Development of White LEDs in Japan

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1. Introduction

LED (Light Emitting Diode) is a light source applying the other different energy conversion process, so-called electron-hole recombination luminescence than the conventional light sources, such as incandescent lamps, fluorescent lamps and HID lamps. As this energy conversion process is unique by comparing with the conventional process, thermal radiation for incandescent lamps and discharge plasma luminescence for both fluorescent lamps and HID lamps, future improving of conversion efficiency and applying to general lighting sources are now prospectively expected. according to these tendencies, present and future development of LEDs in Japan is reported hereinafter.

2. Brief History of Development of LEDs

1st LED was developed in 1968. This was uni-color (red color) light LED and was planned to apply to indicators. Since this 1st development, another type of uni-color light LEDs, yellow-green, yellow, green and amber light LEDs have been successively developed and put into market. On the other hand, intensity of optical radiation has been increased gradually, and they have been widely used at various application field, taking display sources, indicator lamps, traffic signs, automobile lighting, special field of illumination (contour lighting, small wall washer lighting and so on).

In 1993, blue light LEDs have been developed by Japanese and applicable market of LEDs became hastily larger. And then, In 1996, by combining newly developed high-efficiency YAG phosphor with this blue light LED, white light LED has been developed and put into actual market. And now, this white light LEDs are investigated to apply to general lighting fields.

Table 1. Brief History of LED Development

Year	Development of LEDs
1967	1st LED (red light, GaAs+LaF_3YbEr)
1973	Yellow-green light LED
1975	Yellow light LED
1978	High brightness red light LED
1993	Blue light LED
1997	White light LED (blue LED + phosphor)
2001	White light LED (UV LED + phosphor)

Recently, new white light LEDs applying new UV LEDs and phophor, are also under development in Japan. White light LEDs are expected as light sources in 21st Century. A brief history of LED development is summarized in Table 1.

3. LED Industries in Japan

In Japan, total production amount of uni-color light LED s has recently reached to about 8,000 million per a year. As a unit price of uni-color light LED is about \8/pc, a total amount of money is 64,000 million yen.

As is mentioned above, in 1996, white light LED was developed and in 1997, it was put into market. Now total production amount in Japan reaches to 12 million per a year. At present, unit price of white light LED is rather expensive (unit price : \100/pc).

4. METI Project in Japan

As is shown above, white light LED s are expected as new light sources at 21st century. And in Japan, the new National Project (METI (Ministry of Economic, Trade and Industry) Project): Light of 21st Century (High-efficient white light emitting chemical compound semiconductor) has been started in August, 1998, to develop high-efficient white light LED for general lighting services.

5. Recent States of white light LED

5.1 Materials and Luminous Efficacy

There can be considered several types for developing white light LEDs till now. Applied materials and luminous efficacy obtained now are shown in Table 2, for several representative types of present white light LEDs

Table 2 Materials and Luminous Efficacy of Principal White Light LEDs

Types	Materials & Construction	lm/ W
3 chips	Blue + Green + Red	20
1 chip	Blue + Phosphor	20*
	UV + Phosphor	?
	Blue + Single Crystal	8

*: Commercially available value. 40 [lm/W] can be obtained as test samples.

5.2 Problems to be Improved

As is shown in Table 2, the present level of luminous efficacy of white light LEDs is not enough for applying to general lighting purposes, because general level of lm/W for conventional light sources for general lighting, is much higher than that of white light LEDs. Taking average value of lm/W for conventional fluorescent lamps for instance, the luminous efficacy of 40 watt type tri-color fluorescent lamp is larger than 80 lm/W.

Table 3 Comparison of White LEDs with Compact Fluorescent Lamps

Item	Compact FL	White Light LED	
		in 2000	in 2010
lm/W	60	20	> 50
unit lumen	200 —9000	1.3	> 25
usable lm	30 %	60 %	> 70 %
life [hr]	3,000-9,000	> 100,000	> 100,000
% lm (at 10,000 hrs)	> 70 %	< 50 %	> 70%
cost/lm	< $0.01	$0.35	< $0.01

Including this problem, related problems of present white light LEDs to be improved, for applying to general ighting uses, are as follows;

(1) Improvement of internal quantum efficiency
(2) Improvement of external quantum efficiency
(3) Development of operating circuit for commercial electric power source (100 V or 200 V)
(4) Improvement of temperature dependency
(5) Increasing of unit lumen
(6) Improving lumen depreciation
(7) Cost reduction

As LEDs are newly developed sources, there can be expected that many new breakthroughs for improving lm/W and other related problems will be realized in future. For examples, lm/W of white light LEDs can be expected to increase to larger than 50 lm/W in 2010.

Estimated level of development in white light LEDs is summarized in Table 3, comparing with typical conventional competitive light sources, compact fluorescent lamps. This table shows possibilities of white LEDs to light sources for general lighting fields in 2010.

6. Standardization of White Light LEDs for General Lighting

For applying LEDs to general lighting uses, standardization is one of the most important items. The standard shall include at least items, in order to assess and justify the need for general illuination.

In Japan, the JELMA (Japan Electric Lamp Manufacturers Association) is regarding as standardization is one of the most important subjects for large distribution of LEDs to general lighting fields. Now the JELMA is promoting following two items for standardization of LEDs;

(1) To standardize product specification of white light LEDs for general lighting services
(2) To standardize photometry of white light LEDs

The JELMA is now proceeding these standardization by organizing a Standardization Committee on White LEDs for General Lighting, with two Sub-Committees.

7. Conclusion

White light LED is now expected as a new light source by its particular energy conversion process however, to apply widely, many new breakthroughs for improving characteristics shall be necessary.