

# Thermal Properties of Materials

## Araldite

$$T\_C_{AR} := 0.24 \frac{W}{m \cdot K} \quad \text{Thermal Conductivity}$$

$$D_{AR} := 2360 \frac{kg}{m^3} \quad \text{Mass Density}$$

$$S\_H_{AR} := 1386 \frac{J}{kg \cdot K} \quad \text{Specific Heat}$$

## Allcomp (SD)

$$T\_C_{ALLC} := 20.3 \frac{W}{m \cdot K} \quad \text{Thermal Conductivity}$$

$$D_{ALLC} := 220 \frac{kg}{m^3} \quad \text{Mass Density}$$

## Copper

$$T\_C_C := 390 \frac{W}{m \cdot K} \quad \text{Thermal Conductivity}$$

$$D_C := 8900 \frac{kg}{m^3} \quad \text{Mass Density}$$

$$S\_H_C := 390 \frac{J}{kg \cdot K} \quad \text{Specific Heat}$$

## Fiber\_xyz

$$T\_C_{FI} := 180 \frac{W}{m \cdot K} \quad \text{Thermal Conductivity}$$

$$D_{FI} := 1750 \frac{kg}{m^3} \quad \text{Mass Density}$$

## Foam

$$T_{C_F} := 20 \frac{W}{m \cdot K} \quad \text{Thermal Conductivity}$$

$$D_F := 400 \frac{kg}{m^3} = 0.4 \frac{gm}{(cm)^3} \quad \text{Mass Density}$$

## Hysol 9396 + 30% Graphite

$$T_{C_H} := 2.5 \frac{W}{m \cdot K} \quad \text{Thermal Conductivity}$$

$$D_H := 1190 \frac{kg}{m^3} \quad \text{Mass Density}$$

## Polyimide

$$T_{C_P} := 0.2 \frac{W}{m \cdot K} \quad \text{Thermal Conductivity}$$

$$D_P := 1370 \frac{kg}{m^3} \quad \text{Mass Density}$$

## Silicon

$$T_{C_{SIL}} := 148 \frac{W}{m \cdot K} \quad \text{Thermal Conductivity}$$

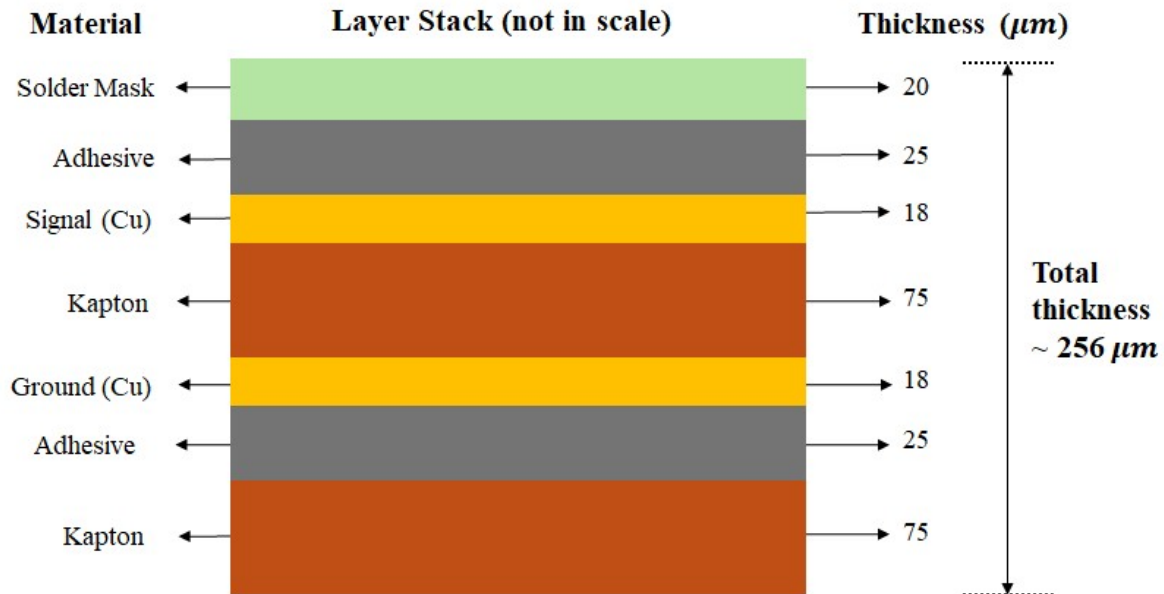
$$D_{SIL} := 2330 \frac{kg}{m^3} \quad \text{Mass Density}$$

## Timetal 35A CP Titanium (ASTM Grade 1) 99.1 Ti

$$T_{C_T} := 14 \frac{W}{m \cdot K} \quad \text{Thermal Conductivity}$$

$$D_T := 4510 \frac{kg}{m^3} \quad \text{Mass Density}$$

## Readout Flex



### Materials / Properties

The materials that will be used in calculations are

1. Polyimide (Solder Mask)
2. Hysol 9396+30% Graphite (Adhesive)
3. Copper (Signal (Cu), Ground (Cu))
4. Kapton (properties from internet)

For Kapton: Thermal Conductivity by Grade and Type

Standard Kapton (HN):  $\sim 0.12 \text{ W/m}\cdot\text{K}$  (serves as a strong thermal and electrical insulator).

Kapton MT:  $\sim 0.46 \text{ W/m}\cdot\text{K}$  (engineered for improved thermal management).

Kapton MT+: Up to  $\sim 0.80 \text{ W/m}\cdot\text{K}$  (highest thermally conductive grade available for power electronics).

Density of Kapton is  $1.420 \text{ kg/m}^3$  (web)

## Length

The length of each material is

$$L_{\text{Polyimide}} := 20 \mu\text{m} = 0.02 \text{ mm}$$

$$L_{\text{Copper}} := (18) \mu\text{m} + (18) \mu\text{m} = 0.036 \text{ mm}$$

$$L_{\text{Hysol}} := (25) \mu\text{m} + (25) \mu\text{m} = 0.05 \text{ mm}$$

$$L_{\text{kapton}} := (75) \mu\text{m} + (75) \mu\text{m} = 0.15 \text{ mm}$$

$$L := L_{\text{Polyimide}} + L_{\text{Hysol}} + L_{\text{Copper}} + L_{\text{kapton}} = 0.256 \text{ mm}$$

## Density

$$D_{Polyimide} := 1370 \frac{kg}{m^3} \quad D_{Copper} := 8900 \frac{kg}{m^3}$$

$$D_{Hysol} := 1190 \frac{kg}{m^3} \quad D_{Kapton} := 1420 \frac{kg}{m^3}$$

The final Density of Readout Flex should be:

$$D_{Readout\_Flex} := \frac{L_{Polyimide} \cdot D_{Polyimide} + L_{Hysol} \cdot D_{Hysol} + L_{Copper} \cdot D_{Copper} + L_{kapton} \cdot D_{Kapton}}{L} = 2423.047 \frac{kg}{m^3}$$

$$D_{Readout\_Flex} = 2423.047 \frac{kg}{m^3}$$

## Thermal Conductivity

$$T\_C_{Polyimide} := 0.2 \frac{W}{m \cdot K} \quad T\_C_{Copper} := 390 \frac{W}{m \cdot K}$$

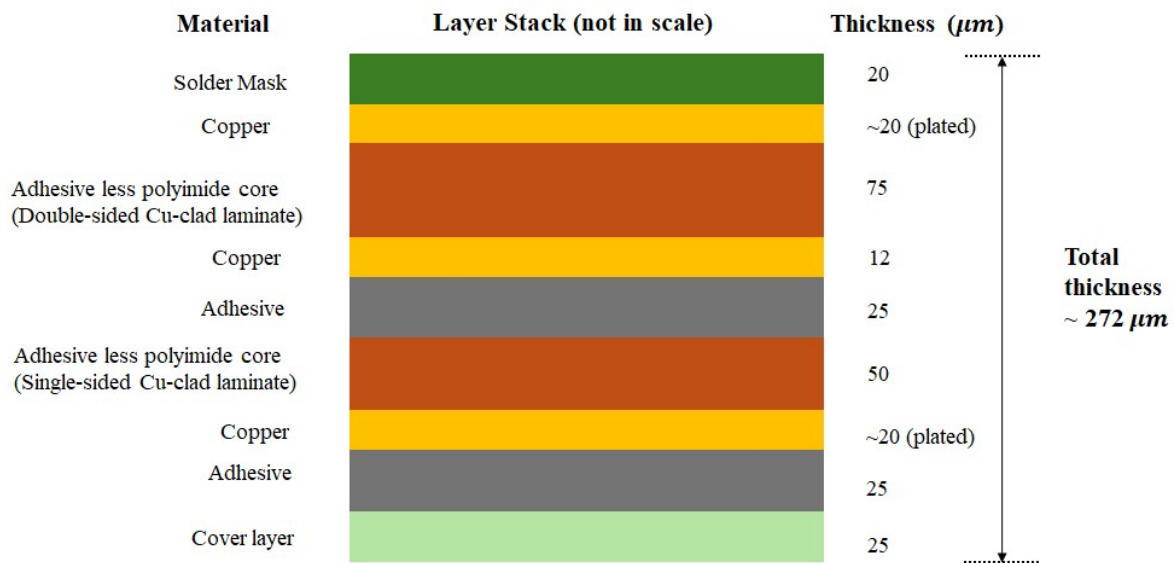
$$T\_C_{Hysol} := 2.5 \frac{W}{m \cdot K} \quad T\_C_{Kapton} := 0.46 \frac{W}{m \cdot K}$$

The final Thermal Conductivity of Readout Flex should be:

$$T\_C_{Readout\_Flex} := \frac{L_{Polyimide} \cdot T\_C_{Polyimide} + L_{Hysol} \cdot T\_C_{Hysol} + L_{Copper} \cdot T\_C_{Copper} + L_{kapton} \cdot T\_C_{Kapton}}{L}$$

$$T\_C_{Readout\_Flex} = 55.617 \frac{W}{m \cdot K}$$

## Hybrid Flex



The thermal conductivity of *double-sided copper-clad laminate (CCL)* depends entirely on the type of base substrate material used.

Standard FR-4: Typically 0.3 to **0.5 W/m·K**. High-performance or filled FR-4 variants can sometimes push up to 0.8 W/m·K. Density is 1.85 g/cm<sup>3</sup> (Web)

## Length

The length of each material is

$$L_{Polyimide} := 20 \mu m + 25 \mu m = 0.045 \text{ mm}$$

$$L_{Copper} := 20 \mu m + 12 \mu m + 20 \mu m = 0.052 \text{ mm}$$

$$L_{Hysol} := 25 \mu m + 25 \mu m = 0.05 \text{ mm}$$

$$L_{CCL} := 75 \mu m + 50 \mu m = 0.125 \text{ mm}$$

$$L := L_{Polyimide} + L_{Hysol} + L_{Copper} + L_{CCL} = 0.272 \text{ mm}$$

## Density

$$D_{CCL} := 1.85 \frac{gm}{cm^3} = 1850 \frac{kg}{m^3}$$

The final Density of Hybrid Flex should be:

$$D_{Hybrid\_Flex} := \frac{L_{Polyimide} \cdot D_{Polyimide} + L_{Hysol} \cdot D_{Hysol} + L_{Copper} \cdot D_{Copper} + L_{CCL} \cdot D_{CCL}}{L} = 2997.059 \frac{kg}{m^3}$$

$$D_{Hybrid\_Flex} = 2997.059 \frac{kg}{m^3}$$

## Thermal Conductivity

$$T\_C_{CCL} := 0.5 \frac{W}{m \cdot K}$$

The final Thermal Conductivity of Hybrid Flex should be:

$$T\_C_{Hybrid\_Flex} := \frac{L_{Polyimide} \cdot T\_C_{Polyimide} + L_{Hysol} \cdot T\_C_{Hysol} + L_{Copper} \cdot T\_C_{Copper} + L_{CCL} \cdot T\_C_{CCL}}{L}$$

$$T\_C_{Hybrid\_Flex} = 75.281 \frac{W}{m \cdot K}$$

There are two chip scenarios, Basic and Advanced, as shown in the attached figure. The chip consists of two main sections, with the second section divided into three subsections. The corresponding power densities are:

Pixel Matrix: 158 mW/cm<sup>2</sup>

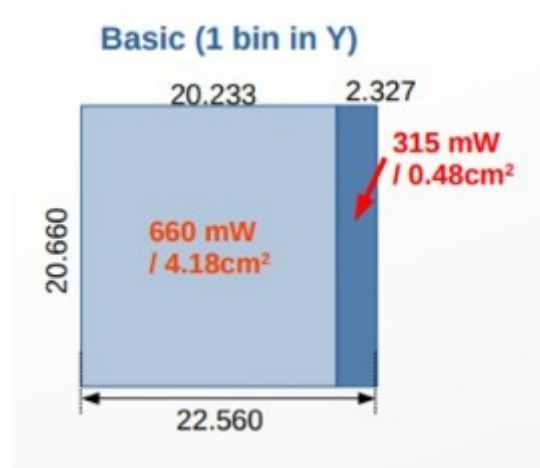
Periphery: 656 mW/cm<sup>2</sup>

PPL: 1957 mW/cm<sup>2</sup>

$$PM1 := 660 \frac{mW}{4.18 \text{ cm}^2} = 0.158 \frac{W}{\text{cm}^2}$$

$$DP1 := 315 \frac{mW}{0.48 \text{ cm}^2} = 0.656 \frac{W}{\text{cm}^2}$$

$$PD_1 := 660 \text{ mW} + 315 \text{ mW} = 0.975 \text{ W}$$



$$PM2 := 660 \frac{mW}{4.18 \text{ cm}^2} = 0.158 \frac{W}{\text{cm}^2}$$

$$DP2 := 135 \frac{mW}{0.23 \text{ cm}^2} = 0.587 \frac{W}{\text{cm}^2}$$

$$PPL := 45 \frac{mW}{0.023 \text{ cm}^2} = 1.957 \frac{W}{\text{cm}^2}$$

$$PD_2 := 660 \text{ mW} + 2 \cdot 135 \text{ mW} + 45 \text{ mW} = 0.975 \text{ W}$$

