The Need for Long-Term Quantitative Characterization of SSL Diffusers

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Soraa History Milestones

1962 — FIRST LED (RED)

1993 — FIRST BLUE LEDS

2006 — GaN on GaN LEDs INVENTED

2008 — SORAA FOUNDED

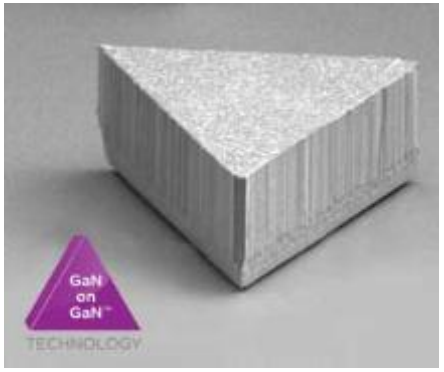
2012 — FIRST GaN ON GaN™ FULL SPECTRUM LIGHTING PRODUCT

2014 — GaN-on-GaN™ FULL SPECTRUM LAMP PORTFOLIO

2015 — OPTICAL LIGHT ENGINES

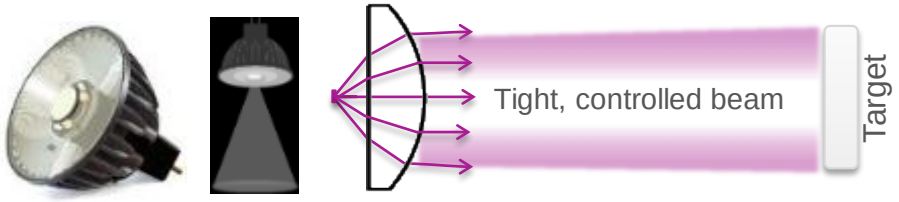
BR

Soraa Technology: Elements of Perfect Light



High efficiency GaN on GaN LEDs enable highest lumens per LED area

POINTSOURCEOPTICS™

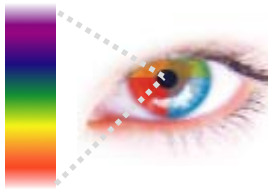


Point source with prism optics creates brightest, most uniform beams at lowest power

VP3 NATURALWHITE™

Violet emission with proprietary phosphor enables accurate and natural whites

VP3 VIVIDCOLOR™



Exceptional rendering of colors across the full spectrum

SSL Products vs. Materials Testing

- End product testing is the most direct way to evaluate both short and long term performance, with a high level of confidence.
- However, the outcome of such testing can be much too product-specific and is not always useable across the full product line.
- Long term product testing creates a significant financial burden (especially if done on each and every SSL product) and delays introduction of new products.

- Material level testing is applicable to all products using the same material.
- The hardship here is translating correctly the specific testing conditions used for the materials to “real life” operation conditions in end products.
- A mix of product and material testing is usually needed for optimal time and testing resources management.

Initial vs. Long Term Testing

- Initial performance and light quality testing is done routinely on each new SSL product, and does not create an undue burden or introduction delays.
- Long term product testing is a very different matter. It is often a gating item for the release of new SSL products, especially those using design concepts radically different from those in the already existing product lines.
- The SSL industry (especially SSL lamp and luminaire design) is still evolving, and new design concepts are being evaluated all the time.
- Long term material testing (if done right) can help greatly with projecting the long term product performance and finding design flaws early on.
- "Doing it right" involves choosing test conditions leading to interpolation (rather than extrapolation) for "real life" situations, whenever possible. This applies to both key design parameters (such as temperature and irradiance) and key data collected (such as full spectra rather than single wavelength values).

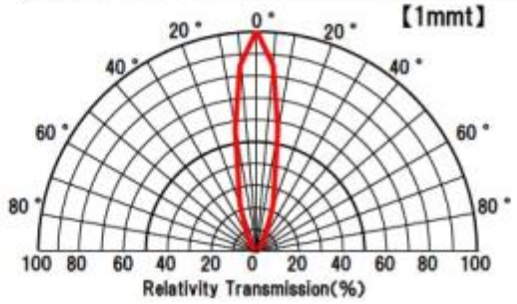
“Transparent” and “Diffuser” Materials

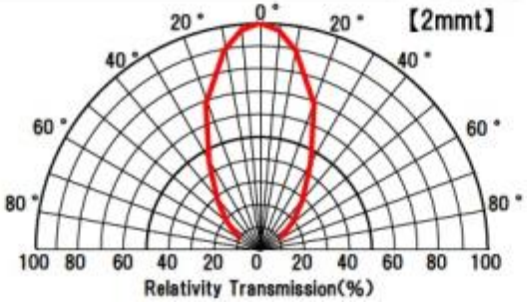
- Some materials can be used for both transparent components (such as lenses in a lamp) and diffuser components (such as “frosted” lamp envelopes).
- There are also materials designed exclusively for diffusers, e.g. containing scattering particles in a transparent polymer matrix.
- Whenever a “transparent” version of a “diffuser” material (e.g. a polymer matrix) is separately available, its evaluation can provide valuable additional information about the properties of that material, especially long term light degradation.
- Of course, certain properties require actual diffusers to be evaluated.
- BSDF is the most comprehensive diffuser characterization, particularly if collected over the entire spectral region of interest (especially over time). Virtually all information of interest can be extracted from BSDF data.
- There are also some lesser known metrics such as the diffusion angle.

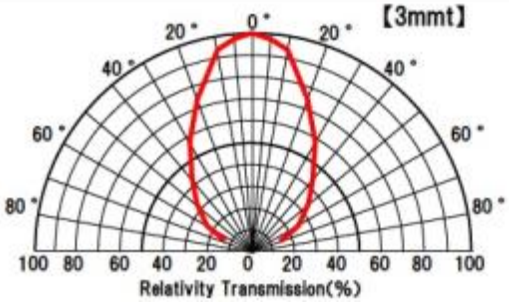
A Typical Data Sheet for Diffuser Material (Optical Properties Section)

Optical		
Total Luminous Transmittance, 1mmt/2mmt/3mmt, %	ISO13468	92 / 87 / 78
Haze, 1mmt/2mmt/3mmt, %	ASTM D1003	96 / 98 / 99
Diffusion Angle, 1mm/2 mm/3mm, %		11 / 21 / 28
Relativity Transmission		-

PROPRIETARY TESTS







Summary of Available Tests

- ASTM Yellowing Index
- ASTM Weathering Tests
- ASTM UV Exposure Tests
- ASTM Haze Tests
- Other ASTM Tests?
- Other Tests???

No industry-wide test protocol seems to exist for collecting full transmittance or reflectance spectra over time, as a function of ambient temperature and/or irradiance

Some Past Efforts Towards Developing a Method for Evaluating Long Term Degradation of SSL Polymers

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Excerpt from a Project Initiation Form in IES TPC SC S (SSL):

Currently, there is no industry-wide method for evaluating and comparing the degradation of polymers used in LED packages, lamps, engines and luminaires.

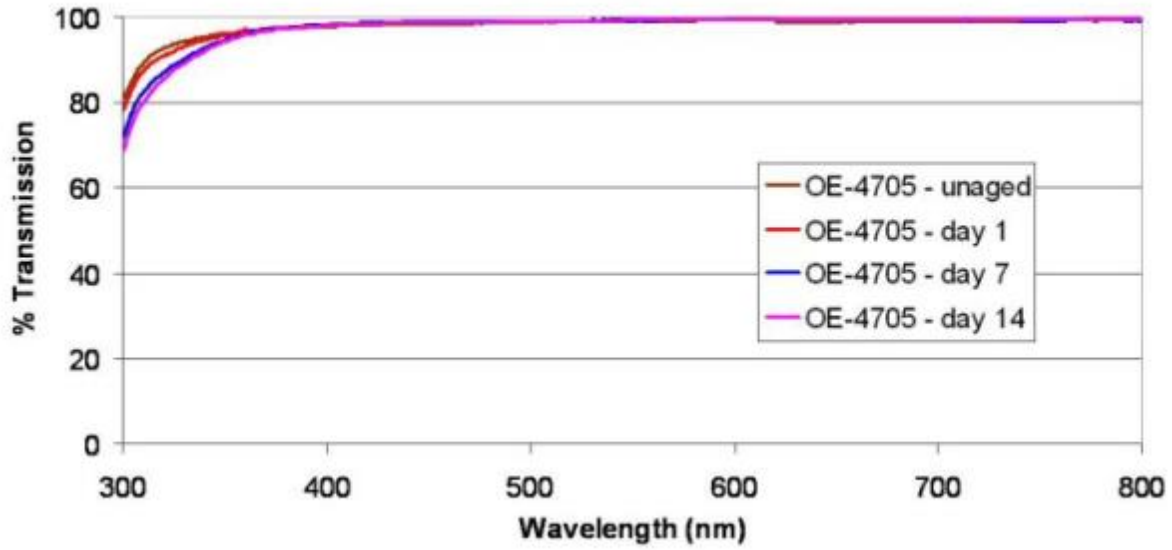
Internal testing protocols exist at various locations but are typically not shared, and each has its own set of test conditions. This makes the comparison of similar materials evaluated at different locations very difficult.

It is therefore necessary to develop a standardized method for testing and clearly reporting both the test conditions and results, to enable accurate comparisons, which should benefit the users of SSL products in the end.

This project was turned over to ASTM in June 2015. There has been no further action from there since.

Existing (Less and More Useful) Data

- Data available in the public domain are mostly for unaged materials at room temperature.
- These data are often values for a single wavelength (e.g. n=1.586 at 589 nm). This is much less useful than providing Sellmeier coefficients instead.
- Limited spectral data are available for materials aged at elevated temperatures, as in the published graph shown below which can be considered a “best practices” example.



Irradiance is Also a Major Factor

- **Virtually no data for it exist in the public domain**
- **At least one manufacturer providing an elevated temperature + irradiance test chamber**

Aging Factors for Consideration

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Most Important:

- Temperature (limited by material chemistry)
- Irradiance (also limited by material chemistry)
- Range for each of them (in a matrix fashion)

Additional:

- Light Wavelength Range (e.g. blue vs. violet)
- Humidity
- Other?

Other Parameters for Consideration

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Most Important:

- **Sample Thickness (data for several thicknesses should be required)**
- **LED Package vs. Lamp/Luminaire Materials (different irradiance and temperature ranges; also different chemistry – e.g. mostly silicone for packages and mostly PC for lamps/luminaires)**

Additional:

- **Tested area (smaller is more economical but possibly restrictive for optical measurements)**

“Wish List” for The Output from a Full Method:

- **Full spectrum data for transmission, reflection, and absorption.** Single transmission values usually provided leave the amount reflected vs amount absorbed completely unexplained.
- **BSDF measurements for diffusers.** While diffusion angle measurements is a step up from haze measurements, a full BSDF measurement describes the performance incomparably better. On the other hand, BSDF is more difficult to work with as it’s an array of data vs a few values for diffusion angle or haze.
- **Multiple thicknesses measured for materials.** Not unheard of on diffusers, but it would be useful information even for transparent materials.
- **Change in all of these characteristics over time.** This is a lot to ask for, but it would be very useful information to have. Helpful in predicting color performance and light distribution after the product has aged.
- **Standardization in reporting of data.** It would make it much easier to research and compare materials by their users.

Summary:

- Long term quantitative data for SSL optical materials (including but not limited to diffusers) is of the highest value to SSL manufacturers.
- An industry-wide method has yet to be developed to test long term degradation in a consistent and meaningful fashion.
- Testing conditions need to be standardized to the extent possible.
- Temperature, irradiance and sample thickness are particularly important.
- Ideally, data should be collected over the entire spectral region of interest (e.g. 300 nm to 800 nm).
- The data reporting format also needs standardization.

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