Economical aluminum substrates make light work of visible LED circuits…

Advances in solid state light emitting diodes (LEDs) over the last several years have opened new applications for these devices. Traditionally used only in low power, low light output applications, modern high power LEDs are finding their way into a wide variety of applications. LEDs for lighting applications offer several advantages over traditional incandescent lighting methods. They significantly lengthen the life of the lighting system (an important consideration in that lighting defects account for a considerable portion of warranty and maintenance budgets), offer cooler operating temperatures, and they are considerably more efficient compared to incandescent bulbs, using significantly less energy for a given light output. LEDs are also rugged and highly resistant to shock and vibration, which is especially important in automotive, heavy vehicle and industrial lighting applications.

LEDs, however, suffer from one drawback in that their light output diminishes as their temperature increases, typically by as much as 1.25% per degree C. As a result, thermal management is very critical.

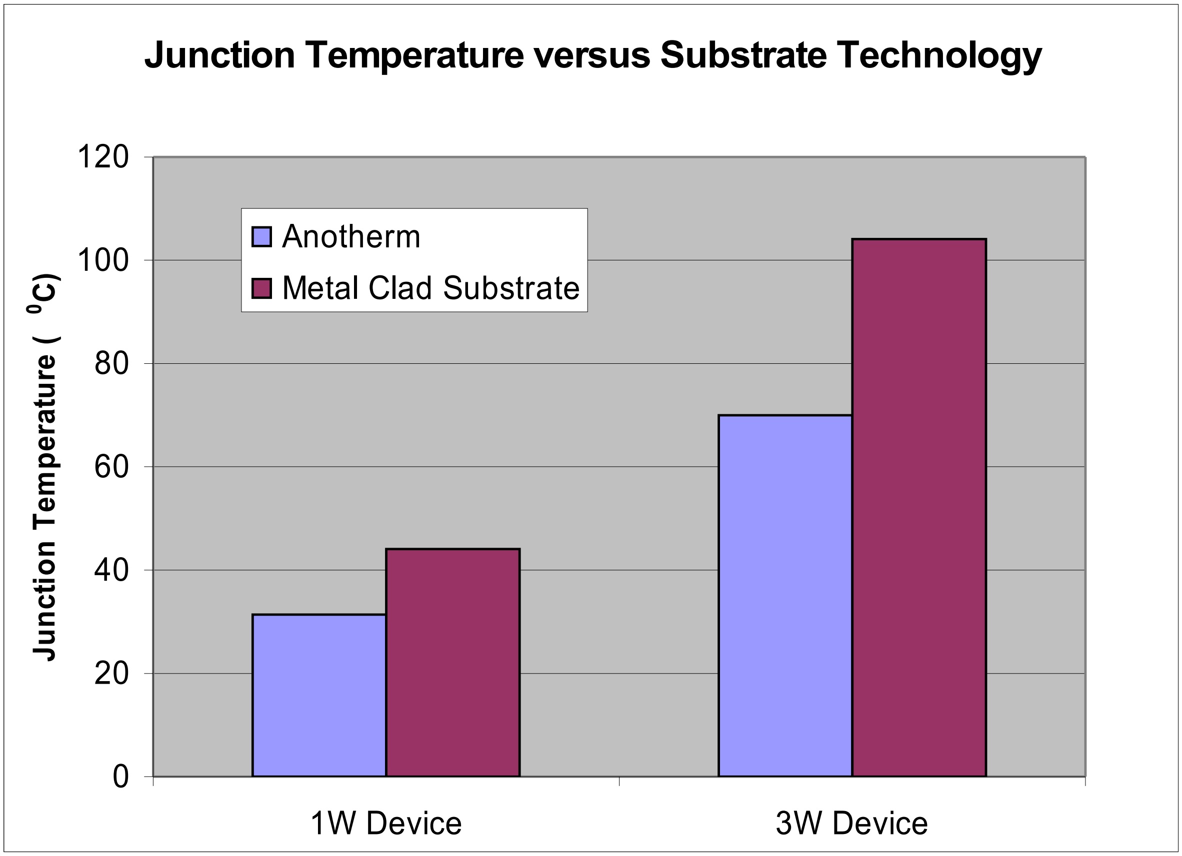
Fortunately, there are a number of advancements in the electronics industry today that offer design engineers better options for dissipating heat in direct-mounted LED applications.

High power LED applications invariably require the use of thermally conductive substrates to manage the heat produced, and one of the most widely selected materials for this application is aluminum alloy substrate.

Many manufacturers cover a bare piece of aluminum with a film of epoxy to insulate the mounted components as well as transfer the heat. Even when filled with thermally conductive media, filled epoxies are generally not efficient thermal conductors. Also, reliability problems can be encountered if the aluminum is not perfectly clean; if the epoxy is not cured properly; or if the epoxy layer delaminates during heat fluctuations. However, recent developments by IRC in thick film materials allow using an aluminum alloy substrate to give lighting system designers a lighter, cooler and less expensive method of mounting visible LEDs.

IRC has developed a thick film low temperature fired dielectric and conductor system for use on an aluminum alloy substrates. This technique of printing and firing on the thin, inorganic dielectric and conductor system produces an insulated, yet thermally conductive PC board with extremely low thermal resistance from the die or chip to the substrate in power LED applications. These substrates reduce operating temperature, allow higher operating power/density, improve reliability and reduce failures due to thermally induced problems. This material is sold and marketed under the “Anotherm” name.

Because the insulation layer between the aluminum and printed traces is very thin, and its composition is an filled glass type material (to be thermally conductive), the thermal performance is very good. Tests results comparing aluminum alloy substrates with common epoxy insulated metal substrate boards are summarized below.



Although possessing many positive features, there is a limitation to this technology that deserves mentioning. First, the maximum voltage withstanding capabilities of the anodization insulation material is directly dependent upon its thickness. It becomes difficult to anodize very thick layers of anodic coatings on aluminum due to the increased time and the dissolution of the anodized coating back into the bath. As a result, the maximum thickness that can routinely be achieved (cost-effectively) is approximately 55 microns, resulting in a typical breakdown voltage of about 500 VAC (rms). This factor currently prevents this material from use in high voltage applications.

The Aluminum substrate's thermal conductivity (the ability to dissipate heat) is characterized at 173W/m-K – far superior to other types of traditional substrates (0.8W/m-K for FR4 PC board; 17.3W/m-K for 304 stainless steel; or 21W/m-K for 96% alumina ceramic).

An aluminum alloy substrate consisting of either 3003 or 6061 aluminum delivers high thermal conductivity and low cost. The thermal expansion coefficient of this material corresponds favorably with traditional PC board materials as shown in the table below. Long term thermal shock testing confirms the ruggedness of the dielectric medium.

Material	**Thermal Conductivity (W/m-rK)**	**Thermal Expansion Coefficient (ppm/rK)**
FR-4 P.C. Board	0.8	16-20
304 Stainless Steel	17.3	16.4
96% Alumina Ceramic	21	6.5
3003/6061 Aluminum	173	23.4
Copper	386	16.5

Aluminum alloy substrates have been proven through many hours of laboratory testing. One such test, consisting of 2000 thermal shocks (between -55ºC to +125ºC) resulted in continued superior performance with no degradation in thermal characteristics or delamination. Also, thick film power resistors using similar aluminum alloy process have demonstrated reliability in automotive applications for several years.

The insulation system used with aluminum alloy substrate systems is a glass type dielectric and filled with materials to enhance the thermal and expansion properties. The dielectric, after firing, is approximately 0.0014” thick (0.035mm) with excellent adhesion to the aluminum surface. This inorganic dielectric layer gives a high quality insulation that is not affected by temperature or chemicals.

Additionally, vias can be placed in the dielectric, and conductor material applied directly to the aluminum to allow soldering of electrically isolated packages to the aluminum substrate, making the best possible thermal characteristics. Also, a wide range of substrate configurations can be processed, such as finned, extruded, CNC machined, and special shapes can be accommodated.

Because of the its extremely low thermal impedance and versatility, aluminum alloy substrate material is quickly gaining in popularity for a host of power LED applications, including automotive, interior/exterior light fixtures and display signage, laptop computer backlighting and flashlights.

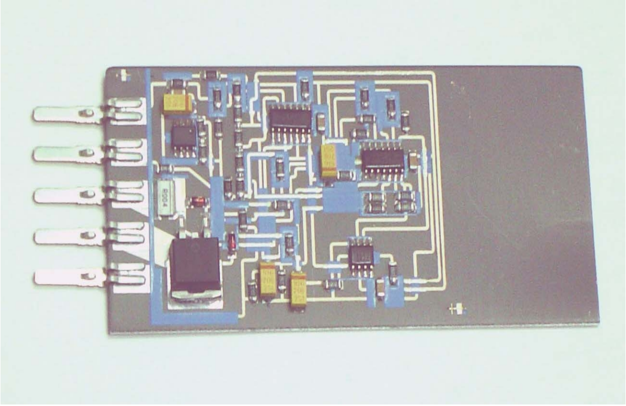
The thermally-conductive aluminum alloy material enables design engineers to mount high power LEDs and other components directly to it, thus eliminating the need for attached heatsinks, mounting hardware and the associated assembly costs. Economical solderable thick film conductors can be screen-printed directly to the anodized substrate to connect surface mount packaged components as well as wire-bonded die.

Conclusion

Aluminum alloy thermally conductive substrates offer several advantages in applications that require effective thermal management such as in high brightness automotive LED applications. Among the advantages offered are exceptional thermal conductivity, versatility in size and configuration, and cost effectiveness.

Benefits of Aluminum Alloy Substrates Include:

- Very low thermal impedance to the substrate (<0.01ºC/watt/in^2)
- Conductors that are directly solderable using standard solders (Sn62/Pb36/Ag2 or Sn96/Ag4).
- Breakdown voltage >1500VDC.
- Crossovers or multiple layers
- Inorganic composition allows extended operation at high temperatures without degradation.
- Increase power density
- Lower operating temperatures.
- Eliminate assembly of heatsinks and mounting hardware.
- Finned Heat sinks



IRC produces this Anotherm® aluminum alloy substrates with a power supply integrating both signal and power onto circuit board acting as a heatsink. Components are directly soldered to the heatsink.

About the Author: Tom Morris is an Applications Engineering Manager at T.T. Electronics IRC Advanced Film Division in Corpus Christi Texas, specializing in thick and thin film products. Tom has been with IRC since 1983 and is presently involved with development of thermally conductive substrates.