Claims

What is claimed is:

1. A thermal test head for an integrated circuit device including a die mounted on a substrate, the thermal test head comprising:

a heat exchanger assembly~~;~~,

a die-contact member configured to contact the die~~;~~, and

a thermal control assembly disposed between the heat exchanger assembly and the die-contact member, the thermal control assembly ~~including~~comprising

a Peltier device in thermal contact with opposing surfaces of the heat exchanger assembly and the die-contact member, and

a spacer in physical contact with the opposing surfaces of the heat exchanger assembly and the die-contact member~~.~~;

an inclination-adjustment device coupled to a surface of the heat exchanger assembly and disposed opposite the thermal control assembly, wherein the inclination-adjustment device comprises:

an alignment plate coupled to the surface of the heat exchanger assembly,

a lock plate disposed above the alignment plate and configured to move towards and away from the alignment plate, and

multiple springs disposed between the lock plate and the alignment plate,

wherein the multiple springs bias the lock plate away from the alignment plate;

wherein the inclination-adjustment device further comprises one or more springs disposed between the alignment plate and the heat exchanger assembly and configured to bias the alignment plate away from the heat exchanger assembly;

a substrate-contact member and at least one support member connecting the substrate-contact member to the alignment plate, the substrate-contact member being configured to contact the substrate and apply a compressive force thereon.

2. The thermal test head of claim 1, wherein the spacer is disposed at least partially around the Peltier device.

3. The thermal test head of claim 1 or claim 2, wherein the heat exchanger assembly is configured to circulate a fluid therethrough.

4. The thermal test head of claim 3, wherein the heat exchanger assembly includes

a manifold defining ~~-~~a cavity,

a cold plate including micro-fins on a first surface of the cold plate, and

a channel body defining fluid-flow channels, the micro-fins and the channel body being disposed in the cavity of the manifold,

~~the micro-fins and the channel body being disposed in the cavity of the manifold.~~

preferably

~~5. The thermal test head of claim 4~~, wherein the cold plate includes thermally conductive metal, and/or the manifold includes plastic material, and/or the channel body includes one of metal or plastic material.

5. The thermal test head of claim 4, wherein the one or more springs between the alignment plate and the heat exchanger assembly are disposed on one or more recesses defined on a surface of the manifold.

6. The thermal test head of ~~claim~~any one of claims 1 to 5, wherein the spacer has an annular shape defining a central opening, and wherein the Peltier device is disposed in the central opening of the spacer.

7. The thermal test head of claim ~~1, further including~~6, wherein the spacer includes a body having at least one channel for a respective electrical lead of the Peltier device to extend through a respective channel of the at least one channel when the Peltier device is positioned in the central opening of the spacer.

8. The thermal test head of any one of claims 1 to 7, wherein the spacer comprises a plastic or ceramic material.

9. The thermal test head of any one of claims 1 to 8, further comprising

a first layer of thermal interface material disposed between the Peltier device and the die-contact member, and

a second layer of thermal interface material disposed between the Peltier device and the heat exchanger assembly,

wherein a height of the spacer is substantially equal to a sum of a height of the Peltier device, a height of the first layer of thermal interface material, and a height of the second layer of thermal interface material.

10. The thermal test head of claim 9, wherein the first layer of thermal interface material is in physical contact with the Peltier device and the die-contact member, and the second layer of thermal interface material is in physical contact with the Peltier device and the heat exchanger assembly.

11. ~~8. The thermal test head of claim 1, further including an inclination-adjustment device coupled to a first surface of the heat exchanger assembly and disposed opposite the thermal control assembly, wherein the inclination-adjustment device includes~~

~~an alignment plate coupled to the first surface of the heat exchanger assembly,~~

The thermal test head of claim 1~~a lock plate disposed above the alignment plate and configured to move towards and away from the alignment plate, and~~

~~multiple springs disposed between the lock plate and the alignment plate,~~

~~wherein the multiple springs bias the lock plate away from the alignment plate.~~

~~9. The thermal test head of claim 8~~, wherein the alignment plate includes a substantially convex shaped projection extending towards the lock plate, and wherein the multiple springs of the inclination-adjustment device are disposed around the projection.

~~10~~12. The thermal test head of claim ~~8,~~ 1 or claim 11,

wherein the inclination-adjustment device is configured to vary an angular alignment of a contact surface of the die-contact member, ~~wherein the contact surface is configured to contact the die.~~

wherein the

~~11. A thermal test head for an integrated circuit device including a die mounted on a substrate, the thermal test head comprising:~~

~~a heat exchanger assembly configured to circulate a fluid therethrough;~~

~~a die-contact member including a~~ contact surface~~, the contact surface being configured to contact the die; and~~

~~a thermal control assembly disposed between the heat exchanger assembly and the die-contact member, the thermal control assembly including~~

~~a Peltier device in thermal contact with opposing surfaces of the heat exchanger assembly and the die-contact member, and~~

~~one or more spacers disposed at least partially around the Peltier device, the one or more spacers being in physical contact with the opposing surfaces of the heat exchanger assembly and the die-contact member; and~~

~~an inclination-adjustment device coupled to the heat exchanger assembly opposite the thermal control assembly, wherein the inclination-adjustment device~~ is configured to ~~change an angular alignment of the contact surface of the die-contact member when the contact surface contacts the die.~~contact the die.

~~12~~13. The thermal test head of claim ~~11, further including~~

~~a first layer of thermal interface material disposed between the Peltier device and the die-contact member, and~~

~~a second layer of thermal interface material disposed between the Peltier device and the heat exchanger assembly,~~

~~wherein a height of the one or more spacers is substantially equal to a sum of a height of the Peltier device, a height of the first layer of thermal interface material, and a height of the second layer of thermal interface material.~~

~~13. The thermal test head of claim 11, wherein the one or more spacers include plastic or ceramic material.~~

~~14. The thermal test head of claim 11, wherein the inclination-adjustment device includes~~

~~an alignment plate coupled to a surface of the heat exchanger assembly,~~

~~a lock plate positioned above the alignment plate and configured to move towards and away from the alignment plate, and~~

~~multiple springs disposed between the lock plate and the alignment plate, wherein the multiple springs bias the lock plate away from the alignment plate.~~

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~~15. The thermal test head of claim 14, wherein~~

~~a first surface of the alignment plate that faces the lock plate includes a substantially convex shaped projection extending towards the lock plate, and~~

~~a second surface of the alignment plate opposite the first surface is directly attached to the surface of the heat exchanger assembly.~~

~~16. The thermal test head of claim 11, wherein the heat exchanger assembly includes~~

~~a manifold defining a cavity,~~

~~a cold plate including micro-fins, and~~

~~a channel body defining fluid-flow channels,~~

~~the micro-fins and the channel body being disposed in the cavity of the manifold.~~

~~17. A thermal test head for an integrated circuit device including a die mounted on a substrate, the thermal test head comprising:~~

~~a heat exchanger assembly configured to circulate a fluid therethrough;~~

~~a thermally conductive die-contact member including a contact surface, the contact surface being configured to contact the die; and~~

~~a thermal control assembly disposed between a first surface of the die-contact member and a second surface of the heat exchanger assembly, wherein the thermal control assembly includes:~~

~~a Peltier device,~~

~~a first layer of thermal interface material disposed between, and in physical contact with, the Peltier device and the first surface of the die-contact member,~~

~~a second layer of thermal interface material disposed between, and in physical contact with, the Peltier device and the second surface of the heat exchanger assembly, and~~

~~one or more spacers disposed at least partially around the Peltier device and in physical contact with the first surface of the die-contact member and the second surface of the heat exchanger assembly, wherein a height of the one or more spacers is substantially equal to a sum of a height of the Peltier device, a height of the first layer of thermal interface material, and a height of the second layer of thermal interface material.~~

~~18. The thermal test head of claim 17, further including an inclination-adjustment device coupled to a third surface of the heat exchanger assembly opposite the second surface, wherein the inclination-adjustment device is configured to change an angular alignment of the contact surface of the die-contact member when the contact surface contacts the die.~~

~~19. The thermal test head of claim 18, wherein the inclination-adjustment device includes~~

~~an alignment plate coupled to the third surface of the heat exchanger assembly,~~

~~a lock plate disposed above the alignment plate and configured to move towards and away from the alignment plate, and~~

~~multiple springs disposed between the lock plate and the alignment plate, wherein the multiple springs bias the lock plate away from the alignment plate.~~

~~20. The thermal test head of claim 18, wherein~~

~~a surface of the alignment plate that faces the lock plate includes a substantially convex-shaped projection extending towards the lock plate, and~~

~~the multiple springs are disposed around the projection.~~

21. A thermal test head for an integrated circuit device including a die mounted on a substrate, the thermal test head comprising:

a heat exchanger assembly;

an inclination-adjustment device disposed above the heat exchanger assembly, wherein the inclination-adjustment device is configured to be moved towards and away from a contact assembly;

the contact assembly disposed below the heat exchanger assembly, the contact assembly including

a die-contact member configured to contact the die and apply a compressive force thereon, and

a substrate-contact member configured to contact the substrate and apply a compressive force thereon; and

a thermal control assembly disposed between the heat exchanger assembly and the contact assembly, the thermal control assembly including

a Peltier device in thermal contact with opposing surfaces of the heat exchanger assembly and the die-contact member, and

a spacer in physical contact with the opposing surfaces of the heat exchanger assembly and the die-contact member.

22. The thermal test head of claim 21, wherein the inclination-adjustment device is configured such that an initial movement of the inclination-adjustment device towards the contact assembly applies the compressive force on the die and a further movement of the inclination-adjustment device towards the contact assembly applies the compressive force on the substrate.

23. The thermal test head of claim 21, wherein the inclination-adjustment device includes

an alignment plate disposed above the heat exchanger assembly,

a lock plate disposed above the alignment plate,

one or more first springs disposed between the lock plate and the alignment plate and configured to bias the lock plate away from the alignment plate, and

~~one or more second springs disposed between the alignment plate and the heat exchanger assembly and configured to bias the alignment plate away from the heat exchanger assembly.~~

~~24. The thermal test head of claim 23, wherein the heat exchanger assembly includes~~

~~a manifold defining a cavity,~~

~~a cold plate including micro-fins on a surface of the cold plate, and~~

~~a channel body defining fluid-flow channels,~~

~~the micro-fins and the channel body being disposed in the cavity of the manifold, and~~

~~wherein the one or more second springs are disposed on one or more recesses defined on a surface of the manifold.~~

~~25. The thermal test head of claim 23, wherein an effective stiffness of the one or more second springs is greater than an effective stiffness of the one or more first springs.~~

~~26. The thermal test head of claim 23, wherein a surface of the alignment plate that faces the lock plate includes a substantially convex shaped projection that extends towards the lock plate, and wherein the one or more first springs includes multiple springs disposed around the projection.~~

~~27. The thermal test head of claim 23, further including at least one support member connecting the alignment plate to the substrate-contact member.~~

~~28. The thermal test head of claim 21, wherein the die-contact member includes a contact surface configured to contact the die, and wherein the inclination-adjustment device is configured to vary an angular alignment of the contact surface when the contact surface contacts the die.~~

~~29. The thermal test head of claim 21~~, wherein

the die-contact member includes a pedestal that extends through an opening on the substrate-contact member, the pedestal having a contact surface configured to contact the die, and

the substrate-contact member includes a flange extending at least partially around the opening, the flange having a contact surface configured to contact the substrate.

~~30~~14. The thermal test head of claim 13, wherein the flange is shaped to form a square or rectangular annulus.

15. The thermal test head of claim ~~21~~13 or claim 14, wherein

the die-contact member includes one or more guide pins that are configured to fit into corresponding one or more recesses in the substrate-contact member when the die-contact member moves towards the substrate-contact member, and

the substrate-contact member includes one or more locating pins that are configured to fit into corresponding one or more locating holes of the integrated circuit device when the substrate-contact member moves towards the integrated circuit device.

~~31~~16. The thermal test head of ~~claim 21, wherein the thermal control assembly further includes~~

~~a first layer~~ any one of ~~thermal interface material disposed between the Peltier device and the die-contact member, and~~

~~a second layer of thermal interface material disposed between the Peltier device and the heat exchanger assembly, and~~

~~wherein a height of the spacer is substantially equal~~claims 1 to ~~a sum of a height of the Peltier device, a height of the first layer of thermal interface material, and a height of the second layer of thermal interface material.~~ 15,

~~32. A thermal test head for an integrated circuit device including a die mounted on a substrate, the thermal test head comprising:~~

~~a heat exchanger assembly configured to circulate a fluid therethrough;~~

~~a contact assembly disposed below the heat exchanger assembly, the contact assembly including~~

~~a die-contact member configured to contact the die, and~~

~~a substrate-contact member configured to contact the substrate;~~

~~a thermal control assembly disposed between the heat exchanger assembly and the contact assembly, the thermal control assembly including~~

~~a Peltier device in thermal contact with opposing surfaces of the heat exchanger assembly and the die-contact member, and~~

~~one or more spacers disposed at least partially around the Peltier device, the one or more spacers being in physical contact with the opposing surfaces of the heat exchanger assembly and the die-contact member; and~~

~~an inclination-adjustment device disposed above the heat exchanger assembly,~~ wherein the inclination-adjustment device is configured such that an initial movement of the inclination-adjustment device towards the integrated circuit device causes the die-contact member to contact the die, and a further movement of the inclination-adjustment device towards the integrated circuit device causes the substrate-contact member to contact the substrate.

17. ~~33. The thermal test head of claim 32, wherein the inclination-adjustment device is configured to change an angular alignment of a die-contact surface of the die-contact member when the die-contact surface contacts the die.~~

~~34. The thermal test head of claim 32, wherein the inclination-adjustment device includes~~

~~an alignment plate disposed above the heat exchanger assembly,~~

~~a lock plate disposed above the alignment plate,~~

~~one or more first springs disposed between the lock plate and the alignment plate and configured to bias the lock plate away from the alignment plate, and~~

~~one or more second springs disposed between the alignment plate and the heat exchanger assembly and configured to bias the alignment plate away from the heat exchanger assembly.~~

~~35. The thermal test head of claim 34, further including at least one support member connecting the alignment plate to the substrate-contact member.~~

~~36. The thermal test head of claim 34,~~ The thermal test head of any one of claims 1 to 16, wherein an effective stiffness of the one or more ~~second springs~~springs between the alignment plate and the heat exchanger assembly is greater than an effective stiffness of the ~~one or more first springs.~~multiple springs between the lock plate and the alignment plate.

~~37~~18. The thermal test head of ~~claim 32,~~ any one of claims 1 to 17, wherein the ~~thermal control assembly further includes~~

~~a first layer of thermal interface material disposed between the Peltier device and the~~ die-contact member~~, and~~

~~a second layer of thermal interface material disposed between the Peltier device and the heat exchanger assembly,~~

~~wherein a height of the~~ includes one or more ~~spacers is substantially equal to a sum of a height of the Peltier device, a height of the first layer of thermal interface material, and a height of the second layer of thermal interface material.~~

~~38. A thermal test head for an~~ temperature sensors configured to monitor a temperature of the integrated circuit device ~~including a die mounted on a substrate, the thermal test head comprising:~~.

~~a heat exchanger assembly configured to circulate a fluid therethrough;~~

~~a contact assembly disposed below the heat exchanger assembly, the contact assembly including~~

~~a die-contact member configured to contact the die, and~~

~~a substrate-contact member configured to contact the substrate;~~

~~a thermal control assembly disposed between a first surface of the die-contact member and a second surface of the heat exchanger assembly, wherein the thermal control assembly includes~~

~~a Peltier device,~~

~~a first layer of thermal interface material disposed between, and in physical contact with, the Peltier device and the first surface of the die-contact member,~~

a second layer of thermal interface material disposed between, and in physical contact with, the Peltier device and the second surface of the heat exchanger assembly, and

one or more spacers disposed at least partially around the Peltier device, wherein the one or more spacers are in physical contact with the first surface of the die-contact member and the second surface of the heat exchanger assembly, wherein a height of the one or more spacers is substantially equal to a sum of a height of the Peltier device, a height of the first layer of thermal interface material, and a height of the second layer of thermal interface material; and

an inclination-adjustment device disposed above the heat exchanger assembly, wherein the inclination-adjustment device includes

an alignment plate disposed above the heat exchanger assembly,

a lock plate disposed above the alignment plate,

one or more first springs disposed between the lock plate and the alignment plate and configured to bias the lock plate away from the alignment plate, and

one or more second springs disposed between the alignment plate and the heat exchanger assembly and configured to bias the alignment plate away from the heat exchanger assembly.

39. The thermal test head of claim 38, wherein an effective stiffness of the one or more second springs is greater than an effective stiffness of the one or more first springs.

40. The thermal test head of claim 38, further including at least one support member connecting the alignment plate to the substrate-contact member.