

This document describes technological features of printed alumina substrates (PS) production in ELCERAM corp. PS design should be based on technological characteristics described below and if there are no other important reasons it is recommended to follow the design rules described below.

### **Thick film technology application**

Thick film technology is an alternative to PCB production technology, and therefore similar rules are applied at thick film network design. This technology is used in demanding applications where long life, thermal endurance, mechanical strength, thermal conductivity, electrical strength, low dielectric losses, etc., are needed. Printed alumina substrates are of considerable use in aggressive environments and in cases where classical materials as FR4 fail. They are applied in automotive and aerospace industry, medical industry, LED illumination, power electronics, hybrid microelectronics, microwave circuits, sensors, electronic components, etc.

### **Terms definition**

#### **Thick film technology**

Conductive, resistive and dielectric films are selectively deposited by screen printing on ceramic substrates, mostly on 96 % alumina substrates. These films are dried and fired. They are of a fired thickness between 5 to 20  $\mu\text{m}$  in one print according to the type of the paste used. If there is a requirement for thicker films it is necessary to use either special pastes or to print several times. The films are generally fired at temperatures higher than 500 °C.

#### **Standard substrate – alumina ceramic – $\text{Al}_2\text{O}_3$**

It is chemically resistant printed film pattern carrier that is resistant to high temperatures. It is outstanding electrical insulator and thermal conductor as well. ELCERAM uses 96 % alumina ceramics made by own company process. It is also possible to provide other ceramic materials, e.g. alumina 99 %, AlN or  $\text{ZrO}_2$ .

#### **Printed substrates**

This is usually a ceramic substrate printed with conductive, dielectric or resistive films. Maximum external substrate dimensions of are 200 by 200 mm, thickness can vary between 0.1 mm and 1 mm. The substrates can be printed on one or on both sides. The patterns on both sides can be connected by metallised through-holes (vias). Each substrate side can be provided with more film levels (one-sided or double-sided multilayer film structure).

#### **Screen printing**

Technological process where conductive, resistive and dielectric pastes are applied using screen masks. The screen is made mostly of a stainless mesh. In some cases printing stencils made of thin stainless sheet are used.

#### **Screen**

A stainless mesh mask is fixed in a metallic frame. The mesh mask is photo-processed using a light sensitive emulsion. The emulsion covers openings in the mesh and thus it masks the part of the substrate that should not be covered by the paste. Open part of the meshes allows the paste deposition. For each film pattern deposition one screen is needed.

#### **Thick film resistor**

Resistors are made by resistive paste printing, drying and firing. The resistance of a resistor is set by its dimensions and the paste type.

#### **Resistor trimming**

The precise resistance value is set by laser trimming. The resistor geometry is modified by sophisticated cuts. It is possible to attain precision of 0.5 % or better from nominal value of the resistor's resistance.

#### **CO<sub>2</sub> laser**

Laser system designed for machining fired alumina substrates (scribing, cutting and drilling). This procedure enables cutting out almost any pattern needed.

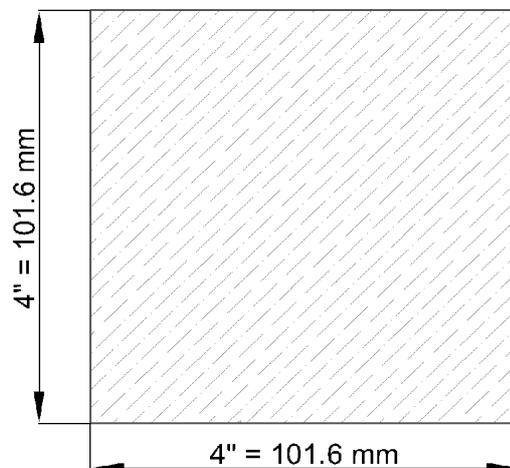
**When designing the printed substrate customer should specify:**

- 1) External dimensions of the substrate, other important dimensions and their tolerances.
- 2) Number and material of the films for the TOP and the BOTTOM side, minimum line width.
- 3) Geometry of resistors, nominal resistor resistance, tolerance of this value, nominal power load of this resistor.
- 4) Surface treatment of the printed substrate: passivation, tinning and pads solderability, size of the pads for wire bonding, etc.
- 5) Screens and printing templates production, working out programs, production data.
- 6) Special customer requirements.

**1. External dimensions of a basic substrate and its tolerance**

In this section all basic information concerning dimensions and mechanical machining of alumina substrates (96 % Al<sub>2</sub>O<sub>3</sub>) are mentioned. Final tolerances after machining are mentioned as well.

Dimensions of a ceramic substrate



**Ceramic substrate processing**

Alumina substrates usually contain more printed systems (circuits, components). The systems can be separated by breaking the substrate in designed lines. These lines are scored either at punching the green sheet (not fired substrate) or by laser scribing of the fired substrate. If higher precision is required it is better to cut the substrate by CO<sub>2</sub> laser. When there is a requirement for very accurate and smooth surface, there is a possibility to edge and polish the ceramics. The less accurate, but in large batches economical way, is to obtain external dimensions by stamping the green sheet.

Summary of operations used for separating printed systems and attainable accuracy is shown in the table below.

Technological operation	Reachable accuracy after machining
Stamping green sheet	± 0.5 % from the substrate dimension
Breaking substrates – thickness of 0.3 mm	+0.1 mm / -0.05 mm
Breaking substrates – thickness of 0.635 mm	+0.2 mm / -0.05 mm
Breaking substrates – thickness of 1 mm	+0.3 mm / -0.05 mm
Laser cutting	± 0.05 mm
Grinding	± 0.001 mm

## 2. Design of conductive, dielectric and resistive films

In this section basic materials and basic design rules are described.

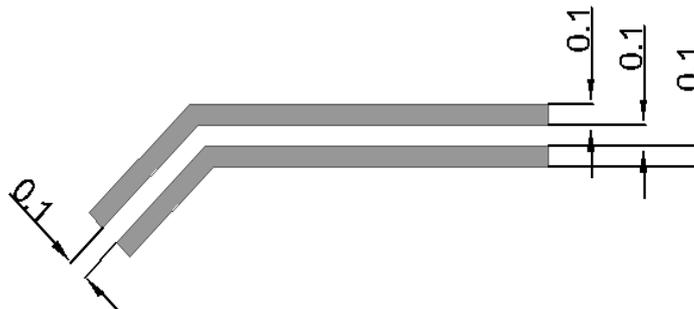
Typical materials	
Material	Parameters / use
Ag	Very low resistivity, low resistance against corrosion, should be passivized
AgPt	Very low resistivity, very good solderability
AgPd	Very low resistivity, very good solderability, bondable
Au	Resistant film showing low resistivity, it does not oxidize, it is bondable. It is used especially for a contact bonding pads.
Au resinate	Very thin gold film – below 1 $\mu\text{m}$
Polymer	Not solderable cover film
Glass cover film (overglaze) firing temperature 550 °C	Resistant not solderable overglaze – green colour
Dielectric glass cover layer (overglaze) firing temperature 850 °C	Resistant not solderable overglaze – transparent
Resistive films – typical value of square resistance	0.1 $\Omega/\text{sq}$ - 1 $\text{G}\Omega/\text{sq}$

It is recommended to follow the typical design parameters listed below. Not keeping the recommended dimension values can increase technological demands and thus increase printed substrates prices.

Tolerance of conductive, dielectric and cover films	
Max. size of printed pattern	Standard 101.6 by 101.6 mm max. 200 by 200 mm
Min. conductor width	0.1 mm
Min. gap between conductors	0.1 mm
Min. gap between the hole and the conductors	0.1 mm
Min size of hole through metallisation	0.1 mm
Min. distance of soldering mask from solder pads	0,05 mm

In the picture below recommended minimal dimensions of conductors and gaps are shown. Conductor dimensions should be designed with a respect to their max. current load.

### Minimum conductors and gap widths



Typical thicknesses of printed and fired films of the typical materials are listed in the table below.

Material	Typical film thickness after firing
Ag	$14 \pm 2 \mu\text{m}$
Au	$10 \pm 2 \mu\text{m}$
Dielectrics for cross overs	$40 \pm 2 \mu\text{m}$
Resistive films	$9 \pm 2 \mu\text{m}$
Overglaze for solder masks	$12 \pm 2 \mu\text{m}$

### 3. Printed resistors and their design

The following resistor parameters should be given by customers:

- 1) Nominal resistor resistance
- 2) Tolerance of a nominal resistor resistance
- 3) Nominal resistor power load

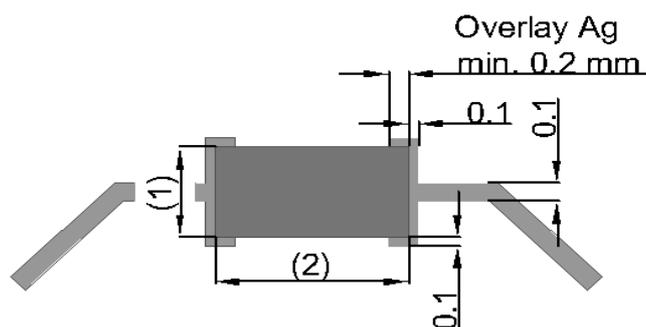
When designing resistor dimensions, it is recommended to keep to the following rules:

- 1) Minimum overlap of conductor film and resistive film should be at least 0.2 mm
- 2) The area of a printed resistor should correspond to the maximum resistor power load, and this is also the case when the resistor is trimmed to accurate value. This maximal power load value is different for different pastes and can be found in paste datasheets. The highest permissible DC voltage (V/mm) – this information can be found in paste datasheets.

Minimum nominal resistance value of resistor, resistance tolerance, power load and the highest permissible permanent resistor voltage should be specified.

Minimum overlap of a conductive path and resistive film is depicted below.

#### Typical dimensions of printed resistor

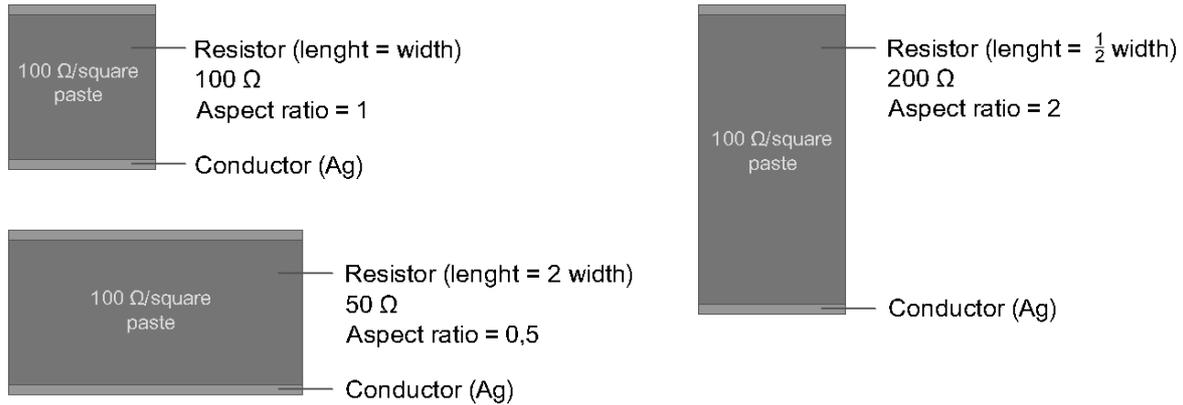


#### General rules concerning resistor design:

Resistor resistance is defined by its geometric dimensions (width, length, thickness), and the parameter of the paste, which is called sheet resistivity. General relation is  $R = R_{\text{square}} \times L/W$  ( $\Omega$ ), where  $R_{\text{square}}$  is sheet resistivity and can be found in the paste data sheet,  $L$  is resistor length, and  $W$  is resistor width.

The given sheet resistivity is always related to a typical film thickness after firing, which is usually in the range of 8 to 10  $\mu\text{m}$  according to the paste manufacturer and according to the printing process set up. Graphical demonstration of resistor design is illustrated in the picture below.

## Aspect Ratio Variation



### Thick film resistors trimming:

Laser trimmers in ELCERAM production can trim resistors in the range of Ohms to hundreds M Ohms at the tolerances listed below.

Resistor size	Tolerance
0.1-10R	±1 %
10R-1000K	±0,5 %
1-10M	± 1 %
10-100M	±3 %
100-500M	±5 %

### 4. Surface protection of printed substrates

Conductive silver paths and resistors have to be passivized – covered with a protective layer. That is done either using pastes based on polymers or glass. Polymeric pastes show a similar resistance to mechanical and thermal damage as compared to surface protection films of PCBs. In case of higher requirements for thermal resistance, passivation is done with glass pastes, where resistivity to mechanical and thermal damage is remarkably better.

#### Temperature resistance of surface cover films:

Polymeric cover film: approx. up to 250 °C

Glass cover film: approx. up to 500 °C

## 5. Production of the screens, printing templates, production programs, setup and production data

### Production of screen masks and screen templates

Films are deposited by screen printing (thick film technology). For each film deposition a new screen has to be made. The screens are different in size, type of used weave and number of mesh per unit area. The type of used weave and mesh count depend on required accuracy of a printed pattern. If there is no other order, ELCERAM stores screens for one year. In a case of a longer period of supplies, ELCERAM can offer the possibility of buying customer screens, which will be owned by the customers.

### Production programs, setup

Single circuits are machined on the basic ceramic substrate by CO<sub>2</sub> laser. For this procedure it is necessary to work out and to debug the machining program. This program is worked out after the first order. It is also archived for one year after the last delivery.

**Production data preparation**

The optimal format for production data creation is dwg, dxf or Gerber. If necessary, it is possible to process data from technical drawings (format pdf., jpg. ) and other common formats.

**6. Special customer requirements**

It concerns situations in which better technological parameters are demanded. In this case ELCERAM consults the customer. If necessary, ELCERAM is able to do uncertified climatic or electric tests of designed circuits in its laboratory.