Luminescence Day to Day Life and Fluorescent Lamps, Light Emitting Diodes: Role of nanophosphors

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In discharge lamps light is generated by gas discharge. Atoms of gas or metal vapors are exited by the fast moving electrons. When these atoms come back to their original state, they emit radiation. This radiation may be in the region of UV or visible or infrared region. UV radiation cannot be seen, so it is converted into useful visible light by using proper fluorescent powder.

Rare-earth-doped phosphors are known to emit at distinct and different wavelengths in the electromagnetic spectrum and have been widely used in color cathode ray tubes (CRT), tri-phosphor fluorescent lamps, X-ray intensifying screens and newly developed vacuum mercury-free lamps, as well as various types of displays such as plasma display panels, field emission displays and projection TVs.

Recently, breakthroughs in inorganic light emitting diodes (LEDs) technology are significantly catalyzing the development of energy-efficient solid-state lighting (SSL) with long lifetime.

Requirements of LED Phosphors :

The basic requirements of LED phosphors are as follows:

- their excitation spectra should overlap well with emission spectra of LED (420-490 nm blue LED) or (360-400 nm near UV LED),
- their emission spectra should lie in the green and red (500-650 nm) region for blue LED and RBG region for near UV LED,
- they should not absorb the visible light emission from blue LED or those from other phosphors,
- LED materials should exhibit high quantum efficiency,
- Light emission should not saturate at very high excitation density of LED chips (200 W cm-2 which is 3 times higher than FL),
- LED phosphors must withstand temperatures up to 1500C without significant reduction in luminescence efficiency. So phosphors with very high thermal quenching temperature are desired,
- their color rendering index (CRI) should be > 80, and finally 8) their chemical and physical stabilities during LED manufacturing are important.

Conventional phosphors used in fluorescent lamps are not ideal for solid-state lighting because they have poor absorption for the LED light (near UV or blue). So researchers worldwide have been investigating other chemical compounds for their suitability as phosphors for solid-state lighting. Band-to-band transitions in direct gap semiconductors such as ZnS, ZnSe, ZnO and CdS offer the strongest absorption to LED light.

But the main difficulty of their real value in phosphor converter LED arises from strong temperature dependencies. Strong absorption can also be expected from dipole-allowed electron transitions in dopant ions, the best examples being Ce3+ and Eu^{2+}, which can be crystal field shifted in the spectral location of their absorption and emission lines. One essential difference between Ce^{3+} and Eu^{2+} is the width of their emission band: While Eu^{2+} shows typical half widths of 30 to 60 nm, depending on the host material, Ce3+ has the widest emission of any RE ions – 80 to 100 nm because of a spin-orbit ground state. In most hosts, the two transitions are so much broadened that they overlap completely into a broad asymmetric band.

The first white LED by NICHIA, Japan is composed of a blue $In_{0.3}Ga_{0.7}N$ LED and $(Y_{1-a}Gda)3(Al_{1-b}Ga_b)_5O_{12}:Ce_{3+}$ popularly known as YAG:Ce yellow phosphor was developed for LCD back lighting in cellular phones. These LEDs introduced in market in 1996 had a life time – 100,000h and luminescence efficiency ~ 50 lm/W. However, combination of such yellow and blue colors gives insufficient color rendering index (CRI) due to the lack of red component in the emission spectra.

Some efficient nitride-based phosphors such as $CaAlSiN_3:Eu^{2+}$ have been developed which meet some of the spectral requirements of LED lighting. Recently a lot of effort has been put for shifting the emission spectrum of YAG:Ce into the red spectral region by co-doping with other RE ions such as Tb^{3+}, Gd^{3+} etc .

Challenges Ahead for Indian Scientists :

Commercial phosphors for display like PDP, CPT and others are well established but till today, small quantities (10 to 100 grams) of nanophosphors are manufactured in controlled manufacturing conditions. Various types of phosphors are being synthesized by sol-gel, homogenous precipitation, colloidal suspension, capping, cluster formation, chemical vapor, aerosol, flame diffusion, micro-emulsion, laser pyrolysis, flame pyrolysis, combustion, hydrothermal, and solid state reaction.

Some of the techniques such as flame and laser pyrolysis and sol-gel process are mostly employed to manufacture nanophosphors. Important physical properties viz. crystallization, morphology (particle size and shape) of different nanophosphors are to be concentrated.