Heat Sink Materials
Ken Gilleo, PhD
Ken@ET-Trends LLC
Warwick, RI

Question: Is there a market for a new heat sink material with a low thermal coefficient of expansion?

Heat sinks have been used before the dawn of solid-state electronics and the industry is well established on a global basis including plants in China. Aluminum is the *de facto* standard material even though it is far from ideal. Copper has better thermal conductivity and is gaining share as smaller, more efficient heat sinks and related products are required. Copper alloys and constructions using copper are also being used today. It should be noted that low TCE alloys are already in use and a new material must be compared to these products that are described later. Non-metals are also likely to appear soon as nanotechnology attacks thermal management problems. Some specifics on heat sink materials are now provided.

CAST ALUMINUM HEAT SINKS

Examples include a microprocessor cooler used by a leading semiconductor company. This low-cost cast aluminum heat sink measures 89mm by 64mm by 35mm (including blower), with a total thermal resistance of 0.29 °C/W. The volumetric thermal efficiency equals 0.013 W/°C/cc. Total weight 195 grams. All photos are from Novel Concepts, Inc.

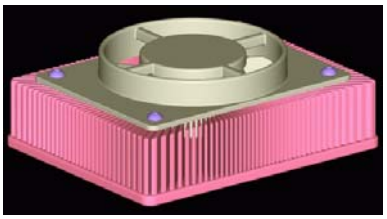
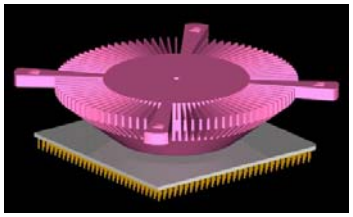
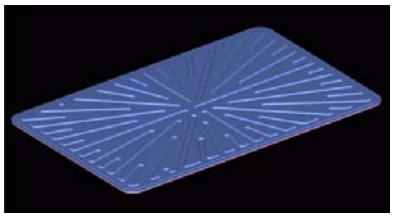

FIGURE 1A - Aluminum Casting Advanced (Al) Heat Spreader

Examples of more complex heat sinks and coolers:

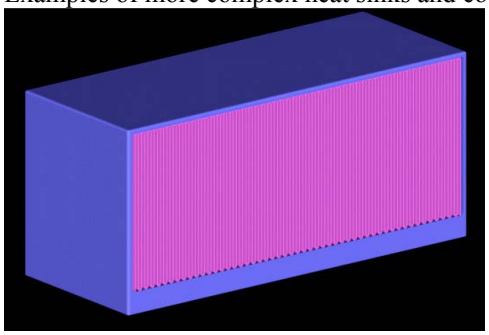
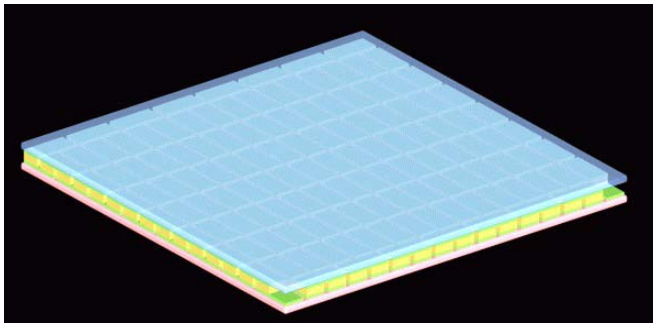

FIGURE 1B - Convoluted Fins Peltier Cooler (TEC)

Novel Concepts, Inc., 11752 Feinberg Place, Las Vegas, NV 89138, Phone: 702 363-8443, e-mail: info@novelconceptsinc.com. Daniel L. Thomas is Chief Technology Officer. The company does research and designs, but apparently does not manufacture. They may be a useful source of further information.

Many heat sinks are extruded shapes made from aluminum. Extruded profiles, with fins on 1-side, are widely available (see FIGURE 3 on p.3). Aluminum is also extruded into shapes with fins on two sides and common profiles are shown in FIGURE 4 (Last page).

Accel Thermal, Inc., 3709 Medford Street, Los Angeles, CA 90063, Phone: 323-261-5156, E-Mail: info@accelthermal.com, has been making extruded aluminum heat sinks for nearly a half-century.

WHAT ABOUT THE MATERIAL?

Aluminum is the most common material because of lower cost, ease of manufacturing, and the existing infrastructure. A higher conductivity material is preferred however. Copper is starting to find more use for both heat sinks and chip IC lead frames. A material that was more conductive than aluminum, but not as costly as copper would be viable, especially if easily shaped. TABLE 1 shows thermal properties.

Newer materials, both clads and alloys, have become available in recent years, however. Copper-Tungsten (Cu/W) is offered by several companies. The very low TCE values are its main feature. Copper-Molybdenum (Cu/Mo) also has a low TCE and is available. Sumitomo Electric sells both products as heat sinks.

Material	Thermal Conductivity- W/mK	TCE – ppm/C
silver	422	19.2
copper	402	17.6
gold	298	14.4
aluminum	**226**	23.4
steel	73.3	12.4
lead	34.8	29.0
Copper/Tungsten	180-200	6.5-8.3
Copper/Molybdenum	160	7
Silicon	1.25	~2.6

TABLE 1

Composite heat sinks are emerging and this area is getting increasing attention since Nanotechnology can be applied. The structure below was developed under US sponsorship at the Goddard Space Flight Center. We can expect other composites to be developed with nano materials such as carbon Nanotubes (CNT) in the near future. Metal and nano materials may possibly be used together as composites.

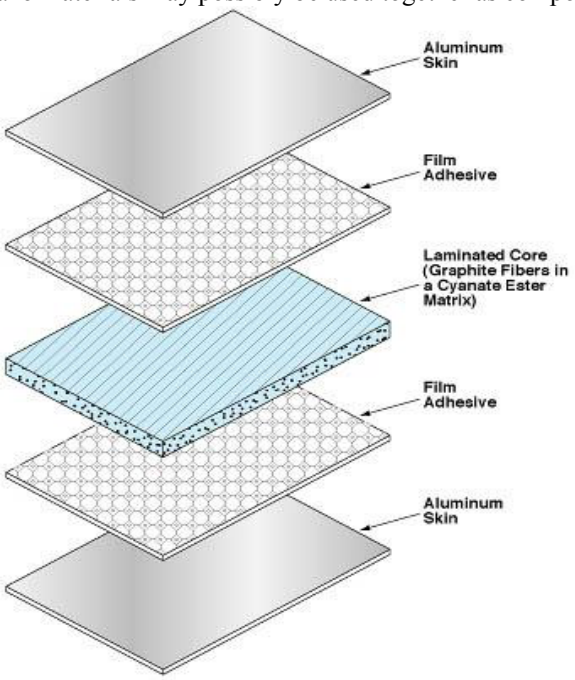

FIGURE 2 – THERMAL COMPOSITE

CONCLUSION

Heat sinks have been used for over 50 years and this is a very mature and competitive business. Easily made, low cost aluminum heat sinks are a commodity and China is becoming an important "lowest cost" producer. More sophisticated and commensurably more expensive heat sinks are being made for computers, especially servers, where higher thermal efficiency and smaller size justify the higher cost. Copper metal, alloys, clads and inserts are available from competent sources, particularly in Japan.

Low thermal expansion alloys have also become available that come close to matching the TCE of ceramics. These alloys are based on copper, especially copper-tungsten, and are available from capable companies such as Sumitomo Electric.

Future heat sink materials will likely use nano materials like carbon nanotubes, that have extremely high (~3000 W/mK) thermal conductivity, especially since considerable funding is available for nanotechnology research.

In my opinion, a new metal-based system would need to have exceptional properties to successfully enter this completive market area.

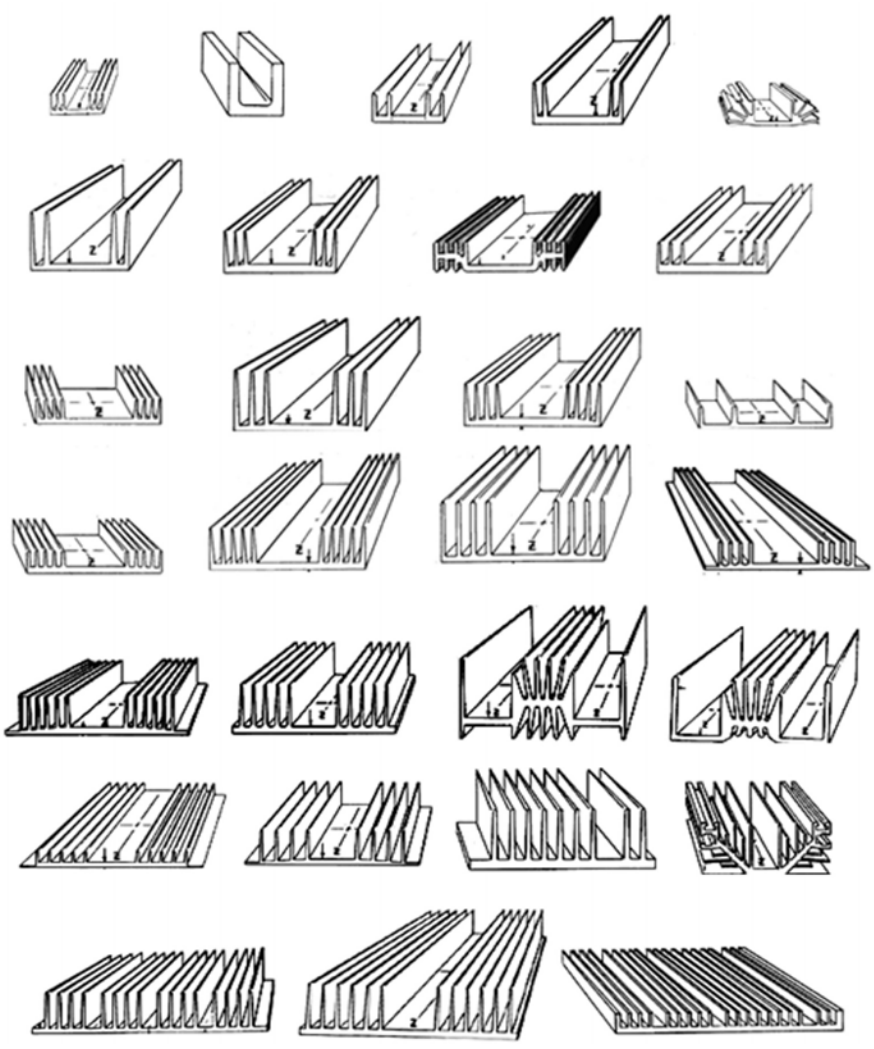

FIGURE 3 - Extruded Aluminum Heat Sinks (flat one side)

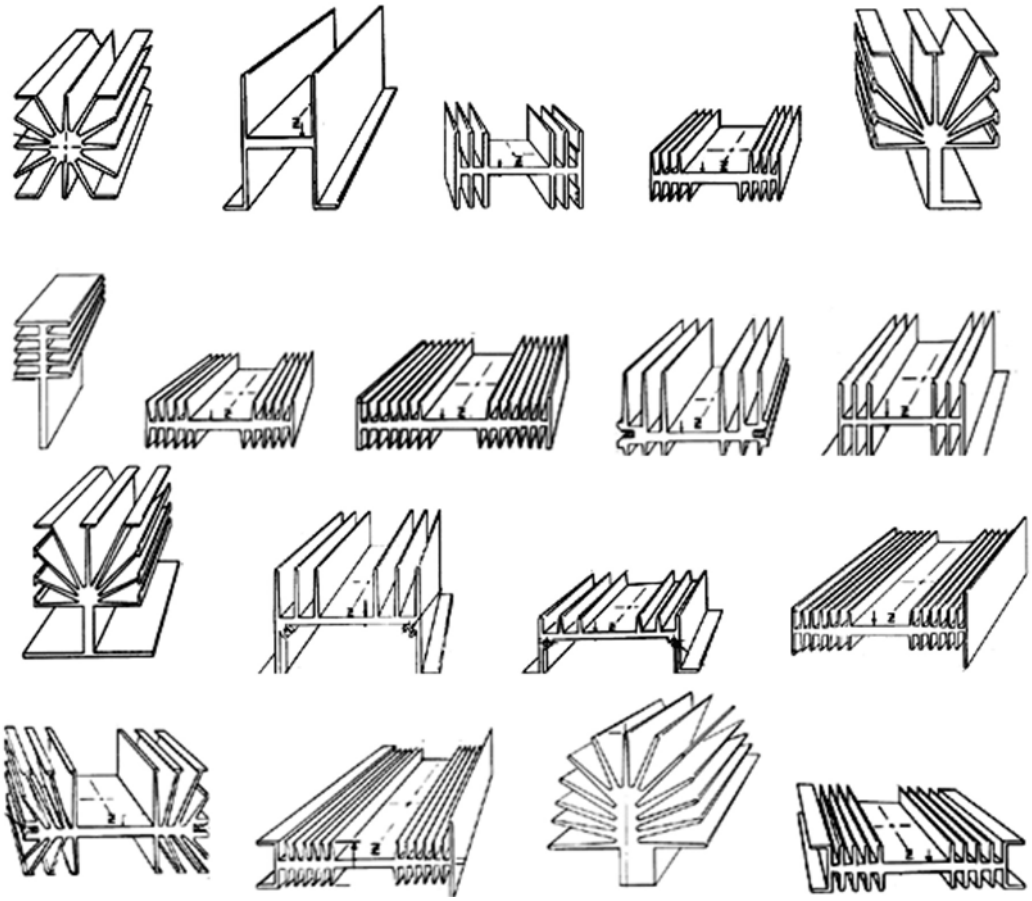

FIGURE 4 – Extruded Aluminum Heat Sinks – Fins 2-Sides