Industry Developments:

Heat Spreader Options and Materials

A heat spreader is typically a solid or liquid filled chamber that disperses the heat on a surface that is larger than the heat source size. A heat spreader is generally used when the heat source tends to have a high heat-flux density, (high heat flow per unit area), and its size is much smaller than the contact area to the heat exchanger or heat sink.

A typical example is a plate between a small component and the base of a larger footprint heat sink. The heat sink's performance can be improved with a heat spreading plate. The plate, e.g. made of copper, has a high thermal conductivity and heat from a smaller source will spread out over the plate and more effectively transfer into the secondary heat exchanger.

Along with copper, heat spreaders are made from different high thermal conductivity materials and in some designs feature an internal vapor chamber for added thermal spreading. [1]

Figure 1. A Solid, 99.99% Pure Copper Heat Spreader from Impactics

Graphene Heat Spreaders

Scientists at Chalmers University of Technology in Sweden found that a heat spreader made from multiple layers of graphene showed strong heat conducting properties when tested on hotspots on electronic components. Graphene is a two-dimensional material comprising carbon atoms arranged in a hexagonal pattern. Tests have shown that by placing a thin layer of graphene layer on the hot spots the temperature of the hot spot can be reduced by 13°C. [3]

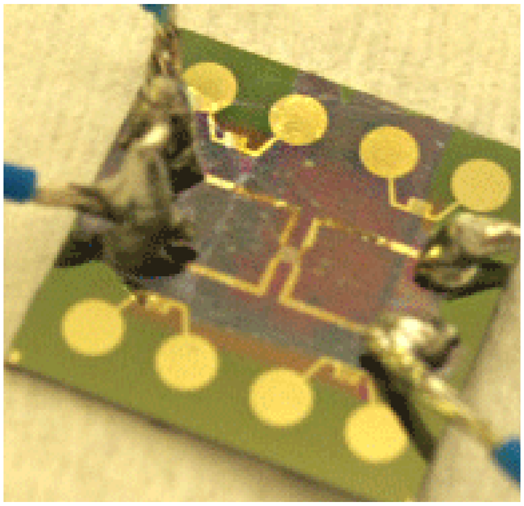

Figure 2. Graphene Layers Have Been Shown to Reduce Hotspot Temperatures Markedly [3]

Researchers at North Carolina State university developed a heat spreader that consists of a copper-graphene composite and attached it to an electronic device with an indium-graphene interface film. Tests showed that the increased thermal conductivity provided by the graphene increased heat dissipation about 25% above pure copper. It was also noted that graphene is less expensive than pure copper, which could potentially reduce the cost of heat spreaders in the future.

In a paper related to the NC State University studies, published in Metallurgical and Materials Transactions, test results showed how a 200 micron thin film of copper-graphene delivered a thermal conductivity of 460 W/mK vs. just 380 W/mK for electrolytic copper, at a temperature of 27°C [4]. However it is not clear if the researchers addressed the issue of TIM effect on the performance.

Aluminum Diamond

In the microwave industry, aluminum diamond metal matrix composites (MMCs) are proving to be an effective way to remove heat from discrete RF power transistors and MMICs. The MMCs are used as heat spreaders between active devices and their mounting surfaces. Thermal models and IR scans of MMC applications show a significant reduction in transistor junction temperature of about 25% when compared to a copper/tungsten heat spreader.

Figure 3. Aluminum Diamond Metal Matrix Composites (MMCs) [5]

Aluminum diamond MMCs developed by Nano Materials International Corp. (NMIC) not only provide high thermal conductivity of more than 500 W/mK, but solve other problems long associated with diamond composites. Aluminum diamond MMCs have a coefficient of thermal expansion (CTE) of 4 to 8 ppm/K, which is close to that of SiC (the substrate material of choice for most high-performance GaN devices)[5], however, substrate cooling due to thermal mismatch appears to have been minimized.

Vapor Chamber (VC) Heat Spreaders

Vapor chamber heat spreaders are planar heat pipes that typically spread heat from smaller, concentrated heat source(s) to a larger area of the VC. In their most basic configuration, the vapor chamber consists of a sealed container, a wick formed on the inside wall of the container, and a small amount of fluid that is in equilibrium with its own vapor. As heat from a component is applied to one side of the vapor chamber, the working fluid evaporates. The vapor spreads to the entire inner volume and condenses over a much larger surface. The condensate is returned to the evaporator via capillary forces developed in the wick.

Advanced Cooling Technologies, Inc. (ACT) recently developed a 3mm thick vapor chamber made of a copper-plated ceramic casing that has a coefficient of thermal expansion (CTE) close to silicon. Direct soldering of the chips to the vapor chamber reduces the thermal interface resistance and eliminates the need for mechanical clamping. The chips can be placed anywhere on the vapor chamber surface. The heat sink locations can also be flexible. For example, the condenser can be at the sides as is typical for liquid cooling or over the entire vapor chamber surface opposite the chip locations as is typical for air cooling, as shown in Figure 4.

Another focus of ACT's vapor chamber development effort is a wick design that provides very high heat flux capability and low thermal resistance.

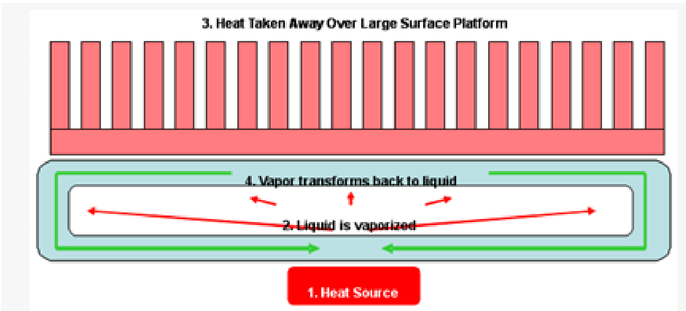

Figure 4. Technology Concept Showing the Sequence of Vaporization and Condensation that Provide Cooling Effectiveness in a Heat Spreader Covering the Full Surface of a Heat Sink. [6]

Advanced wick designs enable effective separation of liquid and vapor phases, resulting in vapor chamber performances exceeding 500 W/cm2 in heat flux. The ACT vapor chambers are used as heat spreaders for high heat flux chips (IGBTs, MOSFETs), high power Laser Diode Array's, Phased Array Radars or similar applications. [7]

References:

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