Technical Trend

Light Sources and Lighting Circuits

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ABSTRACT

According to machinery statistics of the Ministry of Economy, Trade and Industry, the quantity of electric lamps produced in Japan in 2010 was 797,000,000 (129.5% compared to the previous year). Of these, 70,000,000 were general lamps (95.5% compared to the previous year) and 35,000,000 were halogen lamps (109.7% compared to the previous year). The number of fluorescent lamps produced was 545,000,000 (86.9% compared to the previous year), and the number of general fluorescent lamps excluding backlights was 251,000,000 (104.5% compared to the previous year). Furthermore, the number of HID lamps produced was 9,700,000 (127.3% compared to the previous year). On the other hand, when looking at sales compared to the previous year, the results for general lighting electric lamps, halogen lamps, general fluorescent lamps, backlights, and HID lamps were 87.3%, 105.1%, 98.1%, 64.7%, and 110.7%, respectively. Moreover, the sales of bulb-type fluorescent lamps included in general fluorescent lamps were 83.9% when compared to the previous year. Adding up these numbers to discuss trends is not an easy task, but we can glean two conflicting factors from this data: a long-term reduction via transition to LED light sources, and a short-term recovery from the significant reduction caused by the economic downturn of 2009. Only backlights show a significant reduction of more than 30% for 2 years in succession, due in large part to a switch to LED lighting. Our main exhibitions included "LED Next Stage 2010" in March and "LED Japan 2010" in September, both in Japan, while overseas we held "Strategies in Light 2010" in February (Santa Clara USA), and Light + Building 2010 in April (Frankfurt Germany). For research activities, the "12th Symposium on the Science and Technology of Light Sources", and the "3rd Conference on White LEDs" were held jointly in July 2010 (Eindhoven, Netherlands), and abbreviated as "LS-WLED 2010". Changes continue to be made internationally as well in the illumination fields, from conventional tubes using discharge and heat radiation to solid LED light sources. The joint conference made it very clear that the future of these industries will have a strong influence on the direction of scholastic activities. As for incandescent bulbs, a report was made concerning tungsten material, but there was almost no sign of new products or research activities, with worldwide usage bans or stops in production. In Europe, ErP Directive (Energy-related Products Directive) exist to phase out sales, with 2012 set as a phase-out target domestically. A special issue of the Journal of the Illuminating Engineering Institute of Japan took a look back on the incandescent bulb's 130 year history. As for fluorescent lamps, there was no change in direction regarding their development for low energy, long-life sources of illumination, although there was a decrease in the number of new products announced. And although bulb-type fluorescent lamps offer the benefit of an initial low cost, bulb-type LED lamps are clearly dominating the market. New product development and research of LED light sources was very active. From a practicality standpoint, many new bulb-type LED lamp products are now on the domestic market, with luminous efficiency improvements, luminous flux improvements, reduction in weight, and diversification of E17 base products. Narrow light distribution angle was raised as an issue. Standardization activities were also held, and a JEL document was established for GX16t-5 straight tube LED lamps with base by the Japan Electric Lamp Manufacturers Association (JELMA). In the high-intensity discharge (HID) lamp field, product development

and technological research related to ceramic metal halide lamps is as popular as ever. Unsaturated ceramic metal halide lamps and mercury free metal halide lamps were introduced at LS-WLED 2010. There were also many reports about other types of discharge lamps, including inductively-coupled or capacitively-coupled electrodeless lamps, microwave discharge lamps, and excimer discharge lamps. Furthermore, there were many reports with applied examples of nanotechnology as a new light source. With regard to lighting circuits, development of environment-conscious, low energy products is progressing, and there were many research reports on discharge control circuits, covering fluorescent lamps, HID lamps, and electrodeless lamps. There were also many reports on size reduction and light modulation for LED lighting circuits via improved circuit efficiency and simplified circuit structure.

1. Incandescent electric lamps

According to machinery statistics of the Ministry of Economy, Trade and Industry, the quantity of electric lamps produced in Japan in 2010 was 796,617,000 (129.5% compared to the previous year). Of these, 69,759,000 were general lamps (95.5% compared to the previous year) and 34,654,000 were halogen lamps (109.7% compared to the previous year)¹⁾. Production of electric lamps has increased significantly, but this is due to the poor economic situation in 2009, which had led to a significant decrease in production that year. Production is only 88.6% when compared to 2008 production numbers.

There were a very small number of reports related to incandescent electric lamps in 2010.

Regarding materials, there was a report on prototype results using tungsten alloy from tungsten shavings²⁾, and a report on thoriated tungsten wire regulations³⁾.

As for product trends, there was a report providing statistics on household incandescent electric lamps and halogen lamps in Europe. As a directional light source, incandescent electric lamps are increasing, especially 230 V halogen lamps, with 12 V types only slightly increasing, and an expected decrease for reflector incandescent lamps. However, due to a transition to LED directional lamps, the increase in halogen lamps is expected to saturate the future⁴⁾.

Unfortunately, no new products or technologies were found.

Along with the abolishment of incandescent lamps, their development history was introduced⁵⁾, along with their diverse types and uses⁶⁾, and a discussion of their value as seen from a culture of illumination⁷⁾. The incandescent lamp was still regarded as superior, in regards to sensory parts such as brilliance, warmth, and color rendering, and also cost and ease-of-use/handling. Also, the incandescent lamp's potential efficiency improvement technologies, microcavities, and tungsten structures were introduced⁸⁾.

Worldwide usage bans and halts in production of incandescent lamps continue to progress, and although the EU's ErP (revised to now EuP) Directive includes exclusions, usage of incandescent lamps will be effectively banned by 2016. California USA, Canada, and

Australia are also moving toward the abolition of incandescent lamps. Within Japan there is a movement to switch from general incandescent lamps to low energy light sources by 2012, with light manufacturers halting or reducing the manufacture and sale of incandescent lamps⁹⁾.

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2. Fluorescent lamps

According to machinery statistics of the Ministry of Economy, Trade and Industry¹⁾, the production quantity of fluorescent lamps in 2010 was 545,000,000 (86.9% compared to the previous year), the sales quantity was 603,000,000 (85.4% compared to the previous year), and the sales volume was 212,200,000,000 yen (92.5% compared to the previous year). Looking at standard fluorescent lamps excluding backlights, the production quantity was 254,000,000 (104.5% compared to the previous year), the sales quantity was 314,000,000 (101.8% compared to the previous year), and the sales volume was 187,400,000,000 yen (98.1% compared to the previous year). There continues to be a significant decrease

in backlight fluorescent lamps, but the decrease in standard fluorescent lamps seems to have subsided for now. However, bulb-type fluorescent lamps show a production quantity of 2,871,000 (95.2% compared to the previous year), a sales quantity of 34,809,000 (94.4% compared to the previous year), and sales volume of 32,300,000,000 yen (83.9% compared to the previous year), indicating a significant drop most likely attributed to the spread of LED lamps in the market.

In April, the "Light + Building Exhibition 2010" was held in Frankfurt, where an observation report was provided²⁾. The exhibition theme was "design and development of LED technologies to minimize effects of illumination on the environment," with a lot of LED and organic EL on display. Fluorescent lamps on display included those with T5 tubes at 50,000 h, and those with T8 tubes at 90,000 h with the inverter lit. The superiority of LED lamps was stressed in terms of lifespan and initial costs. Seamless lamps have their electrodes bent towards the fixture, providing higher efficiency than conventional lamps. Models of different wattage provide roughly the same brightness, improving the freedom of model selection when designing lamps. Items on display included bulb-type fluorescent lamps, one which is 30% more efficient than past models, at 100 lm/W, and a lifespan of 20,000 h, and another with a 36,000 h lifespan for use in streets, tunnels, parking lots, and public facilities, with a ballast lifespan of 100,000 h to reduce maintenance costs. Bulb-type fluorescent lamps drew attention for providing a lower initial cost than LED lamps, while being able to meet demand for transition from incandescent lamps. Specs include 75 lm/W, 10,000 h lifespan, a flicker resistance of 50,000 times, and a 3-year (or 5-year depending on the model) free replacement warranty to promote transition from incandescent lamps.

Although there weren't many new domestic products, there were quite a few offering a long lifespan, and a high-frequency exclusive FHC model was being sold which offers a high total flux, and a lifespan of 18,000 hours³⁾. The luminescent tube diameter was increased by 0.5 mm compared to previous models, and by performing optimization by adding a binding agent to the phosphor, the total flux and lumen maintenance factor are increased. After that, a high-persistence product also with an 18,000 h lifespan was released by a different manufacturer⁴⁾.

Regarding bulb-type fluorescent lamps, a Type A 40 W mini krypton electric lamp was released, with a lifespan of 8,000 hours and compatibility with sealed equipment⁵⁾. An E17 base type was released as well, with a brightness equal to the 40 W mini krypton lamp, and 11 W power consumption making it a top runner for 2012, also with a lifespan of 8,000 h⁶⁾.

Now for a report of fluorescent lamp related content, taken from preliminary drafts at the 43rd Annual Conference of the Illuminating Engineering Institute of Japan.

In order to bring about high-intensity, highly-efficient, mercury free electric-discharge lamps with a long lifespan, the basic plasma properties of high-frequency capacitively-coupled discharges, using high secondary electron emission factor electrode materials, were measured and evaluated. By increasing Ne and Ar gas pressures, discharge starting voltage will decrease, and plasma density will rise. It was reported that for Ne gas, applying MgO and SrTiO₃ to the Al electrode surface will provide a higher plasma density⁷⁾.

Back-sputtering was used to apply the electrodes of tubular cold cathode lamps for liquid crystal backlights, and when the relationship between the created diamond electrode surface and secondary electron emission coefficient (γ -value) was examined, the following was reported: 1. Back-sputtering caused an MgO micromask to form on the diamond surface, forming a fine needle-like structure, 2. The γ -value of a diamond etched with MgO sintered compact electrodes increased roughly twice as much as a diamond etched with stainless electrodes⁸⁾.

A report was provided regarding lamp current and voltage characteristics when fluorescent lamp electrodes are heated⁹⁾.

Results were reported concerning the measurement of discharge starting voltage, sustaining voltage, and sputter resistance when applying sine wave AC voltage to a cold cathode lamp of Ni cup electrodes and MgO thin film Ni cup electrodes. By using MgO thin film Ni cup electrodes, discharge-sustaining voltage decreases, and sputter resistance improves¹⁰⁾.

A pulse-driven xenon fluorescent lamp's maximum brightness increases significantly, with improved efficiency, by applying voltage synchronized to its main electrode to the external secondary electrodes positioned on the lamp's outer wall. At this time, the positive column expands in a radial direction, barrier discharge forms between the cathode and external electrodes, and the main electrode between internal electrodes is induced¹¹⁾.

It was reported that, in order for a tubular xenon cold-cathode fluorescent lamp to receive external secondary electrode effects, internal electrode structure is optimized, with light flux improving when the cathode is long and thin, and the anode is short and fat¹²⁾.

It was reported that by major inclusion of Ca and Mg, which have little effect of raising specific heat within alkaline-earth elements, the specific heat is reduced to improve workability. And by coating the surface with a non-ionic surfactant, potential scratching is restrained,

and glass durability can be strengthened¹³⁾.

A study was performed concerning the release of hot cathode lamp emitter, and the dependency of electrode temperature gas type and gas pressure. It was reported that an increase in gas pressure combined with a reduction in hot spot temperature will reduce the amount of emitter released¹⁴⁾.

Measurement results were reported for the electron density distribution within a cold-cathode mercury free fluorescent lamp using xenon, performed via the heterodyne interferometric method, using a CO₂ laser light as a probe light¹⁵⁾.

A report was made concerning the development of a mini krypton lamp size, that improves equipment compatibility via development of a small helical luminous tube and inverter circuits, and by setting a constriction to the glass globe and resin cover¹⁶⁾.

The effects on plasma electricity due to a site change of the ferrite core were analyzed for spherical electrodeless discharge lamps. It was reported that by widening the distance between the core and alumina base, losses due to the eddy current are reduced, while plasma electricity and light output are increased¹⁷⁾.

It was reported that when the Xe flow rate is low for high-frequency electrodeless discharge plasma, a larger tube diameter can provide higher luminescence intensity¹⁸⁾.

It was reported that when using a simple optical system with a convex lens and diaphragm, the luminescence intensity distribution of mercury plasma in a spherical electrodeless lamp's internal space can be received for each wavelength¹⁹⁾.

Only one fluorescent lamp related instance was provided in the paper published in the Journal of the Illuminating Engineering Institute of Japan. It was a report concerning the effects of mercury on the cold-cathode lamp's electrode consumption²⁰⁾. A lifespan experiment was performed to visually observe the negative glow of electrode surfaces, by using plate-like Ni electrodes to create lamp prototypes with and without mercury, with Ne/Ar gas pressure of 8 kPa. The results show that negative glow focuses on electrode tops in mercury free lamps, ultimately reducing electrodes. The reason electrode consumption occurs for an actual cold-cathode lamp when lit during end-of-life or in a low-temperature atmosphere, is because mercury ions in proximity to the anode are exhausted, and the electrode surface negative glow contracts, causing ion sputtering.

In July, LS-WLED 2010 (LS-12) was held overseas in Eindhoven, Netherlands. As for fluorescent lamp and low-pressure discharge related items, there were about 10 instances related to mercury free lamps, including dielectric-barrier discharge and excimer lamps, 7 instances concerning plasma analysis, 6 instances con-

cerning electrodes, etc. with 37 instances seen in total²¹⁾.

Finally, discussion content regarding IEC standards will be briefly touched on. In January, a workshop on modulated light was held in Frankfurt, in which a lively debate ensued on whether voltage display or current display should be used²²⁾. Other topics discussed include lead wire resistance regulations during measurements, and ballast design via pseudo-resistance. In June, discussions were held in Helsinki regarding meltage prevention for the end-of-life resin portions of fluorescent lamps, and the safety specifications / performance demands of electrodeless fluorescent lamps, while there was also a debate concerning the methods used to measure mercury content²³⁾. In October, discussions were held in Seattle regarding tubes and untargeted power in tubular fluorescent lamp EOL tests, as well as the modular light conditions of T5 tube lamps, while preparations were made concerning safety specifications / performance demands of electrodeless fluorescent lamps²⁴⁾.

Figure 2.1 High-frequency lighting ring type fluorescent lamp having a life of 18,000 hours
(©Toshiba Lighting & Technology Corporation)

Figure 2.2 Compact fluorescent lamp with equivalent brightness of 60 W mini-krypton lamp equipped with E17 base for 11 W
(©NEC Lighting, Limited)

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3. LED light sources

According to a private research firm, the 2010 LED lamp market continued to expand from 2009, and when looking at total sales of incandescent lamps, bulb-type fluorescent lamps, and bulb-type LED lamps, bulb-type LED lamps held less than 1% of the market in 2009, rose to 18.4% in 2010, and surpassed 20% in 2011. E17 base products have continued to increase since February 2010, and increased to 31.9% of all LED lamp structures in May^{*1*2}. In order to avoid consumer confu-

sion under such circumstances, the Japan Electric Lamp Manufacturers Association (JELMA) drew up JEL standard related to "Form Attribution Methods for Compact LED Lamps", while also issuing the "Performance Indication Guidelines for Compact LED Lamps¹⁾". And as a new field, tubular LED lamp JEL regulations were drawn up²⁾, and such products were sold.

As with every year, various exhibitions and seminars were held in 2010. Some of the main events held overseas included "Strategies in Light 2010" in Santa Clara, USA in February, and "Light + Building 2010³⁾" in Frankfurt, Germany in April. In Japan, "LED Next Stage 2010⁴⁾" was held in March, and "LED Japan 2010" (the Japanese version of Strategies in Light 2010) was held in September.

In this section, LED elements and bulb-type LED lamps will be discussed separately.

3.1 LED elements

And academic report stating 197 lm/W for LED element efficiency was provided, showing solid improvement⁵⁾. Trends are provided below by whitening method.

(1) Blue LEDs and phosphor

This is the mainstream method used in markets. The research report offered suggestions for improving efficiency, understanding and handling properties, cost reduction, etc. The following content was presented.

A report was given on visually optimizing the distance between LED and lens at an acceptable range, and using acrylic light diffusion to eliminate color separation, which is a flaw found in complementary white LEDs⁶⁾. LEPCs with ample fluorescent polystyrene spheres to change wavelengths to white were used to produce chromaticity (0.29, 0.36) and CRI80⁷⁾. A report was given concerning use of a simulation to change color temperature and CRI by means of atmospheric temperature and drive current⁸⁾. A report was given regarding the measurement of several types of high-output LEDs on the market, and the proportion of loss due to internal resistance, external quantum efficiency, Stokes shift, and relative luminosity for each⁹⁾.

A MOCVD device was introduced in which six 6-inch wafers can be set to lower LED costs¹⁰⁾. A report was given concerning the use of LEDs on the market in order to measure the electrical current of each LED characteristic for power design¹¹⁾. An AC drive LED chip developed for AC 12 V drive, such as the MR16, was introduced, with an indication of the properties resulting from a change in external condenser capacity¹²⁾. An LED was introduced in which a TFFC (Thin Film Flip Chip) and ceramic phosphor plate are combined, for use with headlamps having an AlN submount and using copper thermal mass¹³⁾. Silica nano-hemispherical par-

*1 http://www.gfkjpn.co.jp/update_file/pdf/232.pdf (2010/6/2)

*2 http://www.gfkjpn.co.jp/update_file/pdf/258.pdf (2010/4/13)

ticles were sequenced for masking, chemical and plasma polishing were performed, etching was performed until a quantum well structure was attained, and lastly the silica was removed to create multiple nano-columns. With that, the optical band gap properties were changed¹⁴. A lamp was suggested as a replacement for 60 W or 40 W incandescent lamps and 25 W candle lamps, which uses a module mounted with red and white phosphor type LEDs, optimized for efficiency¹⁵. It was reported that, by using a structure laminated with resin, with phosphor dispersed to the glass member, for a package using phosphor-dispersed, resin molded caps, phosphor member temperature rise can be suppressed to 40 degrees C, and “temperature characteristic loss” is reduced¹⁶. A plate structured for heat dissipation, with separated electrical connection circuits and heat dissipation flow channels, was suggested as a new structure for HLED (High performance LEDs)¹⁷.

An announcement was made regarding a new phosphor with blue excited luminescence, defined as CaZnOS: Eu^{2+} (650 nm luminescence) and $\text{Sr}_8\text{Al}_{12}\text{O}_{24}\text{S}_2\text{: Eu}^{2+}$ (605 nm luminescence)¹⁸. Evaluation results were announced for the Ce ceramic plate synthesis and optical properties of a Gd-added YAG which does not use encapsulation resin¹⁹.

(2) Near-ultraviolet LEDs and phosphor

Not many products use this method, but research is progressing in this field to increase proficiency. Efficiency was improved for remote-phosphor type COBs with chip and phosphor separated, by positioning an SPF (Short Pass Filter) between the glass caps and phosphor²⁰. 390 nm-peak luminescence was confirmed by using the nano-particle assisted pulsed-laser deposition (NAPLD) method, and producing luminescent diodes by joining n-type ZnO nano-wire and p-type GaN with hetero pn splicing²¹. A report stated that a 370 nm excitation spectrum was obtained with rare-earth borate salt $\text{ABO}_3\text{: Ce, Tb}$ ($A = \text{Lu, Y, Gd}$) as a new near-ultraviolet-excited phosphor²². Another report stated that the strongest luminescence was attained with Y-Si-O-N oxynitride based Tb and Ce, especially $\text{Y}_2\text{Si}_{13}\text{O}_3\text{N}_4\text{: Tb, Ce}$ ²³.

(3) Blue, green, and red LEDs

In this field, improved efficiency of green LEDs is the key focus. A report stated that, by performing metalorganic chemical vapor deposition (MOCVD) with the pre-TMIn (pre-trimethylindium) flow process, internal quantum efficiency was improved²⁴. It was reported that forming SiO_2 nano-column optical crystals in p-GaN selective areas increased output by 70%²⁵.

(4) Others

LED reliability must be constructed with customized conditions from the beginning. A system for determining reliability based on the failure rate of each part was suggested as a means of improvement²⁶. An initial check was reported on which uses an acceleration test to estimate the reliability of LEDs connected with solder²⁷. A report stated that by using MOCVD to form InN islands in GaN, the GaN crystal quality will improve²⁸.

3.2 Bulb-type LED lamps

At the conference presentation, there were many commentaries and reports concerning thermal analysis of products released last year. Some were as follows.

A research announcement concerning Thermal Management was made, based on the premise that thermolytic design is a key to improving small bulbs. A report was given on the quantification of envelope volume, fin structure, and radiator thermal emissions for the optimum thermal radiation design^{29,30}. A report stated that efficient thermal interface can be achieved for bulb-type LED lamps of over 1,000 lm by placing thermal interface materials between level surfaces, making contact at more than 1 bar of pressure³¹. The properties of bulb-type LED lamps, etc. with a maximum efficiency of 93 lm/W were introduced as surpassing the efficiency of bulb-type fluorescent lamps³². Exoergic change was verified with a heat-transfer analysis model via bulb-type LED lamp module composition member parameters (insulation layers, chips)³³. Part temperature measures and light distribution properties were introduced for circuit-mounted unit light sources with GX53 bases³⁴.

Trends for 2010 include LED bulbs as an alternative to mini krypton bulbs (E17 base type), as more are being sold by all companies, sizes have been scaled down, and HID lamp alternatives were released as well. Details are as follows.

(1) E17 base compatible small bulb (mini krypton bulb alternative)

The properties of products³⁵⁻³⁸ sold by each company are provided in Table 3.1. Products surpassing 100 lm/W are also included. External views are provided in Figure 3.1. Products in Figure 3.2 can also be used for equipment with light modulation functions.

Since a lot of mini krypton bulb equipment is specialized equipment requiring attachment at an angle, a “base rotation mechanism” as seen in Figure 3.3 is a product on the market that can be used to keep light shining straight downward. This product is light modulation compatible, and specs include outer diameter $\phi 35$ mm, length 67 mm, power consumption 6.4 W, white

Table 3.1 Compact LED lamp with E17 base (Retrofit for mini-krypton lamp)

External diameter	Total length	Power consumption	Total flux		Rated life	Dimmer compliant	References
			White color	Warm white color			
φ 35 mm	67 mm	4.5W	310 lm (5000K)	250 lm (2850K)	25,000 h	○	35)
φ 35 mm	67 mm	6.4W	450 lm (6700K)	370 lm (2800K)	40,000 h	○	36)
φ 35 mm	67 mm	5.4W	550lm (5000K) (Ra70)	410lm (2800K) (Ra80)	40,000 h	—	*3
φ 40 mm	71 mm	3.9W	190 lm (6500K) (Ra70)	250 lm (3000K) (Ra80)	25,000 h	—	37)
φ 45 mm	81 mm	4.3W	340 lm	260 lm	40,000 h	—	38)
φ 45 mm	81 mm	7.0W	480 lm	360 lm	40,000 h	—	38)

Figure 3.1 Small size LED lamp over 100 lm/W (E17 base compatible)
(©Toshiba Lighting & Technology Corporation) Figure 3.2 Small size LED lamp (For E17 base) for dimmer control apparatus
(©Panasonic Corporation)

color 450 lm, bulb color 370 lm, rated life 40,000 hours³⁹⁾. A product was being sold which was combined with a prism lens to control light distribution as indicated in Figure 3.4, increasing its horizontal light output by 1.6 times, with a goal of hassle free, proper replacement on brackets, small ceilings, and pendants. Specs include outer diameter φ35 mm, length 67 mm, power con-

Figure 3.3 Small size LED lamp (For E17 base) equipped with rotating mechanism at the base
(©Panasonic Corporation) Figure 3.4 Small size LED lamp (For E17 base) controlling light distribution with prism lens
(©Toshiba Lighting & Technology Corporation)

sumption 5.4 W, white color 510 lm, bulb color 380 lm, rated life 40,000 hours^{*4}. Mini reflector lamp alternatives were also being sold. Specs include φ50 × 75 mm dimensions, power consumption 3.5 W, max brightness 300 cd (3000/2700 K, Ra 85), rated life 20,000 hours, with brightness in particular equal to current market products⁴⁹⁾.

(2) E26 base compatible electric lamps (replacements for general incandescent electric lamps)

Not as many new products were released in this field as the previous year, but all companies are now selling products without exoergic fins to meet demands for lighter products.

① More than 810 lm (equivalent to 60 W bulb)

Only one company released a new product in this class. Specs include outer diameter φ55 mm, length 105 mm, power consumption 9.2 W, white color 825 lm (6700 K), bulb color 650 lm (2800 K), rated life 40,000 hours, weight 100 g⁴¹⁾.

② 485 lm (equivalent to 40 W bulb) up to 810 lm

Compared to previous year, no major efficiency improvements were made, but product weights continue to become lighter^{42/43)}. Specs are provided in Table 3.2

③ Less than 485 lm

This class was brushed up as well^{44/45)}. Specs are provided in Table 3.3

(3) Special lamp replacements

A ball lamp replacement (E26 base type) LED lamp

*3 http://www.tlt.co.jp/tlt/topix/press/p100916/p100916_2.htm

*4 http://www.tlt.co.jp/tlt/topix/press/p100916/p100916_2.htm

Table 3.2 Compact LED lamp with E26 base (485 lm (40 W Electric Lamp equivalent) to 810 lm)

External diameter	Total length	Power consumption	Total flux		Rated life	Weight	References
			White color	Warm white color			
φ 60 mm	113 mm	7.5W	550 lm (Ra70)	405 lm (Ra80)	40,000 h	120g	42)
φ 60 mm	108 mm	7.2W	600 lm (Ra70)	485 lm (Ra75)	40,000 h	73g	43)
φ 60 mm	108 mm	6.3W	485 lm (Ra70)	380 lm (Ra75)	40,000 h	70g	43)

Table 3.3 Compact LED lamp with E26 base (less than 485 lm)

External diameter	Total length	Power consumption	Total flux		Rated life	Weight	References
			White color	Warm white color			
φ 55 mm	102 mm	4.9W	320 lm (6500K) (Ra70)	260 lm (3000K) (Ra80)	40,000 h	130g	44)
φ 63 mm	112 mm	7.3W	480 lm	350 lm	40,000 h	145g	45)
φ 63 mm	112 mm	4.1W	300 lm	220 lm	40,000 h	95g	45)

was put on the market. Specs include $\phi 95 \times 127$ mm dimensions, power consumption 11.0 W, white color 730 lm, bulb color 520 lm, rated life 40,000 hours⁴⁶⁾. A lamp with three-dimensionally mounted LEDs was also put on the market, with a filament similar to that shown in Figure 3.5. Glass shape = C32, G40, G50 with E12 and E17 base types. Power consumption 0.6 W, bulb color 36 lm, rated life 20,000 hours⁴⁷⁾. Many LED lamps were released as replacements for dichroic halogen bulbs (base types: E11, EZ10, GU5.3). As a representative example, a $\phi 50$ mm lamp with the same dimensions as a MR16 bulb has a higher maximum brightness than that of a 28 W dichroic halogen bulb. Product specs include power consumption 10 W, max brightness 1,110 cd (“beam difference” (according to JIS) 36 degrees, 3000 K, Ra 80), rated life 25,000 hours⁴⁸⁾.

(4) HID lamp replacements

An LED lamp was also put on the market as a replacement for 168 W self-blast mercury lamps. See Figure 3.6 Specs include $\phi 120 \times 157$ mm dimensions, power consumption 18 W, white color 1,400 lm (5500 K, Ra 70), bulb color 1,350 lm (3000 K, Ra 70), rated life 40,000 hours. A high thermal conductive resin is used in the LED lamp’s heat radiation casing. The casing is made entirely of resin, excluding the base, with a mass of 340 g^{49)*5}.

(5) Overseas

A $\phi 6$ -inch LED PAR42 lamp was developed as a replacement for 100 to 150 W metal halide lamps (beam difference 110 degrees, power consumption 22 W, efficiency 65 lm/W)⁵⁰⁾.

“LED module for general lighting service - perform-

Figure 3.5 LED lamp mounted LEDs in filamentous state (©Ushio Lighting, INC.)

Figure 3.6 LED lamp for substituting self-ballast mercury lamp of 168 W (©Iwasaki Electric Co., Ltd.)

ance requirements (JIS C 8155)” was enacted as a JIS standard⁵¹⁾.

In order to avoid consumer confusion, the Japan Electric Lamp Manufacturers Association (JELMA) enacted JEL800 “Form Attribution Methods for Compact LED Lamps”, while also issuing Guide-008 “Performance Indication Guidelines for Bulb-type LED Lamps⁵²⁾”. Also, standardization maintenance is progressing to deal with the pending issue of securing straight tube LED lamp safety, and JEL801 “L-type Pin Base GX16t-5 Straight Tube LED Lamp System (for general lighting)” was enacted⁵³⁾. Standards include the addition of performance requirements related to L-type pin base GX16t-5 straight tube LED lamps, control devices, and sockets, as well as a method of measurement. Base / receipt (GX16t-5) regulations are covered by JEL907^{54)*6}.

Lively debate is being held overseas for enactment of IEC standards. The performance and safety of LED modules and bulb-type LED lamps were discussed at the TC34 LED Workshop. In the United States, handling of the Energy Star was transferred from the DOE (Department of Energy) to the EPA (Environmental Protection Agency). A certification system was also organized for LM-80 etc. Standards include requirements such as lamp efficiency, chromaticity, Ra, etc. China

*5 http://www.iwasaki.co.jp/product/lighting_field/led/lamp/eye-lamp.html

*6 http://www.jelma.or.jp/07kankyou/pdf/LED_Lkata_ChokkanLED.pdf

stated it would move forward with IEC adaptation.

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4. High Intensity Discharge (HID) lamps

According to machine statistics from the Ministry of Economy, Trade and Industry, the 2010 production and sales quantities for HID lamps surpass those of the previous year, suggesting the economy continues to recover¹⁾.

HID lamps, using the discharge optical emissions of high-pressure metal in a steam environment, have been focused on as a highly-efficient, low energy light source²⁾, and are widely used both indoors and outdoors. So its history, special characteristics, and principles of luminescence were introduced as basic HID lamp knowledge³⁾⁴⁾. Among the items introduced were the technology trends, future prospects and issues faced by each company in a quest for ceramic metal halide lamps providing high performance and efficiency⁵⁾⁻⁷⁾, as well as the high expectations for HID lamps with energy-saving effects.

As actual examples of HID lamps being used to save energy, their use and method of energy conservation were provided in various fields, such as commerce facility lighting⁸⁾, street lighting⁹⁾, and when looking at greenhouse gas emissions by category, a total energy savings of about 46% was achieved with factory lighting¹⁰⁾¹¹⁾. Also, efforts to attain low energy lighting don't stop with lamps. An example of retrofitting for lighting facilities already in existence was reported¹²⁾.

In 2010, LS:12 was held in the Netherlands, with a lot of focus put on the remarkable progress of LEDs in the past several years. However, status reports weren't limited to HID lamps¹³⁾, as lamps free of the mercury¹⁴⁾, which is not an environmentally friendly substance, and unsaturated ceramic metal halide lamps¹⁵⁾, were also proposed as future possibilities. A focus has been put on

HID lamps not only for conventional lighting, but for industrial use as well, such as plant growth lighting, etc. In 2010, a report was given on different types and characteristics of artificial light sources used to raise plants¹⁶⁾, as well as the current and future prospects of plant factories using these technologies¹⁷⁻¹⁹⁾. Another report detailed the research, actual use, and results of high pressure sodium lamps and metal halide lamps to raise plants and control insect activity²⁰⁻²¹⁾, while a reproduction-related research report covered the effects of mercury lamp light irradiation on the embryonic development of an exposed egg²²⁾.

4.1 High pressure mercury lamps

Technical reports on high pressure mercury lamps tend to become more scarce every year. In 2010, research results were announced concerning the temporal changes in emission spectral line intensity from each ion, such as mercury, argon atoms, barium, calcium, etc., related to whether or not X-ray irradiation existed in high pressure mercury lamps. The results suggest that electron temperature is almost entirely unaffected by X-ray irradiation²³⁾. Observations of discharge phenomena were shared at LS:12 regarding a mechanism that alters modeling²⁴⁾²⁵⁾ and the electrodes of projector lamps due to various current waveforms²⁶⁾.

4.2 Metal halide lamps

In recent years, ceramic metal halide lamps have become the main focus of attention among HID lamps, found in more technical reports than other lamps, and in 2010 in particular they have taken on a prominent role since LS:12 was held.

Firstly, the following was covered at LS:12 regarding ceramic metal halide lamps. Reports were given concerning lamp properties, including the high energy-saving performance of medium watt lamps²⁷⁾, the correlated color temperature and Duv when moderating light to save energy, research results of emission spectrum changes²⁸⁾²⁹⁾, and a report on the stability of correlated color temperature when initially lit³⁰⁾. Discharge-related reports included the method of emission for metal halide used in light-emitting material³¹⁾, methods of measuring vapor pressure³²⁾, research and observations concerning the emission of cerium, which is a light-emitting material³³⁾³⁴⁾, as well as a report on the modeling of plasma properties³⁵⁾. An understanding of property-altering phenomena of the materials used when a lamp is lit plays a significant role in the improvement of lamp performance. A report was given on the analysis of results taken from a life test on the status of main ingredients in ceramic metal halide lamps, which are PCA (alumina) and electrodes (tungsten)³⁶⁾³⁷⁾, as well as the possible inclusion of materials to increase lifespan³⁸⁾,

and research results on the reactivity of seal parts with halide³⁹⁾. A life test can be used to back the reliability of this performance improvement research, but if the lamp is lit normally, it would take far too much time to obtain results. So forced cooling was discussed⁴⁰⁾, flashing tests were suggested⁴¹⁾⁴²⁾, and evaluation methods using Weibull⁴³⁾ were reported as accelerated tests for confirming reliability.

Other metal halide lamp related reports given at LS:12 include research on luminescence energy and emission spectra⁴⁴⁻⁴⁶⁾, lumen maintenance factor relevance⁴⁷⁾, lamp start-up processes⁴⁸⁾, arc curvature in the acoustic resonance phenomenon, which is now seen as more of a problem⁴⁹⁾, and research related to convection within the arc tube⁵⁰⁾. Other reports included the startability of AC power in automobiles⁵¹⁾, research on breakdown voltage due to high-pressurization⁵²⁾, and suggested low-watt lamps to save energy⁵³⁾.

There were many reports at LS:12 concerning lamps which do not use mercury, an environmental burden, which could generally be divided into discharge-related reports and reliability-related reports. Discharge-related reports included a plasma modeling report⁵⁴⁾, a report related to metal halide emission spectra⁵⁵⁻⁵⁸⁾, the relationship between dysprosium density and plasma temperature⁵⁹⁾, and research on the effects of impurities which enter into the arc tube due to no mercury⁶⁰⁾. Reliability-related reports included a report concerning rupture experienced in automobile lamps⁶¹⁾, electrode temperature measurement results⁶²⁾, and the phenomenon and mechanism of alumina corrosion due to the influence of light-emitting material in ceramic metal halide lamps⁶³⁾.

Metal halide lamp reports other than those at LS:12 included some on retrofitted ceramic metal halide lamp characteristics and their effectiveness and issues⁶⁴⁾⁶⁵⁾, acoustic resonance phenomenon simulation results⁶⁶⁾, the relationship between light modulation and frequency⁶⁷⁾, discharge modeling results (plasma)⁶⁸⁻⁷¹⁾, and a report on the significant relationship between glow discharge time with HID lamp deterioration⁷²⁾. Since HID lamps are often used in automobiles, reports were given on their structure, principles of luminescence, and characteristics when used for automobiles⁷³⁾⁷⁴⁾. However, the issue of rupturing in this situation was also covered. Since the properties of mercury free lamps are highly dependent on Xe charged pressure, a high charged pressure setting is desirable, but if too high it can increase the possibility of rupture danger, so it must be set appropriately. This makes the ability to correctly measure the charged pressure very important, and research reports were given on a new nondestructive estimation method⁷⁵⁾⁷⁶⁾. Since visibility is an important factor for automobile headlights, results were reported

concerning street brightness, glare, and visibility^{77,78}).

Metal halide lamps are used for purposes other than conventional lighting, such as plant growing, with results of their use for gene splicing in rice cultivation provided⁷⁹, as well as research results related to the application of light radiation to biosystems (plants/insects)⁸⁰.

Other than technical reports, there were numerous new HID lamp products in 2010, but as expected, only ceramic metal halide lamps were really considered “energy-saving” products. LED lamps garner much attention for their impressive lifespan of 40,000+ hours, but high initial costs remain an issue. With 2 arc tubes per lamp, a ceramic metal halide lamp offering a lifespan of 40,000+ hours has been put on the market⁸¹, which combines the low initial costs and outstanding features of ceramic metal halide lamps with low energy use and a solid lifespan. For use in commercial facilities, a low-energy 35 W lamp is now on the market⁸², in the shape of a halogen lamp, offering the same design shops are comfortable with, and low energy use. Along with performance improvements, wattage and size decreases are progressing as well. In 2010, the world’s largest “Light & Building” exhibition was held in Frankfurt, Germany in which observation reports were given with a main focus on the expansion of “energy-saving” products⁸³, a keyword shared by the domestic market.

Although not new products for 2010, lamps were introduced which focus on red reproducibility, a weak point of conventional metal halide lamps, improve the special color rendering index (red: R9), and offer the added function of cutting UV by more than 90%, which is responsible for color degradation in industrial factories^{84,85}.

4.3 High pressure sodium lamps

Most years offer reports on high pressure sodium lamps concerning their use for plant growing, but in

Figure 4.1 Ceramic metal halide lamp attained long life of 40,000 hours by embedding two arc tubes in a lamp (©Iwasaki Electric Co., Ltd.)

2010 there were more technical reports about the lamps themselves. Firstly, technical reports on the lamp itself included a report regarding irradiations focused on sodium D-lines⁸⁶, the relationship between electrode emitter effect and discharge^{87,88}, research results concerning the significant effects of sodium loss on lamp life and performance shift, naming sealing frit as the main cause, and pointing out the need to increase sodium resistance to frit⁸⁹.

Reports concerning plant growth included one on the prevention of owl moth dangers to wide-scale open potato fields⁹⁰, and stimulating the flowering of long-day plants⁹¹.

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5. Other discharge lamps and radiation sources

As related to inductively-coupled electrodeless lamp plasma properties, reports were given on the influence of operating frequency on electron temperature, electron density, and ultraviolet radiation in spherical lamps with mercury¹⁾, the measurement of mercury emission line intensity for each torus-shaped discharge part us-

ing Abelian transformation²⁾, and confirmation of the transition from E-discharge to H-discharge as analysis of the start-up mechanism via high-speed camera³⁾. Also, regarding mercury-free cylindrical lamps using a fusion of Ne and Xe gases, the effect of Xe gas density⁴⁾ and tubes⁵⁾ on plasma parameters and emission brightness were reported. Reports were given on spherical lamps for the loss of plasma power and each part, if the ferrite core location of magnetic circuit parts is changed, when the design uses the finite element method of magnetic circuits called "power couplers" for electromagnetic field analysis⁶⁾⁷⁾. Reports were given on a lighting circuit which has lighting frequency E-level power amplification circuits with a 13.56 MHz 3rd harmonic filter⁸⁾, light moderation via E-level power amplification circuits separately-excited using the intermittent oscillation method⁹⁾, and a 140 lm/W electrodeless metal halide lamp system with circuits using an LDMOS power transistor¹⁰⁾. There was also a report given on the inductively-coupled atmospheric pressure micro-plasma light source, as a portable light source using MEMS processing technology, for use in emission spectrophotometers¹¹⁾.

As for capacitively-coupled electrodeless lamps, there was a report on the relationship between high-frequency discharge gas pressure with dielectric electrodes of a high secondary electron emission coefficient surface, and discharge opening voltage or plasma density¹²⁾.

There were also reports on microwave discharge low-pressure electrodeless lamps, concerning the plasma resonance conditions of Ar-Hg lamps for use as an ultraviolet light source¹³⁾, and vacuum ultraviolet light sources of 2 m in length, using CO and Xe¹⁴⁾. For electrodeless HID lamps, reports were given on the relationship between input and emission spectra within In halide lamps¹⁵⁾, and measurement of chemical reaction product within a quartz arc tube using metallic bromide¹⁶⁾. Reports related to lighting methods included a report on a circularly-polarized microwave system eliminating the need for arc tube rotation¹⁷⁾, a report on a 20% light modulation system¹⁸⁾, and a report on a system using a dielectric resonator¹⁹⁾.

Dielectric-barrier discharge is excellent as a method for excimer lamps from an efficiency and cost perspective. Regarding lamps, there were reports on the development of an ultraviolet-emitting, completely mercury free fluorescent lamp, constructed with a pair of electrodes on the outer surface²⁰⁾²¹⁾, a small lamp with a maximum radiation intensity of 30 mW/cm²⁾²²⁾, a white atmospheric pressure lamp using CdBr²³⁾, a multiwavelength-emitting lamp using a rare gas mixture of HgBr²⁴⁾, the properties of a lamp using diffusional planar discharge²⁵⁾, a micro-cavity dielectric-barrier dis-

charge laminated lamp²⁶⁾, the efficiency and life of a lamp charged with each type of gas used for ultraviolet and vacuum ultraviolet emissions²⁷⁾, the relationship between resonance radiation and gas pressure in Xe²⁸⁾, and the effects of impurities in Xe dielectric-barrier discharge lamps on emission spectra and electrical properties²⁹⁾. As for lamps with secondary electrodes other than main electrodes, reports were given on the improvement of brightness and emission efficiency via application to the pulse pressure of external secondary electrodes synchronized with main electrodes³⁰⁾³¹⁾, and the improvement of brightness and emission efficiency via optimization of phosphor thickness on the front and back surfaces of a flat plate lamp³²⁾³³⁾. A report was also given on deliberation regarding the pressure jump phenomenon via thermodynamic processes in a lamp using KrCl³⁴⁾³⁶⁾. A report was given on the use of a CCD camera and infrared laser absorption spectroscopy to perform emission spectrochemical analysis of space and time for measurements³⁷⁾. Practical examples were reported for use of the excimer lamp as an ultraviolet light source, such as wastewater treatment tests³⁸⁾, OH radical base generation via water decomposition³⁹⁾, treatment of skin disease⁴⁰⁾, and yeast disinfection⁴¹⁾. Reports were given on lighting circuits and lighting methods, including the relationship between electric power properties and ultraviolet emissions⁴²⁾, transformerless full-bridge circuits⁴³⁾, the lamp and system efficiency of current and voltage controls⁴⁴⁾, pulse current mode power supply⁴⁵⁾, vacuum ultraviolet radiation and loss mechanisms via application of 2.5 MHz high-frequency burst excitation voltage waveforms⁴⁶⁾, the changing of frequency and waveforms of KrCl coaxial type lamps by voltage application with electronic control device⁴⁷⁾⁴⁸⁾, the influence of applied voltage waveforms / amplitude on uniform emission and efficiency of Ne-Xe flat plate lamps⁴⁹⁾, a cylindrical emitting region which applies an approximately 10 kV small-amplitude voltage pulse to a small sealed-off lamp provides an ultraviolet light source of approximately 1 mm, with a 1 to 3 mm diameter⁵⁰⁾. Reports were given on the observation of a self-organization phenomenon in pure He gas, within an excimer lamp using a piezoelectric transformer⁵¹⁾, and vacuum-ultraviolet light emission in a premier lamp using He-Xe mixed gas⁵²⁾. Reports were given regarding the influence of various simulations on the plasma density, gas temperature, and energy conversion efficiency of xenon gas pressure⁵³⁾, one-dimensional fluid modeling of a coaxial excimer lamp driven by distorted square voltage⁵⁴⁾, one-dimensional drift diffusion modeling of a flat lamp⁵⁵⁾, regarding sheaths, plasma sheath description is possible under high pressure, correct predictions for discharge behavior waveforms are made possible by models including cath-

ode potential decrease, positive columns, and dielectrics⁵⁶⁾, formation, experimentation, and analysis of cathode sheaths⁵⁷⁾, applying a fixed orthogonal disassembly method to a lamp's partial differential equation model⁵⁸⁾, and analysis of coaxial-structured lamps using equivalent circuits⁵⁹⁾.

A review was given on new sources of light and radiation⁶⁰⁾, and many practical examples of nano-technology were reported.

Observations were provided regarding black radiation emissions from carbon nanotube membranes⁶¹⁾, and light sources generated via structure devices that emit electrons from the side, using carbon nanotubes⁶²⁾⁶³⁾. Reports were also given on funnel-shaped electrode structured field electron emitting light sources using diamond membranes⁶⁴⁾, and field electron emitting light sources for plant growth⁶⁵⁾. Reports were also given on field electron emitting light sources for automobiles⁶⁶⁾, and low-pressure gas discharge ultraviolet light sources using thermal field emission carbon nanotube array cathodes⁶⁷⁾. Reports were also given on the progression of photon source research using quantum dots⁶⁸⁾⁷¹⁾, and pure white light-emitting elements⁷²⁾ with 92 for special CRI R9 indicating 94 for average CRI and red CRI. Other nanoscale light sources reported on include light wells⁷³⁾, nanorod-tetrapod pair particle shapes⁷⁴⁾, photon sources using a plasmon structure⁷⁵⁾, quantum entangled photon-pair sources⁷⁶⁾, and deep ultraviolet emitting light sources using an aluminum nitride quantum well⁷⁷⁾. As for incandescent lamps, a review was given on micro-cavity light sources and cluster light sources⁷⁸⁾, and reports were provided on a lamp with a conversion rate of over 80%, using a selectable emitter that offers low discharge in infrared regions or high discharge in visible regions, due to sputtering of Cr and Cr₂O₃ on the copper substrate⁷⁹⁾, and an incandescent luminescent lamp with silica loaded inside its filament core spiral⁸⁰⁾. Also, there was a report on a new, highly-efficient lamp that emits diatomic transition metal oxide⁸¹⁾. This lamp mixes metal halide and metal oxide, generating a volatile oxygen compound with a chemical cycle making regeneration possible in the lamp. Experimental results for inductively-coupled electrodeless discharge were as follows: a plasma radiation efficiency of 68%, a visual radiation output of 48%, a correlated color temperature of 5436 K, and an average color rendering index (CRI) of 87.8. Due to excitation wavelengths combining phosphors applied to ultraviolet radiation of less than 400 nm from this lamp, it can reach an efficiency of 160 lm/W.

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6. Lighting circuits

Due to the global financial and economic crisis resulting from Lehman's fall of 2008, housing starts declined, which ultimately caused the lighting market to shrink significantly. And this difficult market situation carried into 2010.

However, enforcement of the revised Energy Saving Act, eco-points, and other measures to increase demand for energy-saving products has led to an increase in high-efficiency, long-life LED lighting fixtures and lamps on the market. There has also been an upward trend in housing starts, and these factors are seen as a sign of future recovery for the illumination industry.

As with last year, the development and proposition of highly-efficient, eco-friendly lighting fixtures continues to accelerate in the field of fluorescent lamps. Efforts of improvement for ballasts are moving forward as well, such as a reduction of electronic components, compatibility with light modulation systems previously designed for incandescent bulbs, etc. which result in less environmental strain when converting or abandoning existing lighting fixtures.

In the field of LED lighting, LED lamps and downlighting with highly-efficient output, LED lighting fixtures such as base lights for facilities and residential ceiling lights are now on the market, which can replace incandescent lamps, but development is also accelerat-

ing so that LED lamps can replace fluorescent and low-output HID lamps as well as the next generation light. The Japan Electric Lamp Manufacturers Association (JELMA) enacted JEL801: 2010 “L-Type Base Tube Shaped LED Lamp Systems (for general lighting)”, as a starting point for standardization of the LED lighting field.

As for the HID lamp illumination field, fixtures are being developed for general illumination purposes which use high-efficiency, high color rendering, long-life ceramic metal halide lamps. Moreover, HID lamp fixtures and ballasts continue to grow smaller, more efficient, and lower in cost to compete with LED lighting fixtures.

Research presentations in the lighting circuit industry in 2010 are discussed below, mainly covering presentations and papers from academic conferences.

With regard to fluorescent light circuits, there were many presentations about a simple circuit configuration for modulated light control, improved efficiency, decrease in size, and cost reduction, and also covering new control methods and circuit configurations for longer lamp life. There were many reports on other topics as well, such as LCD backlight and circuit analysis related information.

Reports related to modulated light control included a modulated light module offering low-energy light modulation, a low cost, and can be used with a single output electron ballast already on the market by simply connecting it parallel to the lamp¹²⁾. Other reports given include an electric ballast which is compatible with a phase-controlled modulation device for incandescent lamps, offering a wide range of light modulation, and low-light beam³⁾, and an electric ballast compatible with a triac-style light modulation device using simple interface⁴⁾.

Reports on efficiency improvements included one on copper/iron ballasts⁵⁾, offering A2 class emission efficiency comparable to the lamp current of a small T5 lamp, and from a standpoint of emission efficiency and ballast lifespan, they are even superior to electronic ballasts.

There were many reports on products offering small size and low cost due to the adoption of a simple circuit configuration, such as the commoditizing of circuits with improved input power factor, and inverter circuits. One covered a neutral-point type buck-boost converter, which can improve input current distortion and lower inrush current⁶⁾, while another was given on a single-switch electronic ballast offering a high power factor for bulb-type fluorescent lamps⁷⁾, and then there was a report on a bolt free, neutral-point type buck-boost converter compatible with 100 V and 200 V power via an external toggle switch⁸⁾.

Reports regarding long lifespans for lamps included one on a method of reducing lamp current peak-to-rms ratio by controlling the half-bridge inverter circuit switching duty for smoothing circuit output, with simple configuration, and low-cost smoothing circuit parts⁹⁾.

Reports regarding cold cathode lamps used for LCD backlights included a self-exciting electronic ballast using push-pull circuits, and offering superior emission efficiency at a low cost¹⁰⁾, and a method of unifying multiple lamp currents connected parallel to each other, while using digital control to calibrate current variation caused by part variation and ambient temperature change¹¹⁾.

Reports on analysis via logical analysis and simulators included one on the design approach to a light modulating electronic ballast more practical and precise than past models¹²⁾, and the design approach for a self-exciting electronic ballast, operating between 250 to 2,000 kHz with consideration given regarding parasitic components of elements, a high-frequency drive issue¹³⁾.

Many reports were given on LED light circuits, such as on circuit efficiency improvements and low-energy operation, simple circuit configurations for low-cost products, and reports on light modulation.

Reports on circuit efficiency improvements and low-energy use included a proposal of drive circuits that repeat charge and discharge cycles at 4 times the power frequency in order to avoid influence on power-supply voltage fluctuations¹⁴⁾, a proposal of nonhypotensive DC-type circuits using LED lamp multi-switch circuits and inrush current control circuits, using MOSFET¹⁵⁾, and a proposal of circuits achieving high efficiency and high power efficiency with single-stage flyback circuits, using variable boost inductance compatible with universal power supplies¹⁶⁾.

Reports concerning low-cost through simple circuit configuration included a proposal of an LED drive circuit which can reduce cost and part quantity by operating the converter in discontinuous conduction mode¹⁷⁾, a circuit proposal for controlling a PFC that used peak current mode control parts (PCMIC)¹⁸⁾, and a proposal of a circuit that modulates peak current for DC voltage and LED voltage, and controls to keep the LED lamp's average current constant¹⁹⁾.

Reports on light modulation included the proposal of a circuit that prevents camera video flicker by operating pulse width control at high frequency, and uses amplitude control and pulse width control separately when using a dimming control method²⁰⁾, as well as the proposal of a circuit that offers high efficiency because it can use low-voltage MOSFET and diodes thanks to a new DC-DC converter with twin-bus²¹⁾.

Other reports were given on long lifespan, replacement of conventional light sources, and external influ-

ences such as noise and flicker. For example, by using 4 passive LED drivers, a switch and electrolytic capacitor are no longer necessary, and a long lifespan is achieved²²⁾, a circuit with few parts, which does not use integrated circuits or inductor, can be used for emergency lights²³⁾, and the interfering wave producing mechanisms of bulb-shaped lighting equipment, along with general countermeasures, were discussed as well²⁴⁾.

With regard to lighting circuits for HID lamps in general purpose lighting applications, there were many reports about decreasing size and reducing costs by simple circuit configurations. Furthermore, there were reports regarding such things as the acoustic resonance phenomenon characteristics of HID lamps, and control methods for new lighting circuits.

Reports on simple circuit configuration included one using a single switch to combine a power factor improvement converter with a rise and fall pressure converter for more power and efficiency²⁵⁾, a streamlining of the start-up process with igniter pulse time control and polar tracking for higher efficiency²⁶⁾, and a circuit that can provide higher efficiency and size reduction by using zero voltage switching mode phase control from the Penta-Phase Series-Parallel LCsCp Resonant Inverter²⁷⁾. Reports related to the sonic resonance phenomenon included one on the increase of efficiency by operating a synchronous step-down converter soft switch²⁸⁾, one on the design approach for the switching delay time of a high-frequency, self-exciting oscillation circuit, and the power switching element parasitic capacity²⁹⁾.

Other reports included a reduction in size via power sandwich technology, used to perform high-precision mounting of surface mounted laminated converters³⁰⁾, one regarding a thermal design method through heat simulation models³¹⁾, and one on light modulation control, explaining the improvement of V-I and V-W property drift via the constant power function's current control method³²⁾.

Reports concerning the lighting circuits for HID lamps used in automobiles included one on reducing power consumption, size, and cost during the start-up phase by using full digital control for simple currents and power control³³⁾, one on increasing efficiency by changing switching elements to a zero volt switch, using both the charge mode's forward converter and discharge mode's fly-back converter, and using a high-insulated step-up forward fly-back active clamp converter³⁴⁾, and a report on a circuit that can increase efficiency with a fly-back boost converter, which has a voltage rectifier connected between the fly-back converter and boost converter as parallel input/serial output connection³⁵⁾.

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