader comprises an integrated heat spreader or lid of the electronic device; and

the method further comprises curing an adhesive to attach the central processing unit to the integrated heat spreader or lid, whereby during the curing the TIM1 flows to form a thin bond line between the central processing unit and the integrated heat spreader or lid.

19. The method of claim 17 or claim 18, wherein:

the TIM1 comprises one or more of a thermally conductive thermal plastic, a thermally conductive temperature reversible gel, and/or a low melting alloy; and/or

positioning the TIM1 comprises positioning a multilayered TIM1 including a heat spreader and one or more layers of the TIM1 on one or both sides of the heat spreader; and/or

the softening or melting temperature of the TIM1 is within a range from 100 °C to 200 °C or from 125 °C to 175 °C.

20. The method of any one of claims 12 to 19, further comprising positioning a second thermal interface material (TIM2) between a heat sink and the heat spreader, whereby a thermally conductive heat path is established from the heat source through the TIM1, the heat spreader, and the TIM2 to the heat sink such that heat is transferrable from the heat source to the heat sink through the TIM1, the heat spreader, and the TIM2.

21. The method of any one of claims 12 to 20, wherein the thermal interface material is operable for reestablishing or restoring the thermal joint after a loss of contact between the thermal interface material and the heat spreader and/or the heat source.

22. An electronic device comprising:

a heat spreader;

a heat source having a normal operating temperature range;

a first thermal interface material (TIM1) formed from the method of claim 1 or claim 12, between the heat spreader and the heat source, wherein the TIM1 comprises:

a phase change thermal interface material having a softening temperature that is below or within a normal operating temperature range of the heat source; and/or

a thermoplastic thermal interface material having a softening or melting temperature above a normal operating temperature range of the heat source; and/or

a thermal interface material that establishes a restorable thermal joint between the heat spreader and the heat source.

23. The electronic device of claim 22, wherein:

the electronic device comprises a semiconductor device having the heat source, the heat spreader comprises a lid of the electronic device, and the TIM1 is between the semiconductor device and the lid; and/or

the heat source comprises one or more heat generating components of the electronic device, the heat spreader comprises an integrated heat spreader or lid of the electronic device, the TIM1 is between the integrated heat spreader or lid and the one or more heat generating components, the TIM1 has a softening or melting temperature higher than the normal operating temperature of the one or more heat generating components, the TIM1 being flowable to a thin bond line when heated to at least the softening or melting temperature while under pressure.

24. The electronic device of claim 22 or claim 23, further comprising:

a heat sink; and

a second thermal interface material (TIM2) between the heat source and the heat sink;

whereby a thermally conductive heat path is established from the heat source through the TIM1, the heat spreader, and the TIM2 material to the heat sink.

25. The electronic device of any one of claims 22 to 24, wherein the thermal interface material establishes the restorable thermal joint between the heat spreader and the heat source such that if delamination of the thermal interface material occurs during thermal cycling then interfacial contact resistance and thermal resistance of the thermal joint will increase whereby heat from the heat source will cause the thermal interface material to soften, reduce contact resistance, and reestablish the thermal joint.

26. A thermal interface material for establishing a restorable thermal joint for conducting heat between a heat spreader and a heat source of an electronic device, the thermal interface material comprising a thermoplastic and/or phase change material configured such that if delamination of the thermal interface material occurs during thermal cycling then interfacial contact resistance and thermal resistance of the thermal joint will increase whereby heat from the heat source will cause the thermal interface material to soften, reduce contact resistance, and reestablish the thermal joint.

## CLAIMS

1. A method of establishing a thermal joint for conducting heat between a heat spreader and a heat source of an electronic device, the method comprising positioning a thermal interface material (TIM1) between the heat spreader and the heat source, wherein the TIM1 comprises:

a phase change thermal interface material having a softening temperature that is below or within a normal operating temperature range of the heat source; and/or

a thermoplastic thermal interface material having a softening or melting temperature above a normal operating temperature range of the heat source;

and heating the TIM1 to a temperature above the normal operating temperature range, such that the TIM1 is flowable under pressure; and

allowing the TIM1 to return to a temperature below or within the normal operating temperature range, whereby the TIM1 establishes a thermal joint between the heat spreader and the heat source.

2. The method of claim 1, wherein the TIM1 is operable for establishing a restorable thermal joint between the heat spreader and the heat source, such that if delamination of the TIM1 occurs during thermal cycling then interfacial contact resistance and thermal resistance of the thermal joint will increase whereby heat from the heat source will cause the TIM1 to soften, reduce contact resistance, and reestablish the thermal joint.

3. The method of claim 1 or claim 2, further comprising heating the TIM1 to a phase change temperature while under pressure such that the TIM1 flows to form a thin bond line between the heat spreader and the heat source; and allowing the TIM1 to return to a solid state, whereby the TIM1 establishes a thermal joint between the heat spreader and the heat source.

4. The method of claim 1 or claim 2, further comprising:

applying the TIM1 to the heat spreader or to the heat source before positioning the TIM1 between the heat spreader and the heat source; and/or

wherein the method includes curing an adhesive for attaching the heat spreader to the electronic device, which curing process also heats the TIM1 to at least the softening temperature.

5. The method of any one of claims 1 to 4, wherein:

the softening temperature of the TIM1 is below or within the normal operating temperature range of the heat source; and/or

the TIM1 comprises a phase change material having a softening temperature range from 45 °C to 70 °C; and/or

the TIM1 has a phase change temperature below or within the normal operating temperature range of the heat source; and/or

the TIM1 is shear thinning and thixotropic such that the thermal interface material is not flowable at the phase change temperature except under pressure; and/or

the TIM1 has a phase change temperature above the normal operating temperature range of the heat source, such that the TIM1 softens, without melting, within the normal operating temperature range of the heat source.

6. The method of any one of claims 1 to 5, wherein:

the electronic device comprises a semiconductor device having the heat source;

the heat spreader comprises a lid of the electronic device;

the TIM1 comprises a first thermal interface material between the semiconductor device and the lid; and

the method further comprises positioning a second thermal interface material (TIM2) between a heat sink and the lid spreader, whereby the semiconductor device is in effective thermal communication with the heat sink via the first thermal interface material, the lid, and the second thermal interface material.

7. The method of any one of claims 1 to 5, wherein:

the heat spreader comprises an integrated heat spreader or lid of the electronic device;

the heat source comprises one or more heat generating components of the electronic device;

the TIM1 comprises a thermoplastic thermal interface material having a softening or melting temperature above a normal operating temperature of the one or more heat generating components; and wherein the method comprises:

positioning the thermoplastic thermal interface material between the integrated heat spreader or lid and the one or more heat generating components;

heating the thermoplastic thermal interface material to at least the softening or melting temperature while under pressure such that the thermoplastic thermal interface material flows to form a thin bond line between the integrated heat spreader or lid and the one or more heat generating components; and

allowing the thermoplastic thermal interface material to return to a solid state, whereby the thermoplastic thermal interface material establishes a thermal joint between the integrated heat spreader or lid and the one or more heat generating components.

8. The method of claim 7, wherein:

the electronic device comprises a central processing unit having the one or more heat generating components; and

the heating of the thermoplastic thermal interface material to at least the softening or melting temperature while under pressure occurs during a curing process of an adhesive that attaches the integrated heat spreader or lid to the central processing unit.

9. The method of claim 7 or claim 8, wherein:

heating the thermoplastic thermal interface material comprising heating the thermoplastic thermal interface material to a temperature within a range from 100 °C to 200 °C or from 125 °C to 175 °C while under a pressure within a range from a range

from 5 pounds per square inch (psi) 34474 $N/m^2$ to 100 psi 689476 $N/m^2$ or from 10 psi 68947.6 $N/m^2$ to 50 psi 344740 $N/m^2$; and/or

the thermoplastic thermal interface material is sandwiched between the integrated heat spreader or lid and the one or more heat generating components with the thermoplastic thermal interface material compressed against the one or more heat generating components; and/or

the thermoplastic thermal interface material comprises a thermally conductive thermal plastic or a thermally conductive temperature reversible gel; and/or

positioning the thermoplastic thermal interface material comprises positioning a multilayered thermal interface material including a heat spreader and one or more layers of the thermoplastic thermal interface material along one or both sides of the heat spreader.

10. The method of any one of claims 7 to 9, wherein:

the normal operating temperature of the one or more heat generating components is within a range from 60 °C to 100 °C;

the softening or melting temperature of the thermoplastic thermal interface material is within a range from 100 °C to 200 °C; and

heating the thermoplastic thermal interface material comprises heating the thermoplastic thermal interface material to a temperature of at least 100 °C or more.

11. The method of any one of claims 7 to 10, wherein operation of the one or more heat generating components heats the thermoplastic thermal interface material to no more than the normal operating temperature due to the presence of the thermal joint, whereby the thermoplastic thermal interface material remains below the softening or melting temperature in the solid state thereby retaining the thermal joint.

12. A method of establishing a thermal joint for conducting heat between a heat spreader and a heat source of an electronic device, the method comprising positioning a thermal interface material (TIM1) between the heat spreader and the heat source, wherein:

the TIM1 establishes a restorable thermal joint between the heat spreader and the heat source; and/or

the method comprises positioning the TIM1 prior to curing an adhesive for attaching the heat spreader to the electronic device

and heating the TIM1 to a temperature above the normal operating temperature range, such that the TIM1 is flowable under pressure; and

allowing the TIM1 to return to a temperature below or within the normal operating temperature range, whereby the TIM1 establishes a thermal joint between the heat spreader and the heat source.

13. The method of claim 12, wherein the TIM1 establishes the restorable thermal joint between the heat spreader and the heat source such that if delamination of the TIM1 occurs during thermal cycling then interfacial contact resistance and thermal resistance of the thermal joint will increase whereby heat from the heat source will cause the TIM1 to soften, reduce contact resistance, and reestablish the thermal joint.

14. The method of claim 12 or claim 13, wherein the method comprises positioning the TIM1 between the heat spreader and the heat source prior to curing an adhesive for attaching the heat spreader to the electronic device.

15. The method of claim 14, further comprising attaching the heat spreader to the electronic device by curing the adhesive.

16. The method of claim 14, further comprising:

attaching the heat spreader to the electronic device by curing the adhesive, and wherein during the curing, the TIM1 is heated under pressure such that the TIM1 flows to form a thin bond line between the heat spreader and the heat source; and

allowing the TIM1 to return to a solid state, whereby the TIM1 establishes a thermal joint having low thermal resistance between the heat spreader and the heat source.

17. The method of any one of claims 12 to 16, wherein the TIM1 has a softening or melting temperature higher than a normal operating temperature of the heat source, whereby the TIM1 will flow to form a thin bond line when heated to at least the softening or melting temperature while under pressure.

18. The method of claim 17, wherein:

the electronic device comprises a central processing unit having one or more heat generating components;

the heat spreader comprises an integrated heat spreader or lid of the electronic device; and

the method further comprises curing an adhesive to attach the central processing unit to the integrated heat spreader or lid, whereby during the curing the TIM1 flows to form a thin bond line between the central processing unit and the integrated heat spreader or lid.

19. The method of claim 17 or claim 18, wherein:

the TIM1 comprises one or more of a thermally conductive thermal plastic, a thermally conductive temperature reversible gel, and/or a low melting alloy; and/or

positioning the TIM1 comprises positioning a multilayered TIM1 including a heat spreader and one or more layers of the TIM1 on one or both sides of the heat spreader; and/or

the softening or melting temperature of the TIM1 is within a range from 100 °C to 200 °C or from 125 °C to 175 °C.

20. The method of any one of claims 12 to 19, further comprising positioning a second thermal interface material (TIM2) between a heat sink and the heat spreader, whereby a thermally conductive heat path is established from the heat source through the TIM1, the heat spreader, and the TIM2 to the heat sink such that heat is transferrable from the heat source to the heat sink through the TIM1, the heat spreader, and the TIM2.

21. The method of any one of claims 12 to 20, wherein the thermal interface material is operable for reestablishing or restoring the thermal joint after a loss of contact between the thermal interface material and the heat spreader and/or the heat source.

22. An electronic device comprising:

a heat spreader;

a heat source having a normal operating temperature range;

a first thermal interface material (TIM1) formed from the method of claim 1 or claim 12, between the heat spreader and the heat source, wherein the TIM1 comprises:

a phase change thermal interface material having a softening temperature that is below or within a normal operating temperature range of the heat source; and/or

a thermoplastic thermal interface material having a softening or melting temperature above a normal operating temperature range of the heat source; and/or

a thermal interface material that establishes a restorable thermal joint between the heat spreader and the heat source.

23. The electronic device of claim 22, wherein:

the electronic device comprises a semiconductor device having the heat source, the heat spreader comprises a lid of the electronic device, and the TIM1 is between the semiconductor device and the lid; and/or

the heat source comprises one or more heat generating components of the electronic device, the heat spreader comprises an integrated heat spreader or lid of the electronic device, the TIM1 is between the integrated heat spreader or lid and the one or more heat generating components, the TIM1 has a softening or melting temperature higher than the normal operating temperature of the one or more heat generating components, the TIM1 being flowable to a thin bond line when heated to at least the softening or melting temperature while under pressure.

24. The electronic device of claim 22 or claim 23, further comprising:

a heat sink; and

a second thermal interface material (TIM2) between the heat source and the heat sink;

whereby a thermally conductive heat path is established from the heat source through the TIM1, the heat spreader, and the TIM2 material to the heat sink.

25. The electronic device of any one of claims 22 to 24, wherein the thermal interface material establishes the restorable thermal joint between the heat spreader and the heat source such that if delamination of the thermal interface material occurs during thermal cycling then interfacial contact resistance and thermal resistance of the thermal joint will increase whereby heat from the heat source will cause the thermal interface material to soften, reduce contact resistance, and reestablish the thermal joint.