"White light" from LED´s

New explosion protected indicating lamp for process engineering

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Figure 1: Explosion protected indicator light lamp 8017 from the year 1976 with 7 LED´s

Explosion protected indicator lights with LEDs as the light source have been used since the mid-seventies in the chemical industry and other hazardous areas. The diodes available at the time had a luminous intensity of 30 to 50 mcd, depending on the colour of light. But it was necessary to fit seven LEDs arranged in the form of a wreath (Figure 1) to achieve the perceived brightness of the flameproof indicator lights conventional until then for mounting dimension D 30, which were equipped with 4 or 5 W incandescent or glow lamps. The range of diodes available at the time was almost only monochromatic and could be produced only in the colours red, yellow and green. Despite this restriction, this solution had one crucial advantage for users. The possible service life of these diodes is 50,000 or more hours. By comparison with the 1,000 to 2,000 hours of an incandescent lamp, this means no lamp change during the conventional service life of an installation. In the hazardous area, the related circuit generally needs to be disconnected in order to change the lamp. This required either an expensive special design of the lampholder or shutting down a system section.

Current in and light out

On the types of lamp conventional today, light is produced on the basis of three different physical effects:

- Radiation emission of a solid in thermal equilibrium (thermal radiation of the incandescent bulb)
- Collision excitation of atoms, ions and molecules in the gas phase(radiation spectrum of discharge lamps)
- Recombination of positive and negative charge carriers in solids (electroluminescence, light-emitting diodes)

LEDs number amongst the electroluminescence radiant light sources. As on a solar cell, the basis of an LED is a semiconductor crystal. In simple terms, the LED is the reverse of the solar cell. On the latter, light is converted to electrical current and, on the LED, the current flowing through generates light. The semiconductor consists of two layers, one of which is doped with impurity atoms in such a manner as to produce an excess of electrons. Additional atoms in the other layer produce an excess of positively charged holes. If we connect a voltage source to this pn junction in forward direction, the electrons migrate towards the positive pole and collide with the positive holes at the pn junction. The charge carriers recombine and release electromagnetic radiation during this process. The wavelength of this radiation depends on the energy gap between conduction band and valence band (Figure 2).

From discovery to use

As early as 1907, H. J. Round observed light phenomena when conducting investigations into detection of radio waves with silicone crystals. Since the crystal did not heat up, it was clear that the light in question was "cold light". However, this effect was not further investigated. Many decades passed until, in 1951, these light phenomena were interpreted as the recombination of electrons and holes during current flow through a pn junction when conducting research into solid-state physics.

Commercial use began in the early sixties. In 1962, General Electric offered the first Ga-As-P light-emitting diode with red light and an as yet very modest light output.

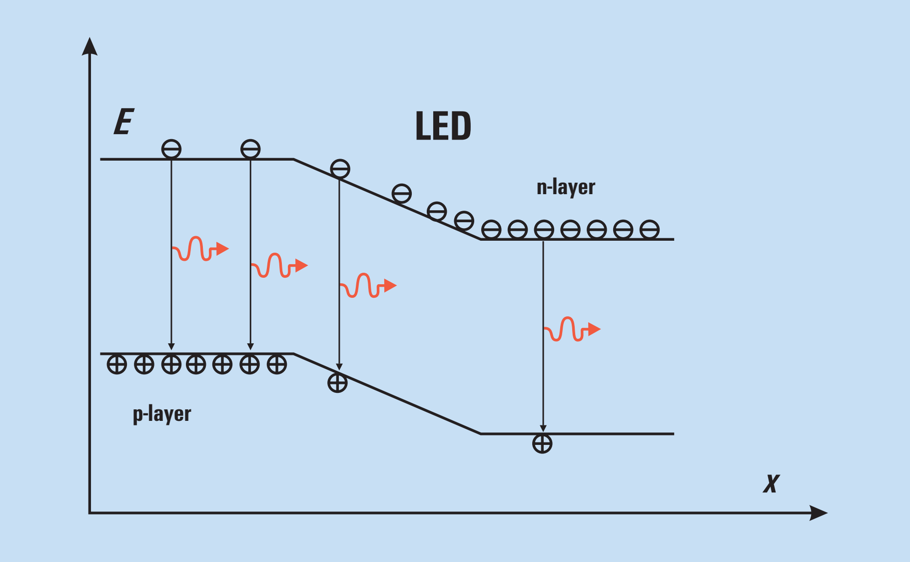

Figure 2: Recombination of electrodes and holes in a diode operated in conducting direction

The blue LED

The efficiency of diodes was constantly improved to the nineties so that it reached that of modern fluorescent lamps (Figure 3). However, the radiation spectrum is restricted, owing to the usable semiconductor materials Al Ga As or Al In Ga P, to colours red, yellow and green. Owing to the small band gap (energy gap), these materials were unable to achieve high-energy light emission in the blue or ultraviolet radiation band.

This is a disadvantage for signalling in an electrical installation. The new colour coding for indicating lamps defined in 1992 (EN 60204, Part 1, 1992 [2]) meant that the signal colours blue and white had a new significance so that it was no longer possible to dispense with these indicating colours (Table 1). Whilst white could be simulated by yellow-green diodes and a white-tinted diffuser lens, this technique does not have the blue colour.

It was only in 1994 that Shuji Nakamura, in Japan, managed to develop an effective LED which emitted luminous blue light [3] with material combination In Ga N on a sapphire substrate.

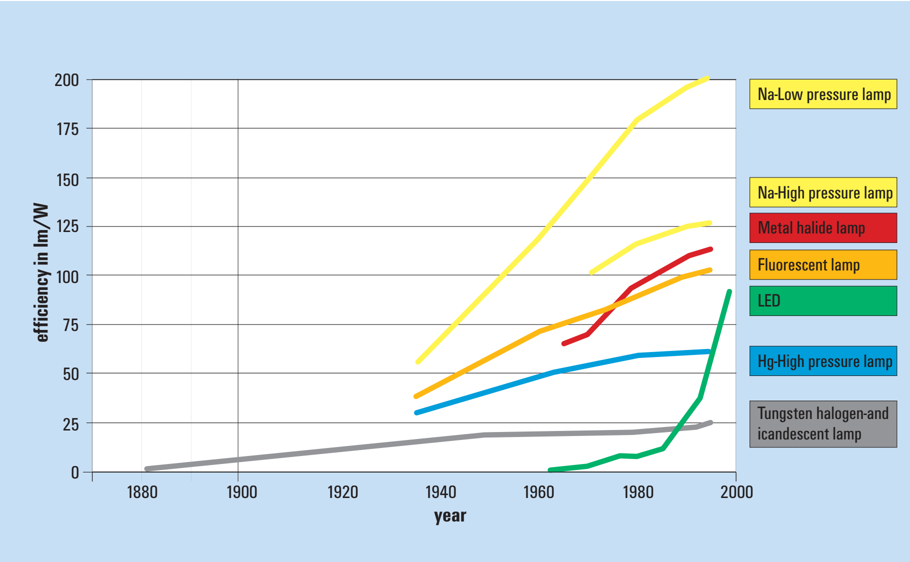

Figure 3: Luminous efficiency of electrical light sources

White light with LED´s

Development of the blue LED with an adequate intensity made it possible to produce white light as well in this way. It is still the case that the individual LEDs emit light only in a narrow spectral range. But combining blue, green and red leads to white light, if the colour components are weighted correctly.

However, the problem of this additive colour mixing relates to the fact that different LEDs age differently and that their original spectrum shifts during this process. This effect can, admittedly, be counteracted with a sophisticated electronic control system but the costs of such a solution far outweigh the benefits.

So we are left with light conversion: A monochromatic LED with ultraviolet or deep-blue spectrum is enriched with a luminescent material, which absorbs this light and then radiates a broad spectrum in the visible band (Figures 4 and 5). This technology has been used successfully for many years now, for instance, on fluorescent discharge lamps.

Table 1: Colours of indicating lights and their meaning				
Colour	Meaning	Explanation	Action by operator	Application examples
RED	Emergency	Dangerous Status	Immediate action to react to dangerous status (e.g. by actuating Emergency Off)	Pressure/ Temperature outside of safe limits voltage drop break down Going over stop position
YEL-LOW	Abnormal	Abnormal status, Prior to critical status	Monitoring and/or interference (e.g. by returning to intended function)	Pressure/ Temperature exceeds normal ranges tripping of protective mechanism
GREEN	Normal	Normal Status	Optional	Pressure/ Temperature within normal ranges Authorized to continue
BLUE	Obligatory	Indication of status, requiring action by operator	Obligatory action	Instruction to enter present values
WHITE	Neutral	other status: May be used, if there are doubts regarding use of RED, YELLOW, GREEN or BLUE.	Monitoring	General Information

Figure 6: Indicator lights 8010 and 8013

Explosion protected indicating lamp with white LED

The new generation of indicator lights 8010 and 8013 is designed with types of protection Flameproof enclosure "d" and Increased safety "e" and can be used in hazardous areas of Zone 1 and Zone 2, fitted in an Ex e enclosure (Figure 6).

These indicator lights are based on light-converting, white-luminescent light-emitting diodes.

A special electronic circuit with very low power loss achieves a broad voltage range of 12 to 270 V for DC and AC voltage. The low power loss affords the advantages of very little heat development and, thus, a very long service life of the indicator lights, reaching 100,000 hours.

The light signal is guided by a transparent insert into preferred observation directions. This means that signalling of the indicator lights can be recognised well even under difficult lighting conditions.

The signal colours red, yellow, green, blue and white are achieved with coloured inserts by colour filtration. This and the broad voltage range mean that the products are able to cover all applications with only one single indicator light version. This leads to a substantial reduction in costs in production and stocking.

If the indicator light is switched off, a special electronic circuit ensures luminescence suppression on the basis of capacitive and/or inductive, conducted interference. This is a major advantage, if the indicator lights are used in disturbed mains systems, such as those occurring, if the control cables are not adequately shielded with respect to the power cables.

Outlook for future

The white LEDs currently available on the market have a light output of around 20 lm/W and a power consumption of approx. 70 mW. This corresponds to a luminous flux of 1.4 lm. It means that application in the industrial sector is restricted to indication and signalling. However, the luminous flux level would have to be boosted to 30 to 50 lumen in order to allow use for lighting purposes, e.g. in a handlamp. Newly developed white LEDs achieve a light output of 30 lm/W thanks to ongoing improvement of the deposition technology, the increase in quantum efficiency and exterior design. The power

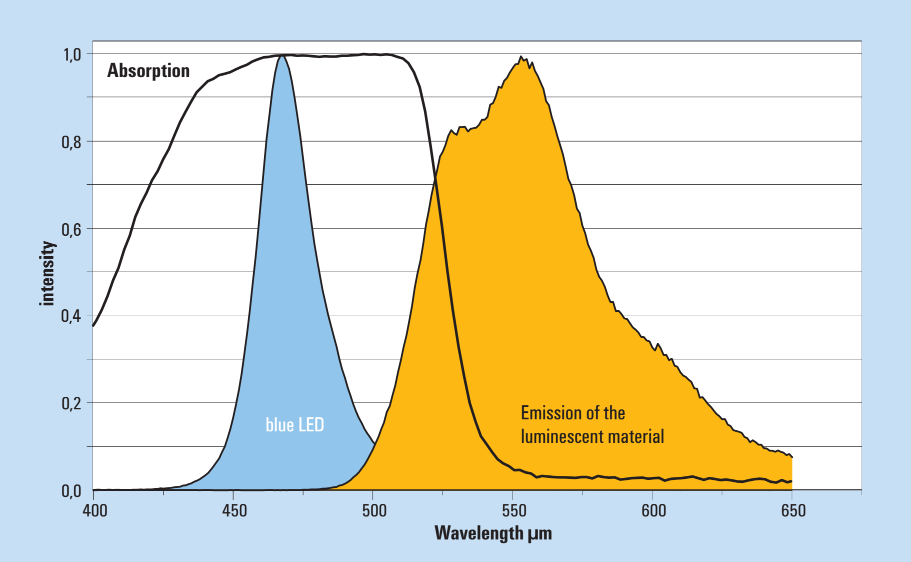

Figure 4: Light conversion of a white luminescent LED

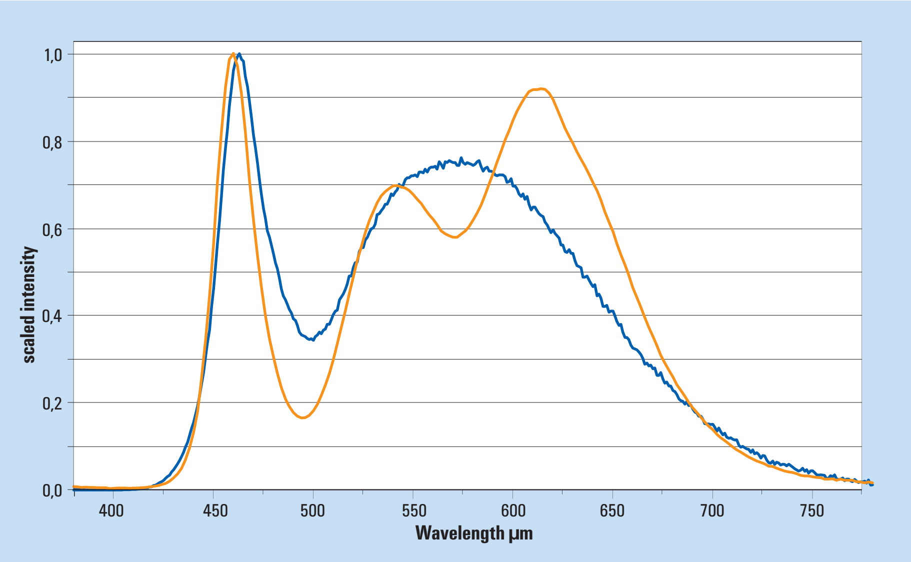

Figure 5: Spectrum of a white LED on the basis of an InGaN chip with the luminescent material YAG: Ce (blue curve) or SrGaS:Eu and SrS:Eu (orange curve)

consumption can be increased substantially by increasing the chip surface area and better heat dissipation, thus achieving the order of magnitude of a few Watts. If such LEDs are available at a feasible price, using them in explosion protected lighting fittings certainly offers very many advantages. Besides the high luminous efficiency and long service life, it is primarily the low level of heat development which optimally meets the requirements of explosion protection.

Literature

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Credits: figures 2, 3, 4, 5 taken from Lit [1]
Figures 1 and 6: R. STAHL Schaltgeräte GmbH