

# PEC (printed electronic circuit) process for LED interconnection

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*PCB mounting of LEDs has to date been limited to mechanical interconnection or the use of printed circuits boards built on thermally conductive copper clad aluminum substrates. This paper discusses the use of enhanced thermally conductive inks for LED interconnection.*

Higher wattage LEDs/power components or their placement in higher densities requires a larger dissipation of heat in a more effective way.

The following is quoted from *Canadian Electronics* magazine:

*“With rapid advancements in power reduction, and minimizing and controlling LED heat, it is expected that future applications will use less-expensive, rigid aluminum-backed printed circuit boards for proper heat dissipation and move towards more cost-effective flexible circuits. This is also being driven by signal and display applications, where most of the future LED growth is expected.”*

—Gijs Werner, FCI

PCB mounting of LEDs has to date been limited to mechanical interconnection or the use of printed circuits boards built on thermally conductive copper clad aluminum substrates.

These laminated substrates which are available from several specialty laminate manufacturers, typically consist of a copper foil that is laminated to the aluminum using a glass cloth impregnated with heat conducting additive filled epoxies. The cloth offers small window openings between the weave patterns where the filled epoxies can make contact with the both the copper foil and the aluminum to transfer heat. The glass cloth, which comprises 50 percent of

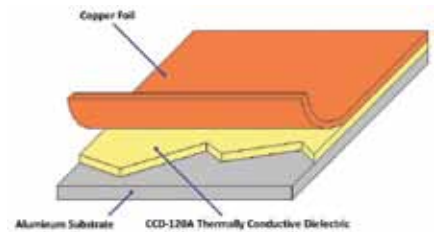


Figure 1. Copper clad aluminum substrate.

the prepreg, significantly reduces the thermal conductivity. Additionally, the existing available thermal prepregs are thicker at 100 microns (.004 mils), which increases the effective thermal resistance limiting the maximum watts per square inch dissipation.

A printed circuit board manufacturer would employ this laminate material, laminating photo-imageable etch resist, exposing with UV light then developing to form a circuit image, then etching away unwanted copper to produce circuit traces. All exposed aluminum must also be well masked off, a time- and material-consuming task.

## Printed electronic inks

Enhanced thermally conductive inks are much more versatile.

They can be used to make a more efficient thermally conductive copper clad aluminum laminate substrate by the PCB fabricator themselves (Figure 1) or could be used by

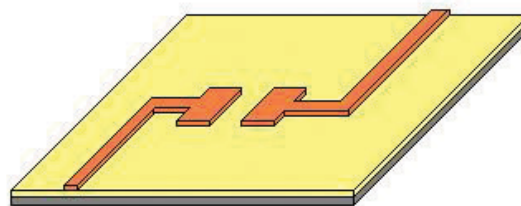


Figure 2. Etched copper circuit trace on thermal dielectric & actual etched circuit; 60X.

selectively printing both the dielectric and conductive traces to make a thermally conductive circuit by anyone with a silk screen printer and a thermal oven (See Figure 3).

Using CCD-120A thermally conductive dielectric ink with its nano technology enhanced formulation in making PCB boards or even making copper clad aluminum circuit laminate will deliver lower thermal resistance than that of other currently available copper clad aluminum substrates.

### Copper-clad aluminum

The thermally conductive B-stage ink is applied to the surface of either the copper foil or the aluminum and is semi cured (B-Stage) using a thermal oven. Application is typically a silk screening operation to deposit a thin film of thermal ink approximately .001" thick. The ink is then baked at 250° F for 20-30 minutes, at which time the material reaches the desired B-stage cure.

The coated B-stage aluminum is laminated with the copper foil of choice using a typical vacuum-assist laminating press and fully cured under pressure.

The end result is a thin layer only 25 microns thick of the thermal material sandwiched between the copper and aluminum. With this version of a copper clad aluminum, the B stage thermal ink offers lower thermal resistance, because the surface area contact and the thickness of the deposit. As well, the pressure of the lamination cycle constricts the ink allowing a closer contact between thermally conductive ceramic particles increasing the thermal conductance. A one mil thick layer of thermal ink properly applied has a 2500 volt rating.

Processing the panel to make a simple single-sided circuit is a done by the time-honored "print and etch" method requiring PCB fabrication equipment and wastewater treatment facilities because of the copper etching process.

Figure 2 shows the etched circuit trace paths on the Thermally Conductive dielectric. Adhesion to aluminum with our 2 w/mc ink is excellent; the thermal dielectric has a hard surface due to its high ceramic content but can accept a coat of soldermask before the final cure. A compatible solder mask could later be applied.

### Print-only circuits

A selectively deposited thermal conductive ink on the aluminum offers the benefit of being deposited only where thermal heat transfer is needed, reducing consumables

costs when compared to the currently popular copper clad aluminum substrate, which has full coverage of the underlying surface with the glass cloth impregnated with heat conductive material.

The circuit traces are screened on using new nano silver solderable inks. The net result is that by using a thermal ink selectively applied under the silver traces, less of the thermal material is used per the same overall area yet will deliver better heat transfer capability because it is thinly applied.

Building a printed circuit utilizing the print-only process can not only simplify the manufacturing, but it will reduce its costs. Print-only is manufactured with a full additive green technology that will in the end deliver better heat transmission performance. No etching equipment is required.

### Print only

Printing the thermal dielectric ink selectively where needed and then printing electrically conductive traces on top the thermal dielectric with low resistance silver ink reduces costs, as the dielectric is applied only where needed (Figure 3).

Screen printing a slightly wider surface area than that of the conductors, then curing the dielectric at a temperature of 250° F for 30 minutes establishes a non-tacky but yet uncured surface, which is then overprinted with the silver conductive traces. The silver ink is then cured at 150° C for 30 minutes, which fuses the silver trace into a solid metal track. A compatible

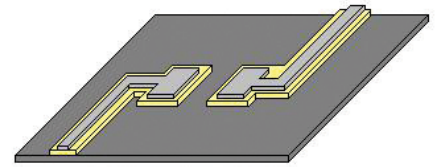


Figure 3. Silver trace on selective print thermal dielectric.

solder mask can be applied and tack dried, followed by an overall full encompassing a cure of 300° F for 60 minutes, which forms the final circuit. Using thermal/silver ink combinations offers many more build options and cost concession possibilities. As there is no requirement to etch and therefore no need to mask off the aluminum when etching or processing, labor is tremendously reduced.

When utilizing the silver ink trace technology, assembling and soldering the components requires a lower temperature solder which is typically used in assembly houses.

The thermal characteristics are vastly improved over that of a normal copper-clad aluminum etched type circuit. The area of the aluminum that is not covered by the dielectric material and silver traces has a larger thermal conductance (380 w/mc) than the aluminum with a layer of 2 w/mc thermal material.

Figure 4 shows a comparison between three heat conducting and dissipating constructions. Clearly evident is the larger amount of exposed aluminum made possible with an all printed version of the board

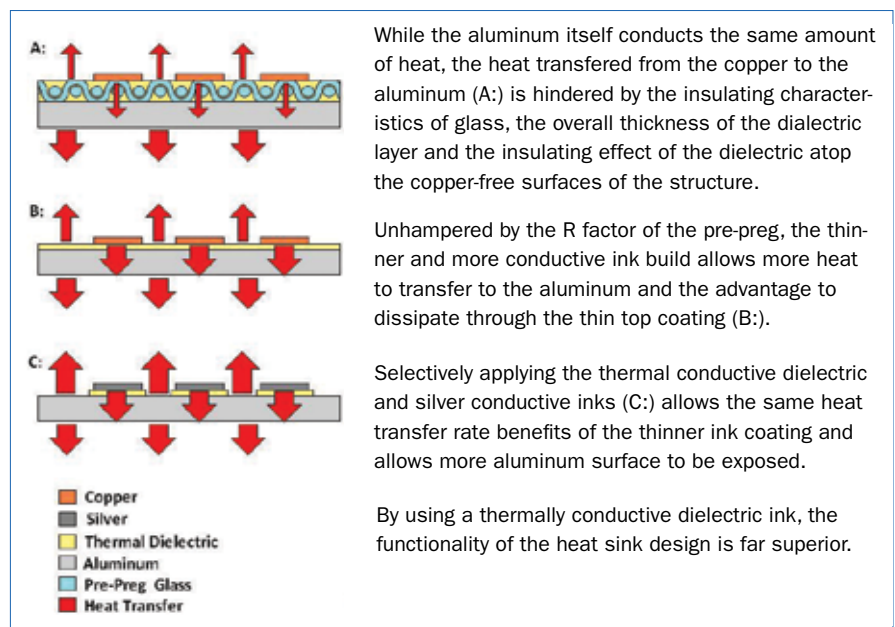


Figure 4. Heat radiating comparison.



Figure 5. PECs developed LPI dielectric.

and the resulting superior heat dissipation available.

### Printed electronics versatility

Using ink technology, more complex circuit boards can be manufactured by using the more advanced and “green” PEC technologies described below.

### Thermally conductive PEC process

Silk-screen-coating the aluminum with thermally conductive dielectric, a second layer of a specially formulated LPI dielectric ink is deposited at some 1 to 1.2 mil thickness depending on screen mesh selections. If desired, extra layers of the dielectric will provide for thicker conductor lines.

Tack-cured and then exposed using ordinary UV exposure units, the LPI is spray developed on typical developing equipment and chemistry. What remains is a coating on the substrate with trenches and pad openings (Figure 5).

A thermally conductive PEC’s third component is a nano technology silver conductive ink that is applied onto the surface of the LPI. Filling of the trenches and pads is accomplished and the conductive ink is cured. The ink fuses into a solid mass with a slight deposit on the surface of the LPI, which is easily removed (Figure 6).

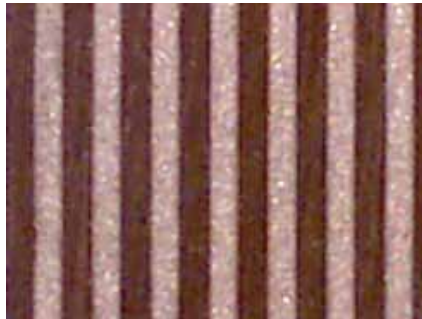


Figure 6. PEC 4 mil lines/space flush silver.

The next step is a repeat of the second, except that this interconnection layer will be a via formation layer only. Coat, tack, expose, develop and silver fill.

Because the LPI is never stripped off and the entrenched silver conductive ink is level with the top of the LPI, everything conductive is flush to the dielectric.

The same process is repeated again for the second conductive layer.

The result is that the interconnect “vias” are buried, and there is a 100% metal connection to the first layer. In the end, anything reliability-wise to a PCB PTH interconnect has been eliminated.

The process is repeated for as many layers as is required by design. The last top layer has pads left exposed for component mounting. All circuitry and interconnections are buried.

Versatile, boards can be configured to use the PEC full additive process even on two sides of the aluminum if desired or build multilayer circuits all on one side of the aluminum backing.

Figure 7 shows a typical PEC build configuration: A multilayered, single-sided thermally conductive PEC technology PCB. Designs could be altered a number of ways, allowing many new interconnect possibilities.

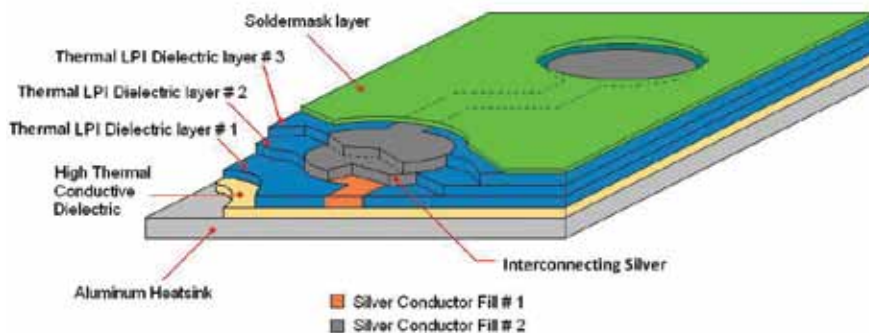


Figure 6. PEC 4 mil lines/space flush silver.

### Conclusion

In summary, using printed electronic ink products and processes to manufacture high performance thermally conductive circuit boards offers clear advantages in manufacturing flexibility, performance and cost.

When using these inks in the full additive print only process or the PEC method, these high performance heat-dissipating circuits are also environmentally friendly.

*Mike is an industry veteran going back to military board manufacturing using shoe eyelets for interconnection of layers. Joining the ranks of Caledon Controls, a growing distribution firm, Mike is involved in diversification efforts and searching for alternative PCB processing methods.*