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Coronene and liumogen as VUV sensitive coatings for Si CCD imagers: a comparison

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Phosphor coatings have long been employed in the detection of UV radiation.[1] With the interest in the use of silicon charge coupled device (CCD) imagers as the detector for the space telescope and other space-borne astronomical missions, a UV sensitive phosphor is desired the emission spectrum of which usefully matches the spectral response of the CCD. Such a phosphor would provide an unparalleled opportunity to image in the UV, the visible, and near IR wavelengths with the same detector. A recent study has suggested that coronene and sodium salicylate (which emit at 500 and 420 nm, respectively) are the most promising candidate phosphors.[2] The potential of a third organic phosphor, liumogen, is the subject of this Letter.

The use of coronene with a rear illuminated CCD detector has been recently reported.[3] The emission peak of coronene at 500 nm represents a reasonable overlap with the sensitive region of the CCD spectral response. In addition, thin films of the phosphor have been shown not to degrade the imaging response of the CCD at visible and near IR wavelengths. The emission peak of liumogen is at 520 nm with a strong secondary peak around 560 nm[4] as shown schematically in Fig. 1. This represents a better match to the spectral response of the silicon CCD than coronene, and a much better match than sodium salicylate. Consequently, it was felt that a comparison of the response of coronene and liumogen would be useful.

United Detector Technology pin photodiodes model 10DP were used to evaluate the UV response of liumogen and coronene. The pin devices were preselected for nearly equal quantum efficiency in the neighborhood of 500 nm. To simulate the eventual use of the phosphor, the window of the package was removed, and the diodes were coated with a thin layer (~0.025 mg/cm^2) of either coronene or liumogen: 1600–2000 Å in the case of coronene and 3600 Å in the case of liumogen. The phosphors were deposited using an evaporative technique.[3]

Figure 2 presents the results of spectral response measurements on several coated devices. In the figure, the quantum efficiency of the detector/coating is presented as a function of incident wavelength from 121.6 nm (Lyman-α) to 460 nm. The measurements from 122 to 280 nm were performed at the University of Wisconsin at Madison using a Jarrell-Ash model 205 monochromator with a gas discharge source. An EMI 543-P-09-00 calibrated photodiode was used to measure the incident energy. Measurements between 320 and 460 nm were performed in our laboratory using a 1000-W Xe source, a Schoeffel model GN 250-1 grating monochromator, and a calibrated Tektronix model J6504 probe to measure incident flux. The quantum efficiency of the phosphor coated diode was determined from the relation

$$\eta_{\text{diode}} = \eta_{\text{ref}} \times 1_{\text{diode}}/1_{\text{ref}}, \tag{1}$$

where η_{diode} is the quantum efficiency of the device under test, η_{ref} is the quantum efficiency of the reference detector, 1_{diode} and 1_{ref} are the signal currents of the test device and reference diode, respectively. All measurements were performed at room temperature.

As may be noted from Fig. 2 the conversion efficiency of coronene decreases rapidly near 370 nm, while the diode response does not become significant until ~400 nm. This results in a region with reduced quantum efficiency for the coated detector ~30 nm wide centered near 385 nm. (Rear illuminated CCDs exhibit identical behavior.[3] The spectral response of the uncoated photodiodes from 350 to 550 nm is very similar to that observed with rear illuminated CCDs.)

On the other hand, the liumogen coated samples do not exhibit this dip in response. Indeed, since the absorption edge of liumogen is at ~460 nm, this layer absorbs photons that could be more efficiently detected by the uncoated photodiode.[4]

The second observation concerning liumogen is that, in general, this phosphor is less efficient than coronene in converting UV photons to useful signal. This is true, in some

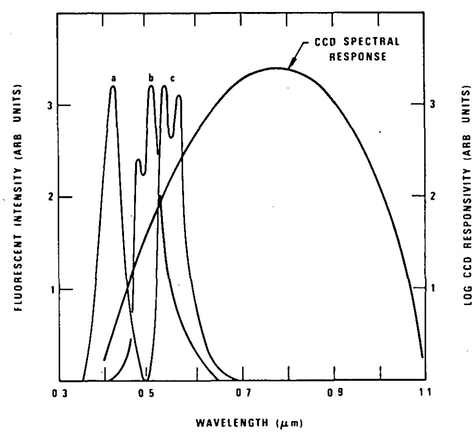

Fig. 1. Fluorescent emission intensity as a function of wavelength for (a) sodium salicylate, (b) coronene, and (c) liumogen compared schematically with the spectral response of a rear illuminated Si CCD.

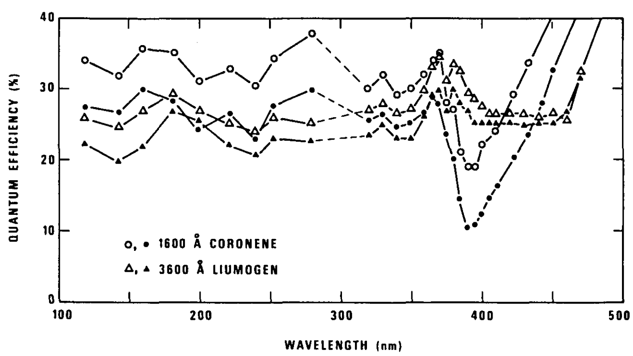

Fig. 2. Quantum efficiency of coronene and liumogen coated pin photodiodes.

cases, by a factor of as much as 2/3 in spite of the fact that the liumogen layers were about twice as thick.

Previous measurements have indicated response for liumogen to 200 nm. The present data have shown that useful response can be obtained to at least Lyman-α. Overall it appears, however, that coronene is the more desirable phosphor for use as a deep UV wavelength convertor with Si CCDs, although in the 360–410-region liumogen is clearly superior.

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The Albert A. Michelson Collection

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The Albert Abraham Michelson Collection had its beginning at the Naval Ordnance Test Center, China Lake, California, in May 1948 when some of Michelson's original equipment was brought together for a display. Considerable interest was generated by the display, a proposal was made to set up a permanent exhibit, and the "Michelson Museum" was born. The goals of the Museum eventually became the collection of all available Michelson-related materials and the creation of location records for those Michelson materials held by others. These materials were then to be made available to interested persons for historical research.

In September 1977, in order to make the Collection more accessible to researchers and to ensure its continued growth and support, the Michelson Museum was transferred from China Lake to the Special Collections Department of the Nimitz Library at the United States Naval Academy in Annapolis, Maryland.

It was especially appropriate that the Collection should come to Annapolis. Michelson was a graduate of the Naval Academy in the Class of 1873. His scientific career was launched at the Academy in 1878 and 1879 when the then Ensign Michelson, while serving at the Academy as an instructor in chemistry and physics, carried out his first experiments to determine the velocity of light.

For purposes of description, the Michelson Collection can be divided into four parts: papers, photographs, museum items, and memorabilia.

The papers portion of the Collection contains approximately five feet of originals of Michelson's publications, data sheets, notebooks, and correspondence; fifteen feet of photocopies on Permalife paper of items located elsewhere (Mount Wilson, Yerkes, and Lick Observatories, Carnegie Institution of Washington, Clark University, etc.); and one foot of originals and copies of shop notes, summaries of work for and with Michelson, and correspondence, donated by Michelson's assistant, Thomas O'Donnell.

The Collection contains approximately six hundred photographs. Eighty of these are group pictures and portraits of Michelson. Another eighty show various Michelson displays and exhibits at the Naval Weapons Center, China Lake, and other locations, and one hundred and fifty are of the Michelson Laboratory dedication and later open house exhibits. The remainder are of pieces of Michelson equipment, of buildings named for him, and the like. The Collection also includes a small set of lantern slides. Thirteen of these slides were hand-painted by Michelson himself in connection with his study of the metallic coloring in birds and insects.

The museum portion of the Michelson Collection contains approximately one hundred and fifty original instruments and related hardware. Of particular interest among these are such items as an electrically driven tuning fork used by Michelson to regulate the period of his rotating mirror and a working replica of the original rotating mirror which he employed in his velocity of light experiments. There are also a variety of pieces which he used in several applications of interferometry, including a parallel interferometer and an Etalon VIII. These artifacts and others are permanently displayed in the lower lobby of Michelson Hall at the Naval Academy. Four additional pieces of equipment (a diffraction grating, harmonic analyzer, quartz gravity meter (partial replica), and a small ruling engine built by Michelson in 1898) are on indefinite loan to the Smithsonian Institution in Washington, D.C.

Michelson's ability extended far beyond his scientific work into the fields of music and painting. These interests are represented in the Collection by three of his original watercolors and by copies of the musical scores for his "Grandpa's Lullaby". Also included among the memorabilia are medals and other awards received by Michelson during his lifetime.

Unpublished name and partial subject indexes to the Collection are available. Inquiries about the Michelson Collection should be directed to the Special Collections Department, Nimitz Library, United States Naval Academy, Annapolis, Maryland 21402.