

# Thick-film heaters and LED heat spreaders made from dielectric-coated aluminum substrates

An update from ESL ElectroScience

## 1. Introduction

Insulating dielectric materials can be screen printed onto aluminum and either cured at 150-320°C or fired at 500-530°C to make substrates that have high breakdown voltage (BDV). These may be used for heat dissipation (heat spreading) purposes or for heaters.

## 2. Materials

There are a number of different aluminum alloys that may be insulated. Each alloy has its own TCE. Alloys are divided into series with the major alloying element determining the series designation.

The International Alloy Designation System (IADS), introduced in 1970 and now widely accepted, uses a classification developed by the Aluminum Association of the United States. It works as follows. Each wrought alloy is given a 4 digit number. The first digit indicates the major alloying element or elements, as shown. The 1XXX series contain no alloying elements; the 2XXX series contain copper as the major alloying element, etc.

Series	Major Alloying Elements
1XXX	99% Aluminum
2XXX	Copper
3XXX	Manganese
4XXX	Silicon
5XXX	Magnesium
6XXX	Magnesium and Silicon
7XXX	Zinc
8XXX	Other (including Lithium)

### IADS Terminology for Wrought Aluminum Alloys

The third and fourth digits are significant in the 1XXX series but not in the others. In the 1XXX series the last two digits describe the minimum purity of the aluminum; thus 1145 has a minimum purity of 99.45%; 1200 has a minimum purity of 99.00%. In all other series, the third and fourth digits are simply serial numbers, so that 5082 and 5083 are two distinct aluminum-magnesium alloys. The second indicates a close relationship so that 5352 is closely related to 5052 and 5252, and 7075 and 7475 differ only slightly in composition. To these serial numbers are added a suffix indicating the state of hardening or heat treatment. The suffix F means "as fabricated". Suffix O means "annealed wrought products". The suffix H means that the material is "cold worked". The suffix T means that it has been "heat treated".

For any higher temperature processing using insulating cermet dielectrics, care should be taken to find out the melting point of the chosen alloy. It should also be borne in mind that aluminum alloys are susceptible to warp so that the thickness of the chosen alloy may be an issue. Large aluminum heat sinks require longer profiles than the usual one hour profile when cermet pastes are used to allow the thermal mass to reach processing temperature.

### 3. The three systems

There are a number of ways whereby aluminum alloys may be insulated. We have tested three systems over many months:

A polymer system

A polyimide system

A cermet system

Each system has its merits and demerits. Some systems have good dielectric properties but have limited conductor options for the top layer. Some systems require a different processing temperature for the conductor from the dielectric.

This is also true as far as applications are concerned. For example, in order to dissipate the heat produced locally in high power LEDs, there may be a variety of breakdown voltage (BDV) requirements placed upon different systems. The same is true in heating applications though it is expected that the insulated aluminum be a viable alternative to heaters made on insulated steel and, consequently, be capable of handling mains voltage with the ability to withstand much higher voltages for safety reasons. Some systems may not be able to handle power and high current flow.

### 4. Polymer system

This system should be considered for LED heat dissipation applications.

The material choice for the polymer approach is to use [243-S](#) as the dielectric with [1906](#) as the conductor and either [242-SB White](#) or [243-White](#) as the reflective overcoat. 40µm should be obtained using three layers of 243-S with a 200 mesh screen. Curing is at 150°C.

#### Features

- Low thickness dielectric gives high BDV (40 µm gives 4000V AC)
- White dielectric may be used to reflect light generated by the LEDs
- May be applied to large heat sinks.
- Additive process
- Low temperature cure ≤ 150°C
- Flexible, quick and easy to process
- Material cost savings
- Less LEDs for the same lumen output
- Improve expected life time of devices
- One part polymers used throughout
- <50mΩ/□ for 1906 at 10µm
- Poor solderability of polymer conductors means that conductive adhesive is the only alternative

### 5. Polyimide system

This system should be considered for heat spreading applications (see [Polymer Thick-Film Material Application Notes](#)).

[14404](#) should be used as the dielectric with [19102-A](#) as the conductor. [243-White](#) may be used as a reflective overcoat.

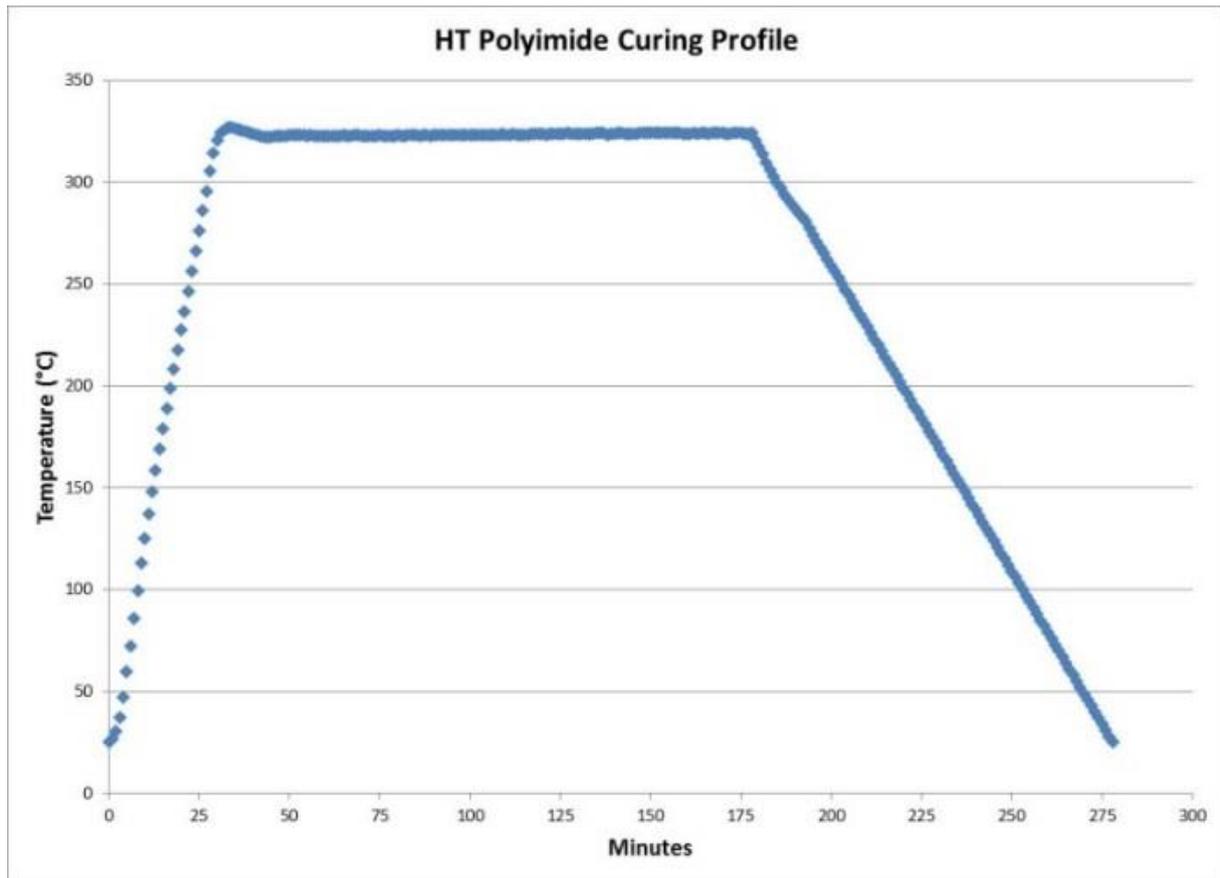
Special emulsion (such as Murakami SP 9501) squeegee and screen adhesive are required to withstand the NMP-cleaning solvent. After cleaning with a minimum amount of NMP, use acetone to remove the NMP residue.

Print the 14404 using a 145 mesh screen with 0µm emulsion. Dry at 125°C for 10 minutes. A single layer dried thickness should be < 20µm. Print a total of 3 layers of 14404.

Print the [19102-A](#) with 325 mesh screen right after the last dielectric layer is applied and dried without delay. Dry at 125°C for 10 minutes. Co-cure all dried layers at 320°C for 150 minutes with a heating rate of 10 °C per minute.

Materials arrive frozen with some dry ice still inside. Due to the extremely low temperature of dry ice, care should be taken when opening the box and handling the products. Thermally insulated gloves should be worn. At any time during handling of dry ice, if fingers or hands get cold, stop work immediately, warm up hands, and upgrade the gloves that are used.

Please refer to the MSDSs for additional safety information.



Print the [243-W](#) and dry at 125°C for 10 minutes. Cure at 150°C for 15 minutes.

## Features

[14404](#) polyimide based dielectric with [19102-A](#) conductor

Low temperature co-cure at 320°C

Additive process

White dielectric overcoat cured at 150°C may be used to reflect light generated by the LEDs

May be applied to large heat sinks

One part pastes throughout for insulating aluminum alloy substrates

Provides outstanding insulation resistance

Achieves  $\geq 2,000V$  AC breakdown voltage at  $>35\mu m$  cured film

RoHS compliant

Good solderability and adhesion

If longer than four weeks storage is planned, the product should be stored at -18°C.

Contains NMP

Special screens and squeegees are required

## 6. Cermet system

This system may be considered for both heat spreading and heating applications. Based on a heater size of 50mm x 50mm an aluminum substrate with a thickness of **4mm** is advised.

Three separately fired layers of [4606](#) may be used to insulate 3003, 3103 or 4XXX aluminum. The thickness should be 60-70µm. A 145 mesh 0µm emulsion screen is recommended. The dielectric is fired at 530°C (one hour profile).

[9912-K](#) is used as the conductor which is fired at 500°C. Either a 325 mesh or 200 mesh screen may be used to print the conductor depending on definition requirements.

A **two part** dielectric system is recommended using [4606](#) and [4031-B](#) fired using a one hour 530°C profile (sandwich of [4606/4031-B/4031-B/4606](#)) with [9912-K](#) as the conductor on 6XXX as there are known issues about enamel delamination on untreated 6XXX. It is for this reason that 3XXX and 4XXX are grades used for enamelled cookware and these are the preferred grades for any cermet work on aluminum. Delamination issues may be overcome using surface treatment of 6XXX such as chromatization.

Resistive/conductive pastes capable of being fired at 500°C (one hour profile) may be used as heating tracks. The conductor **must be** fired at a lower temperature than the dielectrics at 500°C to achieve good solderability.

[4606](#) fired at 500°C may be used as an overcoat.

### Features

Low temperature 530°C firing profile for dielectrics with conductors fired at 500°C

Very robust and stable

Material cost savings

Additive process

Speeds up and simplifies manufacturing process

Less LEDs for the same lumen output and improves expected life time of devices

RoHS compliant

Provides outstanding insulation resistance

Achieves 2,000VAC breakdown voltage consistently

[9912-K](#) has excellent solderability and adhesion

<2.5mΩ/□ @ 11.5µm

Care must be taken with the choice of alloy

3XXX is preferred (less problems with humidity)

6061 to be used in preference to 6082 (susceptible to warp) when 6XXX alloys are considered

Thin aluminum alloy substrates are liable to warp.