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Wire-bond Array for Enhanced Cooling of Integrated Circuits

ABSTRACT

The trends of increasing transistor density and computational load have converged to create very high temperatures at integrated circuits (IC). Water cooling has been introduced as a heat-dissipation technique for ICs with heavy thermal load. However, just as for air-cooling, water-cooling works optimally when there is adequate contact area between the flowing coolant and the heat source (the IC). This disclosure describes techniques to enhance the heat dissipated during water cooling of ICs using an array of metallic wires bonded at right angles to the IC package at one end and to a metallic manifold at the other end. The manifold and the package form a channel into which cold water is pumped in and hot water exits. Wire bonding, a robust technique originally developed to establish electrical coupling, is repurposed to enhance direct liquid cooling via increased contact area.

KEYWORDS

- Wire bonding
- Thermal load
- Heat dissipation
- Heat fins
- Water cooling
- Heat pipes
- Integrated circuit (IC)
BACKGROUND

The trends of increasing transistor density and computational load have converged to create very high temperatures at integrated circuits (IC). Some examples of high-density ICs that experience high temperatures include ICs used in GPUs, custom ASICs, etc.; ICs used in servers and data centers; ICs for applications in artificial intelligence, imaging; etc. Undissipated heat can lead to slowdowns, malfunctions, and shortened life of the IC.

Conventional heat dissipation techniques, e.g., air-cooled heat fins, heat pipes, etc., are unable to scale with the increasing thermal load of high-density, high-performance electronics. In response, water cooling has been introduced as a heat-dissipation technique for ICs with high computational and thermal load. Having a greater specific heat capacity and thermal conductivity than air, water is generally more efficient at heat dissipation. However, just as for air-cooling, water-cooling works optimally when there is adequate contact area between the flowing coolant (water) and the heat source (the IC) as well as between the flowing coolant and a sink.

Separately, wire bonding is a technique to electrically bond metallic, e.g., copper, gold, etc., wires of thin diameter, e.g., 0.18-500 microns, to metallic contact pads on an IC, such that electrical signals can flow into and out of the IC.

DESCRIPTION

This disclosure describes techniques to enhance the heat dissipated during water cooling of ICs using an array of metallic wires bonded at right angles to the IC package at one end and to a metallic manifold at the other end. The manifold and the package form a channel into which cold water is pumped in and hot water exits. The wire-bonded metallic wires that connect the manifold to the IC package intersperse the channel at periodic spacings and provide a contact
area for heat to transfer from the package to the flowing water. Wire bonding, a robust technique originally developed to establish electrical coupling, is repurposed for heat transfer.
Fig. 1 illustrates an example procedure to wire-bond an array of metallic wires to a package to enable enhanced cooling of integrated circuits, per the techniques of this disclosure. Fig. 1(a) illustrates a side view of a finished chip package (102) comprising chips (ICs), interposer, substrate, etc., installed on a board. As explained earlier, the chips are a source of heat that is to be rapidly drawn away.

A metallized surface (104) is established on exposed silicon sections of the semiconductor chip to enable wire-bond coupling of wires to the chip. The metallized surface can be made of, e.g., titanium, nickel, gold, or other metal that enables wire bonding. The metallized surface can be created using a physical vapor deposition method (PVD) or other metal-deposition processes compatible with wire bonding.

An array of wires (106) is coupled, e.g., ball-bonded, to the metallized surface as shown in Fig. 1(b). The wires can be of diameter, e.g., 2 to 6 mils, and can be made of, e.g., copper, gold, or other bondable wire. The material and diameter of the wires can be selected based on thermal requirements and semiconductor process characteristics. The upper ends of the wires can be balled and snipped. The wires can be in circular or ribbon form. The wire pitch can be uniform or non-uniform depending on cooling requirements.

A metallic manifold (108) is placed atop and coupled to the wires, as shown in Fig. 1(c) such that a sealed fluid channel is formed between the manifold and the package. The manifold has vents through which cold water is pumped in and hot water exits. The array of wires draws heat from the chip, and, due to their increased surface area, efficiently transfers heat to the flowing coolant (water).
Alternative to an array of vertical wire-bonded wires that are balled and snipped at their upper ends, the wires can be looped between their bases, e.g., contact pads. Such loops (202) are illustrated in Fig. 2, with Fig. 2(a) being the top view and Fig. 2(b) a side view.

In this manner, wire bonding, a technique originally developed to establish electrical coupling, is repurposed to enhance direct liquid cooling of ICs. Some advantages of the described techniques include:

- Wire bonding can be a package-level procedure with no impact on upstream process flow.
- Wire bonding is a widely-practiced, simple, and low-cost procedure with strong existing infrastructural and technical support and readily-available process tools.
- Wire bonding is a low-temperature, low mechanical-stress procedure that raises no reliability concerns.
CONCLUSION

This disclosure describes techniques to enhance the heat dissipated during water cooling of ICs using an array of metallic wires bonded at right angles to the IC package at one end and to a metallic manifold at the other end. The manifold and the package form a channel into which cold water is pumped in and hot water exits. Wire bonding, a robust technique originally developed to establish electrical coupling, is repurposed to enhance direct liquid cooling via increased contact area.