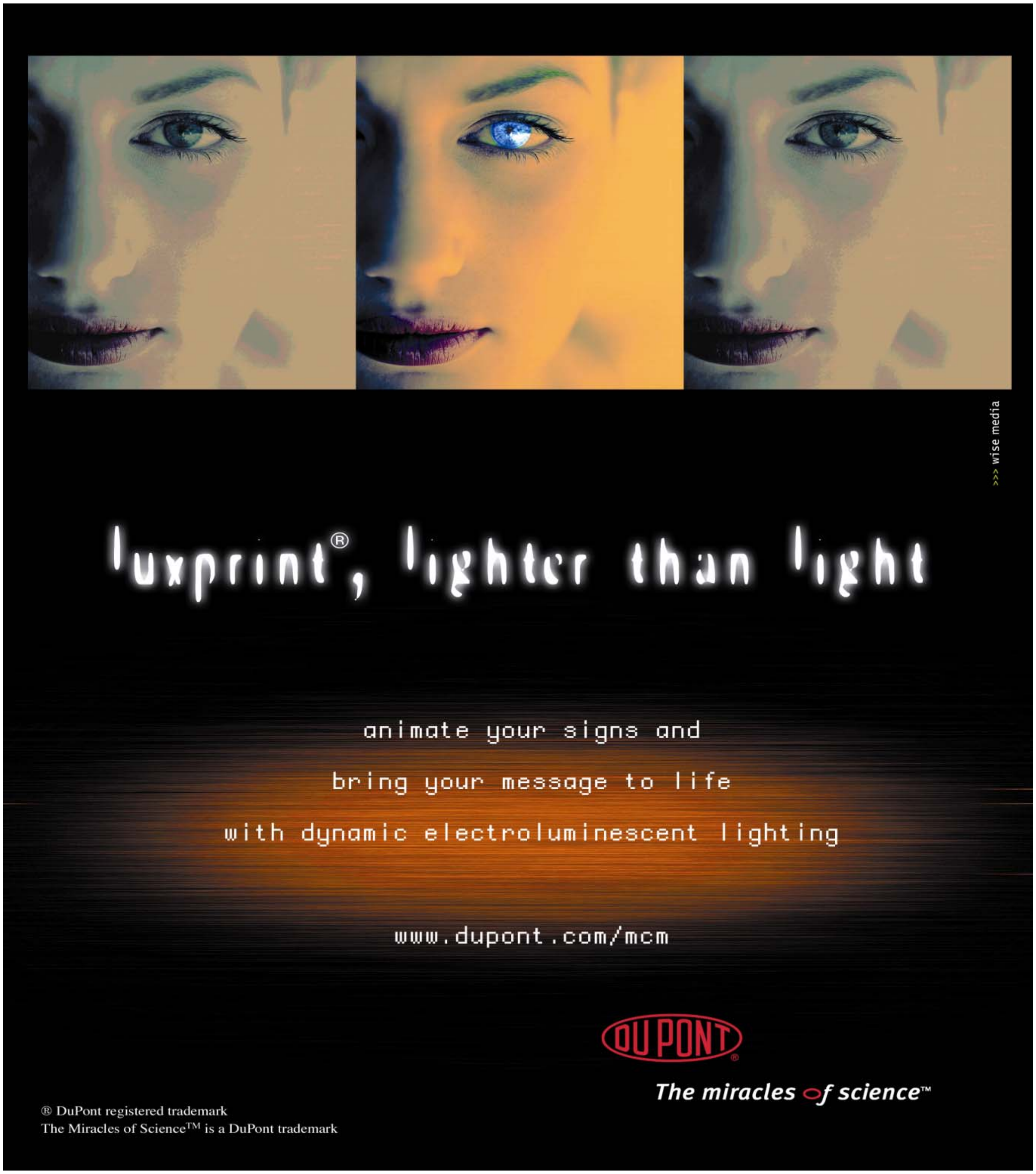
Processing Guide for DuPont Luxprint® Electroluminescent Inks



(Revised May 2012)

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 electroluminescent (EL) technology. For that reason, DuPont has developed a system of conducting, insulating and luminescent 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

The EL lamp is essentially a capacitor structure with an inorganic phosphor (zinc sulphide compound) sandwiched between the electrodes. Application of an AC voltage across the electrodes generates a changing electric field within the phosphor particles causing them to emit light. For most EL lamps, an inverter is used as a power source. An inverter is a DC-AC converter, which typically generates 60-115V AC and frequencies in the region of 50-1000 Hz. For signage applications much higher frequencies can be used to increase lamp brightness.

Light output gradually decays with time, as the luminescent efficiency decreases. 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 barrier, which further protects against moisture-related aging phenomena.

Higher voltages and frequencies, as well as elevated temperatures during operation, will reduce the lifetime of the lamps. Operation at lower temperatures, voltages and frequencies should be encouraged, with 80 - 120 V AC and 400 Hz being typical conditions.

The following provides descriptions of process steps and materials which have proven important in successful implementations of the DuPont Luxprint® EL system to date. The recommendations and descriptions found herein are based upon experience gained during the development of these inks. Process optimization 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 Luxprint® materials system provides the inks needed to make EL lamps by screen printing. Other materials, such as the transparent sputtered ITO (Indium Tin Oxide) polyester substrate, 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 utilized as a thin conductive coating on polyester, or other film base.

EL Application - Advertising (POS) An eye-catching series of
Sequenced lighting patterns

81XX Type System: Higher brightness/moisture resistance than the 71XXJ System and designed for more demanding applications.

Table 2	Product Number
Phosphors	8150B or 8150L White Phosphor 8152B or 8152L Blue-Green Phosphor 8154L Yellow-Green Phosphor
Dielectrics	8153 High K Dielectric Insulator
Conductors Build Sequence 1	8144 Rear Electrode, Carbon Conductor (with UV Encapsulants) 7152 Rear Electrode, Carbon Conductor (with 7165 Encapsulant) 7162 Front Electrode, ATO (Antimony Tin Oxide) Translucent Conductor 9145 Rear Electrode, Silver Conductor (also for bus-bar and termination)
Conductors Build Sequence 2	7102 Rear Electrode, Carbon Conductor (if overprinting 5000 Ag) 7105 Rear Electrode, Carbon Conductor 5000 Rear Electrode, Silver Conductor (also for bus-bar and termination) 7164 Front Electrode, ATO (Antimony Tin Oxide) Translucent Conductor
Protective Encapsulant Build Sequence 1	5018A Clear UV Cure Ink 5018G Green UV Cure Ink 5018 Blue UV Cure Ink 7165 Clear Solvent Ink (single print only)

EL Application – Advertising (POS) – Glowing Eyes Sequence

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. For outdoor use additional moisture protection and UV protection are essential.

There are various lamp builds possible, with the two most common constructions described below.

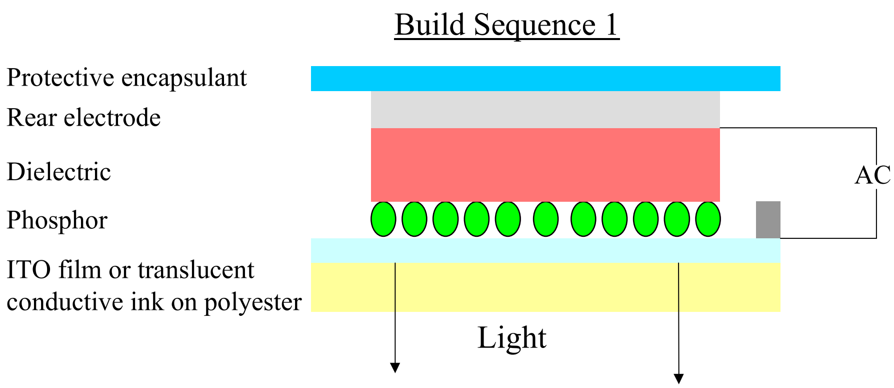
Build Sequence 1

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 (< 25 microns total dried thickness), which will give a brighter lamp but may reduce the yield and reliability, or
(b) 3 prints of dielectric (> 25 microns total dried thickness) (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 alone, unless it is overprinted with a silver grid, as the carbon resistance is too high. The final product should be laminated to provide protection from moisture and electrical isolation, for safety reasons. Alternatively, a protective layer can be screen-printed using UV cure ink or solvent ink. (See Diagram Build Sequence 1).

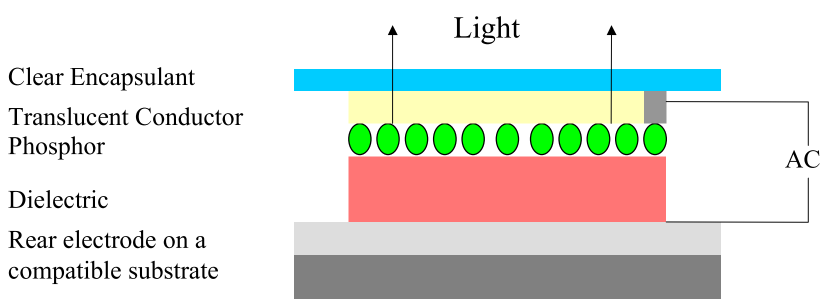
5018/A/G screen printable UV cure inks or 7165 solvent ink can be used as an encapsulant in order to provide electrical insulation and extra protection against humid environments. The UV encapsulants do not adhere well to ITO-sputtered film, so it is recommended to limit the print area of the 5018/A/G to that of the underlying dielectric. 7165 adheres well to ITO film but can only be used in a single print. In more complex EL lamp constructions, 2 layers of 5018/A/G can be used as an effective insulator where conductor crossovers are present. Printing local crossovers may cause cracking over the dielectric, and it is therefore advisable to print the first UV encapsulant layer over the whole lamp area. A thick, single print of 7165 solvent encapsulant can be used as an option. When using a carbon rear conductor, 7165 should be used over 7152 instead of 8144.

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 elevated temperature drying conditions.

Build Sequence 2



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).

Lamps must be protected against moisture and fully evaluated prior to use.

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/sq can be used although 200 Ω/sq or less is recommended. Heat stabilized 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/sq to 3000Ω/sq. 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, screen printable translucent conductive ink can be used as the front electrode. 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. Consequently, lit areas need to be kept small so that good uniformity of illumination is achieved. Test lamps have been constructed with an area 10cm x 5cm without noticeable darkening towards the center of the lamps (powered at 100V/400Hz). Although there are 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 center of the lamps. It is advisable to use frequencies below 800Hz.

Bus-Bar

It is highly recommended to print a silver bus bar close to the lit area around the perimeter of the translucent conductor. This improves the light uniformity by lowering the contact resistance and minimizing voltage drop across the surface (vs. using 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 stabilized, print treated polyester.

- Translucent conductor 7162 is printed first. This uses ATO conductive particles, which have a neutral gray color.

- 9145 silver bus bar printed next (optional if carbon rear electrode).

- Phosphor is printed next, with a choice of output color.

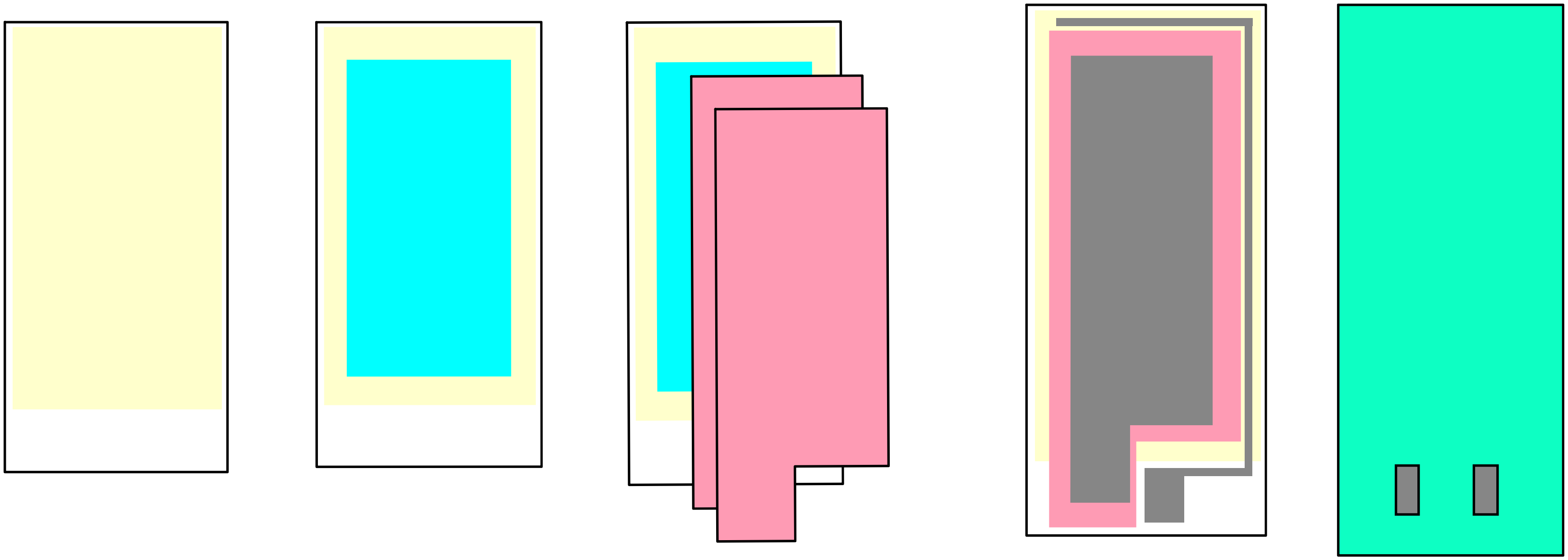
- The phosphor is followed by 2-3 layers of dielectric.

- 9145 Silver or 8144 Carbon is printed onto the dielectric. These compositions are compatible and their use is highly recommended. It has been found that various alternative conductors have adversely impacted the short/long term lamp performance.

- Lamp encapsulation with UV cure ink 5018/A/G or solvent based 7165 has been found to provide additional protection.

Lamp Build Sequence 1
DuPont Electroluminescent Material Recommendation

BASE/ PRINT 1	PRINT 2	PRINTS 3 & 4	PRINT 5	PRINT 6



Front Electrode on Base ITO Polyester Film 7162 ATO on Polyester 9145 Silver bus bar	**Phosphor** 8150B or L White 8152B or L Blue-Green 8154L Yellow-Green	**2 – 3 Dielectric Layer** 8153 High K	**Rear Electrode &** **Front Bus bar** 8144 Carbon 7152 Carbon 9145 Silver	**Protective** **Back Layer** 5018/A/G UV Cure 7165 Solvent Ink

b) Build Sequence 2

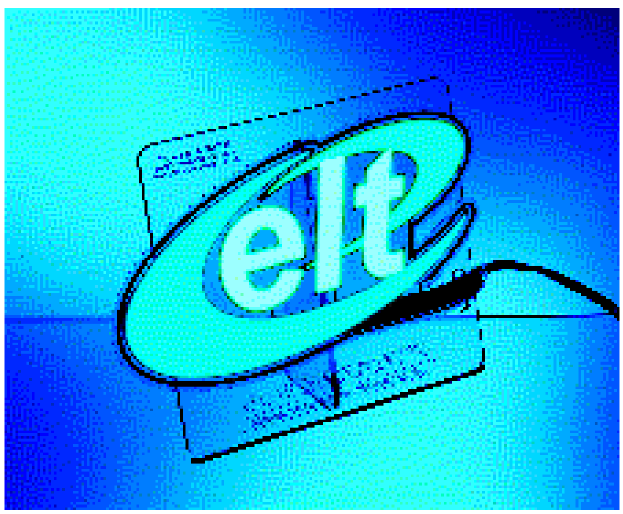
- With polyester, it is advisable to use a heat stabilized, print treated surface. Other substrates can be used, e.g. FR4 printed circuit board, providing they are compatible with the solvent and resin system and can withstand drying at 130°C.

- 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 / 7105 Carbon as the rear electrode.

- This is followed by 8153 dielectric over the rear electrode.

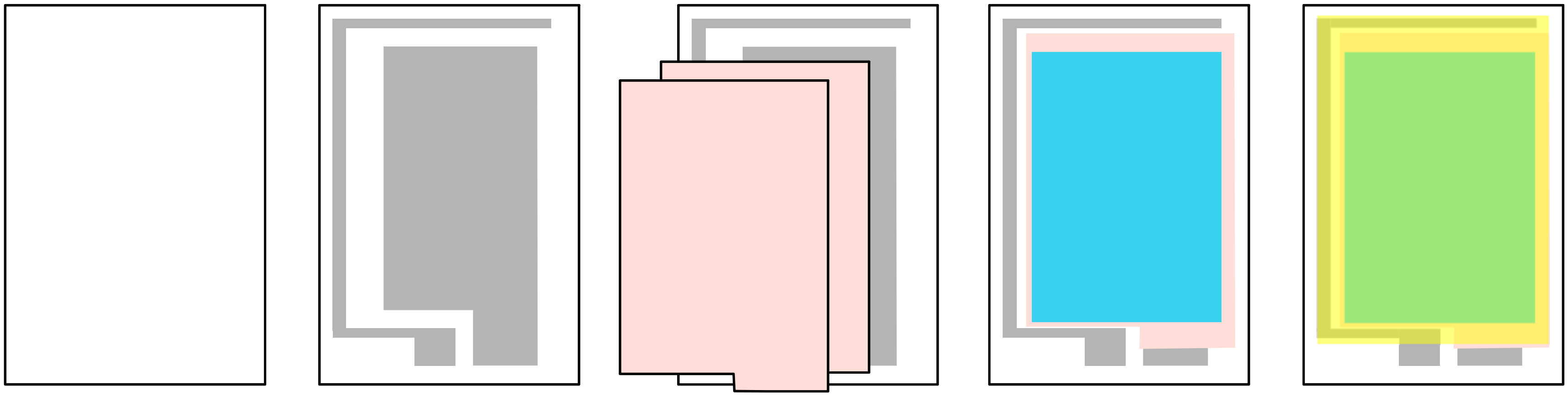
- The next print is phosphor.

- Finally, the translucent conductor 7164 is printed over the phosphor ensuring there is good contact to the silver bus bar.



El Application – Advertising. Multi-color sequence design.

Lamp Build Sequence 2
DuPont Electroluminescent Material Recommendation



BASE	PRINT 1	PRINTS 2 & 3	PRINT 4	PRINT 5
Base Substrate	**Rear Electrode & Front Bus bar**	**2 - 3 Dielectric Layer**	**Phosphor**	**Translucent Front Conductor**
Various e. g. polyester, FR4 Printed Circuit Board	5000 Silver 7102 Carbon 7105 Carbon	8153 High K	8150B or L White 8152B or L Blue-Green 8154L Yellow-Green	7164 ATO

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. Jar rolling 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 settle, so gentle jar rolling at 2 –5 rpm is recommended before use.

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) 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 optimized 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 losses. However, the use of too much thinner or the use of a non-recommended thinner may affect the rheological behavior 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 3 has a list of suggested polyester screens that may be used. Further optimization may be necessary de-pending on printers and processing conditions used.

Drying

Drying at 130°C for 15 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.

Test Strips

During construction of the lamps, the use of test strips at the edge of the prints is highly recommended. These will enable batch to batch consistency checks as well as on-going quality controls. These areas can also provide vital processing information if fault finding is necessary.

Table 3 Print Screen Selector for 81xx Systems

Product number	Polyester mesh (threads/inch)	Thickness (µm)	Coverage (cm²/g)
Phosphor 8150B or L White 8152B or L Blue-Green 8154L Yellow-Green	156	30 - 40	100 - 150
Dielectric 8153	156 – 195	25 – 30 (3 layers) 18 – 22 (2 layers)	50 – 80 (3 layers) 70 – 100 (2 layers)
Conductors **Build Sequence 1** 8144 Carbon 7152 Carbon 9145 Silver 7162 ATO	195	6 – 10 6 – 10 6 – 10 8 – 12	350 – 400 350 – 400 300 – 350 300 – 350
Conductors **Build Sequence 2** 7102 Carbon 7105 Carbon 5000 Silver 7164 ATO	195	6 – 10 6 – 10 6 – 10 6 – 10 8 – 12	350 – 400 350 – 400 300 – 350 300 – 350 300 – 350
Protective **Encapsulants** 5018/A/G UV Cure 7165 Solvent Ink	195 156	25 – 35 (2 layers) 6 – 10 (1 layer)	200 – 300 (2 layers) 350 – 400

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 that are available upon demand.

EL Product Summary & Selector Guide

Composition	Description	Comments	Product Numbers: High Brightness	Product Numbers: Long Life Automotive Grade	Screen Selector Guide: Screen Mesh Suggested (threads/inch)	Thickness (typical) (µm)	Coverage (approx) cm^2/g
Phosphors	yellow-green		**8154B***	**8154L**	156	30-40	100-150
	blue-green		**8152B**	**8152L**	156	30-40	100-150
	white	Pink off.	**8150B**	**8150L**	156	30-40	100-150
					156	30-40	100-150
					156	30-40	100-150
	Vehicle		**8155**				
Dielectric	Insulator	High K	**8153**		156-195	18-30	50-100
Conductors	**- Build Sequence 1**						
	Ag		**9145**		195	8	300-350
	C	Also Ag migration barrier	**8144**		195	10	350-400
	Translucent	Low cost non-ITO	**7162**		195	10	300-350
	- Build Sequence 2						
	Ag	Only for build seq 2	**5000**		195	6	300-350
	C	Only for build seq 2	**7102**		195	10	350-400
	Translucent	Low cost non-ITO	**7164**		195	10	300-350
Protection	Build seq 1	Solvent/ UV Cure	**7165/5018**		195	6/17	350
	Build seq 2	For small areas	**5018A**				350
	Complex Build Lamps						
X-Overs	Dielectric	Low K	**5018/A/G**		195	25-30 (2 layers)	>350

*8154B under development

EL Luxprint Colours

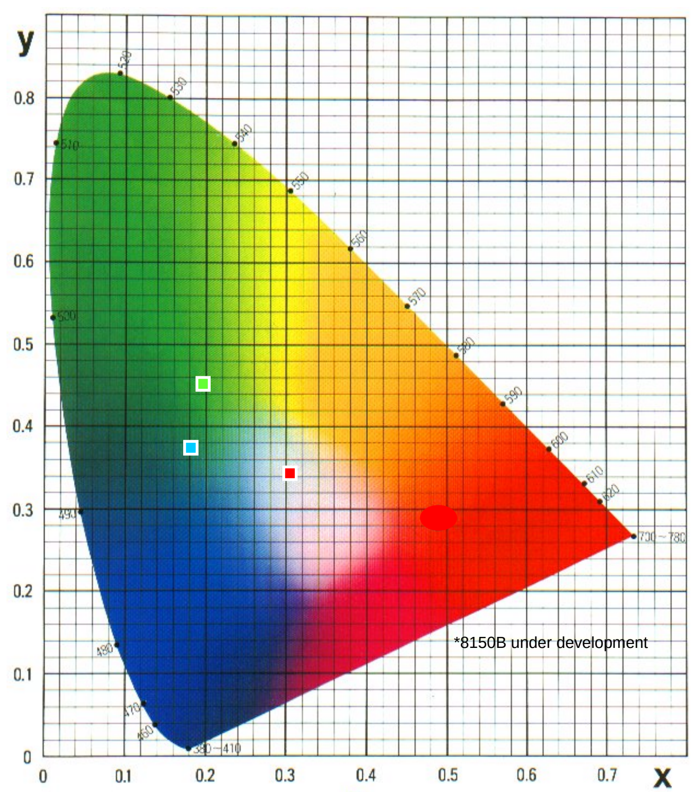
Approximate colour coordinates

CIE 1931 Chromaticity Diagram

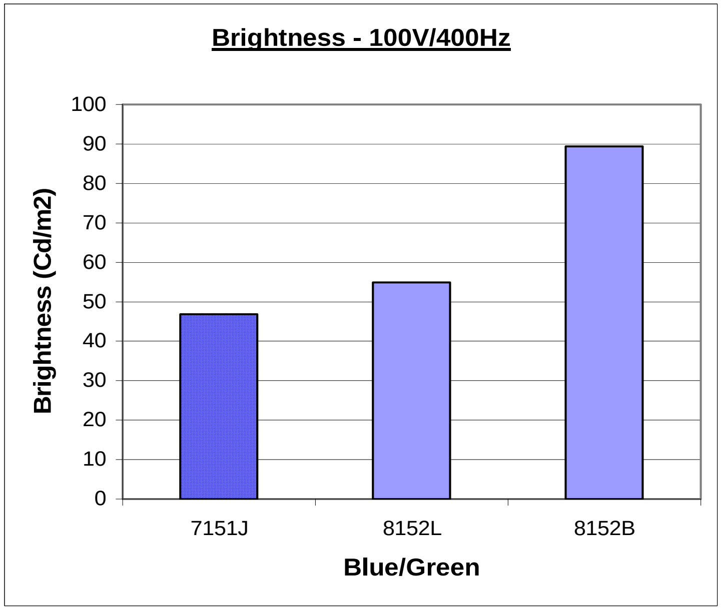
Yellow/Green

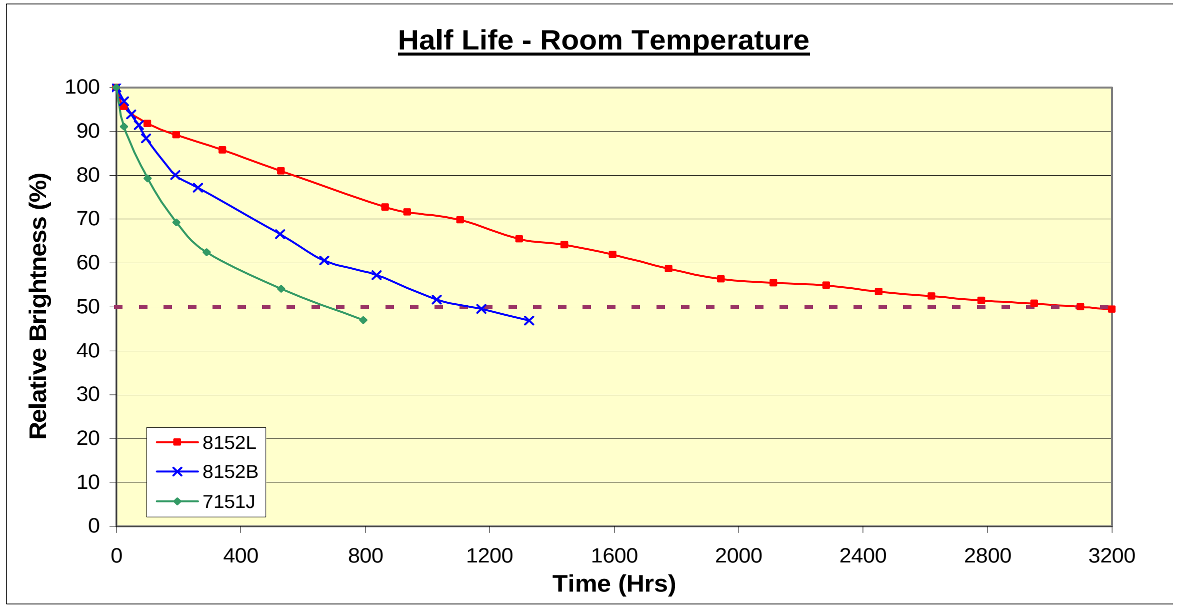
Blue/Green

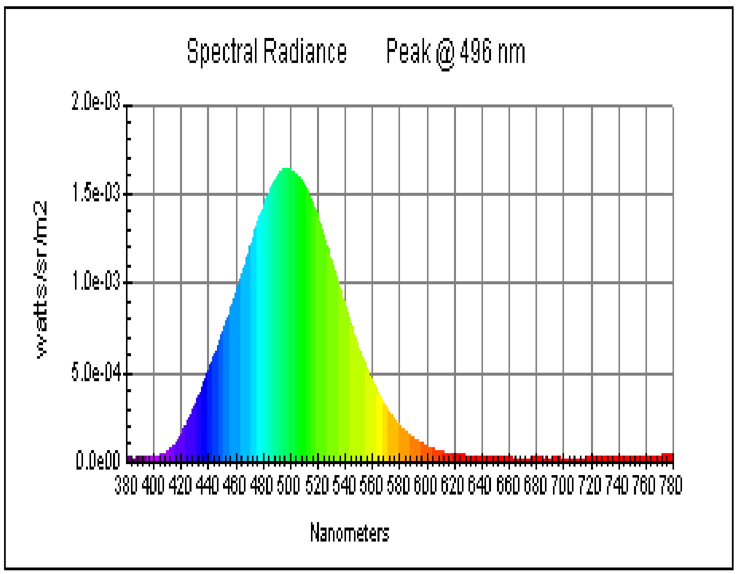
Pink White

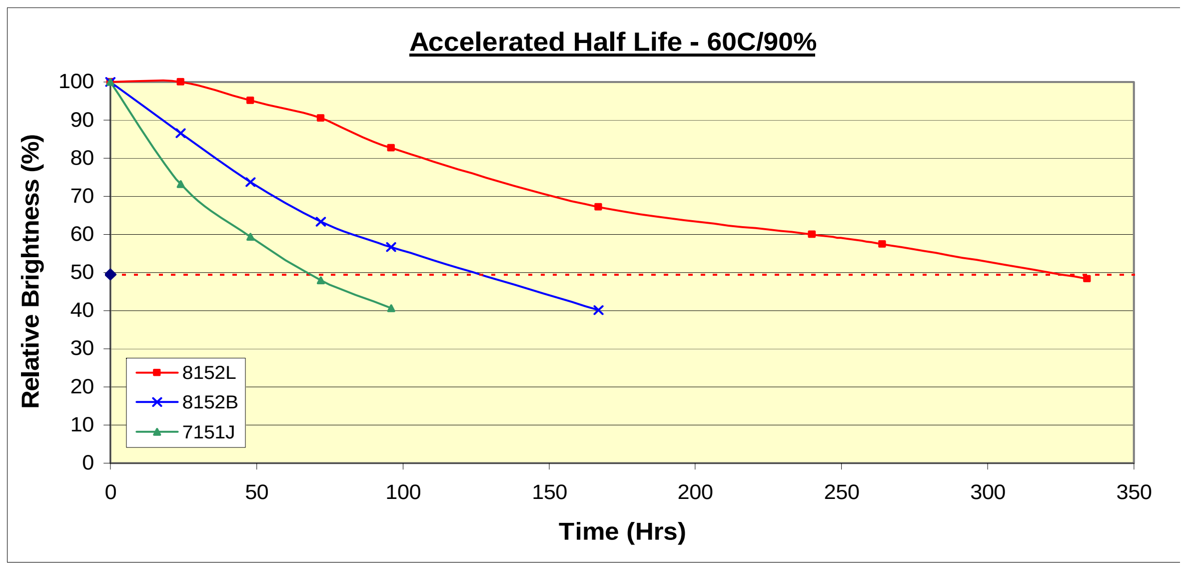


Blue/Green 7151J vs 8152L & 8152B



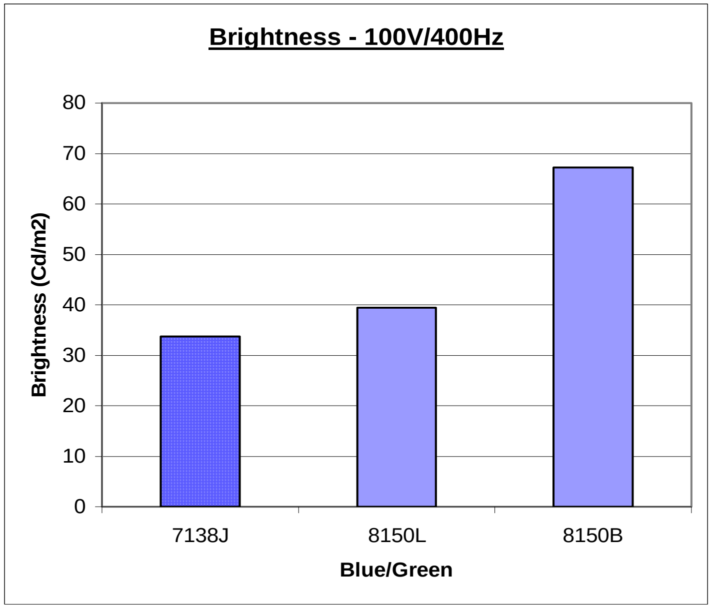


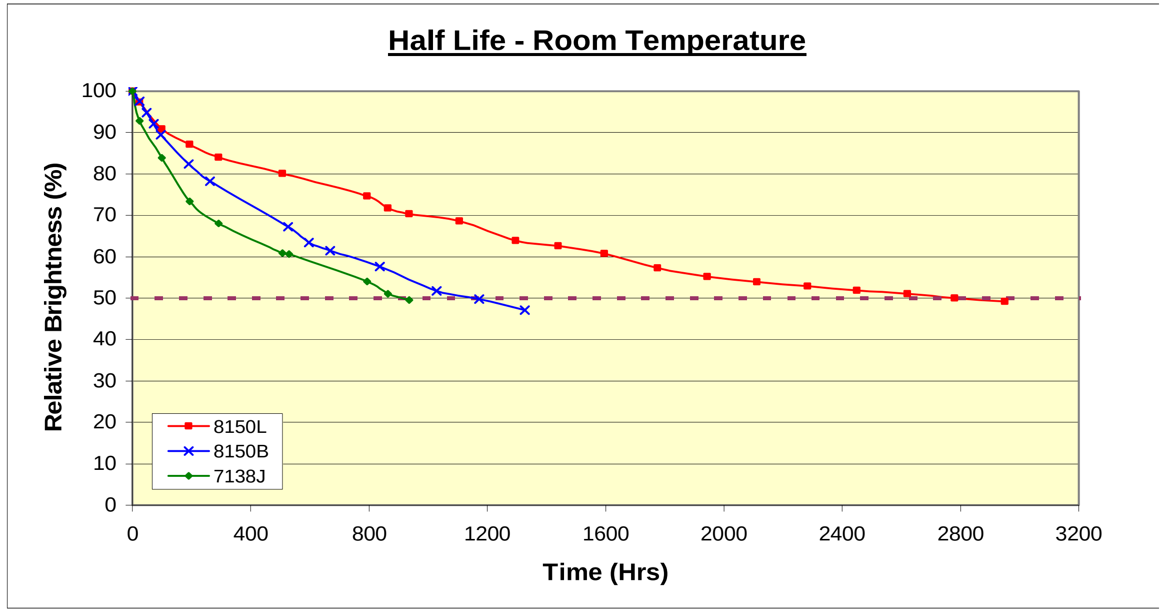


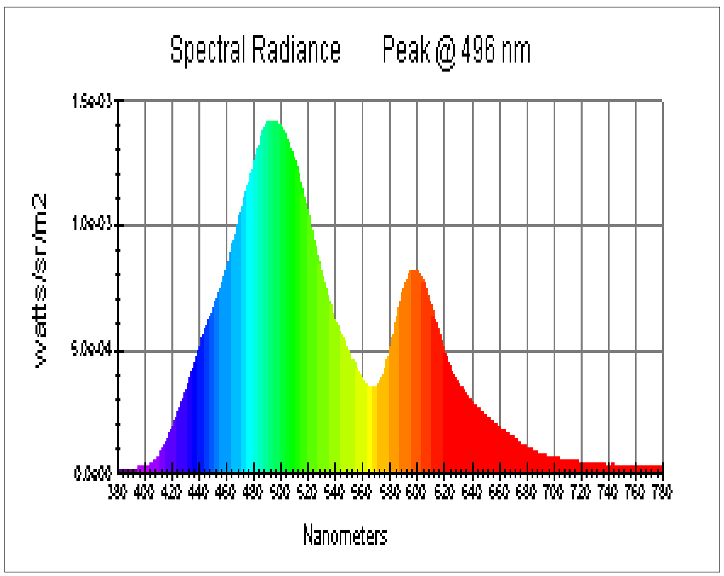


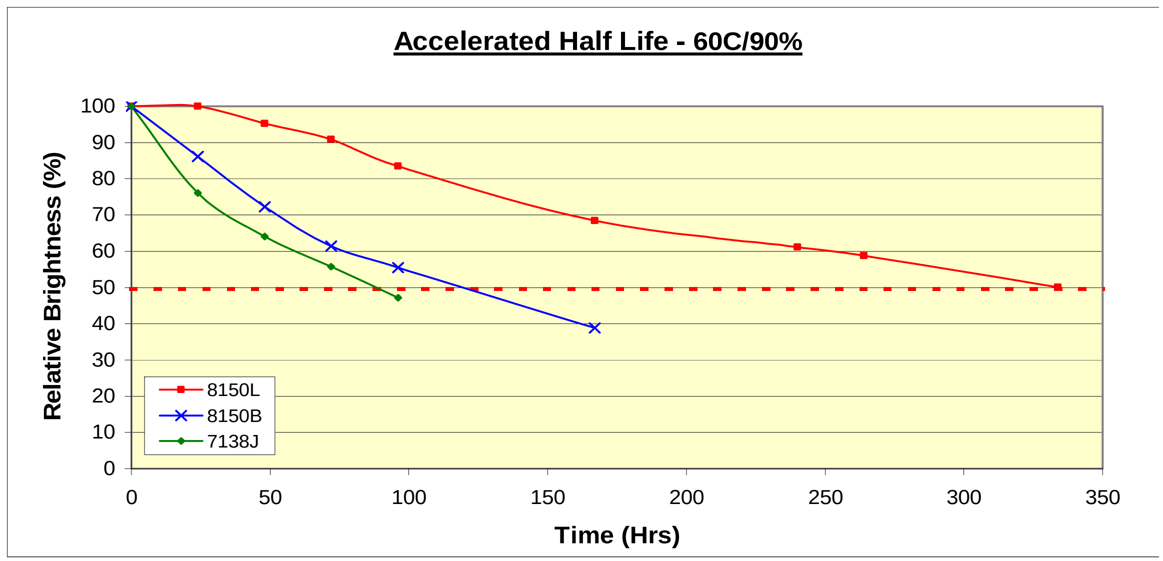
*NOTE 7151J IS NO LONGER COMMERCIALLY AVAILABLE. PERFORMANCE DATA ARE FOR COMPARISON PURPOSE ONLY.

Pink/White 7138J vs 8150L & 8150B



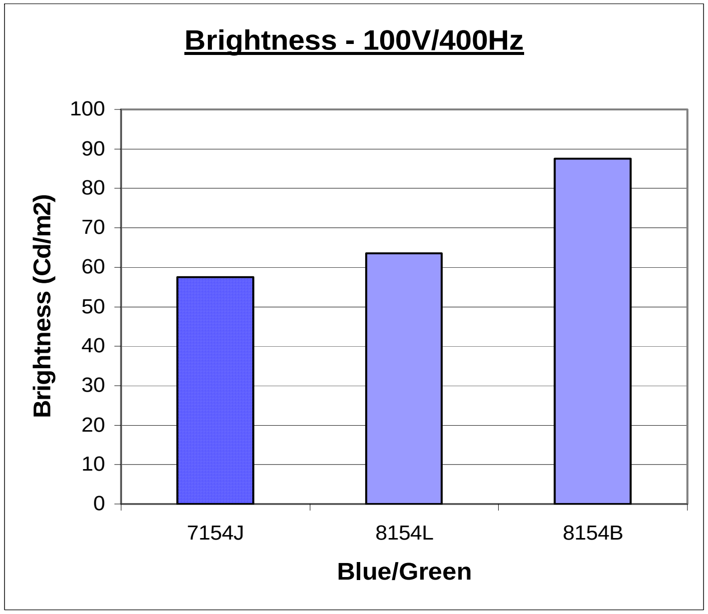


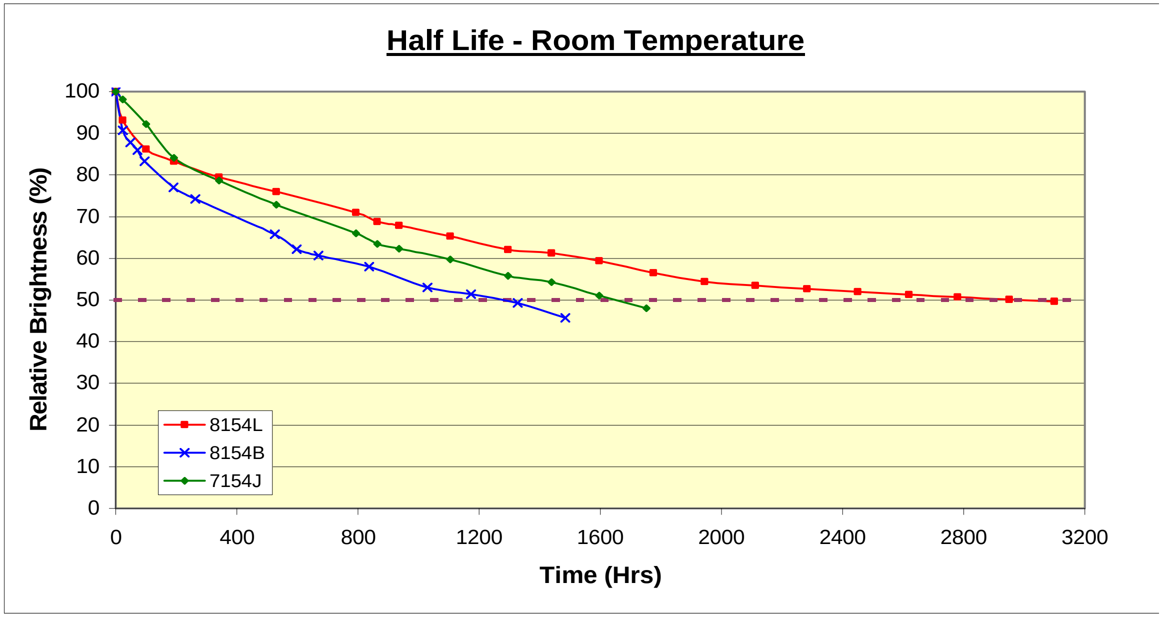


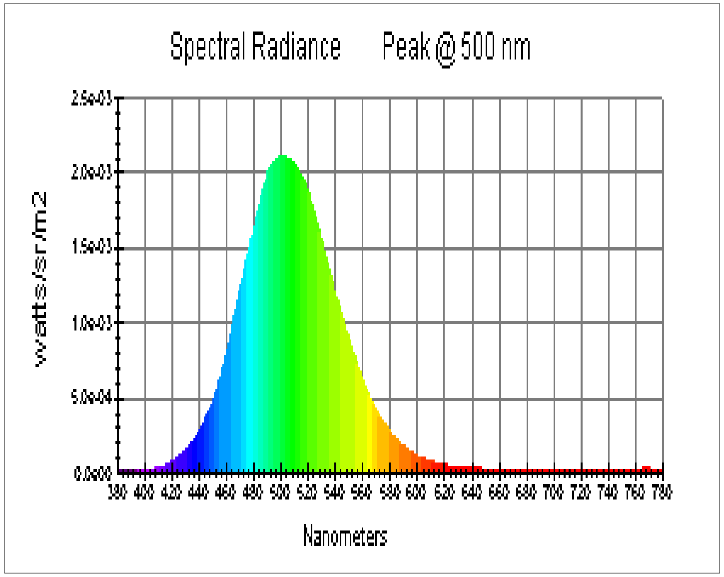


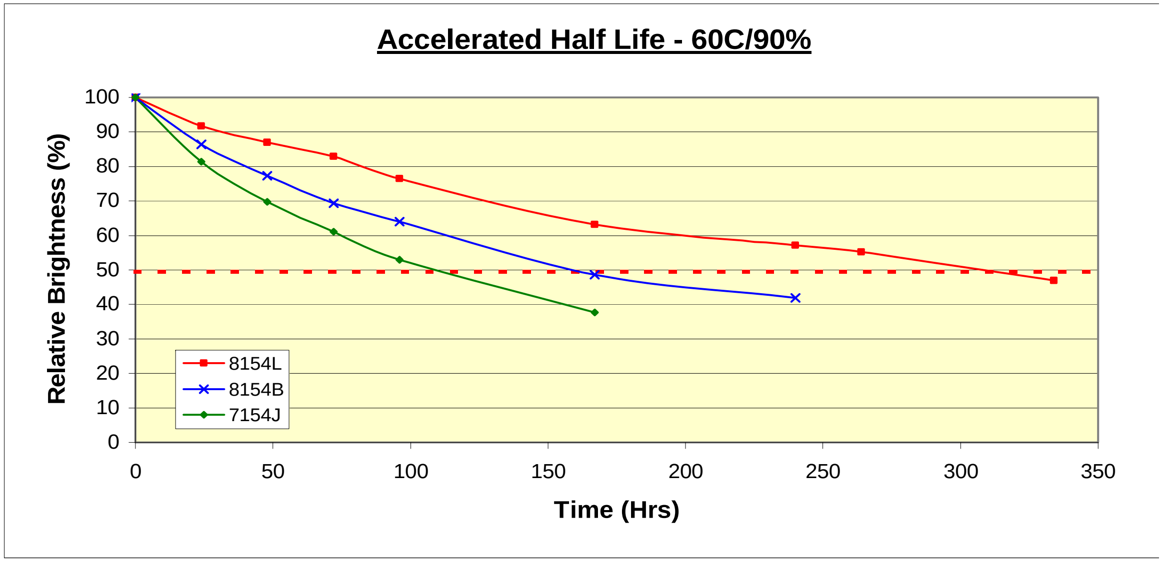
*NOTE 7138J IS NO LONGER COMMERCIALLY AVAILABLE. PERFORMANCE DATA ARE FOR COMPARISON PURPOSE ONLY.

Yellow/Green 7154J vs 8154L & 8154B









*NOTE 7154J IS NO LONGER COMMERCIALLY AVAILABLE. PERFORMANCE DATA ARE FOR COMPARISON PURPOSE ONLY.

Summary of Typical Phosphor Performance Data - Comparison Table

Composition	Colour	Brightness	Colour coord		Half Life		Electrical Properties (1 measurement set @100V/400Hz)						
					R/Temp	60C/90%	Capacitance	Impedance	Resistance		Phase Angle	Power Draw	Efficiency
									Series	Parralel			
							C	Z	Rs	Rp			
		Cd/m²	x	y	hrs	hrs	nF/cm²	Kohm/cm²	Kohm/cm²	Mohm/cm²	- deg	mW/cm²	Lm/W
7151J	blue/green	46.8	0.171	0.350	700	70	0.61	640	110	3.6	79	2.7	5.0
8152L	blue/green	54.9	0.171	0.379	2800	310	0.66	580	110	3.0	79	3.2	5.0
8152B	blue/green	89.4	0.165	0.395	1000	130	0.68	580	110	3.0	79	3.2	8.4
7154J	yel/green	57.5	0.176	0.422	1600	110	0.61	640	110	3.6	79	2.7	5.9
8154L	yel/green	63.5	0.177	0.429	3000	310	0.66	580	110	3.0	79	3.2	5.6
8154B	yel/green	87.5	0.182	0.463	1300	160	0.68	580	110	3.0	79	3.2	7.8
7138J	pink/white	33.7	0.295	0.337	800	90	0.61	640	110	3.6	79	2.7	3.8
8150L	pink/white	39.4	0.301	0.353	2800	330	0.66	580	110	3.0	79	3.2	3.9
8150B	pink/white	67.2	0.295	0.367	1100	120	0.68	580	110	3.0	79	3.2	6.5

*NOTE 7151J, 7154J AND 7138J ARE NO LONGER COMMERCIALLY AVAILABLE. PERFORMANCE DATA ARE FOR COMPARISON PURPOSE ONLY.

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