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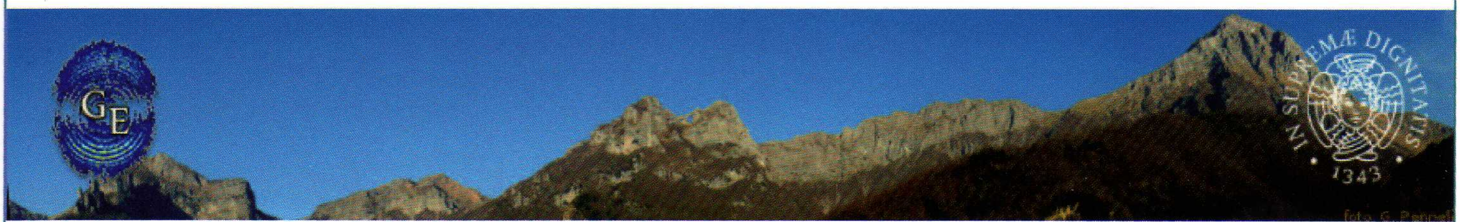

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White LED Light Obtained by Frequency Down-conversion of Perylene-based Dyes

Mauro Mosca*, Fulvio Caruso*, Roberto Macaluso*, Claudio Calì*, Eric Feltin#
*Dipartimento di Ingegneria Elettrica, Elettronica e delle Telecomunicazioni, di tecnologie Chimiche, Automatica e modelli Matematici (DIEETCAM), University of Palermo, viale delle Scienze, Edificio 9 – I90128 Palermo (Italy)
#Novagan, Sàrl, Chemin de Mornex 5/A, CH1003 Lausanne (Switzerland)

In the last decade, the growing demand of the solid-state lighting market for the development of sources in a wider range of colours has led to the fabrication of the first white LED in 1997 [1], through the use of a structure based of gallium nitride (GaN) and the use of phosphorus (Ce: YAG). An alternative way to obtain white light is to use a source that acts as a pump for the photoluminescence of an organic substance [2].
A high efficiency cool white LED was obtained by generation of yellow down-conversion from a GaN/InGaN blue LED. Using photoluminescence of a perylene-based polymer dye we achieved a good substitute for conventional inorganic colour conversion. The dye used is the Lumogen® (BASF) based on perylene, having one of the absorption maxima at 450 nm and a broad fluorescence peak in the neighbourhood of 500 nm.
Standard InGaN-based blue LEDs were fabricated on a sapphire substrate by metal-organic chemical vapour deposition (MOCVD). Peak emission wavelength is centred at 450 nm and the chromatic coordinates are (0.1477, 0.0338) in CIE chromaticity diagram.
Lumogen® dye was dissolved in a poly-methyl-methacrylate (PMMA) solution, using ethyl acetate as a solvent, and different PMMA molecular weights were tested. The bare side of the sapphire substrate was coated by the dye solution by either spinning, or dipping so that different coating thicknesses could be obtained. The emission spectra and chromatic coordinates were measured by an Ocean Optics HR4000 spectrometer, the LED being driven by a constant current (5, 10, or 20 mA); optical power was obtained by a Newport 818-UV calibrated photodiode.
Three solutions were prepared at different weight percentages, two 8% (PMMA1, PMMA2) and a 11% (PMMA3): solutions PMMA1 and PMMA3 were prepared with a polymer of molecular weight 350,000 while the solution PMMA2 employs a polymer of molecular weight 996,000. Equal amounts of dye were used for each solution. Spinner velocity was 1200 rpm. The results are shown in Table 1.
The best results are obtained by dip coating of PMMA1 solution. Emission spectrum and chromaticity diagram are shown in Fig. 1. In this case, coating is scarcely homogeneous, but the thickness is higher than by spin coating. Record values of 9.37 lm of luminous flux and 118.23 lm/W of optical efficacy are achieved (with 20 mA of driving current). A pure and intense white light is emitted, as proven by chromatic coordinates of (0.2687, 0.3629) in CIE chromaticity diagram. Fig. 2 shows two pictures of this LED before and after the dipping process.
In conclusion, we showed that it is possible to obtain a white LED by using an organic material rather than a traditional phosphorus. Given the simplicity of the operation of deposition, the process is suitable to be employed in an industrial production process. The high efficiency at low values of driving current makes the device proper for lighting solutions with low power consumption.

REFERENCES

[1] S. Nakamura, G. Fasol, The Blue Laser Diode (The Complete Story), Springer-Verlag: Heidelberg, 1997
[2] O. N. Ermakov, et al., Microelectronic Engineering, 69, 2003, pp. 208-212

		LED PMMA1	
Supply Current [mA]	5	10	20
Luminous Flux [lm]	1.73	2.99	5.11
Optical Efficiency [lm/W]	106.23	86.74	67.73
		LED PMMA2	
Supply Current [mA]	5	10	20
Luminous Flux [lm]	0.84	1.55	2.72
Optical Efficiency [lm/W]	51.95	45.71	37.29
		LED PMMA3	
Supply Current [mA]	5	10	20
Luminous Flux [lm]	1.40	2.61	4.80
Optical Efficiency [lm/W]	86.59	76.87	64.99

Table 1: Luminous flux and optical efficiency of LEDs prepared with three different PMMA solutions

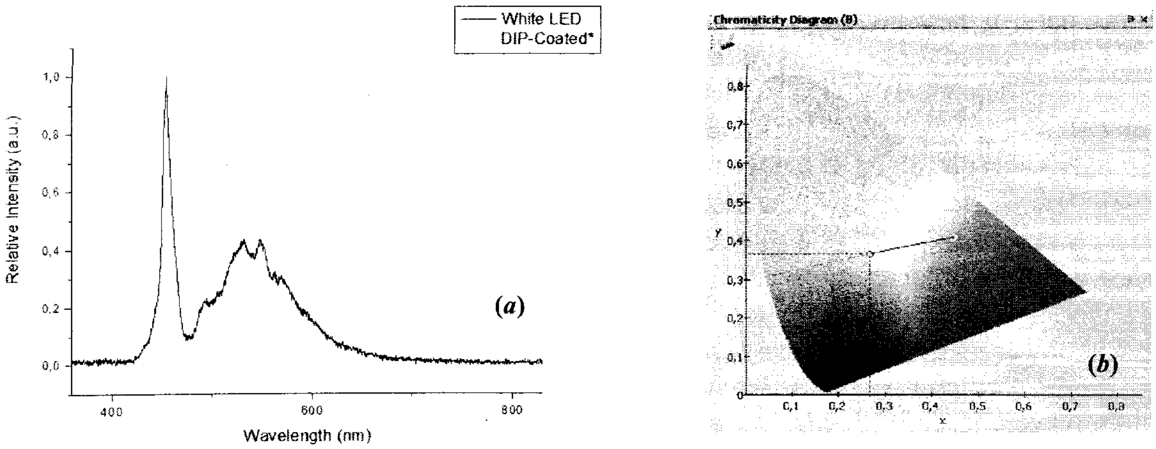

Fig. 1: (*a*) Emission spectrum and (*b*) chromaticity diagram of the dip-coated LED

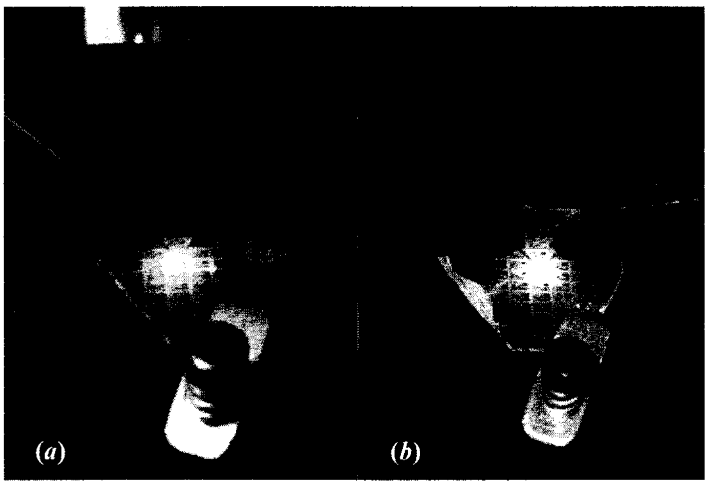

Fig. 2: Pictures of the LED (*a*) before and (*b*) after the dipping process