Technical Note on UV Conversion Coatings: LUMOGEN (also known as LUMILUX, LIUMOGEN AND LUMIGEN)

e2v technologies

The performance of front illuminated Charge Coupled Devices (CCDs) in the ultraviolet (UV) region of the optical spectrum may be enhanced by a UV conversion coating, such as Lumogen.

INTRODUCTION

A problem encountered in using front illuminated (FI) CCDs is the lack of quantum efficiency (QE) in the UV region of the optical spectrum. This problem arises because the UV light is absorbed in the FI CCD electrode structure before it can contribute to the signal charge in the bulk of the CCD.

There are several techniques by which this problem may be overcome. The use of back illuminated CCDs is one such option. A less expensive alternative is to coat the FI CCD with a material that can absorb UV radiation and emit photons in the visible band of wavelengths e.g. blue-green, where they can be more efficiently detected by the CCD. Materials that can absorb UV and convert it to a longer wavelength or lower energy are known as 'Phosphors'.

PHOSPHOR: LUMOGEN

One specific example of a phosphor, used by e2v technologies for CCDs, is Lumogen.

The absorption coefficient (α) for Lumogen exceeds 10^5 cm^{-1} for most wavelengths above 200 nm and below the absorption edge at 460 nm. Thus most UV radiation is absorbed in a layer no thicker than $\sim$300 nm (absorption depth for 90% of light equals $2.3/\alpha$). The absorbed UV radiation causes the phosphor to emit in the spectral band 500 to 650 nm, independent of the excitation wavelength through the range 200 to 460 nm. The efficiency of Lumogen is also temperature dependent and increases with decreasing temperature.

PERFORMANCE

The efficiency of a CCD coated with Lumogen in converting the UV photons to useful signal electrons is determined by many factors: scattering and absorption in the Lumogen film, contaminants in the film, reflection at the air/film and other (e.g. polysilicon) interfaces etc. It is possible that approximately 50% of the light is scattered away from the CCD. Thus the maximum QE of Lumogen coated devices is limited to half of the QE of the CCD in the blue-green region of the spectrum i.e. for a standard front illuminated device a maximum QE of about 10 to 20% may be attainable at room temperature.

Figure 1 illustrates the enhancement of QE in the UV as a result of coating with Lumogen. The visible and Near Infrared (NIR) response and resolution are not significantly degraded by the presence of Lumogen, and the UV QE is typically 10 to 14%. Also shown for comparison is the QE enhancement possible with open-electrode variants.

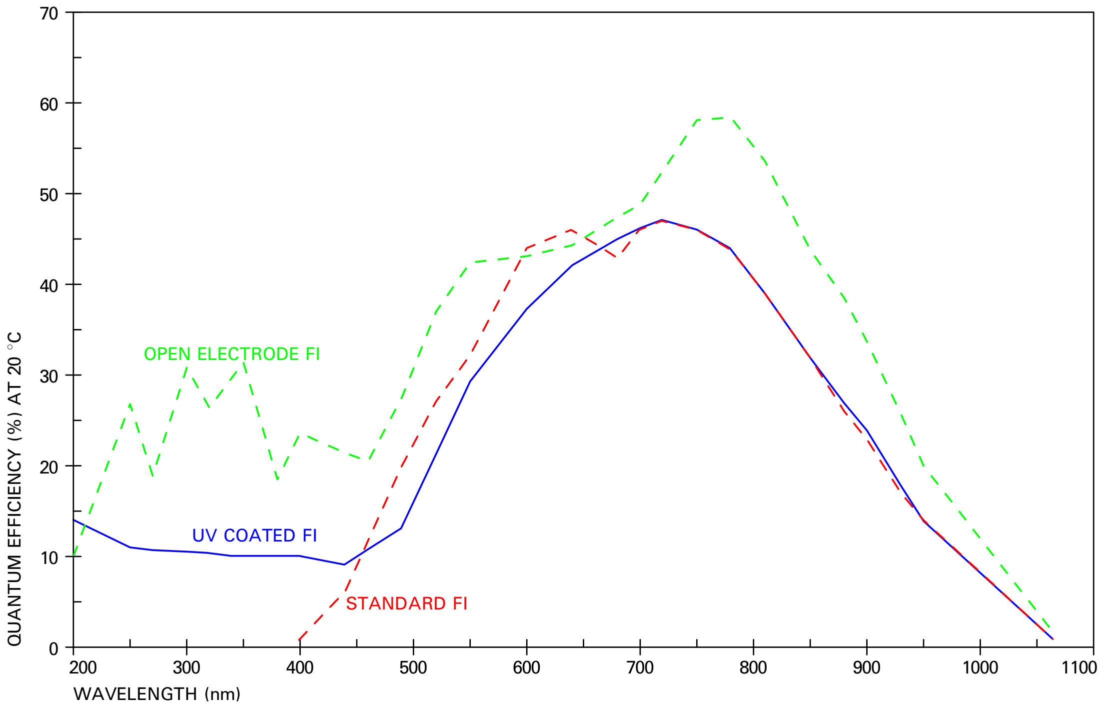

Fig. 1 Typical quantum efficiency enhancement of a front illuminated CCD due to Lumogen

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Figure 2 illustrates the effect of temperature on the QE of a coated CCD.

In uncoated CCDs, lowering of temperature leads to a lower quantum efficiency at longer wavelengths as a consequence of an increase in the bandgap of silicon and a reduction in the density of phonons required to make an indirect transition. This effectively shifts the absorption coefficient to higher photon energies at low temperature. However this reduction in quantum efficiency is most prominent above 650 nm and has little effect at shorter wavelengths. Consequently any change in measured quantum efficiency to higher values on Lumogen coated CCDs at wavelengths below approximately 650 nm is attributed to the increase in the efficiency of the Lumogen and, to a lesser degree, to the higher transparency of the polysilicon electrodes at these wavelengths. Beyond the emission spectral band of Lumogen in the red end of the spectrum, the characteristics of the silicon dominate and a lowering of QE is observed, with the greatest loss of QE occurring at the lowest temperature. This effect is clearly evident from figure 2.

Along with the benefits of UV QE enhancement, there are inevitably some drawbacks. Lumogen is known to sublime at temperatures above 150 °C and, while being generally robust, its stability at temperatures above 110 °C in vacuum (2×10^{-6} mm Hg) is suspect. For this reason, Lumogen coated CCDs are not recommended by e2v technologies for applications in space. However, the chemical and mechanical stability of Lumogen for temperatures down to −130 °C, is good. Further, from a practical view point any variation in the thickness of the coating will result in an increase in the non-uniformity of response from pixel to pixel.

Lumogen coatings bleach or age with prolonged exposure but for most practical imaging applications this is of little consequence. Exposure to sunlight, unnecessary exposure to UV and excessive temperatures will degrade life expectancy. It is recommended that devices with Lumogen coatings be kept in light-tight containers when not in use.

In measuring QE, the spectral purity (bandwidth of any interference filters, scattering of Balmer lines) and the uniformity of the UV radiation in use (i.e. use of a scatter plate to give a flat field illumination) are all important practical considerations. Further the operating environment e.g. presence of oxygen during UV radiation (UV flooding), may lead to hysteresis in QE of Lumogen coated devices. Thus a well controlled environment is vital for stable and reproducible QE measurements.

In this note, the performance in the extreme ultraviolet (EUV) was not discussed. For a short insight to some work carried out on e2v technologies CCD02 with a Lumogen coating, the reader is referred to the publication in reference 1.

Reference

1. Optical Engineering Journal, Vol. 33 No.8, pp 2545 to 2552, August 1994.

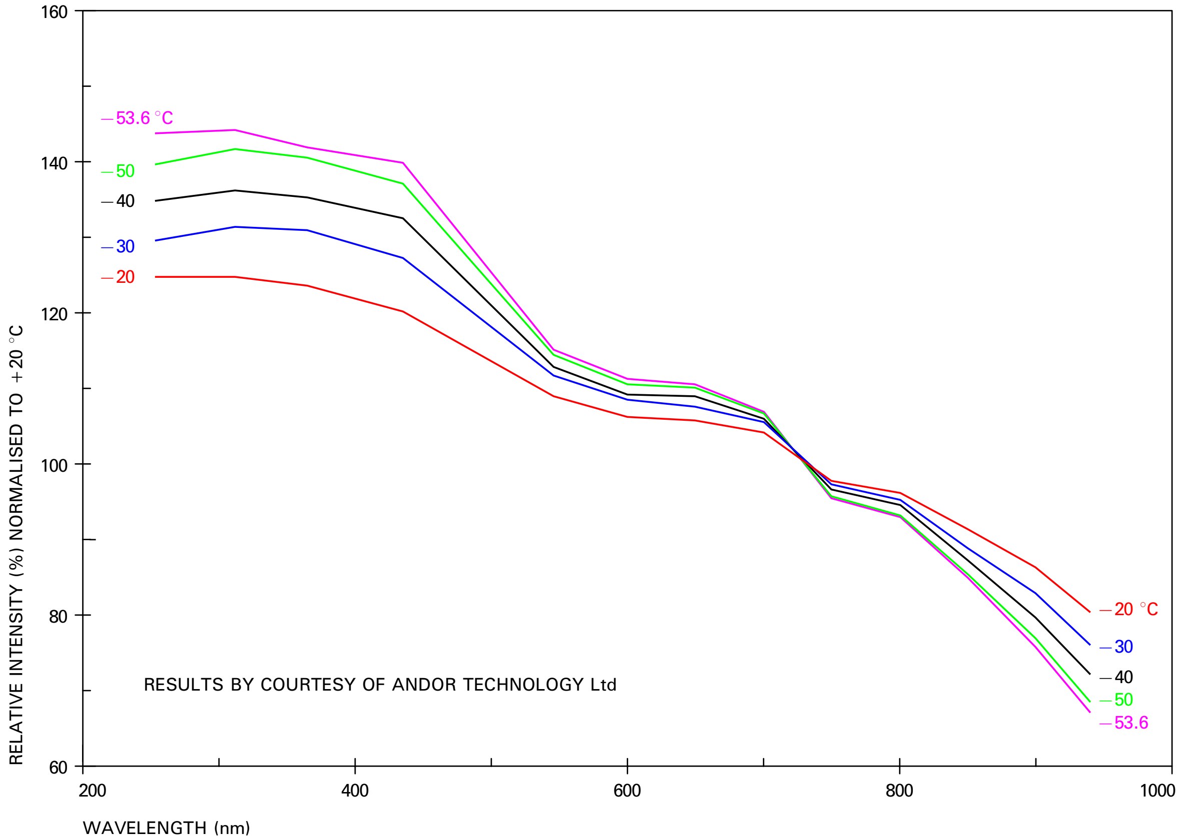

Fig. 2 Change in quantum efficiency as a function of temperature in Lumogen coated CCD15-11