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Photometric Evaluation of Photo-luminescent Materials for Multi-Egress Guidance Placards

Lighting Environment Test Facility

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Background

The purpose of this investigation was to evaluate several photo luminescent (PL) materials being considered for construction of emergency egress placards in the International Space Station (ISS). The use of PL material is intended to allow the placards to be read by ISS crew members in the event of an extensive power failure resulting in the loss of interior illumination.

Several PL materials were included in the study. These fell into two general categories: paints or plastic/plastic laminate sheeting. In each case, the PL material was intended to be used as a luminous substrate over which the placard symbols would be printed in contrasting, opaque ink, allowing the placard information to be read in all illumination conditions. Two colors of paint and five plastic materials were considered. The plastic materials were taken from samples provided by the manufacturer, Luna Technologies, International, Inc. Two paint samples were obtained from the Johnson Engineering Decal Design Production Facility (DDPF). Each sample consisted of a thin sheet of plastic coated with a uniform layer of PL paint. One sample was of a blue color manufactured by Nichia Corporation, and the other was of a yellow-green color manufactured by Wilflex Incorporated.

The five plastic material samples were identified as follows:

Lunaplast card – stiff, laminated 0.063 inch thick structure, having a white reflective layer on the back;

Lunaplast flex – thin, pliant, laminated 0.017 inch thick structure, having a white reflective layer on the back;

Lunaplast acrylic low load – stiff, translucent, homogeneous 0.125 inch thick sheet;

Lunaplast acrylic medium load – stiff, translucent, homogeneous 0.125 inch thick sheet;

Lunaplast polycarbonate – stiff, opaque, extruded 0.10 inch thick with a curved cross-section and textured surface;

All of these PL plastic materials glow with a yellow-green color.

Illumination sources used to excite the materials in the study included fluorescent General Lighting Assembly (GLA) and prototype Solid State Lighting (SSL) luminaires. The sources used were selected to have characteristics most closely resembling those of the luminaires aboard present and future ISS modules.

Experimental Conditions and Apparatus

The experiments were performed in the Lighting Environments Test Facility (LETF). Instruments used included a Photo Research Model PR-1500 luminance meter for measuring the brightness of the samples following excitation and a Photo Research Model 504 illuminance meter for monitoring the illumination falling on each sample during excitation.

Sources of illumination for the experiment included overhead fluorescent luminaires in the LETF, "flight-like" GLA training luminaires, and a prototype SSL luminaire. During the initial screening experiment, the samples were illuminated to approximately 15 foot-candles (fc) by the overhead fluorescent lights in the LETF. Subsequent experiments on the reduced sample set were performed with 10.5fc illumination on the sample provided by the GLA or SSL as indicated.

Experimental Procedure

Sample preparation. The PL materials were cut into two sets of approximately 1.5 by 2.0 inch rectangular samples. Self-adhesive Velcro® tape patches were applied to the backs of all samples to hold them in position during tests, and identifying marks were placed on the samples that were similar in appearance. All samples were stored in the dark for at least 36 hours prior to testing.

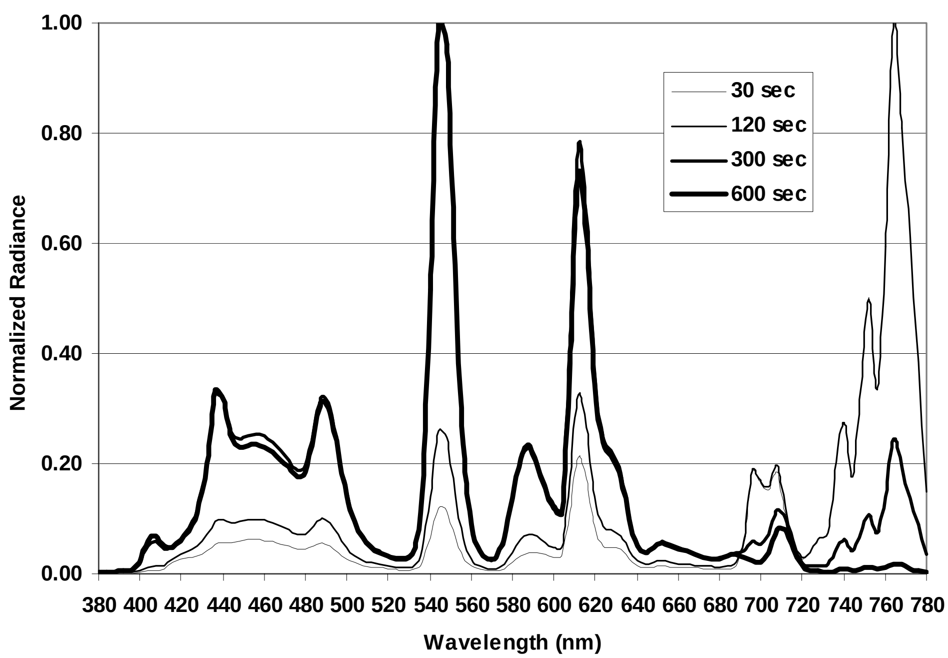
Screening evaluation. To streamline the experimentation, a preliminary subjective evaluation was performed on all of the samples to eliminate obviously inferior materials from subsequent objective testing. This evaluation was performed following simultaneous illumination of all samples under overhead fluorescent lights for 30 minutes. The lights were switched off, and the apparent brightness of the samples was observed for a period of about 15 minutes.

Following the period of observation, one material was eliminated from further study. The Nichia blue PL paint sample initially seemed dim compared with all the others, but appeared to maintain its luminance over the time of observation. This impression may have been an accurate estimate of the relative brightness of the blue paint, but it was likely in part to have been influenced by the gradual dark adaptation of the observer. In any case, the blue paint sample was the dimmest of all initially, and so it was eliminated.

Objective testing procedure. Samples of the six remaining materials were wrapped in black velvet and stored in a dark cabinet for 36 hours prior to further testing. In turn, these samples were then individually exposed to 10.5fc illumination from the prototype SSL luminaire for a 10-second period. Luminance measurements were made and recorded for the sample at 10 seconds and 60 seconds after the end of the exposure period. After the second data recording was completed, the sample was exposed to an additional 600 seconds of the same illumination, followed by luminance measurements at the same sampling intervals. This pattern was repeated for the balance of the samples, and then the samples were returned to dark storage for about 48 hours prior to further testing.

Upon reviewing the brightness of the materials following SSL illumination, the experimenters eliminated the extruded Lunaplast polycarbonate sample from further consideration due to its low luminance in comparison to the other materials. In addition, since the Lunaplast acrylic low load material afforded no performance advantage in initial brightness or brightness decay over the similar Lunaplast acrylic medium load material, it too was eliminated.

The remaining four materials were tested under GLA illumination using the same procedure as previously described. Illumination of the sample under test was initially set to 10.5fc after the GLA had warmed up for more than 10 minutes. The GLA was turned off long enough to check the luminance meter calibration and to place the sample in position for the test. At the beginning of testing, the experimenters noted a reddish color from the GLA during the onset of both the initial 10-second and the subsequent 60-second exposure period for each sample. Following the GLA test session, the samples were returned to dark storage, and measurements were made of the visible spectrum of light emitted by a "cold" GLA as it warmed up. The significant changes in the spectrum during the first five minutes of operation prompted questioning of the results obtained following the 600-second illumination of the samples (Figure 1). The experimenters reasoned that the 10-second illumination results could be considered valid, since they were indicative of a realistic short-term illumination circumstance that might result from a power failure immediately following turning on the lights in a module of the ISS. The 600-second illumination results, however, were deemed a less realistic representation of the results of a power failure following long-term steady state illumination of the GLAs. For this reason, the 600-second measurements were repeated with a change in procedure. Under the revised protocol, the GLA was allowed to operate for at least ten minutes prior to the exposure of each sample. Then the 600-second illumination period was followed by measurements as previously described.



Results

10-second excitation. In the case of short-term excitation by fluorescent GLA, the luminance of all materials was quite low, 0.005 foot Lambert or less, with the Wilflex paint the brightest (Figure 2). With short-term excitation by the SSL, the Lunaplast flex material outperformed the others, providing about three times the brightness of the Wilflex paint illuminated by the GLA (Figure 3). Luminance decay rates were greatest for the Lunaplast flex material and the Wilflex paint samples.

600-second excitation. With long-term GLA excitation, the brightness of the Lunaplast flex material increased about thirty-fold over the short-term GLA excitation result, whereas the Wilflex paint brightness increased by a ratio of only 4:1 (Figure 4). The three plastic materials afforded luminances exceeding 0.075fL during the first minute following cessation of excitation — roughly seven times the luminance afforded by the Wilflex paint.

There was little difference in the luminance of the Wilflex paint sample during the minute following long-term exposure to light from the GLA or the SSL. The brightness of all three plastic materials exceeded that of the Wilflex paint by a factor from 4:1 to 7:1, depending on the type of excitation source. The GLA excitation produced higher luminance from the plastic materials than did the SSL excitation (Figure 5).

Luminance decay rates for the plastic materials were nearly identical, regardless of the type of excitation source. The Wilflex paint's luminance decay rate was somewhat greater than that of the plastic materials.

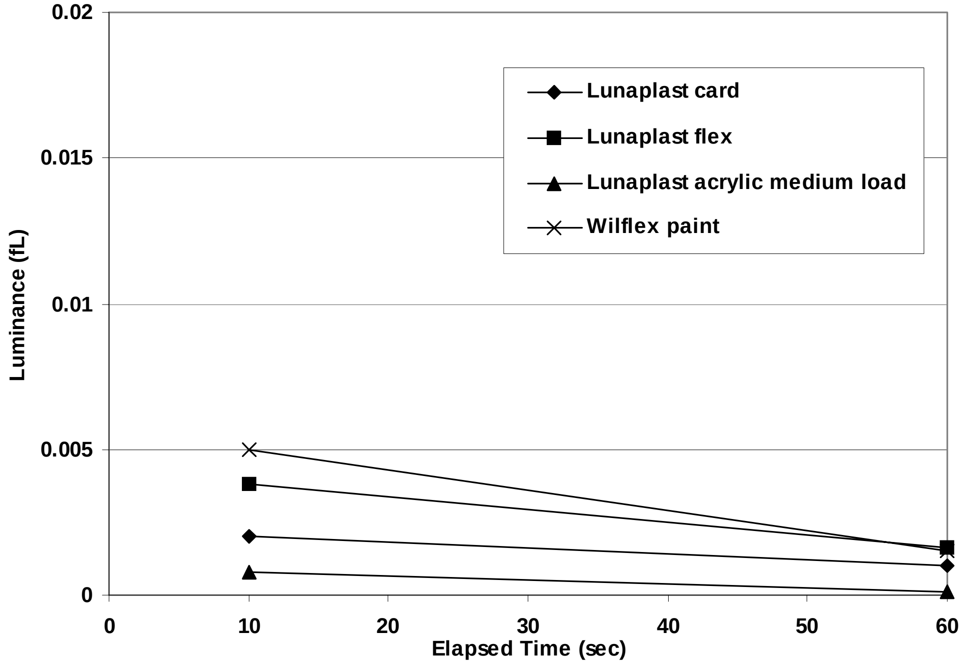


Figure 2. Photoluminescence for 10-second GLA excitation

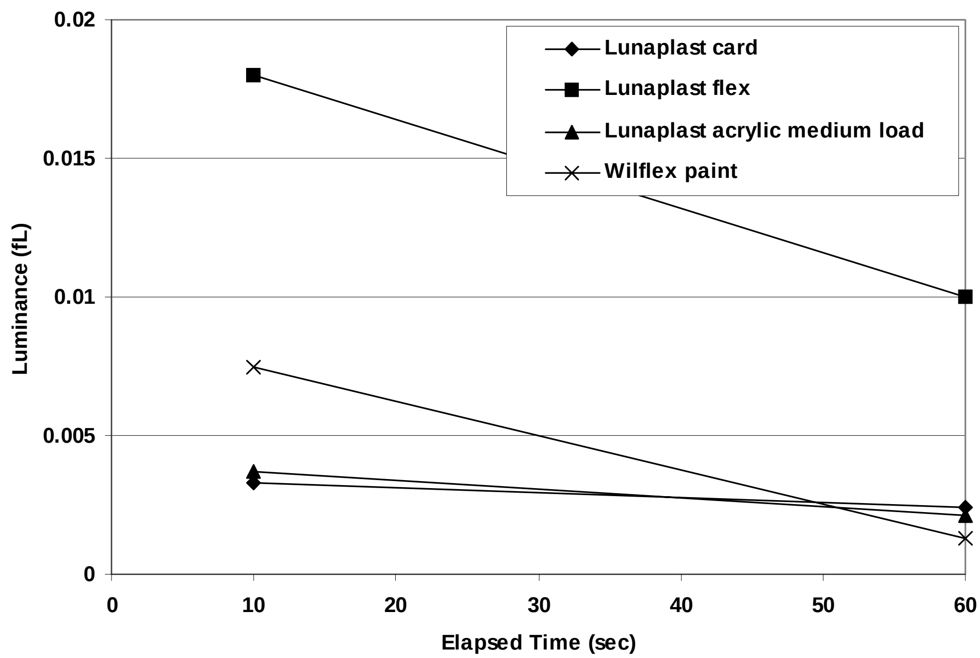


Figure 3. Photoluminescence for 10-second SSL excitation

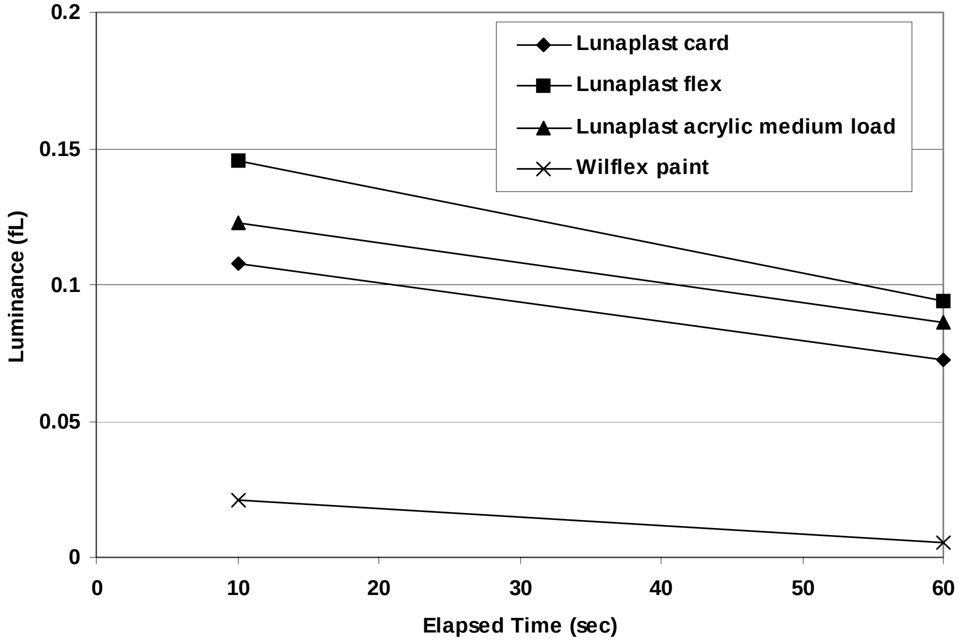


Figure 4. Photoluminescence for 600-second fluorescent GLA excitation

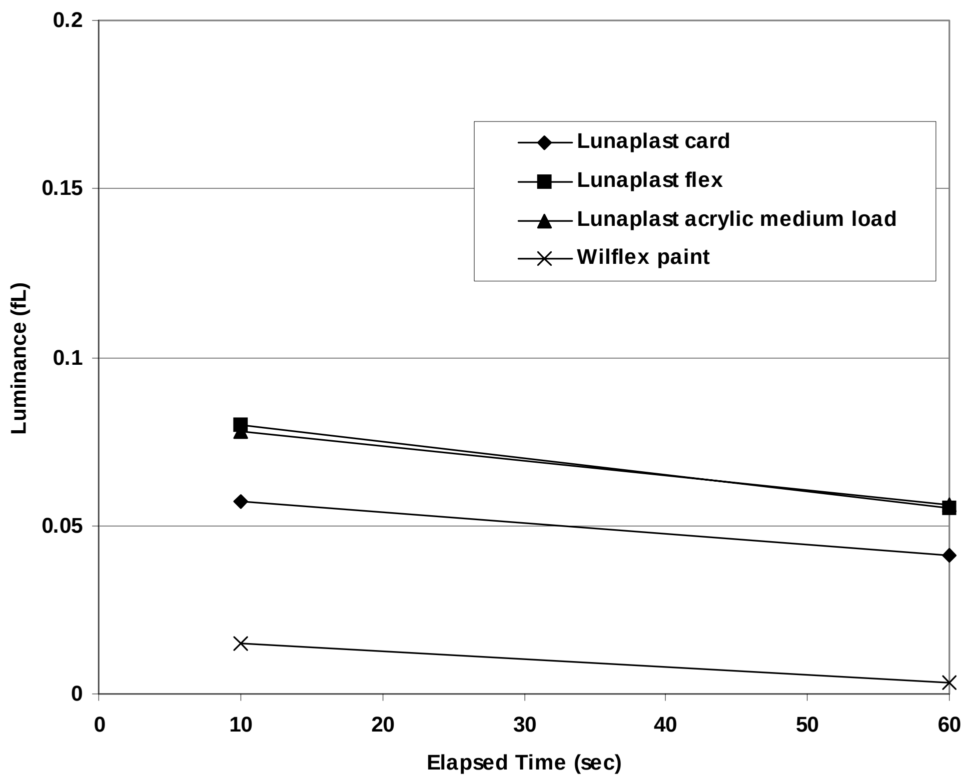


Figure 5. Photoluminescence for 600-second SSL excitation

Discussion

Material characteristics. Of the final four materials studied in the experiment, the brightness and endurance of the Wilflex paint proved inferior to that of the plastic materials. Among the plastics, the Lunaplast flex material offered the best performance overall, with the degree of superiority dependent on the type of excitation illuminant. After having been fully excited, all three plastic materials are bright enough for use in emergency egress placards.

All three plastic materials responded more strongly to long-term GLA excitation, compared to long-term SSL excitation. Differences between this pattern and some short-term results may probably be explained in terms of changes in the spectrum of light emitted by the GLA as it is warming up. Initially, the GLA emits very long wavelength (red) light, which decreases as short (blue) and middle (yellow, green) visible wavelengths increase with time (Figure 1). The spectrum of the SSL, in contrast, is stable from the time it is turned on, with most of its energy concentrated in the short (visible blue) wavelengths (Figure 6). It is likely that during the first half minute of operation the SSL produces considerably more total light energy than does the GLA, and that the PL material used in the plastics is much more sensitive to illumination at shorter visible wavelengths. The manufacturer's specifications for the Lunaplast materials indicate that the wavelength range for excitation includes the range of 200nm to 450nm, with the optimum at 360nm, in the band near the (violet) limit of the visible range.

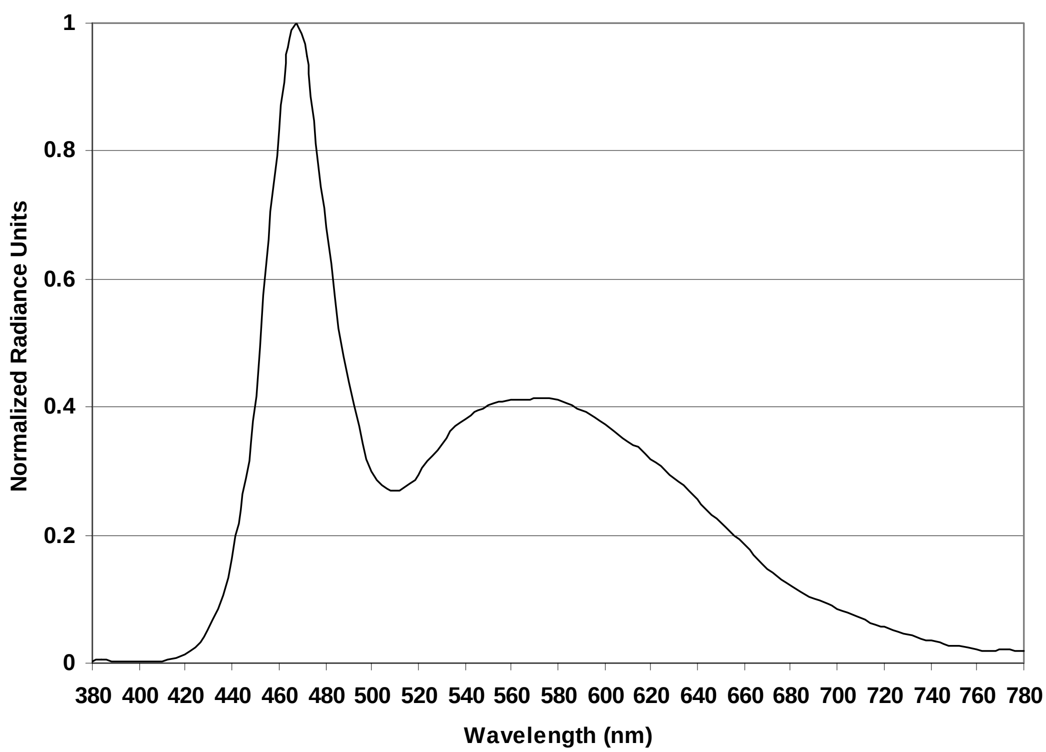


Figure 6. Normalized spectral characteristics of SSL

Thinner materials (Wilflex paint, Lunaplast flex) appeared to be more readily excited under the short-term illumination condition. This may be due to reduced attenuation and scattering of the light as it propagates within the material. The Lunaplast acrylic medium load material might benefit from having the active PL component suspended in a thinner layer of plastic. The addition of a reflective white backing to the Lunaplast acrylic medium load material to capture more of the excitation photons that pass through the plastic without encountering the active PL chemical might improve its “charging” efficiency.

The color of the light emitted by the PL material following illumination should ideally be chosen to correspond to the viewer’s most sensitive wavelength range, considering whether the viewer is light- or dark-adapted. As the human eye adjusts from photopic (cone) to scotopic (rod) receptor dominance, the peak sensitivity in response to color moves from the yellow-green wavelengths of the visible spectrum to the blue-green wavelengths, a phenomenon known as the Purkinje shift (Sekular & Blake, p. 90). In the case of the initial subjective evaluation by a light-adapted viewer, the Purkinje shift probably tended to offset the decrease in actual light production by the Nichia blue PL paint over time. To a light-adapted viewer immediately following the loss of ambient illumination, the yellow-green light emitted by the plastic PL materials in the study should initially appear brighter than equivalent intensity light from blue-emitting PL material.

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Reference

Sekuler, Robert and Randolph Blake (1990) Perception (2nd ed.). New York: McGraw-Hill.

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