Microcircuit Materials

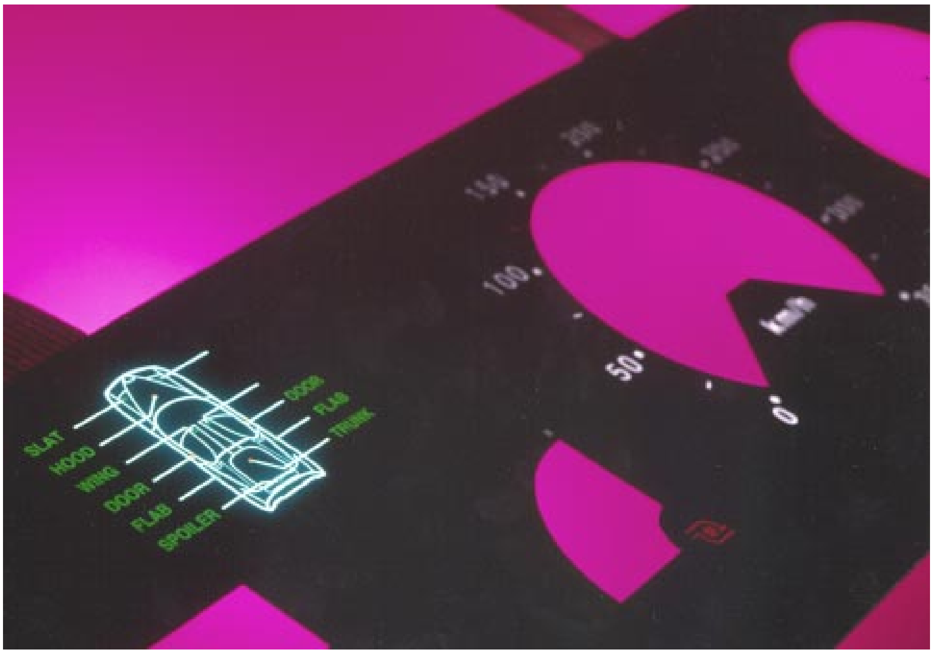
Processing Guide For DuPont Luxprint® Electroluminescent Inks

All values reported here are results of experiments in our laboratories intended to illustrate product performance potential with a given experimental design. They are not intended to represent the product's specifications, details of which are available upon demand.

Introduction

Recent major advances in materials and electronics technology, as well as new demands on lighting technology from the marketplace, have provided the opportunity for a fundamental shift in the role of EL technology. For that reason, DuPont has developed a series of conducting, insulating and phosphorescing inks suitable for manufacturing printed lamps, enabling companies skilled in screen-printing of electronic circuitry to easily manufacture flexible EL lamps. The main EL characteristics are:

- Uniform surface illumination of complex shapes
- Thin, flexible and light weight
- Low power consumption
- Very low heat generation
- Vibration and impact resistant



EL Application – Automotive dashboard for Alfa Romeo Scighera.
Thin, even illumination is achieved

DUPONT LUXPRINT* ELECTROLUMINESCENT INK TYPES

The following provides descriptions of process steps and materials which have proven important in successful implementations of DuPont Luxprint* EL inks to date. The recommendations and descriptions found herein are based upon experience gained during the development of these inks. Process optimisation will be necessary to conform to the particular design of the EL lamp and processing equipment used. These guidelines may not prove applicable for new or different applications, and the user must carefully evaluate their usefulness in each case.

The DuPont materials package provides the inks needed to make EL lamps by screen printing. Other materials, such as transparent sputtered ITO (Indium Tin Oxide) polyester or glass substrates, as well as the power supply, must be obtained from other sources.

Each of these inks is designed to be used without further dilution in a screen-printing process. The products are mutually compatible, and provide excellent adhesion to ITO, which is typically utilised as a thin coating on polyester or other film base.

The DuPont Luxprint* EL product line currently consists of

PHOSPHORS

7138J White Phosphor
7151J Green-Blue Phosphor
7154J Yellow-Green Phosphor

DIELECTRICS

7153E High K dielectric insulator

CONDUCTORS

Build Sequence 1

7144E Rear Electrode, Carbon Conductor
7145L Rear Electrode, Silver Conductor (Also for bus bars and terminations)
7162E Front Electrode, non-ITO

Build Sequence 2

7102 Rear Electrode, Carbon Conductor
5000 Rear Electrode, Silver Conductor (Also for bus bars and terminations)
7164 Front Electrode, non-ITO

PROTECTIVE ENCAPSULANT

Build Sequence 1

5018 UV Cure Ink

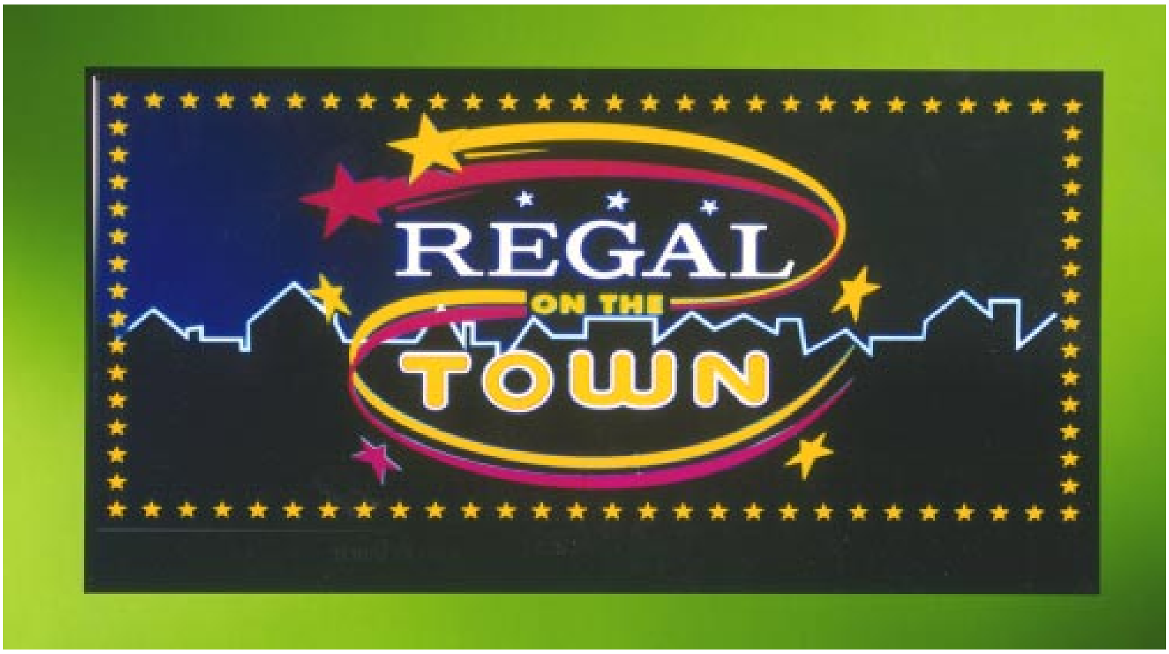
EL BASICS

The EL lamp is essentially a capacitor structure with phosphor sandwiched between the electrodes. Application of an AC voltage across the electrodes generates a changing electric field within the phosphor which causes the phosphor to emit light. For most EL lamps, an inverter is used as a power source. An inverter is a DC-AC converter which generates typically around 60-115V AC at 50-1000 Hz.

Phosphors are powders made of materials such as zinc sulphide which are designed to phosphoresce at characteristic wave lengths (colours). The colour can be defined during the manufacture of the phosphor, or can be achieved by blending phosphors of different colours to achieve the composite colour. The particle size of the phosphor powder is selected to provide the highest efficiency of light emission.

With time, light output gradually decays as the phosphorescent efficiency declines. The presence of moisture accelerates this decline. The phosphors used in DuPont Luxprint* EL inks are micro-encapsulated to hinder the penetration of moisture and thus to prolong the useful life of the lamps. The polymer binders in the DuPont Luxprint* EL pastes have been selected to provide a moisture barrier, which further protects against moisture-related ageing phenomena. This feature also prevents moisture from degrading the capacitance of the lamp, thus providing higher brightness.

Higher voltages and frequencies, as well as elevated temperatures during operation, will degrade the efficiency of the lamps. To improve the lifetime of the lamps, operation at lower temperatures, voltages and frequencies should be encouraged. Typically, 80 - 120 V AC and 400 Hz is utilised. These conditions result in the best useful lifetime.



EL Application – Advertising (POS) An eye-catching series of sequenced lighting patterns.
Frame Size 63 x 33 cm

DESIGN NOTES

The printed EL lamp consists of a sandwich structure containing an appropriate substrate, a rear electrode, an insulating layer, the phosphor layer, a transparent or translucent front electrode and a protective layer (see schematic diagram). The lamp may be terminated by a silver conductor, and crimped connectors (or other means) to allow connection to the power source. Care must be taken in providing a connection with good integrity.

There are various lamp builds which can be constructed. The most common two are described below.

Build Sequence 1

Uses a transparent base substrate.

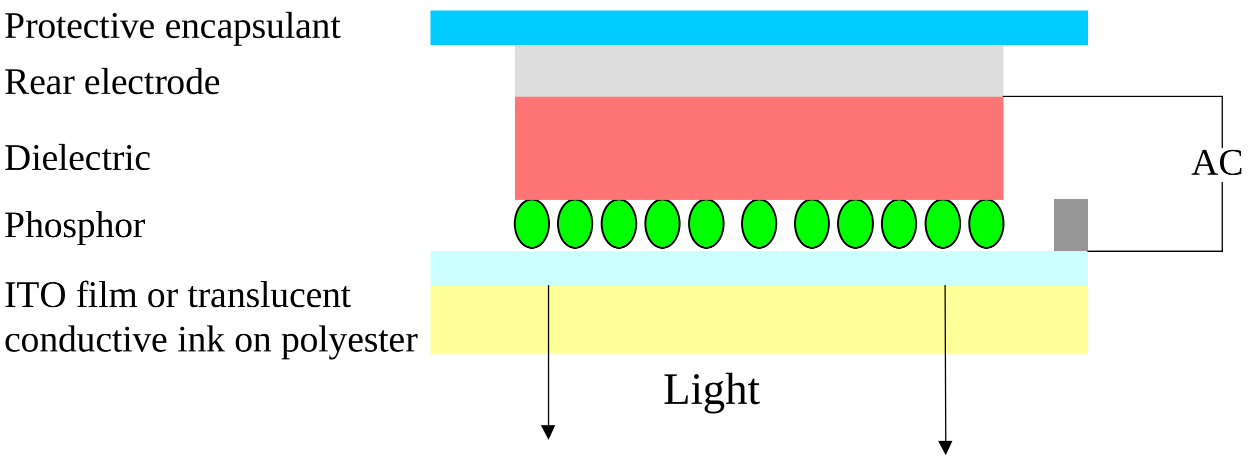
Polyester film, sputtered with ITO or coated with a conducting polymer, can be used as the front electrode. Alternatively, a screen printed conducting translucent ink can be used on a clear base substrate. The build sequence printed on top is simply phosphor, then either:

(a) 2 prints of dielectric, which will give a brighter lamp but may reduce the yield and reliability, or

(b) 3 prints of dielectric (are preferred) for optimum yield and reliability, followed by the rear electrode.

A printed silver bus bar along the perimeter of the lamp should be used for large areas in order to provide more even illumination of the lamp. For the rear electrode, a silver, or carbon conductor is generally used. For larger lamp areas, carbon is not suitable, unless it is overprinted with a silver grid, as the resistance is too high. The final product should be laminated with a protective material in order to provide protection from moisture and electrical isolation for safety reasons. Alternatively, a protective layer can be screen printed using a UV cure ink. (See Diagram Build Sequence 1)

Build Sequence 1



Build Sequence 2

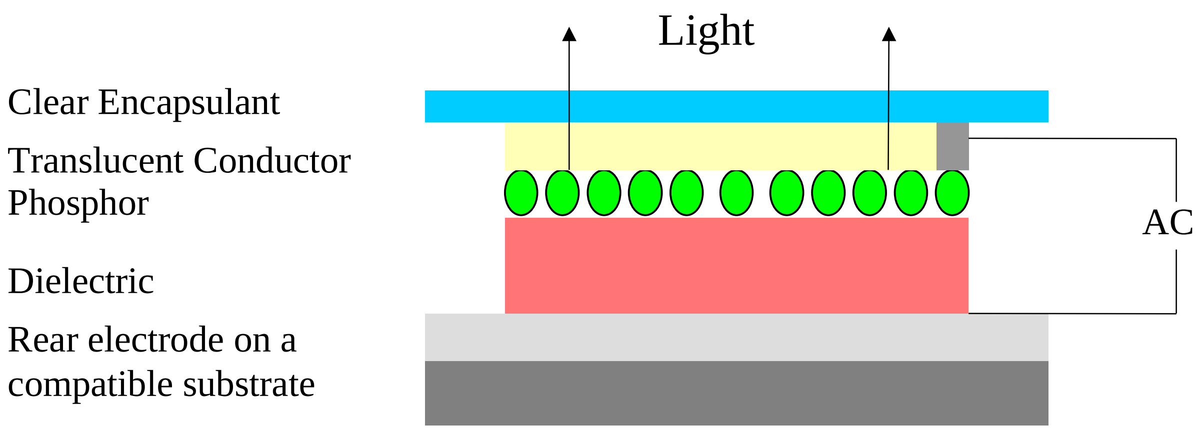
Various substrate types could potentially be used.

Using a translucent conductive ink it is possible to use other base substrates as long as these are compatible with the solvent and resin system and are capable of withstanding the high temperature drying conditions.

The build sequence here is reversed with the rear electrode printed first. Again, as in build sequence 1, a silver bus bar is recommended. A silver underprint should be applied if a carbon electrode is used for larger areas and/or humid environments. Two dielectric layers are then printed followed by the phosphor and finally the conductive translucent front electrode. (See Diagram Build Sequence 2).

Using this build sequence, brightness values may be higher than sequence 1. Lamps must be protected against moisture and fully evaluated.

Build Sequence 2



SUBSTRATE TYPES

-Sputtered ITO Polyester

The substrate is typically obtained with an ITO transparent conductor sputter-coated on one side. Polyester thickness between 100 - 175µm and resistivities ranging from 50 to 300Ω/☐ can be used. Heat stabilised film is highly recommended as drying temperatures up to 130°C may be required. It is also recommended that suitable tests be carried out to verify the compatibility of the substrate with the inks.

-Non ITO Coated Films

These are polyester or other film types coated with a conducting, transparent polymer. Resistivity is high, typically 1000Ω/☐ to 3000Ω/☐. Lamp performance must be thoroughly tested for compatibility, including initial and aged performance.

-Alternative use of Mylar® polyester and conductive translucent inks

In designs with small lit areas, a screen printable translucent conductive ink can be used as the front elctrode. This provides a total screen printed solution to lamp fabrication and a lower cost alternative to lamps manufactured on ITO film or coated polyester. Using this option, some consideration should be given to the following:

Resistivity

The as-printed resistivity of translucent conductors can be around 100 times that of ITO film and as a consequence, lit areas need to be kept small in order to achieve good uniformity of illumination. Test lamps have been constructed with an area 10cm x 5cm without noticeable darkening towards the centre of the lamps (powered at 100V/400Hz). Although there is no data available as to the maximum lamp area that can be lit, this can be established by investigating various lamp designs, processing parameters and drive conditions.

Frequency

Higher frequency operations may cause darkening towards the centre of the lamps. It is advisable to use frequencies below 800Hz.

Bus Bar

It is highly recommended to use a silver bus bar close to the lit area around the perimeter of the translucent conductor. This improves the light uniformity by improving the contact resistance and minimising voltage drop across the surface (vs. a carbon electrode).

Paste Selection

Depending on the build sequence to be used, paste selection is critical to the performance of the lamp.

a) Build Sequence 1

- It is advisable to use a heat stabilised, print treated polyester.

- Translucent conductor 7162E is printed first. This uses non-ITO conductive particles, which have a neutral grey colour.

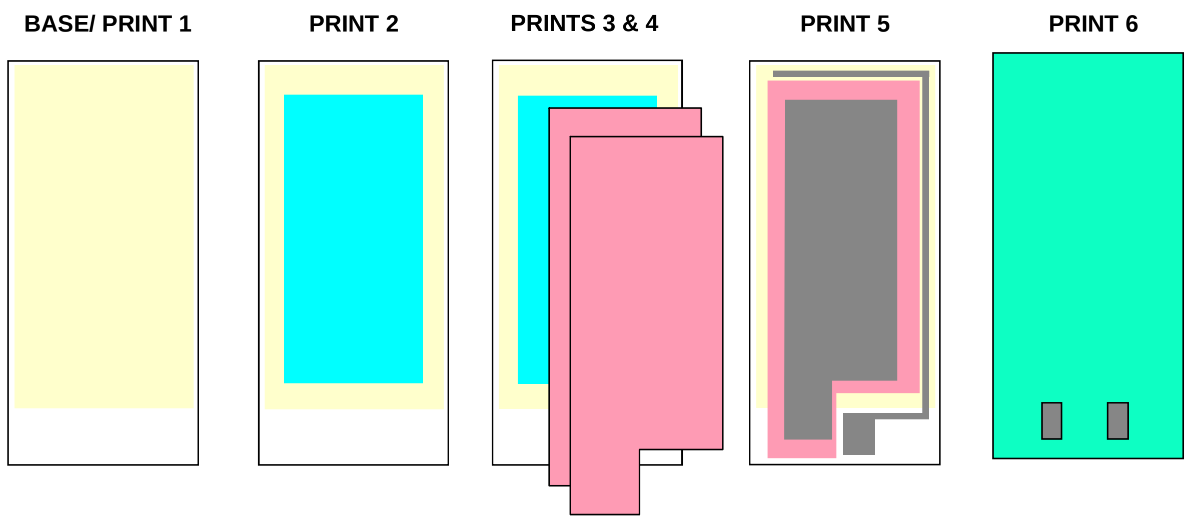
- Phosphor is printed next. There is a choice in output colour between 7151J, 7154J or 7138J.

- This is followed by 7153E dielectric

- 7145L Silver or 7144E Carbon is then printed onto the dielectric. These compositions are compatible with 7153E and their use is highly recommended. It has been found that the use of various alternative conductors has adversly impacted the short/long term lamp performance.

- Lamp encapsulation with UV cure ink 5018 has been found to provide additional protection

Lamp Build Sequence 1
DuPont Electroluminescent Material Recommendation



Front Electrode on Base
• ITO Polyester Film
• 7162E on Polyester

Phosphor
• 7138J White
• 7151J GreenBlue
• 7154J YellowGreen

2 - 3 Dielectric Layers
• 7153E high K

Rear Electrode & Front Busbar
• 7145L Silver
• 7144E Carbon

Protective Back Layer
• 5018 UV Cure

b) Build Sequence 2

- If polyester is to be used, it is advisable to use a heat stabilised, print treated surface. Other substrates can be used, e.g FR4 Printed circuit board, providing they are compatible with the solvent and resin system and can withstand the high temperature drying of 130°C.

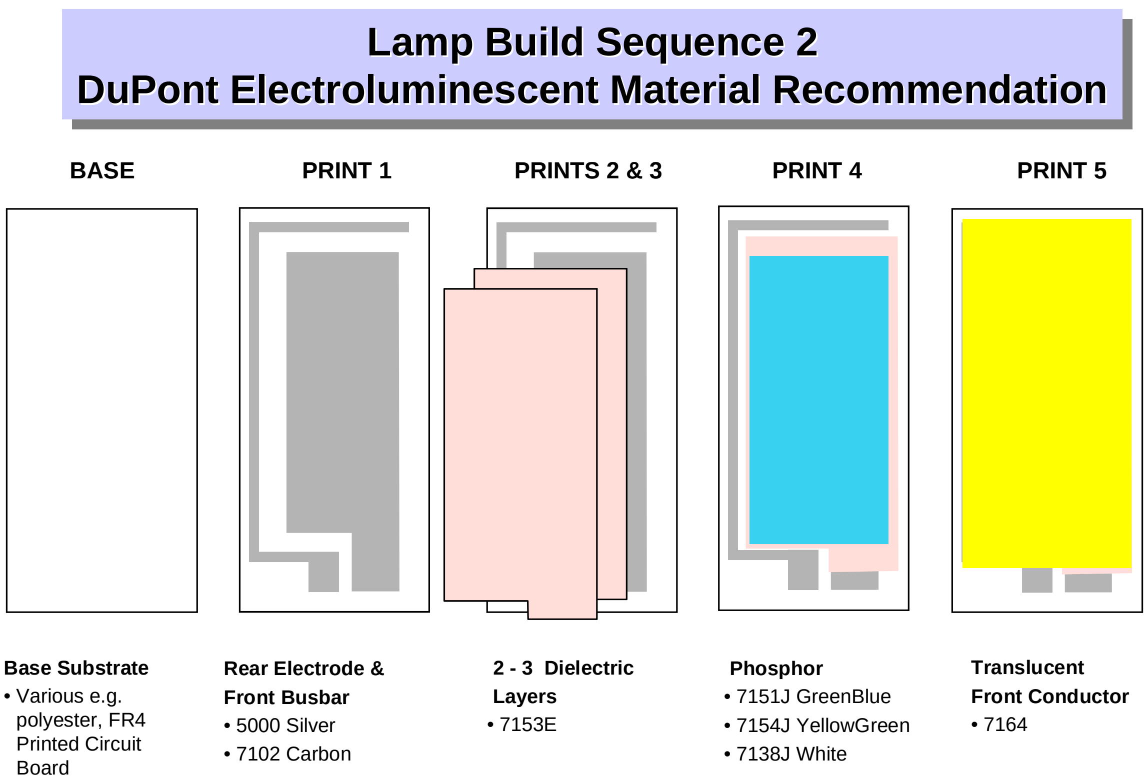
- The rear electrode and bus bar are printed first. It is recommended to use 5000 Silver for the bus bar, and 5000 Silver or 7102 Carbon as the rear electrode.

- This is followed by 7153E dielectric over the rear electrode.

- The next print is phosphor.

- Finally, the translucent conductor 7164 is printed over the phosphor ensuring there is good contact to the silver bus bar. Although this translucent conductor uses non-ITO power the brightness levels seen in the final lamp are higher than those expected from a lamp made with ITO film. This composition gives negligible colour shift

- an encapsulant is recommended for additional protection.



PROCESSING

Storage

Containers of DuPont Luxprint* EL Inks may be stored in a clean, stable environment at room temperature (≤25°C), with their lids tightly sealed. Storage in freezers (temperature <0°C) is not recommended, as this could cause irreversible changes in the material. In general, jar rolling is unnecessary and is not recommended for the Carbon, Silver, and Dielectric inks, as this could change the rheology of these materials. The Phosphor inks and Translucent conductors tend to settle, so gentle jar rolling is recommended.

Handling

DuPont Luxprint* EL inks should be thoroughly mixed before use. This is best achieved by slow, gentle hand stirring with a clean, burr-free spatula (flexible plastic or stainless steel) for 1-2 minutes. Particular care should be given to the Phosphor inks, as the micro-encapsulation may be damaged by vigorous agitation. Printing should be carried out in a clean, well-ventilated area. Additional information on requirements for printing areas is available in DuPont Technical Guide EUT 7.3 “Screen Printing Rooms” which is available on request. Although DuPont Luxprint* EL inks are optimised for screen printing and thinning is not normally required, the appropriate DuPont Thinner may be used sparingly for slight adjustments to viscosity or to replace evaporation loses. However, the use of too much thinner or the use of a non-recommended thinner may affect the rheological behaviour of the materials and their printing characteristics.

Printing

Optimum printing characteristics of DuPont Luxprint* EL inks are generally achieved in the temperature range 20 - 23°C. It is therefore important that the materials, in their container, are at this temperature prior to commencement of printing.

Screens

Screen selection is very important to the overall performance of the lamps. Table 1 has a list of suggested Polyester screens that may be used. Further optimisation may be necessary depending on printers and processing conditions used.

Drying

Drying at 130°C for 10 minutes in a well-ventilated box oven has been found to be very effective for these materials. This should be used as a starting point to find the equivalent drying conditions on the production line. Successful trials have been run on a reel-to-reel set-up. This has been found to give more efficient drying and so shorter drying times (around 2 minutes) can be used.

Table 1 Printing - suggested screen mesh		
Product	**Polyester mesh** (threads/cm)	**Thickness** (µm)
Phosphors		
7138J	62T	
7151J	62T	30 - 40
7154J	62T	
Dielectric		
7153E	62T	≈20 (2 layers)
Conductors		
Build Sequence 1		
7144E Carbon	77T	10
7145L Silver	77T	8
7162E Non-ITO	77T	10
Build Sequence 2		
7102 Carbon		7
5000 Silver	77T	6
7164 Non-ITO	77T	10
	77T	
Encapsulant		
5018 UV Cure	77T	≈35 (2 Layers)

Phosphors

These should be printed directly onto the sputtered ITO side of the polyester. To obtain uniform illumination, it is essential that sufficient Phosphor ink be deposited at this step. The amount of Phosphor ink required is around 10 mg/cm^2. If a polyester screen is used, it is recommended to begin with 62T mesh (wires/cm) with 20 - 25 µm emulsion. If a mesh with insufficient open area is used, a double wet pass will improve the particle packing density and results in a more uniform light when powered up. A printed thickness in the range 30 - 40 µm (dry) should be achieved, which represents coverage of approximately 100 cm^2/g of wet Phosphor ink.

Dielectric (7153E)

Printing through a 62T (wires/cm) polyester screen is suggested as a starting point. This should give a film thickness of approximately 10µm (dry). Three separate dried layers are preferred to prevent shorting and total thickness of around 25µm should be maintained. This represents total laydown of 20 mg/cm^2. If voids are observed due to large underlying phosphor, double-wet passes or extra layers may be necessary.

Conductors

- Rear electrodes (Build Sequence 1)

During storage, EL conductor pastes 7144E and 7145L will coagulate and form a gel-like appearance. This is normal behaviour for this type of chemistry and a 30 second stir will bring it back to the original consistency. Printing behaviour and performance is not effected. Best results are obtained when using a faster print speed. A 77T polyester screen may be used to print the silver and/or carbon.

- Rear electrodes (Build Sequence 2)

Standard Processing conditions can be used for 5000 Silver and 7102 Carbon. Using a 77T polyester mesh, an approximate coverage in excess of 230cm^2/g and 350 cm^2/g respectively) can be expected.

- Front Electrode Translucent conductive inks (7162E & 7164)

During storage, particles in these compositions have a tendency to settle out. For best results, jar rolling of the compositions prior to use is recommended. Prior to printing, the paste must be thoroughly stirred. Failure to do this may result in printing a polymer rich composition and this will result in high resistance values. Using a 77T polyester, a total laydown around 3mg/cm^2 can be achieved. This represents a coverage of 350 cm^2/g.

UV Cure Encapsulant (5018)

5018, a screen printable UVcure ink, can be used as an encapsulant in order to provide electrical insulation and extra protection against humid environments. To improve adhesion, it is advisable to extend the area covered by the underlying dielectric so that the 5018 encapsulant is printed onto 7153E dielectric rather than directly over the sputtered ITO polyester substrate.

In more complex EL lamp builds, 2 layers of 5018 can be used as an effective insulator where conductor crossovers are present.

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