

Flexible Phosphor Sheet (8in x 11in)

RadiantFlex™

RadiantFlex™ is a new revolutionary patent-pending flexible phosphor sheet for solid-state lighting and display applications. This product offers unparalleled flexibility, not just in terms of its physical properties, but also the infinite possibilities and high durability that it offers the LED packaging and luminaire designer.

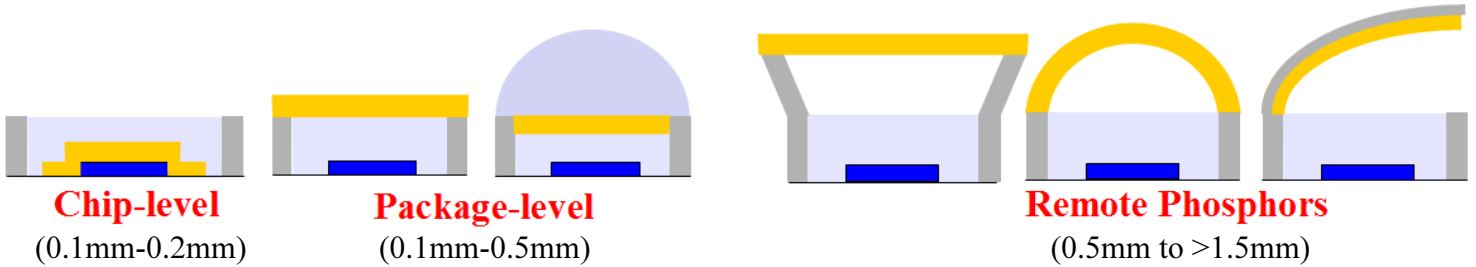
SPECIFICATIONS AND BENEFITS SUMMARY

- Super-strong and very light-weight with +/- 2.5% uniformity in color temperature
- High chemical resistance to oils, mild acids, alkalis, and water. Strong solvents/acids should be avoided.
- User-customizable to various sizes and shapes using off-the-shelf paper cutters
- Can be printed on and patterned using conventional digital printers or screen-printing
- Can be custom-produced with different spectral, CCT, and CRI properties
- Costs under \$0.005 per SMD LED and under \$0.15 per COB LED with bulk discounts
- Works as is or with a variety of adhesives, epoxies, and silicone
- High power density and high temperature operation
- Both on-chip AND remote phosphor applications possible
- 25-35% higher light output (0.2mm) compared to conventional remote phosphor plates
 - More than 10X thinner and 12X lighter
 - Virtually no light-piping or edge losses with Lambertian emission pattern
 - Superior optical properties and low scattering losses

AVAILABLE FORM FACTORS

- Products are currently being supplied as uniform 8in x11in sheets. Other custom shapes and sizes can be supplied upon request. Can be used with commercial die or paper cutters. Sheet thickness varies from 0.1mm to >1.5mm depending on application:
 - For remote phosphor applications, standard thickness is ~ 1mm, which is semi-rigid.
- Current products are produced using a high performance silicone on PET substrates. The silicone polymer is rated up to 260°C, which is also the PET melting temperature. It is, however, recommended that operating temperature be kept below 100C for best phosphor/sheet performance and long-term stability. Other substrates can be used for higher temperature operations. Please contact us for details. Acrylic-based polymers are also available. Lower temperature limit: -40°C
- Additional adhesives or encapsulating polymers can be used by customer for better mechanical, thermal, optical, and environmental performance.
- Special substrates that allow thermoforming can also be used for custom products.

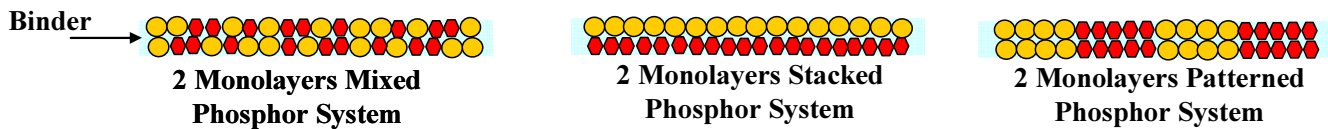
RadiantFlex™





Available Film Thickness Range: 0.1 mm to > 1.5 mm

Standard Remote Phosphor Product Thickness: ~ 1mm

OTHER POSSIBLE FORM FACTORS



The Three Main Components of RadiantFlex:

- Phosphors** (Process compatible with any phosphor, particle size, or shape) 
- Binder** 
 - Acrylic (<150°C)
 - Silicone (<260°C)
 - Inorganic binders (>>260°C) possible in limited cases (By Request)
- Support Substrate** (Any flexible/rigid polymer, thermoplastic, any flexible/rigid glass, any metal surface, sapphire, etc.)



↑
With or without
adhesive layer

OPTICAL PROPERTIES

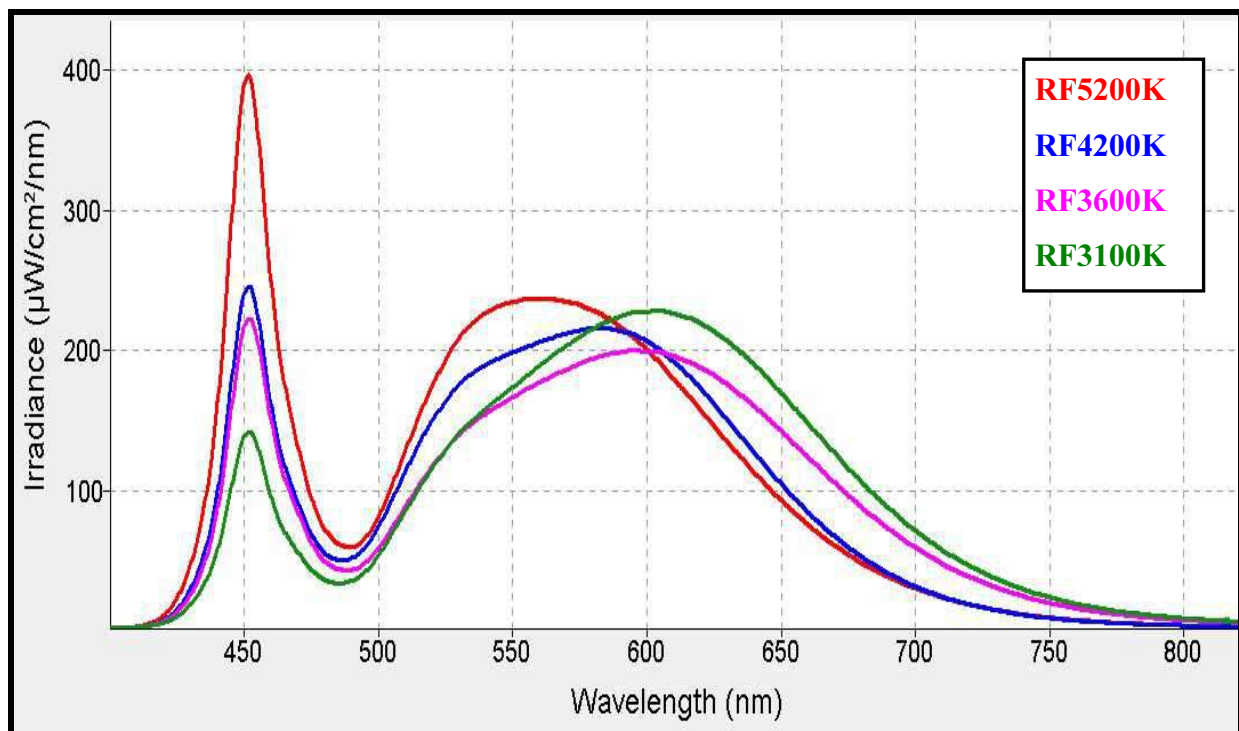
Blue to White (Standard CRI) Products

<i>RadiantFlex</i>	TYPICAL* CONVERSION EFFIC. (lm/W _{rad})	CIE x	CIE y	CRI#	CCT#
RF5200K	300	0.3398	0.3563	74.1	5217K
RF4200K	287	0.3769	0.3870	76.3	4168K
RF3600K	280	0.3957	0.3757	83.2	3597K
RF3100K	273	0.4345	0.4094	80.4	3084K

*Conversion efficacy (lumens out per blue watt in) was measured in transmission mode on 0.2mm thick samples with integrating sphere.

- Note: Additional 25-35% higher conversion efficacies could be achieved by customization to specific LEDs. Contact us for details.

#All CCT and CRI values correspond to CIE (x,y) coordinates on or near the blackbody locus when using a 452nm blue LED.



Relative Spectral Irradiance

RadiantFlex™

Blue to White (High CRI) Products

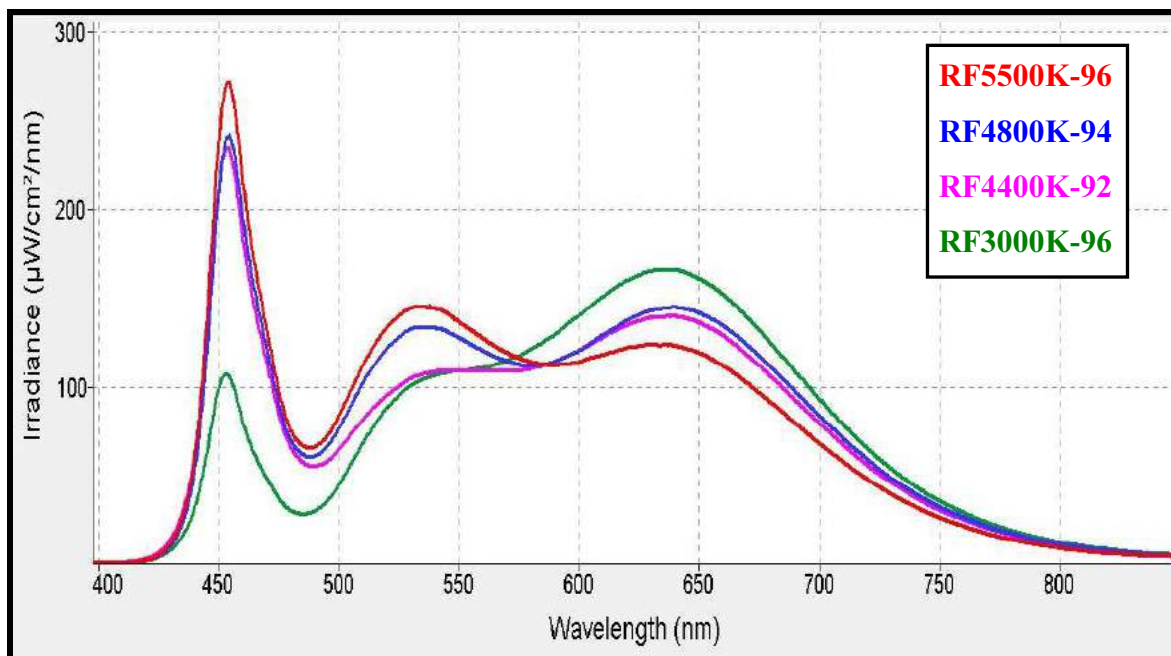
(Now with 30-35% higher efficacies compared to first generation products)

<i>RadiantFlex</i>	TYPICAL* CONVERSION EFFIC. (lm/W _{rad})	CIE x	CIE y	CRI#	CCT#
RF5500K-96	260	0.3326	0.3448	95.7	5495K
RF4800K-94	252	0.3523	0.3483	94.0	4760K
RF4400K-92	245	0.3583	0.3321	92.4	4376K
RF3000K-96	240	0.4319	0.3966	96.1	3025K

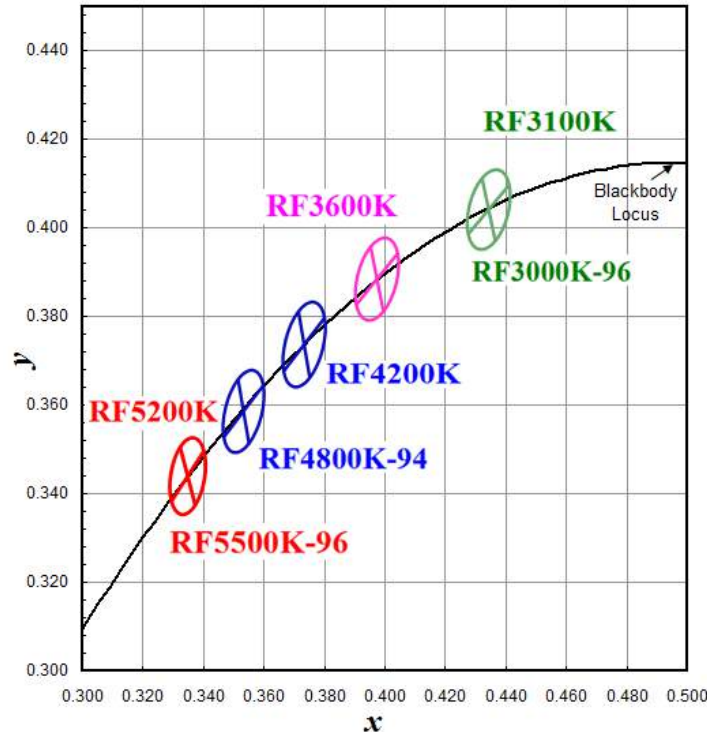
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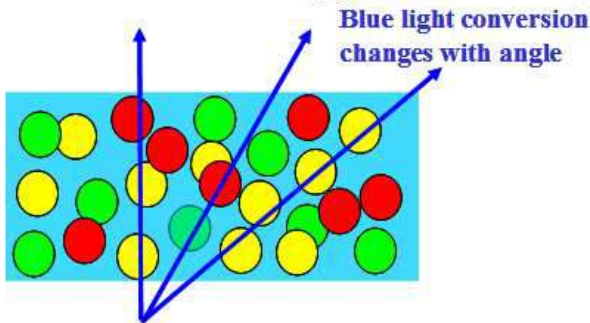


Relative Spectral Irradiance



CIE 1931 Color Chromaticity Diagram

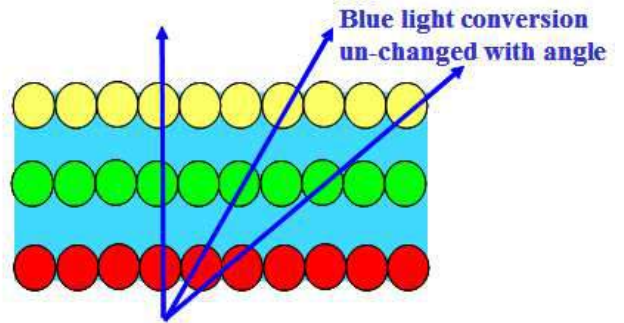
Conventional Approach



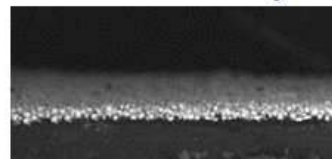
- Lower Efficacy
- Limited Spectral Options
- Color Non-uniformity:
 - with angle
 - with flux density



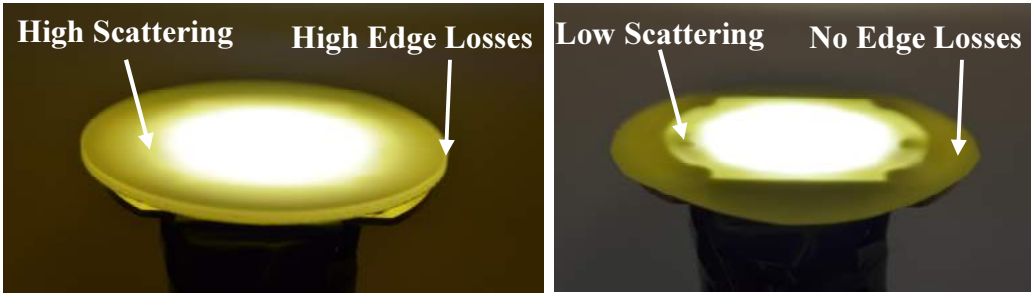
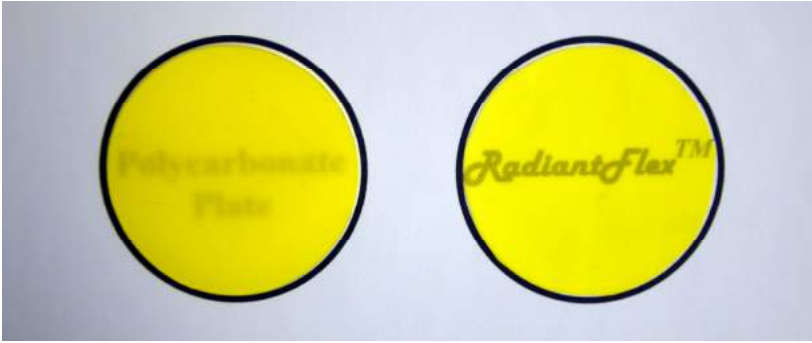
RadiantFlex™ Approach



- Higher Efficacy
- Flexible Spectral Options
- Uniform Color:
 - with angle
 - with flux density

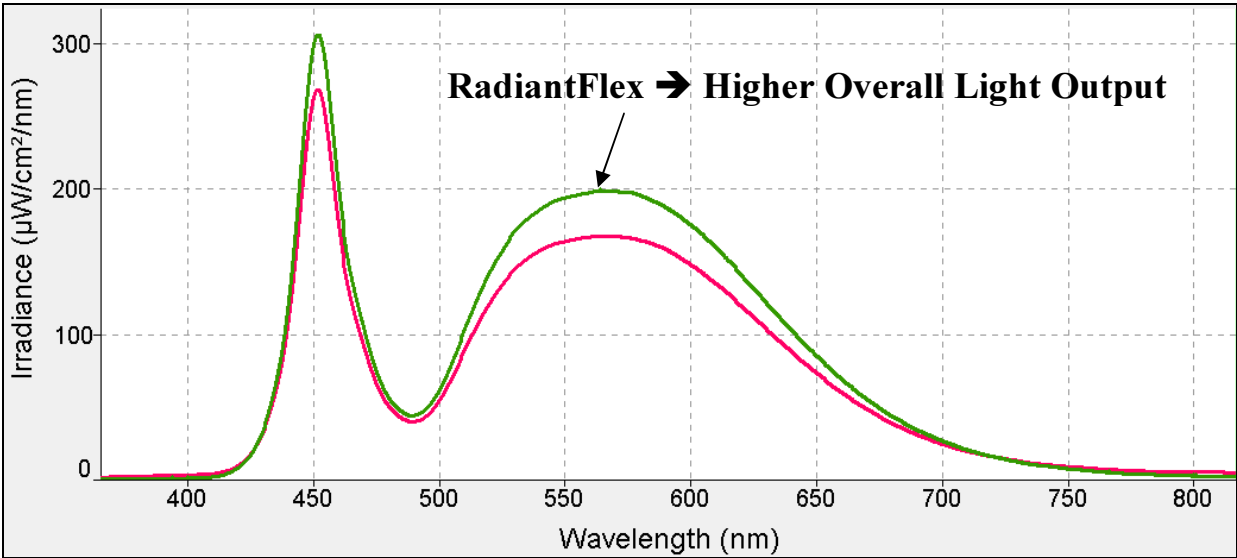


Superior Optical Performance

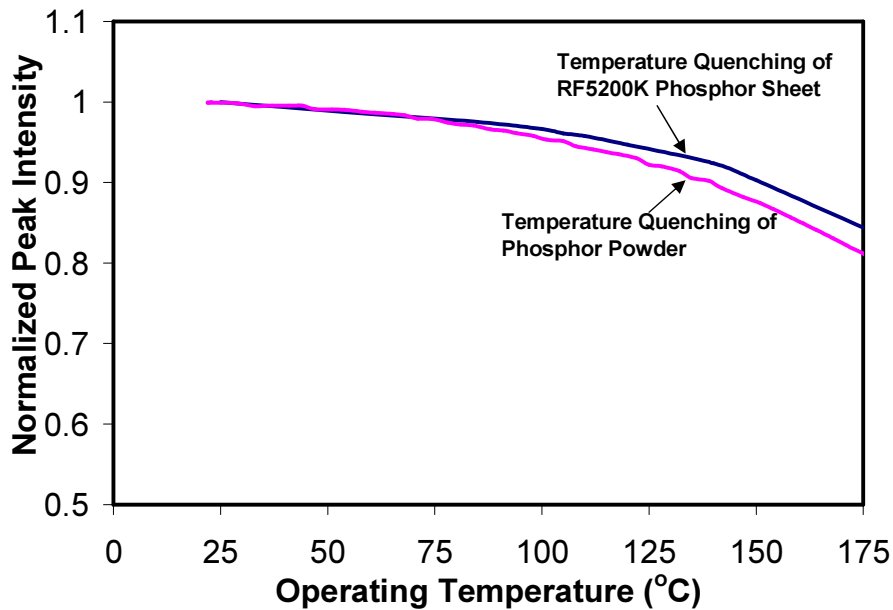


2.5in x 2mm Polycarbonate Phosphor Plate

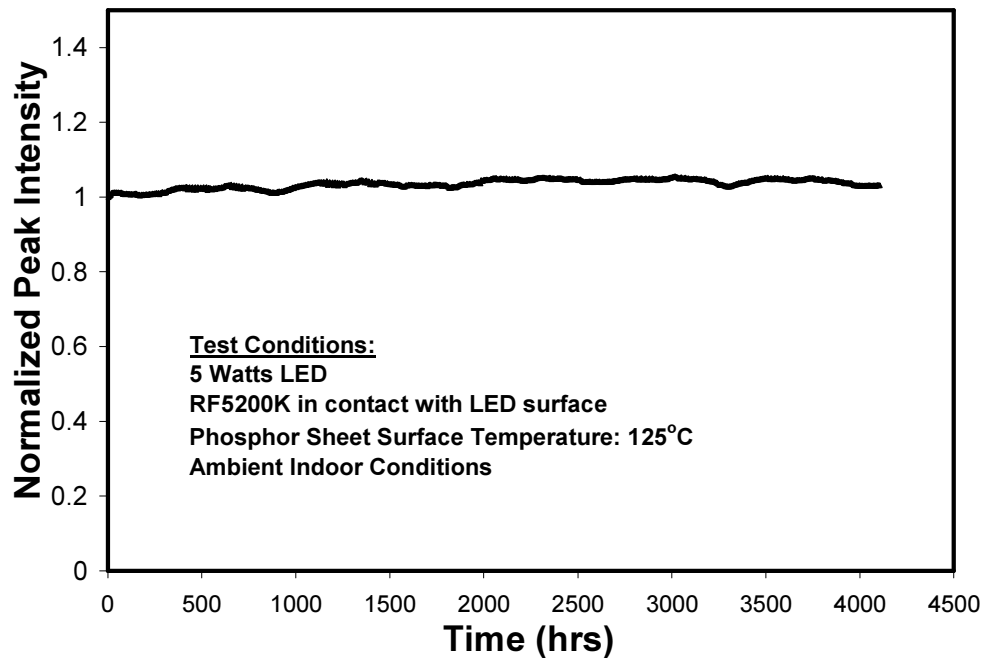
2.5in x 0.2mm RadiantFlex™



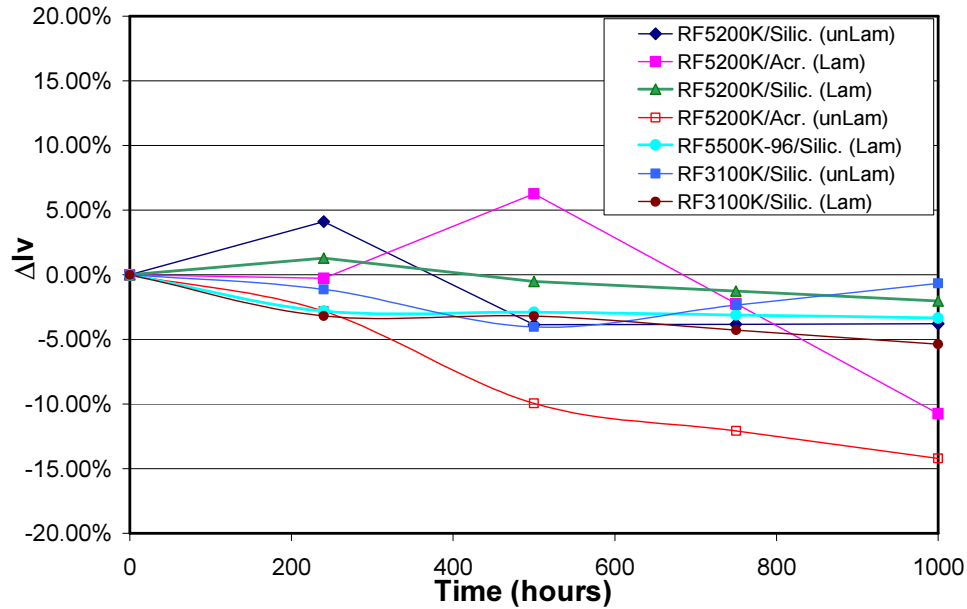
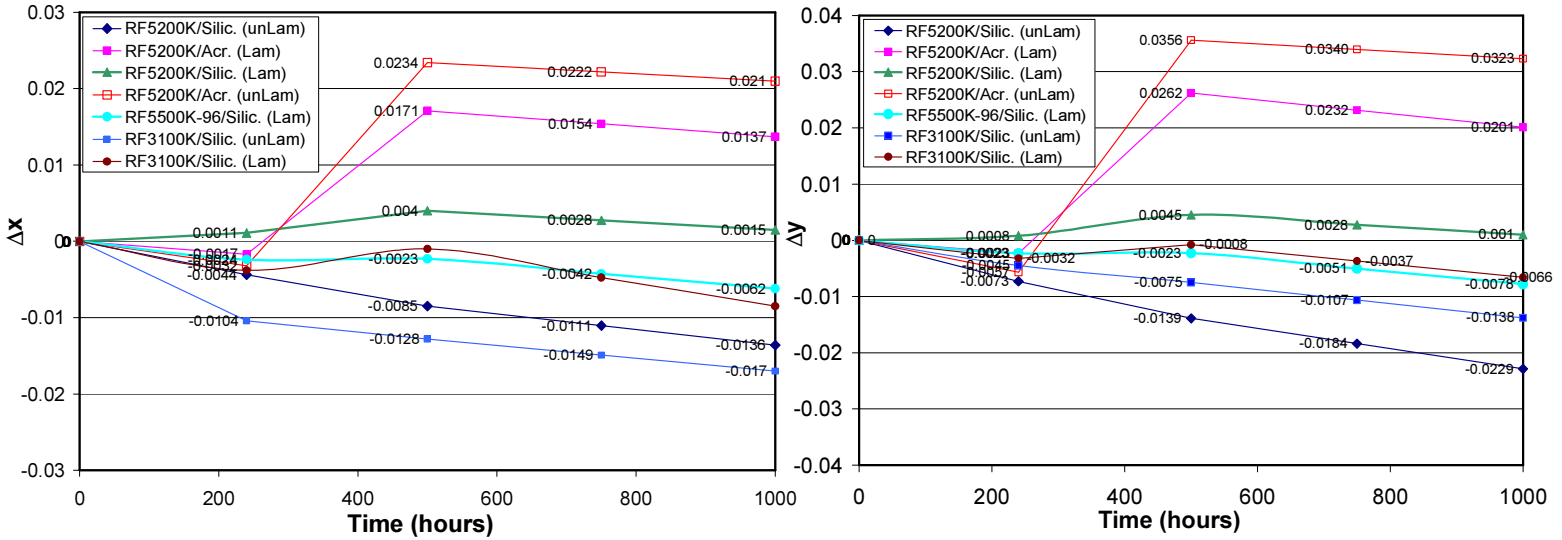
UNIQUE DESIGN WITH ENHANCED THERMAL PERFORMANCE



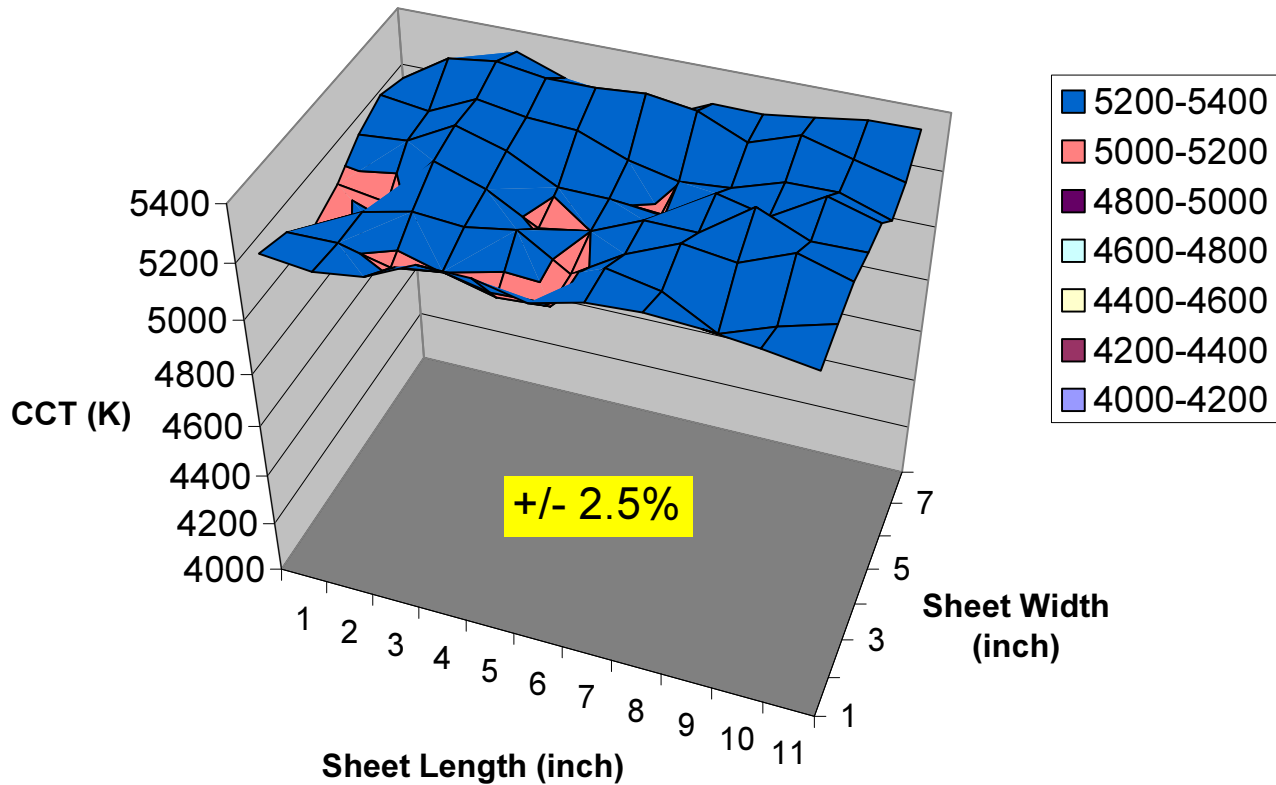
LUMEN MAINTENANCE



ACCELERATED AGING TEST (85°C/85%RH)



Sheet Color Uniformity



* Uniformity data shown is for the RF5200K product

Conventional Phosphor Plates

- High scattering & lower light output
- More than 10X thicker
- More than 12X heavier
- < 95°C operating temperature
- Limited shapes & no flexibility
- Polycarbonate-based, more susceptible to temperature and light aging

RadiantFlex™

- Low scattering & higher light output
- Thickness ~ 0.1mm to > 1.5mm
- Weight ~ 630 mg (2.5in, 0.2mm disk)
- T~260°C possible, in some formats
- Endless shapes & high flexibility
- Silicone/PMMA, less susceptible to temperature and light aging

IMPORTANT NOTES REGARDING THERMAL MANAGEMENT

The standard phosphor sheets supplied for conventional remote phosphor applications are laminated (both sides) to a thickness around 1 mm and are ready for use in lamp fixtures. Lamination protects the phosphors from the environment and provides a semi-rigid sheet that can be easily cut to any size or shape using off-the-shelf paper cutters. We can also supply these sheets pre-cut into any shape or size (strips, disks, etc.) for direct insertion into custom light fixtures. 1-sided laminated (0.5mm) RadiantFlex™ products are also available for applications requiring additional flexibility and performance but care must be taken in handling to prevent damage to the phosphor side. The same is true for the 0.2mm un-protected phosphor sheets, which should be treated with care similar to conventional LED phosphor powders and should also be further encapsulated or laminated for additional protection prior to testing. Encapsulation of the phosphor sheet (whether by PhosphorTech or the user) is required for the following reasons:

- 1) To protect the phosphor layer from damage and/or environmental factors during handling and operation, especially high humidity conditions.
- 2) To achieve higher rigidity for handling and/or remote phosphor applications.
- 3) To increase sheet thickness and thermal performance – a thicker overall sheet allows for better heat dissipation and operation at higher power densities. Applying a thin layer of silicone on one or both sides of the sheet will also aid in thermal management, especially when mounted on a secondary substrate. Inadequate thermal management under high LED power densities can result in localized temperature increase and subsequent damage to the product.

Any of our current or custom products can be applied to a wide variety of substrates. The substrate and binder choices depend on the specific application and power density. Phosphor films for extremely high power density (laser) applications are possible on non-plastic substrates. Phosphor films that can operate at blue (445nm) power densities as high as 30 W/mm² have been demonstrated on both glass and metal substrates. If you have any questions or require additional information, please do not hesitate to contact us. Thank you for your business!

The PhosphorTech Team