PRESS RELEASE

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Hybrid Heat Sink Manufacturing by Cold Spray Process

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Rattenkirchen, 22nd February 2021

Electronic devices, e. g. in telecommunications and high power systems, generate heat during normal operation that must be dissipated to avoid junction temperatures exceeding tolerable limits as this can lead to performance inhibition and deterioration of reliability. It has been shown that every 10 K reduction in the junction temperature will increase the device‘s life and performance. Thus, maintaining the junction temperature below the maximum allowable limit is a primary issue.

The most common way to cool devices has been air/liquid cooling using a heat sink. Conventionally, copper and aluminum heat sinks are used in the combination with such cooling systems. Copper is always a preferred choice for heat sinks due to its cooling capacity superior to aluminum; however, copper‘s weight and cost limit the size, especially for large electronics systems. Whereas due to lower thermal conductivity, aluminum heat sinks do not spread the heat quickly enough; thus, a large surface area or taller fins are required, which is not a plausible option in many cases. Moreover, a problem arises if a heat sink is substantially larger than the integrated circuit devices it resides on. If the electronic device generates heat faster than the heat sink spreads, portions of the heat sink far away from the device do not contribute much to heat dissipation. In other words, if the base is a poor heat spreader, much its surface area is wasted. Furthermore, to connect the aluminum heat sink with electronic devices, a thermal interface material is generally used because soldering of aluminum with direct bond copper of the electronic device is difficult. Typically, this material has a very low thermal conductivity, affecting the overall aluminum heat sink‘s performance.

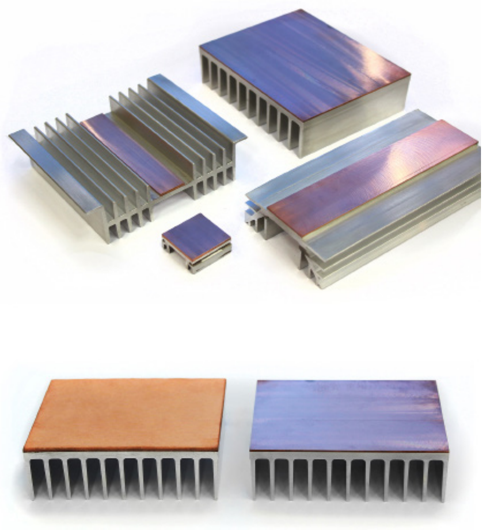

Figure 1: cold sprayed hybrid-heat sinks

A hybrid-heat sink, combining the thermal benefits of copper with lightweight aluminum presents an exciting alternative to overcome the issues associated with conventionally available copper and aluminum heat sinks. In such a concept, the portion of the heat sink that comes in contact with the electronic device is made of copper, while the other portion is made of cheaper and lighter aluminum. However, joining aluminum and copper is a difficult challenge. Soldering and brazing is commonly used to join aluminum with copper in industrial refrigeration, air conditioning, and heat exchangers. However, there are many issues associated with soldering and brazing, such as corrosion at the interfaces and solder materials with different electrical resistance and thermal expansion mismatch. The cold spray (CS) technique is an innovative solution to join copper and aluminum and overcome the issues associated with soldering and brazing. The CS-process is known to deposit the powder particles in solid-state far below the materials‘ melting point; thus, it can avoid common temperature-induced problems such as high-temperature oxidation, thermal stresses, and phase-transformation. Cold spray is a powder-based technology in which micron-size powder particles are accelerated in the supersonic flow of a compressed working gas through a de Laval nozzle. These powder particles impact the substrate, plastically deform, and create bonding with the substrates. CS offers short production times, virtually unlimited component size capability, and flexibility for localized deposition.

The Impact Innovations ISS 5/11 cold spray system and cold spray grade Impact's copper powder (iMatP_Cu01) were used to produce hybrid-heat sinks. A copper layer was deposited on a base plate of a commercially available extruded aluminum heat sink (as shown in Figure 1). The thickness of such a copper layer can be adjusted to the electronic devices' design and operational temperature.
When discussing a heat sink's performance, its cooling capability is typically quantified in terms of the thermal resistance, a measure of the temperature rise above ambient on the top of the device per dissipated unit of power. The lower the value of thermal resistance, the higher is the cooling ability of the heat sink. To demonstrate the performance of hybrid-heat sinks, Impact Innovations conducted experiments to compare the performance of identically structured copper, aluminum, and hybrid-heat sinks. The experiment was performed three times, each time with a different heat-sink design. Thermal impedance and thermal resistance were measured. The thermal impedance of heat sinks was evaluated by running power cycles at specific load currents heating the device until reaching the thermal equilibrium. Then the load current was switched off, and the voltage drop was recorded. When an aluminum heat sink was tested, a maximum temperature of 438 K was registered. This value corresponds to a thermal resistance of 0.7 K/W. For the copper heat sink, the maximum temperature was just 348 K, and the corresponding thermal resistance was 0.33 K/W. Testing the hybrid-heat sink, the maximum temperature was just slightly higher at 349 K, and the thermal resistance was 0.36 K/W.

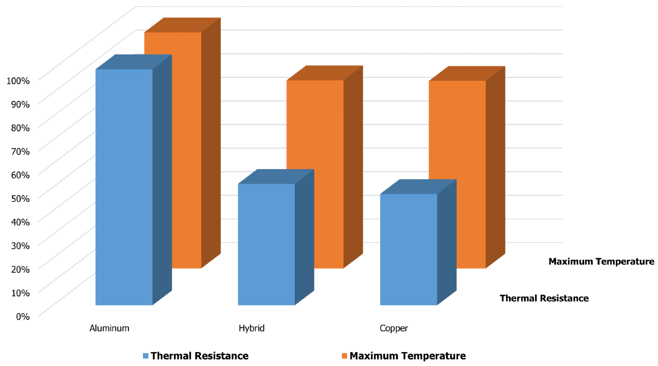

Figure 2: Thermal resistance and maximum temperature obtained at the device using aluminum, hybrid, and copper heat sinks

These results show that the copper and hybrid-heat sinks have almost identical thermal results and outperformed the aluminum heat sink in a substantial fashion, thus showing the importance of quick heat spreading along the base. At the same time, the hybrid-heat sink weighed and cost less than the copper heat sink.
Indeed, hybrid-heat sinks manufactured by cold spraying have slightly higher production cost than commercially available aluminum heat sinks; however, adding a layer of copper on an aluminum heat sink decreases its thermal resistance by 48%. This has a direct effect on the production costs since the semiconductor area can be decreased by 94%. Besides, the deposition efficiency and deposition rates of copper powder by the cold spray process are 95% (including overspray) and 10 kg/h, respectively, indicating the potential of the CS-process to realize a cost-effective large-scale industrial production.