

BERGQUIST APPLICATION NOTES

COPPER

Introduction

Most applications of copper clad insulated metal substrates use an aluminum base. Alloys can be chosen to accommodate the manufacturing process. Silicon bearing, heat treatable aluminum (6061 - artificially age hardened) is chosen for prototype and small quantity assemblies because its machining characteristics allow use of CNC routing for part separation. Where quantities of parts are required, Alloys 1100 and 5052 are available to better accommodate pierce and blank punch press tools. In these constructions, the substrate temper usually ranges from H-14 to H-32 material. Press tool quantities also benefit because the alloys that best accommodate punching are lower cost material. The machinable alloys of aluminum have a lower thermal conductivity, although this is rarely a factor in aluminum alloy selection.

Constructions using copper base materials are usually met using a relatively pure copper (C11000 Alloy, Electrolytic Tough Pitch). This material is often chosen first for its thermal coefficient of expansion in an attempt to reduce thermomechanical stress in the assembly. In cases where power generation is high and in short cycles, the thermal capacity of copper can be important as a thermal management scheme. Sometimes copper functions as a heat pipe, transferring heat in the plane of the substrate. Copper is most often used from 1/4 to 1/2 hard. It does punch adequately and is somewhat difficult to machine. Machinable alloys (Brass) have severely reduced thermal conductivity. Copper alloys require a surface treatment in order to achieve a consistent bond to the dielectric.

Steel and Copper/Invar/Copper (CIC^R) are used where thermal coefficient of expansion is the most important consideration. The steel offered is a low carbon content, commodity material. In cases where the assembly has no good thermal path to ambient and where the waste power density is low, steel's thermal conductivity can be adequate. Steel also requires a surface treatment for consistent dielectric adhesion. Copper/Invar/Copper constructions have been chosen where the coefficient of expansion is the principle factor in base material choice.

Copper/Invar/Copper is difficult to machine and it requires surface treatment for dielectric adhesion. There is a frequently overlooked problem with the thermal coefficient of expansion of the laminated structure. Invar is a poor thermal conductor and when there is a large heat flux, the two sides of the laminate will be at different temperatures, causing a thermomechanical bowing stress.

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Text

The thermal coefficient of expansion often drives the substrate choice toward copper. Our studies of solder joint durability demonstrate that a broad range of component constructions are compatible with copper based T-Clad. *The thermal conductivity of the copper substrate may also be important and some applications make use of the thermal mass of a copper substrate. The materials matching thermal coefficient of expansion can allow the use of thick copper conductive traces with minimum thermal distortion of the fabricated parts.

Bergquist has been supplying Thermal Clad with copper metal substrates. The alloy designation has been C11000, 1/4 to 1/2 hard, but the preparation techniques are not limited by the alloy. Thicknesses up to .25 inches have been used in production. Materials of 0.125, .062 and .040 inches are now common, with raw materials in stock. To control the bonding process and to limit the formation of random oxides on the surface, copper is first surface cleaned and etched, followed with a bond enhancement plating. This is a relatively recent improvement over the original products that were prepared using a "tooth" plating of copper followed by a sulfamate nickel plating.

Following the print/etch processes, the designer should consider having all exposed copper treated with phosphorous nickel electroless plating. This surface has excellent cosmetic durability. The nickel surface functions as a solder barrier, preventing any consideration of the formation of the brittle tin/copper inter-metallic compound during HASL processing or during reflow solder processing. Depending on the application, the designer may choose to have the HASL process applied to the back or, with an additional expense, a protective mask can be applied during the HASL process. The phosphorous nickel coating allows aluminum wire bonding in cases where chip and wire assembly techniques are used.

Mechanical processing of the copper parts is straight forward. Flatness of product parts is considered to be a function of the residual stresses in the final parts caused by the press tools used to pierce and to separate parts from the panel. Prototype parts suffer some because the popular copper alloy is a little difficult to machine. Fine blanking probably offers the best opportunity to prepare very flat parts using copper in volume. Wire EDM could be considered for the profiling of a limited number of prototype parts. These processes have not yet been used in Thermal Clad production.

*NOTE: See Application Note, Solder Joint Durability.

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Summary

The choice of copper as Thermal Clad substrate material is most often driven by its thermal coefficient of expansion. The coefficient of expansion is important to the durability of the component solder joint durability. The coefficient of expansion also allows the use of "massive" printed circuit copper without the thermomechanical bowing of the part that is associated with copper/aluminum constructions. The thermal mass and the thermal conductivity of copper is also useful in some applications. When a very flat part is a requirement, EDM should be considered for limited prototype quantities and fine blanking tools for large quantities.