New generation of white phosphors for LED lighting

Devices based on light emitting diodes (LEDs) are a major disruptive technology expected to dominate the lighting market in the near future. The advantages of solid-state lighting sources are their energy saving (more than 50% compared to conventional fluorescent lamps) and their potential to produce high stability, long lifetime devices. White light is obtained by combining blue light from the LED with yellow light from a phosphor powder, usually containing a lanthanide rare-earth element. At the Institut NÉEL, we are developing a new type of phosphor based on aluminum-borate powders, composed of non-toxic and abundant elements, and especially without using any lanthanide.

The innovative feature of our phosphors is to produce a broad luminescence band throughout the visible spectrum yielding comfortable and safe lighting. The dominant system (around 98% of the market) for producing commercial white-light emitting diodes is based on an Indium Gallium Nitride (InGaN) chip emitting blue light, which is partially converted to yellow by a Cerium-doped Yttrium Aluminium Garnet (Ce^{3+}:YAG) phosphor placed just above the LED. However, due to the lack of a red light component, these phosphors produce bluish white emissions with low values of their "Colour Rendering Index" (the industry standard that effectively compares their colour to black-body light). This yields optically-uncomfortable light-sources, associated with blue-light hazards such as possible retinal damage and disturbance of the biological clock.

To avoid these serious disadvantages, a very large research effort is being undertaken to develop new combinations consisting of LEDs emitting in the blue or near-ultraviolet with new phosphors to produce a comfortable and safe warm-white light, *i.e.* containing a sufficient orange-red component. Moreover, the use of lanthanides in the phosphors should be avoided: Reducing the use of lanthanides is crucial because of the strong increase in prices since 2011, a consequence of the near-monopoly held by China on these elements strategic in the field of materials for energy.

The phosphors we are developing are based on Yttrium Aluminium Borate powders, without any added lanthanide ions. They are composed of non-toxic and abundant elements which make them inexpensive. The powders are prepared from solutions. Evaporation of the solvents leads to a viscous resin which then undergoes different thermal treatments under controlled atmospheres leading to beige-coloured powders.

The innovative property of these phosphors is their broad and intense photoluminescence extending over the whole visible range, 400-800 nm, under excitation with UV light (see Fig. 1). The origin of this intense emission is structural defects or organic radicals formed during the thermal treatment within the amorphous matrix. Thus, using only a single phosphor material, we can generate white light from an initial LED that emits in the near ultra-violet.

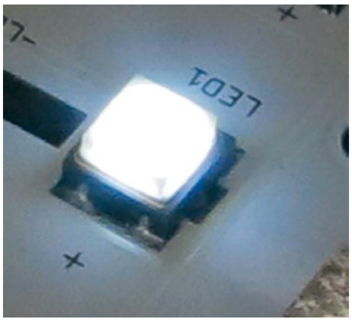

Fig. 2*: A first prototype lighting device involving a UV-LED exciting an Yttrium Aluminium Borate phosphor powder dispersed in a silicone matrix.*

In fact, the main objective of our work is to understand the origin of the light-emitting centres, which are related to structural defects or organic radicals. For that, different spectroscopies and structural-study methods coupled with thermal analyses are implemented. Thus, the optimization of the chemical compositions, the synthesis procedures and the thermal treatments should increase the number of luminescent centres to enhance the luminescence properties. Another crucial point is to increase the absorption of the excitation light to improve the overall photoluminescence efficiency. Based on these promising properties, we have developed a prototype device (Fig. 2) to estimate the lighting performance of this new family of phosphors.

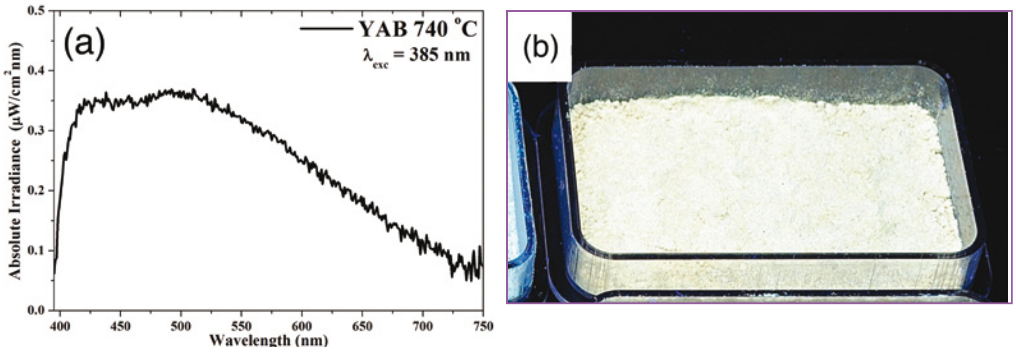

Fig. 1 (a)*: Photoluminescence spectrum recorded for an Yttrium Aluminium Borate (YAB) powder calcinated at 740 °C. The emission is excited by an ultraviolet LED (wavelength 385nm).* ***(b)*** *Luminescent YAB powder under UV light.*

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FURTHER READING...

"Toward a new generation of white phosphors for solid-state lighting using glassy yttrium aluminoborates"
V. F. Guimarães, L. J. Q. Maia, I. Gautier-Luneau, C. Bouchard, A. C. Hernandes, F. Thomas, A. Ferrier, B. Viana and A. Ibanez
J. Mater. Chem. C **3,** 5795-5802 (2015).