International Journal of Physical Science Research
Vol. 1, No.1, pp.1-53, April 2017
Published by European Centre for Research Training and Development UK (www.eajournals.org)

A DEVELOPMENT OF AN ULTIMATE COIL-EEFL LAMP WITH $W_{DC} \approx 0$ FOR GREEN ENERGY PROJECT BY UN

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ABSTRACT: *After the study on the confines of the commercial incandescent lamps, we have a conclusion that the both of W-filament and LED lampshave well optimized as the power hungry incandescent lamps. We have studied the FL lamps with the different viewpoints from the established technologies for more than 80 years. We have found that the FL lamps use the Ar gas phase that allows a great potential for the (i) increase in the illuminance (lm, m^2) and (ii) the reduction in the consumed electric energy to zero. The high illuminance of the lighted FL lamps comes from the superconductive vacuum between Ar atoms that gives rise to the astronomical high quantum efficiency 3 x 10^{13} visible photons (m^3, s)$^{-1}$. The lighted Ar gas always contains the C_{Ar} that is inactive under the DC electric circuit. We have developed the coil-EEFL lamps that brilliantly light up under the external DCdriving circuit. The coil-EEFL lamps in the parallel connection in the vacuum-sealed container can be operated with $W_{DC} = 0$ that allows the reduction of more than 30 % of the electric power generators on the world.*

KEYWORDS: Green Energy, Paris Agreement, FL Tube, Quantum Efficiency, Power Consumption,

INTRODUCTION

Recently, the Paris Agreement of the United Nation on 2016 gives us a target that is the reduction of the pollution level more than 40 % from the present level in the air. However, no one gives a suggestion how to reduce the large amount of the polluted gases in the air on the world. We suppose that the automobiles and electric power generators on the world inevitably release the large amount of the polluted gases and tiny particles (e.g., PM 2.5) in air. If it is so, the largest sources of the pollution in air on the world at present time attribute to (i) driving of automobiles and (ii) light sources in the dark. The automobiles are shitting to the electric cars, resulting in the increase in the pollution level from the electric power generators. The shifting of the automobiles to the electric cars does not reduce the pollution levels in the air on the world.

Here we have considered a real reduction of the pollution level from the electric power generators on the world by the application of the most advanced incandescent lamps. According to the report of COP (Conference of Particles, 2015) of the Unite Nation, the electric power consumption of the lighting lamps on the world is around 31 % of totally generated electric powers on the world. We have paid our attention to the reduction of the electric power consumption of the incandescent lamps.

The incandescent lamps generate the visible lights by the moving electrons in either one of metal, compound, or gas [1]. We have analyzed the fundamentals of the generation mechanisms of the visible lights in the

metals, solid compounds and gases. Then, we have found the coil-EEFL lamps that have zero of the electric power consumption; e.g., $W_{DC} \approx 0$ with the astronomical quantum efficiency, 10^{13} visible photons $(m^3, s)^{-1}$ [1]. The coil-EEFL lamps can be operated with the combination of the solar cells and batteries, eliminating the distribution networks from the electric power generators to the incandescent lamps. By the application of the coil-EEFL lamps to the lighting source, the electric power consumption on the world may reduce to the target of the Paris Agreement of the United Nation on 2016. In this report will describe the fundamentals of the lighting mechanisms involved in the coil-EEFL lamps, remaining the engineering technologies for the mass production of the coil-EEFL lamps by someone else.

A brief summary of developed incandescent lamps

For the developments of the incandescent lamps, we must know about the target of the illluminance level of the incandescent lamps. The required conditions are determined by the characters of the eyes of the human. Human have the daytime activity under the slightly overcastting sky for more than 5 million years. Therefore, the eyes of the human have adjusted to the daytime scenery under the slightly overcastting sky. When they had the activity in the dark night, they used the fire flame of the dried woods, fats, oils, and natural gases that were the candescent light (lamp). The word of candescence comes from the ancient Greek. The candescence means the fire flame. The fire flames are made with the chemical reaction of the materials with the oxygen in air. The chemical reactions with the oxygen release the heat by the change in the entropy. The temperatures of the fire flames determine the illumination levels. The candescent lamps evolved with the time as shown in Figure 1. After the finding of the invisible electrons and atoms in the solid materials and gas phases on early 1800s, the lighting lamps change to the incandescent lamps that generate the visible lights as the results of the moving electrons in the materials in metals, compounds, and gases as shown in Figure 1.

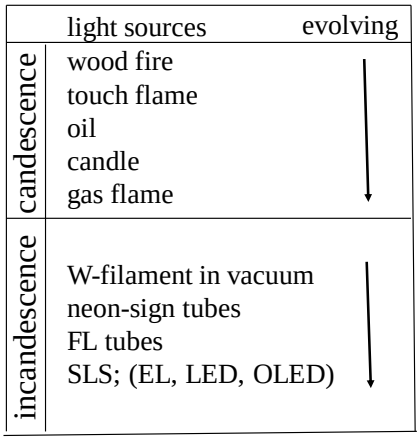


Figure 1 Evolution of candescent and incandescent lamps. SLS is solid lighting sources

The typical incandescent lamps in our life activity are (1) W-filament lamp, (2) light emitting diode (LED) lamp, and (3) fluorescent (FL) lamp. We may scientifically analyze the confines of the developed three

incandescent lamps for the selection which one remarkably saves the electric power consumption, as well as the best performance as the lighting source. For the analysis, we have challenged to a hard subject of the confines of the lighting mechanisms of the commercial incandescent lamps. The lighting mechanisms of the incandescent lamps have not clearly analyzed in the past studies. The electrons in the W-filament lamp move on in the bounding electron shell of the metal atoms that contain the vacancy in the bonding shell. The LED lamp use the conductive solids in which the electrons move on in the narrow vacuum space between atoms at lattice sites. The moving electrons in the W-filament lamps and LED lamps inevitably have the electric resistance (R) caused by the thermal perturbation from the atoms at lattice sites. The electrons in the lighting FL lamp move on in the superconductive vacuum between isolated Ar atoms that float in the vacuum between gas atoms with the large separation distance. As mentioned above, the modern science clarifies the invisible bounding mechanisms of the atoms in the different materials. Therefore, we may analyze the lighting mechanisms of the incandescent lamps with (a) the atomic levels and (b) the space of the moving electrons in the materials.

Tungsten (W) filament lamps

The solids are visible with the naked eyes. The solids are formed with the bonding electrons in the most upper electron shell of the atoms. The bonding shell of the metallic atoms is either one of (s, or p, and d shells). For example, the bonding shell of the tungsten (W) atoms is the $^5d_{10}$ electron shell that may have the capability of 10 electrons. The most upper shell of the metals is not completely filled by the electrons. The $^5d_{10}$ shell of W-atom has only 4 electrons. Consequently, the bounding shell of the W-atoms has 6 vacancies of the electrons. Each W-atom in metal has the capacity of the acceptance of 6 moving electrons in the bonding shell. Consequently, the electrons in the metals move on in the inside of the bonding $^5d_{10}$ shell of the W-atoms, as illustrated in Figure 2 (A). No vacuum space between W-atoms involve in the moving electrons in the W-filament metal.

The moving electrons in the metal unavoidably receive the thermal perturbation from the thermally vibrating atoms at the lattice sites. The electric resistance (R) of the moving electrons in the materials is assigned as the thermal perturbation from the atoms at the lattice sites. Naturally the moving electrons in the metals have R. The moving electrons in the metals generate the Joule Heat (= I^2R). The W-filament lamps use the lights from the heated filament at the high temperatures by the Joule Heat, like as the Sun. Figure 2 (B) schematically illustrates the lighted W-filament lamp. The energies of the photons from the heated W-filament widely distribute from the ultraviolet lights to the infrared lights. Consequently, we cannot calculate the quantum efficiency (η_q) of the W-filament lamps. The light intensity from the W-filament is solely determined by the heated temperatures. The η_q is given by the ratio of the numbers of the visible photons (lights) from the lamps per one moving electrons per second in the considered lamp. Accordingly, the W-filament lamps consume the large amount of the electricity with the heat of the W-filament to the high temperatures. There is no room to reduce remarkably the electric power consumption, W_{DC} or W_{act}, of the W-filament lamps. The evaporation of the heated W-filament determines the operation life shorter than 500 hours.

We may have a conclusion that the W-filament lamps do not have a capability for the contribution to the

green energy project.

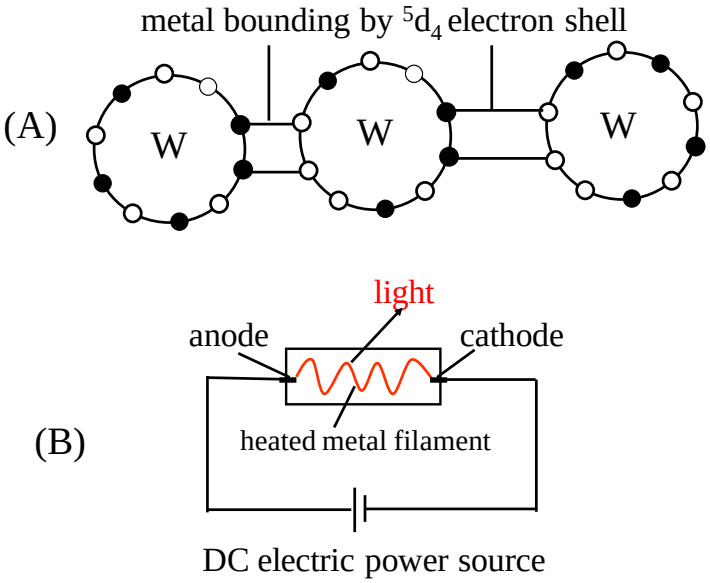


Figure 2 Schematic illustrations of 4 bounding electrons and 6 empty electrons in $^5d_{10}$ electron shell of W atoms (A) and lighting W-filament lamp by Joule Heat under DC power source (B)

LED lamps

The LED lamps use the semiconductor crystals. The semiconductor crystals have well studied by the Si crystals. Figure 3 illustrates the covalent bonding of Si crystal and formation of n-type and p-type semiconductors. The covalent bonding in Si crystal does not have the vacancy of the electron in the bonding shell. Consequently, the pure Si crystal does not have the moving electrons in neither the bonding shell nor the vacuum space between atoms at lattice sites. The pure Si crystal is the electric insulator. As the Si crystal contains a small amount P^{5+}, each P^{5+} has one extra electron in the bonding shell. One extra electron in P^{5+} stays in the narrow vacuum space between Si atoms at lattices. The extra electrons in the Si(P) move on in the vacuum space between lattice sites, giving rise to the n-type semiconductor. As the Si crystal contains a small amount B^{3+}, the covalent bonding lucks one bonding electron (i.e., hole), giving rise to the p-type semiconductor.

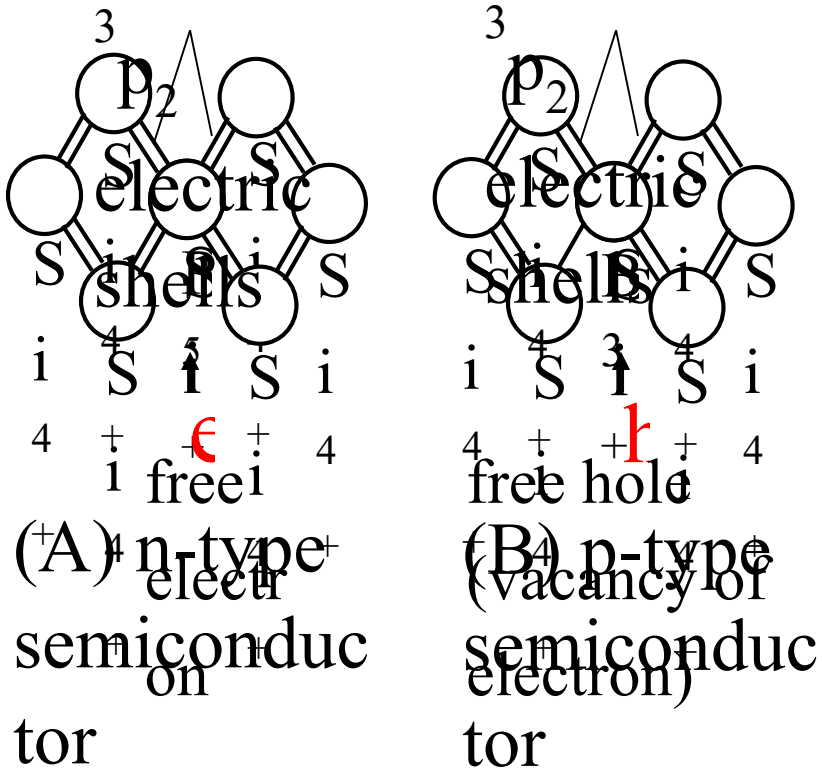


Figure 3 Schematic illustrations of n-type and p-type Si semiconductors

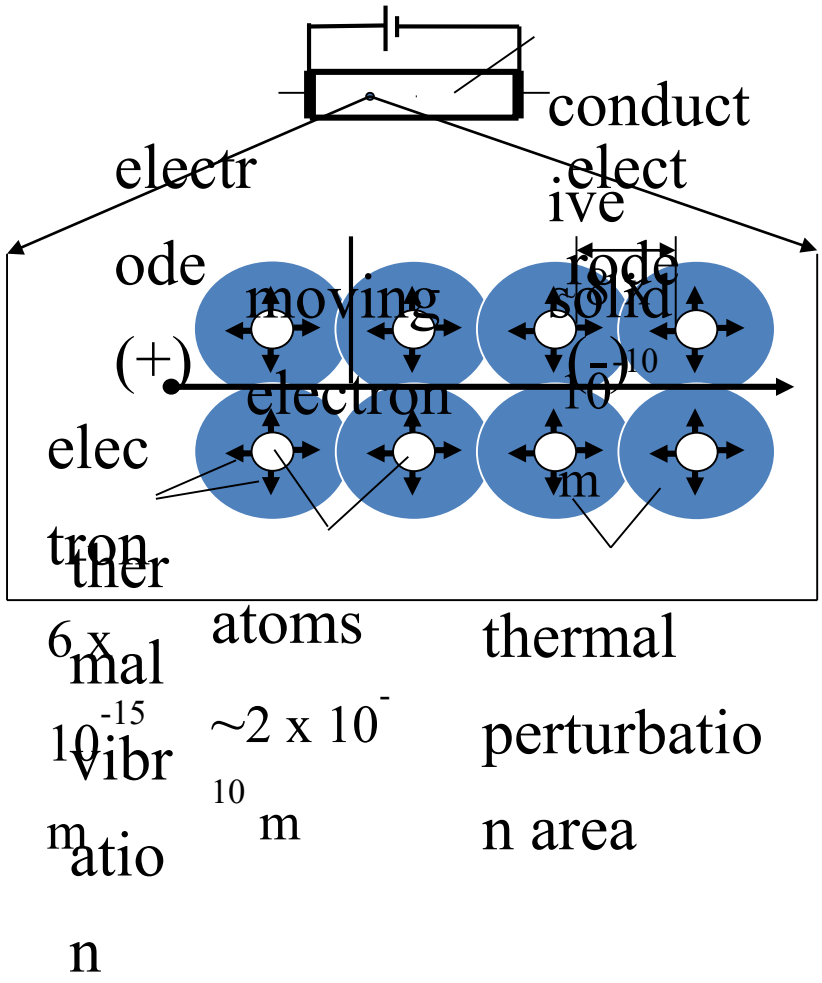


Figure 4 schematic illustrations of moving electron in vacuum between atoms at lattice sites and thermally vibrating atoms at lattice sites

The electrons in the n-type and p-type semiconductors only move on in the vacuum space between Si atoms at the lattice sites. Figure 4 schematically illustrate the moving electrons and holes in the narrow vacuum space between Si atoms at the lattice sites. The Si atoms thermally vibrate at the lattice sites. The range of the thermal vibration extends to the vacuum between Si atoms at the lattice sites. Consequently, the moving electrons in the vacuum between Si atoms inevitably receive the thermal perturbation from the vibrating atoms at the neighbor lattice sites. The thermally disturbed electrons in the narrow vacuum inevitably have R, generating to the Joule Heat (= I^2R) in the operation. The moving electrons in n- and p-semiconductors inevitably lose some amount of the kinetic energy by the Joule Heat. This means the Si semiconductors do not provide the superconductive vacuum for the moving electrons in it. The moving electrons in the semiconductors always lose the kinetic energy by the Joule Heat.

The LED lamps use III-V semiconductor. The bonding conditions of III-V atoms are the same with the Si crystal. The pure III-V compounds are the electric insulators. The n-type and p-type III-V compounds are made by the addition of the small amount of the proper impurities. The extra electrons and holes only move on in the narrow vacuum between atoms at lattice sites, like as the illustration in Figure 4. Here is arisen a

problem in the study on the moving electrons in the semiconductors. In the past study on the solid compounds, the band model has been used. The band model consists with the valence and conduction bands. We may not prove the existence of the band model scientifically. For instance, you may assign the upper band as the electric conduction band. However, the wide bands are caused by the overlapped wave function from the neighbor atoms that do not give the moving paths of the electrons in the solids. The electrons in the solids never move on in the bounding orbital shell. The determined wide band is not the conduction band for the moving electrons in the solids. We cannot use the band model for the analysis of the LED lamps.

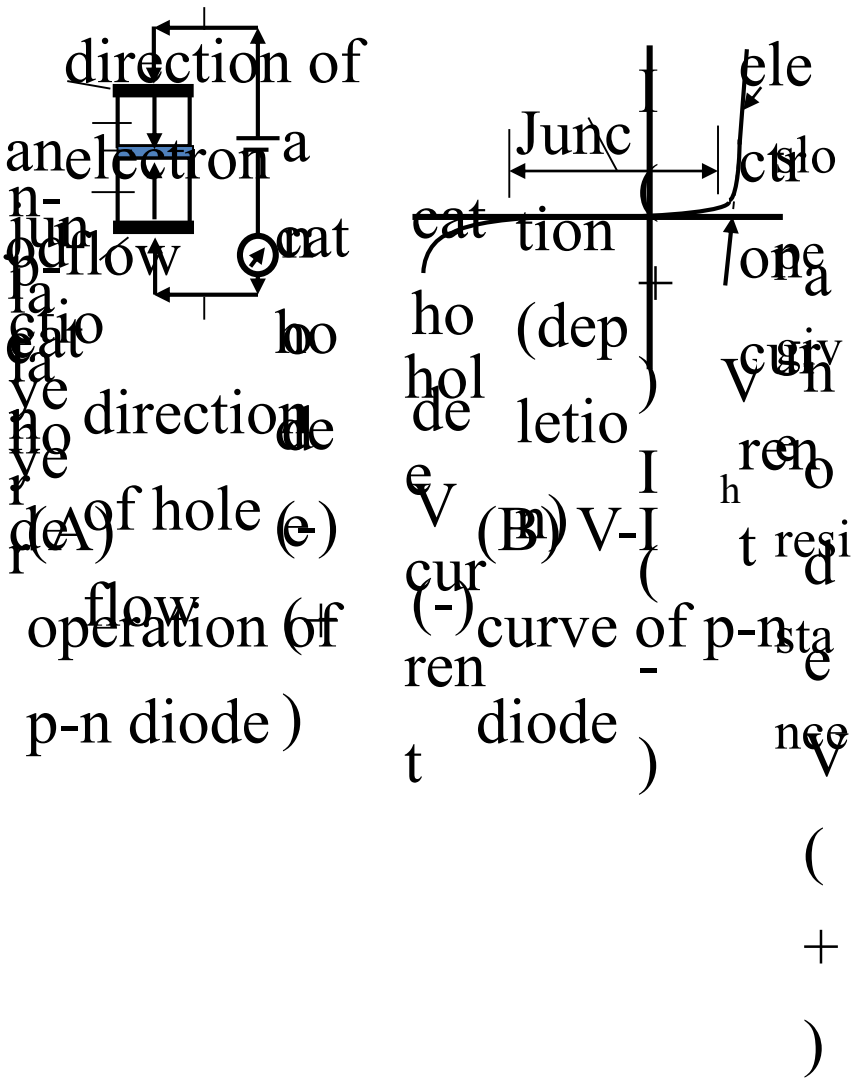


Figure 5 illustrates formation of LED lamp that joins n-layer and p-layer are joined with junction layer (A), and characteristic property of junction in V-I curve in operation (B)

The LED lamps use the moving electrons in the n-type III-V compound and the moving holes in the p-type

III-V compound respectively. The moving electrons in the n- and p- type III-V compounds never generate the lights. For the generation of the lights, n- and p-type compounds are joined with the junction. The junction contains the luminescence centers, as illustrated in Figure 5. The activity of the luminescence centers in the junction starts as the luminescence center in the junction captures the electron from n-type semiconductor. The recombination process in the luminescence center accomplishes by the capture of the hole from p-type layer. The recombination of the electrons and holes at the luminescence center generates the visible lights (photons) and returns to the original recombination center. The numbers of the emitted photons from the junction are related with the numbers of the injected electrons from the positive electrode. An overlook in the study on the LED lamps is the energy loss of the moving electrons and holes by (i) the Joule Heat in n- and p-semiconductors, which the atoms at lattice sites are thermally vibrating, as shown in Figure 4, and (ii) electric energy loss at the junction as shown in Figure 5 (B). The recombination centers do not accept the electrons and holes that have the kinetic energy smaller than the threshold energy for the recombinations. Accordingly, the numbers of the emitted photons from the junction are less than the numbers of the injected electrons from the electrodes of the LED lamps. This means the quantum efficiency is less than 1.0; $\eta_q < 1.0$. There is a reported η_q of around 0.8 [2], but it is too high. Many reported η_q is around 0.5. We take $\eta_q \approx 0.5$ in this report.

Another limitation of the operation of the LED lamps is the stability of the luminescence centers in the junction. The luminescence centers are the impurities that are stable at the temperatures below the threshold temperature at around 70ºC [3]. Above 70ºC, the light output from the LED lamps sensitively decreases with the temperatures. The LED lamps should operate with the temperatures below 70ºC. The heat source is by Joule Heat of the moving electrons in the LED lamps. The LED lamps are operated with the constant DC voltage at 2.8 V. Therefore, we may calculate the minimum electric power consumption from the electric current in the practical LED lamps.

The LED lamps emit the visible photons at the given wave length. Accordingly, we may calculate the required numbers of the visible photons for the illumination purpose. However, the required electric current of the practical operation of the LED lamps for the illumination purpose has ever calculated in the published papers. As already described, the human eyes have adjusted to the daytime sceneries under the slightly overcastting sky for 5 million years. It is not the direct lights from the sun. The comfortable illumination level of the rooms is given by the widely scattered lights, like as the overcastting sky. The comfortable illumination level on the furniture in the room is given by either the luminance (300 cd, m^{-2}) or illuminance (300 lm, m^{-2}), corresponding to the 10^{25} visible photons $(m^2, s)^{-1}$[1]. It should note that the performance of the LED lamps is never made by *the luminous efficiency (lm, W)* that is for the study on the colorimetry. The W in the luminous efficiency is the energy of the visible photons, and is not given by the electric power consumption (W_{act}) of the LED lamps. The confusion comes from the improper denotation of the W. The power consumption of the LED lamps should take the W_{act} of the driving circuit. You never take the W at the electrodes of the LED lamps. Then, we may calculate the required electric current in the operating LED lamps from the 10^{25} visible photons (m^2, s^{-1}). The DC electric current of 1 A is given by 1 Coulomb per second. One electron has 1.6×10^{-19} Coulomb. The numbers of the electrons in 1A DC current are 0.6×10^{19} electrons per second $\{= (1.6 \times 10^{-19} \text{ Coulomb})^{-1}\}$.

Then, we may calculate the required electric current of the practical LED lamps (η_q = 0.5) for the illumination of the room in $1m^2$. The required electric current in the LED lamps is 1.6 x 10^6 A (= 1 x 10^{25} electrons x 1.6 x 10^{-19} Coulomb per second), independent on the applied voltage to the LED lamps. The practical size of the dais of each commercial LED lamp is around (1 x 10^{-3} m)^2 that gives the area of 10^{-6} m^2 (= 1 mm^2). If a practical LED lamp is produced with the arrangement of 10^6 LED lamps on a given board (e.g., 1 m^2) without the space between LED daises, the LED lamp on the 1 m^2 board may comfortably illuminate the furniture in the 1 m^2 room.

We may calculate the electric power consumption W_{LED} of the 10^6 LED lamps on the given board in 1 m^2. A typical LED lamp is operated by the application of the DC 2.8 V. The W_{LED} corresponds to the W_{DC}. The calculated W_{DC} (= VI) is 5.6 x 10^6 watt (= 2.8 V x 2 x 10^6 A). The practical LED lamps in the 1 m^2 board consume W_{DC} = 5.6 x 10^6 watt. The half of them (2.8 x 10^6 watt) is consumed by the Joule Heat (= I^2R). The Joule Heat inescapably heats up the LED lamps to the temperatures higher than 70°C. As already mentioned, the recombination centers (impurities) in the heated LED lamps have the threshold temperature at 70°C for the stability of the operating LED lamps. Unfortunately, we cannot find the solution of the reduction of the huge W_{DC} of the LED lamps. Consequently, we cannot operate the LED lamps with the DC voltage.

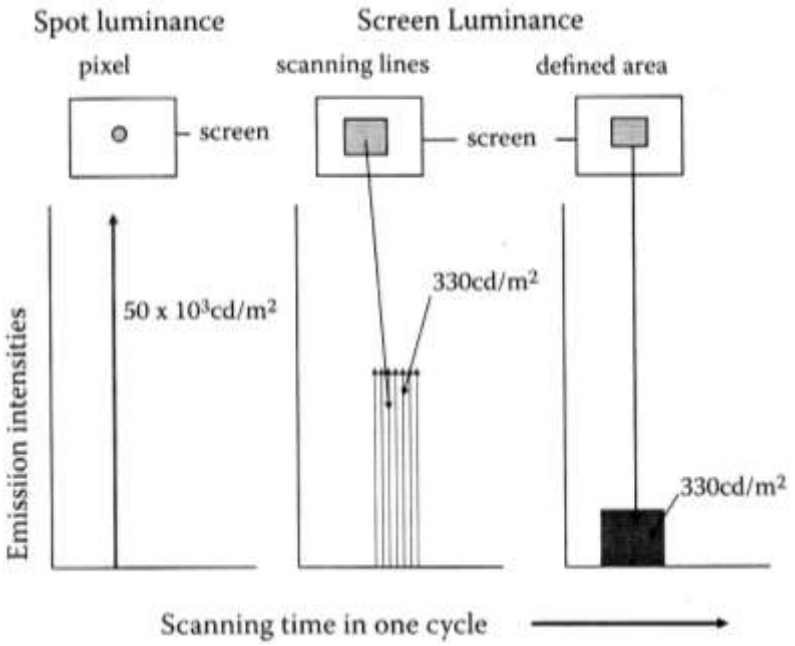


Figure 6 Schematic illustration of same luminance from phosphor screen under different lighting modes under irradiation of electron beam that is a spot, scanning line, and defined area (flame scan)

According to the study on the illuminance (lm, m^{-2}) of the lighting screens of the CRT [4], there is a way for the reduction of the W_{DC} of the lighting LED lamps that use the after image effect of the eyes. One may detect the given images on the lighted phosphor screen with the modified lighting cycles. Figure 6 shows

the results of the spot luminance, scanning lines and defined area of the screen that one may have the same luminance (330 cd, m^{-2}). Accordingly, if the total LED lamps on the given dais are operated by the field-scan of the pulses that have 2.8 V, your eyes may detect the constant light images with the AC operation. As the LED lamps are operated with the field scan of the pulses at 2.8 V, the LED lamps should be operated with the AC driving circuit. Accordingly, the power consumption of the LED lamps is given by the active AC power consumption, W_{act}, instead of the W_{DC}. In general, the W_{act} is higher than the W_{DC}; $W_{act} > W_{DC}$. We do not know the W_{act} in the reports on the LED lamps. We take the W_{DC} in the following calculations.

As the operation of the LED lamps modifies to the flame scan of the pulse at 2.8 V by the AC driving circuit [5], the LED lamp emits the half cycle. The LED lamps do not emit the lights for the subsequent half cycle of the pulse. Considering the conditions described above, we may experimentally determine the operation cycles of the pulses. From the experiments of the projected images on the screen of the CRT, the recommended pulse cycles for the illumination of the room are above 100 Hz for the LED lamps. The actual lighting cycles are 50 Hz. If we take the 100 Hz, the W_{DC} of the illumination of 1 m^2 room may reduce to 10^{-4} W_{DC} that is 300 watt (= 3 x 10^6 watt x 10^{-4}), excluding the power consumption of the AC pulse driving circuit. The ordinal room size is not 1 m^2. The ordinal room size in the house is usually 30 m^2. The required W_{DC} for the illumination of the 30 m^2 is 9 x 10^3 watt (= 300 m^{-2} x 30 m^2) = 9 k watt. The images with the pulse of 100 Hz may damage the eyes by the flickering illumination of the room with a long time.

As the consequence of the calculations based on the material science and optical science, one may allow us to say that the production conditions of the LED lamps have already optimized scientifically. The light output from the LED lamps is determined by the numbers of the injected electrons from the anode of the LED lamps. The numbers of the output of the visible photons are regulated with (a) low $\eta_q \approx 0.5$, (b) threshold operation temperature at 70°C, and (c) no superconductive solids of the LED lamp. The production technologies of the commercial LED lamps have already optimized technically. The operation conditions of the LED lamps by the pulse scan has also optimized. We cannot figure out the claimed advantage of the LED lamps as the energy saving incandescent lamps scientifically.

The LED lamps are the incandescent lamps as the limited illuminance (lm, m^{-2}) with the power hungry with the Joule Heat. The LED lamps have no room for the contribution to the green energy project (COP) on the world as the science, even though someone claims it. For the claim of the energy saving light source of the LED lamps, the claimers should show the scientific evidence. Then, we may evaluate again the LED lamps.

Fluorescence (FL) lamps

Other favorable incandescent lamp is fluorescence (FL) lamp that contains Ar atoms in gas phase. Electrons in the FL lamps move on in a wide vacuum space between Ar atoms that float in vacuum space. Figure 7 shows photograph of the lighted FL lamps (A) and structure of the FL lamps (B). The commercial FL lamps are composed with five parts; they are (i) vacuum-sealed glass tube, (ii) W-filament coil as the electrodes at the both ends of the FL lamps, (iii) Ar gas pressure at 930 Pa (= 7 Torr), (iv) Hg vapor as around 0.1 Pa (= 1 x 10^{-3} Torr) at 20°C, and (v) phosphor screen on inner glass wall. The commercial FL lamps are operated with the AC driving circuit.

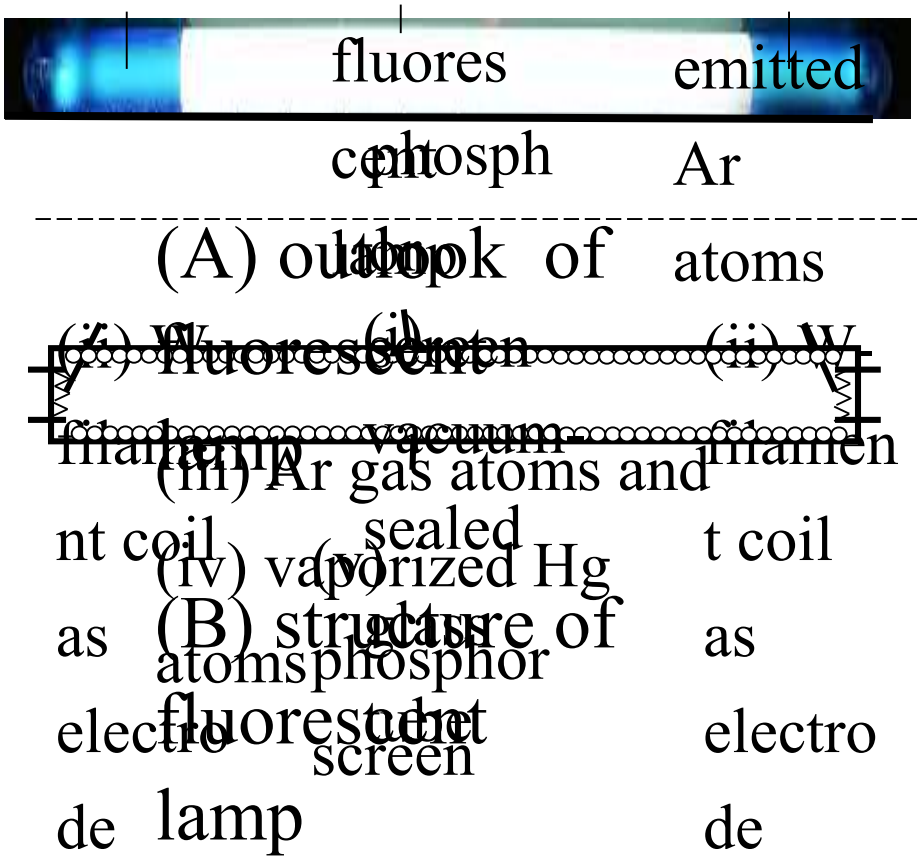


Figure 7 Photopicture of outlook of HCFL lamp (A) and structures of HCFL lamps composed with five parts (B)

The abstractions and concrete matters involve in the study on the lighting mechanisms of the FL lamps. Figure 8 illustrates the concrete matters and abstractions involved in the study on the FL lamp. The concrete matters are visible by the naked eyes, and the abstractions are invisible by the naked eyes. The established FL lamps have very well studied with the concrete matters, but the technologies based on the abstractions are made with many hypotheses. We may clarify the hypotheses by the abstractions in the lighting mechanisms of the commercial FL lamps, before the description of the advanced features of the FL lamps.

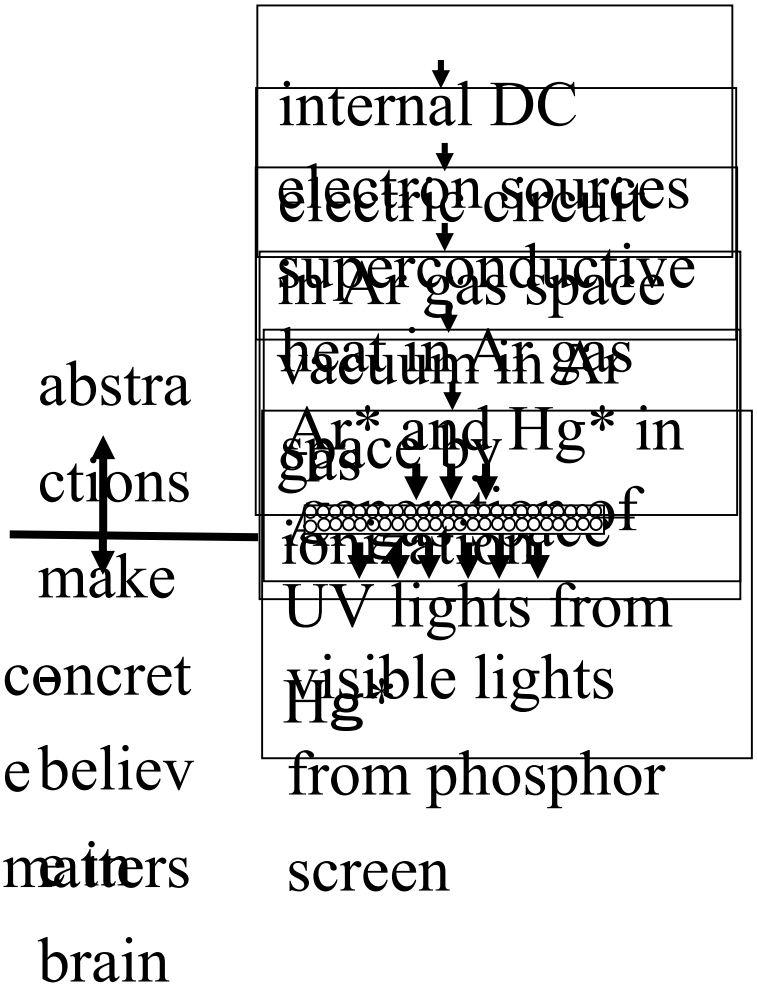


Figure 8 Illustration of abstraction and concrete matters involved in operation of FL lamps

The major material in the FL lamps as the abstraction is Ar gas. The melting point of Ar atoms is -189ºC, and boiling point is -186ºC. At the temperatures above the boiling temperature, Ar atoms only exist as gas phase. The FL lamps use Ar in gas phase. The size of Ar atom is 4 x 10^{-10} m that is invisible by the naked eyes. The Ar atoms in the lighted FL lamps emit the lights in the sky-blue spectral wavelengths as shown in Figure 9. More precisely, the Ar atoms in the FL lamps emit the line emissions at (428.8, 476.5 and 480.6) x 10^{-9} m, respectively. But the sky-blue lights from the Ar atoms are not the important light source of the FL lamps.

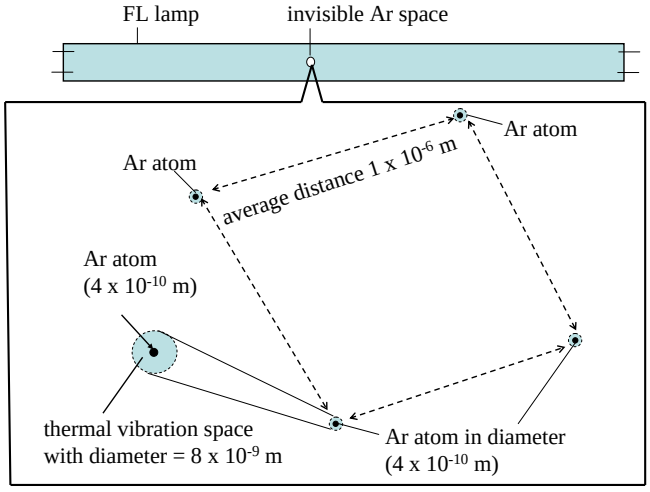


Figure 9 Schematic illustration of distribution of floating Ar atoms in vacuum in FL lamps. Individual Ar atoms in diameter at 6 x 10^{-10} m isolate each other with distance 1 x 10^{-6} m. Each Ar atom thermally vibrates in volume of diameter at 8 x 10^{-9} m.

The Ar gas in the FL lamps always contains small amount of the Hg atoms. The Hg atoms in the Ar gas emit the strong ultraviolet lights at 254 nm and 187 nm. The phosphor screen transduces the UV lights to the lights in the visible spectral wavelengths. The Hg atoms in the Ar gas are small numbers that is 10^{-3} times of the numbers of Ar atoms, but the Hg atoms in the Ar gas space act as the important role in the lighted FL lamps. We must know about the Hg atoms in the FL lamps.

The melting point of Hg atoms is -39ºC and boiling point is at 356ºC. At around room temperatures, Hg atoms are melted phase (liquid). The melted Hg has a high density of 13.6 x 10^{-3} kg at 15ºC. The melted Hg has the large surface tension of 464 (dyne cm^{-1}). The melted Hg forms the droplets in the sizes at around 1 x 10^{-3} m, rather than thin layer or large droplets on the phosphor screen. The small Hg droplets on the phosphor screens in mg orders can be detected by the naked eyes. The droplets on the phosphor screen evaporate a small amount of the Hg atoms into the Ar gas space in the FL lamps. The evaporation of the Hg atoms in to the Ar gas space exponentially increase with the temperatures of the Hg droplets on the phosphor screens between -40ºC and 350ºC. The vapor pressure of the vaporized Hg atoms at the room temperature (20ºC) is 0.13 Pa (= 1 x 10^{-3} Torr). Therefore the FL lamps at the room temperature emit the UV lights from the Hg atoms, but the UV light intensity is a low level. The established commercial HCFL lamps are operated at around 40ºC as the optimal temperature for the evaporation of the Hg atoms. However, no reason has been given as the optimal temperature at 40ºC. It is empirically determined. This is because they did not find the heat source in the HCFL lamps for more than 80 years. Furthermore the deep depth of the gap between positive column and phosphor screen determine the optimal temperature at 40ºC. Therefore, the optimal operation temperature of the HCFL lamps with the shallow depth has not yet optimized theoretically.

Recently, we have found the heat source in the lighted FL lamps. The heat source in the lighted FL lamps

is only ionization of the Ar atoms. The ionized Ar atoms release the heat by the change in the entropy of the Ar atoms [1]. Therefore, the temperatures of the Ar gas increase with the Ar gas pressures. The pressures of the vaporized Hg atoms in the lighted FL lamps with the shallow depth of the gap exponentially increase with the temperatures of the Ar gas [6]; the high Hg pressures with the high Ar gas pressures in the given lighted-FL lamps. However, the studies on the commercial FL lamps have stayed at the optimal temperature at around 40ºC that gives the vaporized Hg at 0.6 Pa (≈ 8 x 10^{-3} Torr). The reasons of the optimal temperature at 40ºC in the commercial FL lamps remained as a future study by the science. We will clarify this in this report.

The majority gas atoms in the lighted FL lamps are the Ar atoms that are 10^3 times of the Hg atoms. With this reason, we may first analyze the moving electrons in the Ar gas space of the lighted FL lamps. This is because the lights in the FL lamps are generated by the moving electrons in the Ar gas space. The electrons move on in the vacuum space between Ar atoms that are floating in vacuum. First, we like to know the numbers of Ar atoms in the FL lamps.

We may calculate the numbers of the Ar atoms in unit volume (m^3) of the FL lamp that contains the Ar gas pressure at 930 Pa (7 Torr). We take, as an example, a FL lamp in 3.0 x 10^{-2} m inner diameter (T-10) with *l* = 1.0 m long. The calculated inner volume of the FL lamp is 7 x 10^{-4} m^3 {= πr^2 x *l* = (1.5 x 10^{-2} m)^2 x π x 1.0 m).The numbers of the Ar atoms in a given FL lamp is calculated from the Boyle-Charles law (PV = mRT) and Avogadro's number. Where P is pressure at atmosphere, V is volume of the FL lamp, m is mole, R is gas constant (8.32 J/K. mol), and T is temperature by ºK. The rounded Ar gas pressure (P) in the FL lamp is ≈0.01 atmospheres {= 7 Torr x (760 Torr)$^{-1}$}. RT = 2.5 x 10^3 (= 8.32 x 300 ºK). P/(RT) = 4 x 10^{-6} {= (1 x 10^{-2}) x (2.5 x 10^3)$^{-1}$}. The mole of the Ar gas in the FL tube is given by {m = V x P(RT)$^{-1}$} that is 2.8 x 10^{-9} mole (= 7 x 10^{-4} x 4 x 10^{-6}). The numbers of the Ar gas atoms in the FL tube is calculated by the Avogadro's number (6 x 10^{23} per mole). The numbers of the Ar atoms in the FL tube are calculated as 1.7 x 10^{15} Ar atoms (= 6 x 10^{23} x 2.8 x 10^{-9}mole).

The separation distance of the Ar atoms in the FL lamps is calculated by the unit volume (m^3). The numbers of the Ar atoms per 1 m^3 are 2 x 10^{18}atoms per m^3 {= 1.7 x 10^{15} x (7 x 10^{-4} m^3)$^{-1}$}. The Ar atoms arranged on one side of 1 m^3 are 1.2 x 10^6 Ar atoms m^{-1} (= (2 x 10^{18} m^{-3})$^{1/3}$. The rounded average separation distance between Ar atoms on the side of the cubic is 1 x 10^{-6} m {= 1 m x (1.2 x 10^6)$^{-1}$} = 1 μm. The vacuum space between 1 μm is much wider vacuum space for the moving electrons in the diameters 5.6 x 10^{-9} μm. The calculated vacuum space (10^{-6} m) between Ar atoms inform us that the electrons in the lighted FL lamps move on in the very wide vacuum space, as compared with the moving electrons in the solids (10^{-9} m vacuum space). The 1 μm vacuum space between Ar atoms for the moving electrons quite differs from the moving electrons in the solids.

The analysis of the moving electrons is an important factor for the study on the FL lamps. The size of the Ar atoms is 4 x 10^{10} m (= 4 Å). As already calculated, the separation distance between Ar atoms is 1 x 10^{-6} m. The individual Ar atoms float in vacuum with the very large separation distance from neighboring Ar atoms, as illustrated in Figure 9. Each Ar atom in FL lamps isolates from neighbor Ar atoms. The large

separation distance indicates that the Ar atoms in FL lamp never bind up with the orbital electrons of the neighboring Ar atoms. Each Ar atom in the FL lamps isolates each other in the vacuum. Isolated Ar atoms in the vacuum thermally vibrate at the floating position. The thermal vibration of each Ar atom is confined in the small volume in the diameter of 8×10^{-9} m (8 nm). Consequently, the moving electrons in the wide vacuum space between Ar atoms in the FL lamps do not have the thermal perturbation from the thermally vibrating Ar atoms at the floating position. The moving electrons in the vacuum in FL lamps do not have the electric resistance R. The electrons move on in the wide vacuum space without R. Figure 9 schematically illustrates the floating Ar atoms in the FL lamps with the wide separation distance.

We may confirm the isolation of the Ar atoms in the FL lamps by the measurement of the optical absorption spectrum of the Ar atoms in the FL lamps. We may detect the weak and sharp absorption lines at around the intrinsic energy levels. Many weak absorption lines at around the intrinsic energy levels have assigned as the splitting of the intrinsic energy levels. It is well know that as the atoms are under the external electric field, the intrinsic energy levels split to the sublevels. The split sublevels have called by the Stark Effect. As the atoms are under the external magnetic field, the sublevels further split to the sublevels that have called by Zeeman Effect.

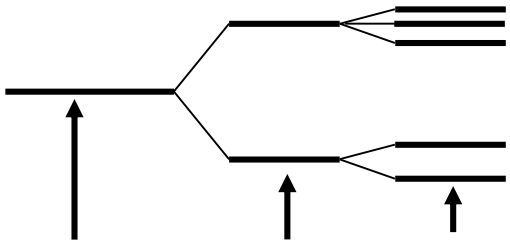


Figure 10 Schematic illustration of splitting of energy level of orbital electron of atoms by electric field (Stark Effect) and magnetic field (Zeeman Effect)

Figure 10 illustrates an intrinsic level that splits to sublevels by Stark Effect and then by Zeeman Effect. The measurements of the optical absorption spectrum of the Ar atoms inform us followings. The vacuum

space between floating Ar atoms in the unlighted FL lamp fills up with the negative electric field from the electrons in the orbital shells of the Ar atoms. The electric field from the electrons in the orbital shell is given by Q x r^{-1}, where Q is the total electric charges and r is the distance from the Q. As shown in Figure 9, r is 0.5 x 10^{-6} m. The measurements of the absorption spectrum provide us that the vacuum space between Ar atoms fills up with the negative electric field from the orbital electrons of the Ar atoms.

Figure 11 schematically illustrates the vacuum space (sky blue) that fills up with the negative electric field from the orbital electrons of the Ar atoms. The negative electric field strongly repulses the approaching electrons from the cathode of the FL lamps. For lighting of the FL lamps, the electrons must step in the vacuum between Ar atoms of the FL lamps. This is an essential problem in the study on the FL lamps. The studies of the FL lamps for nearly 90 years did not give the answer on this point. However, they have developed the lighted FL lamps that have the significant advantages over the LED lamps, except for the operation life and active AC power consumption, W_{act}. When someone wishes to improve the quality of the lighted FL lamps, he must clarify this point at first. Then, the real advantages of the lighted FL lamps will be found with his study. If you learn the established technologies, you cannot develop the advanced products. We have found many hypotheses in the established FL lamps. We will clarify them for the improvement of the FL lamps.

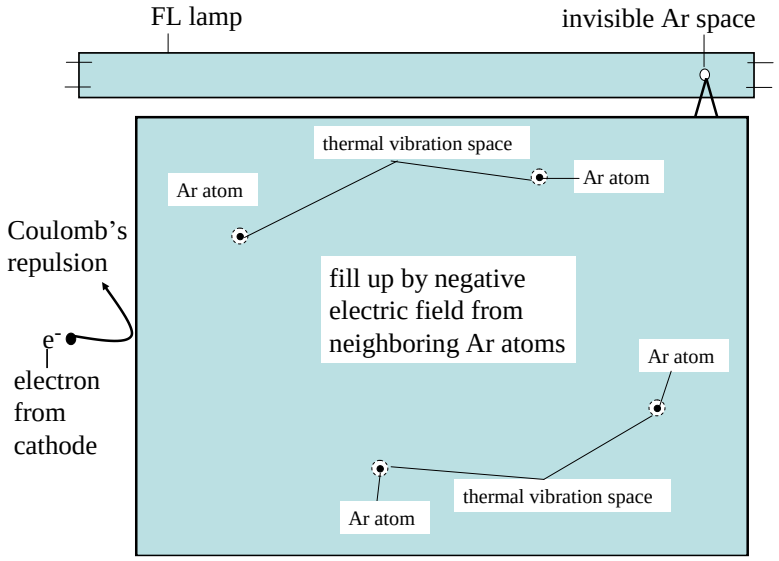


Figure 11 Schematic illustrations that vacuum between Ar atoms fill up negative electric field from orbital electrons in upper shell of Ar atoms. Approaching electrons from cathode of FL lamps cannot get in Ar gas space by strong Coulomb's repulsion.

Invalided technologies of commercial FL lamps on market

The FL lamp had invented by F. Mayer on 1928 [7]. The studies on the FL lamps have the long history for nearly 90 years by many scientists and engineers. After many trials, they have developed hotcathodes FL (HCFL) lamps. The majority of the commercial FL lamps have produced by the HCFL lamps. Their studies have summarized by many publications and books. The typical publications and books are references [8, 9.

10, 11]. The developed products of the FL lamps with the established technologies led them for the mass production.

The first question is why the HCFL lamps are operated by the AC driving circuit? The HCFL lamps can be operated with the DC driving circuit with $W_{DC} = 0$, but the operation life is extremely short less than 300 hours with the continuous heating of W-filament. With this reason, the commercial HCFL lamps are operated with the AC electric circuits that give the long operation life more than 2000 hours. The W_{act} of the AC driving circuit linearly increases with the Ar gas pressures. The compromised Ar gas pressure at 940 Pa (= 7 Torr). The annual production volume of the HCFL lamps on the world is more than multibillions for last 50 years. With the simple structures and with the large annual production volume of the HCFL lamps, it has believed that the technologies of the HCFL lamps have well studied with the mature technologies. Then, one paid his attention to “the share of the energy loss of the lighted HCFL lamps”. Figure 12 shows their results.

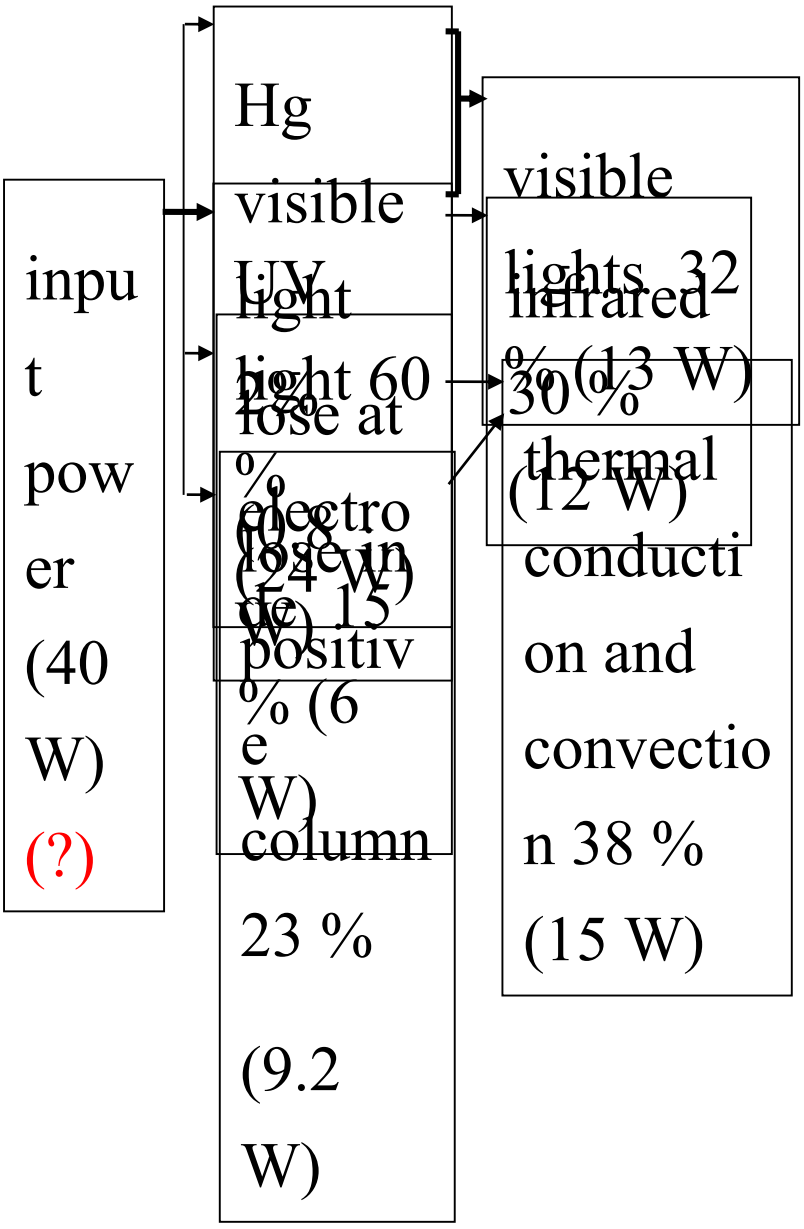


Figure 12 Energy loss diagram of lighted 40W-HCFL lamp under AC operation with 50 Hz [8, 9, 10]

The results in Figure 12 look like the well analyzed results by the science. However, there are the fundamental errors for the determination of the power consumption of each item in Figure 12. For instance, how do determine the input power (40 watt) of the 40W-HCFL lamp. The commercial 40W-HCFL lamps are operated with the AC driving circuit, so that the electric power consumption of the lighted 40W-HCFL lamps is given by the active AC power consumption, W_{act}. The input power (40W) in Figure 12 has determined at the electrodes of the HCFL lamps alone, instead of the W_{act} of the AC driving circuit. Therefore, we cannot take the 40W in Figure 12 for the analysis of the power consumption of the lighted HCFL lamps. We must take the real W_{act} of the lighted 40W-HCFL lamps.

We must study from the most fundamentals of the AC driving circuit of the lighted HCFL lamps. The HCFL lamps are operated with the AC driving circuit (ballast). Figure 13 illustrates the ballast AC riving circuit of the commercial 40W-HCFL lamp and waveforms of the electric current at the AC driving circuits. Recently, the ballast circuit shifts to the inverter circuit. The fundamentals by the inverter circuit are the same with the ballast AC driving circuit, except for the frequencies of the AC driving circuit. The ballast circuit is operated with 50 (or 60) Hz and the inverter circuit is operated with higher than 30 kHz.

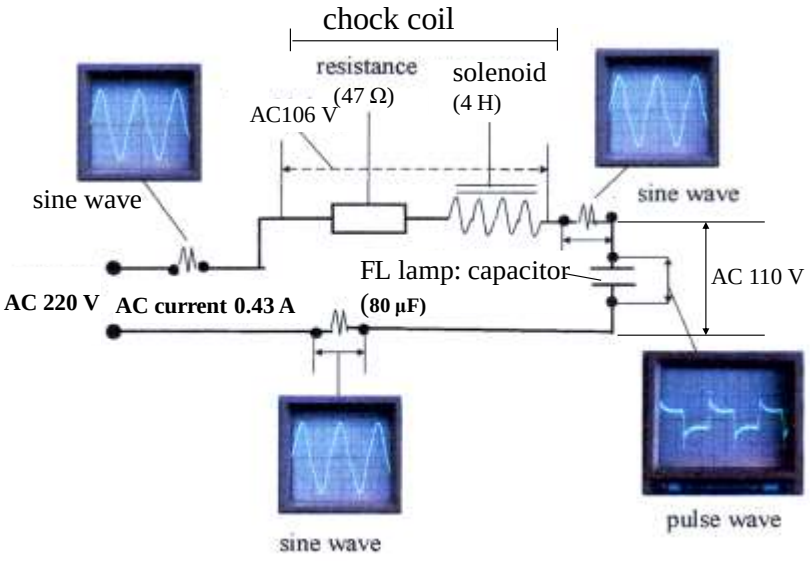


Figure 13 AC driving circuit (ballast) of 40W-HCFL lamp with waveforms at components

The ballast circuit is composed with the choke coil and electrodes of the HCFL lamp. We have detected the sine waveform at each component, except for the electrodes of the HCFL lamp. Here arises a misunderstanding of the waveform at the electrodes of the HCFL lamps. They have believed that the electrodes of the HCFL lamps emit the thermoelectrons into the Ar gas and the electrodes at other side correct arrived electrons from the Ar gas. This is a fundamental mistake. The electrodes of the HCFL lamps never emit the thermoelectrons into the Ar gas and never collect the electrons from the Ar gas. The electrodes of the HCFL lamps only detect the AC induced current from the capacitor C_{Ar}.

We have assigned the waveform at the electrodes to the waveform of the C_{Ar}. The capacitance of the C_{Ar} of the lighted HCFL lamps is calculated as 80 μF. The W_{act} of the C_{Ar} is 42 watt. The choke coil composes with the solenoid (4H) and electric resistance (47 Ω). The W_{act} at the chock coil is 46 watt. The total W_{act} of the lighted 40W-HCFL lamps is 88 watt (42 + 46 watt). Furthermore, the determined power consumptions at other parts in Figure 12 are also questionable. For instance, we cannot determine (a) the energy of the UV lights inside of the FL tube and (b) the energy lose in the positive column and so on. As described latter, the electrons move on in the superconductive vacuum in the positive column. The electrons in the positive column do not lose the electric power by the electric resistance ($V \neq RI$). The results in

Figure 12 are totally unacceptable results for us as the science.

The misunderstandings of the results in Figure 12 come from the misunderstandings of (a) injection of the thermoelectrons from the heated BaO particles on the W-filament coils into the Ar gas space, and (b) induced AC current from the capacitor C_{Ar} in the lighted HCFL lamps. Both subjects are the fundamentals of the lighting FL lamps, but the both subjects have not yet clarified by someone who has studied the FL lamps for the last 80 years. We will clarify the both subjects as below:

First we take the injection of the thermoelectrons into the Ar gas space in the HCFL lamps. The subject is the fundamentals of the operation of the FL lamps. The drilled study on the thermoelectron emission from the heated BaO particles on the metal had made with the study on the cathode ray tube (CRT) and vacuum (radio) tubes. According to their study, only Ba atoms arranged at top layer on the heated BaO particles steadily emit the thermoelectrons into the high vacuum at the pressures below 10^{-5} Pa (10^{-7} Torr). The heated BaO particles never emit the thermoelectrons into the vacuum. The heated Ba atoms under the vacuum pressures higher than 10^{-3} Pa (10^{-5} Torr) quickly damage the capability of the thermoelectron emission. Under the vacuum pressures higher than 1 Pa (10^{-3} Torr), the Ba atoms instantly damage the thermoelectron emission.

The commercial HCFL lamps are operated with the Ar gas pressure at around 930 Pa (~ 7 Torr). The Ba atoms on the heated BaO particles on the W-filament coils in the FL lamps do not have the capability of the thermoelectron emission. Furthermore, the commercial HCFL lamps contain the large amount of the residual gases at around 1 Pa (10^{-2} Torr) with the poor production process [1]. The residual gases are H_2O, CO_2, N_2, O_2,CH_n, and others. We may have the conclusion that the commercial HCFL lamps do not emit the thermoelectrons from the heated Ba on the BaO particles in the W-filament coils. The commercial HCFL lamps actually use the volume of the corona of the heated Ar atoms as the cathode and anode of the internal DC electric circuit. The volume of the corona of the Ar atoms is the fourth generation electron source (4G) in the FL lamps [12].

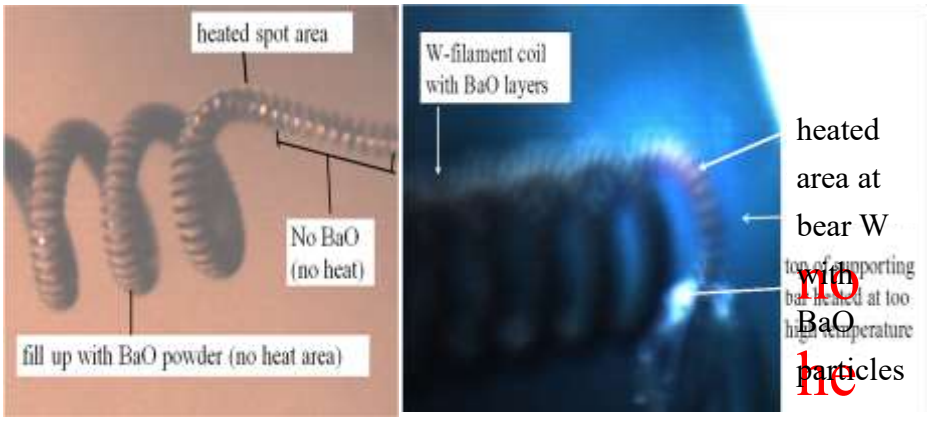


Figure 14 Photographs of produced W-filament coil with ideally packed BaO particles (A), and large unheated area and heated small area in W-filament coil in working HCFL lamp under 40 kHz (B)

Figure 14 shows the photographs of the ideal W-filament coil with the BaO particles for the application to the HCFL lamps (A), and working W-filament coils under 40 kHz (B). The ideal W-filament coil for the HCFL lamps must densely pack the BaO particles in the inside of the W-filament coil. The W-filament coils at the both ends do not have the BaO particles as shown in photograph in (A). As shown in photograph in (B), the densely packed BaO particles in the working W-filament coils in the HCFL lamp do not heat up the temperature to higher than 400ºC. It is dark at below 400ºC, as shown in Figure 14 (B). Only small area of the bear filament coil at one side of the W-filament coil always heats up to the temperature above 600ºC. The heated area in the W-filament coil is limited at the narrow area of the bear W-filament coil that has the BaO particles. The wide bear W-filament coil does not heat up the temperature. The heat source for the W-filament coils is the streamer electron beam from the 4G electrons source [12] for a half cycle of the positive AC voltage. The bear filament spot does not heat up for the subsequent half cycle. The heated spot must hold the temperature for the subsequent half cycle. The heated BaO particles at nearby the heated spot hold the temperature for the unheated half cycle by the electron beam. This is because the BaO particles have the large heat capacitance. The temperatures at the heated spot of the W-filament coil changes with the frequencies of the AC applied voltages; the higher temperature with the low frequency; e.g., 50 Hz. The temperatures at the heated bear spot of the W-filament coils are not high enough for the thermoelectron emission from the Ba atoms on the BaO particles. The thermoelectron emission from the heated BaO particles on the W-filament coils is the illusion in the study on the HCFL lamps. It is not real. The electrodes of the HCFL lamps never emit the thermoelectrons into the Ar gas space and never collect the electrons from the Ar gas space. The detected electric current at the electrodes of the external AC driving circuit in

the lighted HCFL lamps are not by the electron flow. It is the induced AC current from the C_{Ar}.

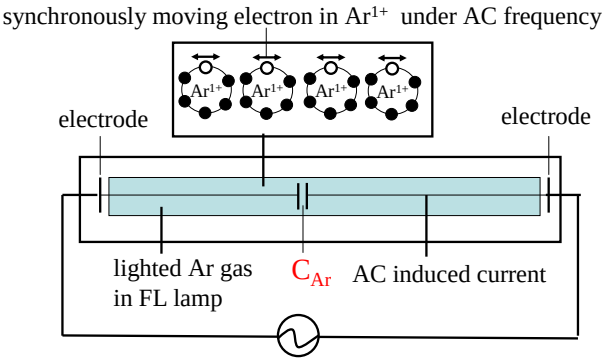


Figure 15 Formation mechanism of capacitor C_{Ar} in lighted FL lamp

Now it is clear that the electrodes of the lighted HCFL lamps do not detect the flowing electrons in the vacuum between Ar atoms. The electrodes of the HCFL lamps are only active under the operation of the AC driving circuit. The electrodes only detect the impedance of the C_{Ar}. The C_{Ar} does not form in the Ar gas space of the unlighted HCFL lamps. Formation mechanism of the C_{Ar} in the lighted FL lamps is ever discussed in the past: The formation of the C_{Ar} in the Ar gas space of the lighted FL tubes is a new concept in the study on the lighted FL lamps. Figure 15 illustrates the formation mechanisms of the C_{Ar}.

As illustrated in Figure 11, the vacuum in the unlighted FL lamps fills up with the negative electric field from the 6 electrons in the upper shell ($^3p_6$) of the floating Ar atoms in vacuum. No C_{Ar} is formed by the unlighted FL lamps. The FL lamps light up by the formation of the cathode and anode of the internal DC electric circuit [1]. The electrons from the cathode of the internal DC electric circuit in the lighted FL lamps move on in the superconductive vacuum between the Ar atoms. The moving electrons may receive the Coulomb's repulsions from the electrons in the $^3p_6$ of the Ar atoms. The repulsed electrons give some amount of the kinetic energy to the electron in the $^3p_6$. One electron in the $^3p_6$ gets out from the $^3p_6$ shell to the vacuum. The Ar atom that lost one orbital electron becomes the ionized Ar atoms (Ar^{1+}). The $^3p_6$ shell of the Ar^{1+} has an empty electron. The electron in the $^3p_6$ shell of each Ar^{1+} has the moving space in the $^3p_6$ shell under the electric field from the electrodes of the lighted FL tubes. If the electrodes have the DC electric field, the movement of the electron in the $^3p_6$ shell is made by the once. As the electrodes of the FL lamps are operated by the AC power supply, the electrons in the $^3p_6$ shell of all Ar^{1+} between the electrodes synchronously move on the position in the $^3p_6$ shell under the AC frequencies, as illustrated in Figure 15. The synchronous movement of the orbital electrons in the $^3p_6$ shell generates the AC induced current in the electrodes of the lighted FL lamps.

The Ar^{1+} is invisible by the naked eyes. We observe the sky-blue lights that emit from the excited Ar atoms (Ar*). The numbers of the formed Ar^{1+} in Ar gas is more than ten times of the numbers of the Ar*. In the past study on the FL lamps overlooks the presence of the majority of the Ar^{1+} in Ar gas in the lighted FL lamps. As described above, the electrodes of the lighted FL tubes pick up the induced AC current from the

C_{Ar} which is formed by the many Ar atoms in the lighted FL lamp. Now it is clear that the results in the input power (W) in the energy loss diagram in Figure 12 invalid in the analysis of the lighting mechanisms of the lighted FL lamps. As if you study the energy lose in the diagram in Figure 12, you will find the erroneous assignments. We cannot accept the results in Figure 12.

Many mysteries involves in the established lighting mechanism. For an example, the optimized commercial HCFL lamps are produced with the glass tube of the outer diameter in 3.2×10^{-2} m (T-10). The light output from the HCFL lamps sharply decreases with the HCFL lamps in the narrow diameters less than 2.5×10^{-2} m (T-8). The HCFL lamps with the diameters less than 2.5×10^{-2} m emit the dim light. The HCFL lamps in the diameter less than 1×10^{-2} m do not light up. No explanation has been given for the narrow HCFL lamps.

As described above, many difficulties remain in the established technologies of the FL lamps. The difficulties come from the neglecting of the following subjects: (a) the isolated Ar atoms in the vacuum, (b) the electric insulator of the Ar gas space in the unlighted FL lamps, (c) break away of the Ar gas from the electric insulator vacuum to the superconductive vacuum, (d) lighting process of the Ar and Hg atoms by the moving electrons in the superconductive vacuum, (e) formation of the cathode and anode of the internal DC electric circuit in the Ar gas space, (f) determination of the actual power consumption of the lighted FL lamps, and so on. For the clarification, we must have the revised version of the lighting mechanisms of the lighted FL lamps.

New Lighting mechanisms of FL lamps

The lighted FL lamps have the great latent potentials that have not clarified scientifically in the past studies for nearly 90 years. It has found that the lighted FL lamps are operated with the coexistence of the disparity of (a) the external driving circuit and (b) the internal DC electric circuit as unit in the operation [13]. The external driving circuit has studied in the past. The internal DC electric circuit in the Ar gas space in the lighted FL lamp only exists in the lighted FL lamps. The internal circuit is covered with the opaque phosphor screen. Consequently, the existence cannot detect by the naked eyes. The existence of the DC internal electric circuit in the Ar gas space is a new concept for the study on the lighted FL lamps. The FL lamps are solely lighted with the moving electrons in the internal DC electric circuit. For the analysis of the lighting mechanisms of the FL lamps, the understanding of the existence of the internal DC electric circuit is an important subject. For the study on the lighted FL lamps, the basics are the formation of the cathode and anode of the internal DC electric circuit in the Ar gas space of the lighted FL lamps.

Formation of cathode and anode of internal DC electric circuit in Ar gas space

We have found a concept that is the formation mechanism of the cathode and anode in the Ar gas space when we flight over the stormy clouds at near North Pole. We observed the small volumes of the corona lights on the clouds before the arc discharge (e.g., thunder lighting). We obtain an idea of the formation of the cathode and anode in the Ar gas space that are the volumes of the glow light on the electrodes. We may make the volumes of the glow light in the Ar gas on the needle metal electrodes in the vacuum-sealed glass tube.

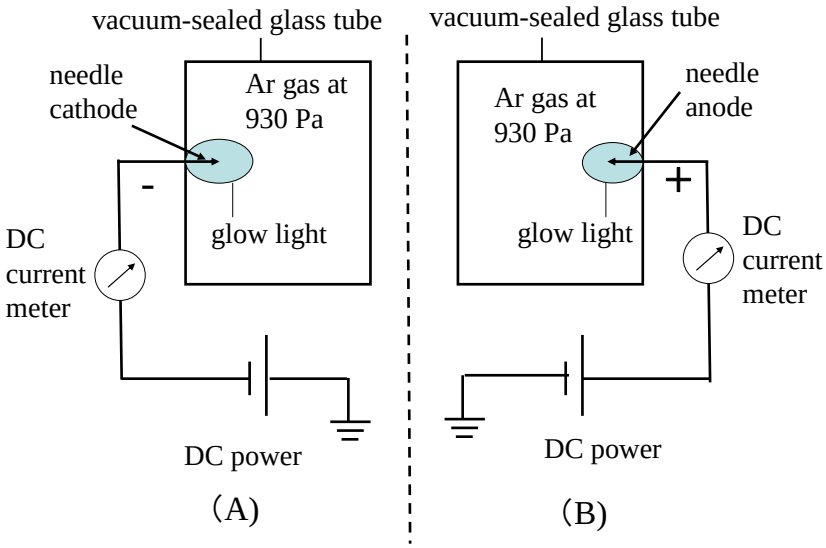


Figure 16 Experimental results of formation of volume of glow lights at around needle electrodes in Ar gas (930 Pa = 7 Torr) in vacuum sealed glass tubes. Needle electrodes respectively have negative potential (A) and positive potential (B) at 2 kV.

Figure 16 shows the experimental configurations. We have taken two vacuum-sealed glass tubes. The glass tubes contain the Ar gas at the pressure of around 930 Pa (~ 7 Torr) for the observation of the formation of the volume of the glow light on the individual needle electrodes that have negative and positive potential, respectively. As illustrated in Figure 16, we surely observe the volume of the glow lights at around the needle electrodes that have the negative and positive potential respectively. When the DC voltages above 1 kV apply to the needle electrodes, we surely observed the volume of the glow light at around needle electrodes that have the negative potential (A) and positive potential (B), respectively. Below 1 kV, there is no glow light. The threshold voltage for the generation of the volume of (A) and (B) is 1 kV. The sizes of the volume of the glow lights do not change with the applied voltages. The following experiments are made with the application of 2 kV to the needle electrodes for the security of the experiments.

The quality of the glow lights on the needle electrodes is the same with the corona lights in the Ar gas space for the 4G electron source. The volume of the glow lights contains (a) ionized Ar atoms (Ar^{1+}), (b) excited Ar atoms (Ar*), (c) free electrons (e-) and (d) Ar atoms. Only Ar* among them emits the sky-blue lights that are visible by the naked eyes. We can use the volume of the sky-blue light as the monitor of the formation of the volume of the glow light at the individual needle electrodes. The attached DC current meter to the needle electrodes shows zero electric current. We have a conclusion that the volumes of the glow light are formed by the electric field from the needle electrodes, and that the volume is not formed by the electron current from the needle electrodes.

The thickness of the volume of the glow light on the needle metal electrodes is about 3×10^{-3} m. The thickness of the glow lights does not change with the applied voltages to the electrodes, except for the light

intensity of the sky-blue lights. The brightness of the glow lights on the needle electrodes increases with the application of the DC voltages higher than 2 kV. We also made the experiments with the Ne gas that gives the red glow light. We have observed the same size of the volume of the red glow lights at around needle electrodes. Thus, we have individually confirmed the formation of the volume of the glow light on the needle electrodes by the electric field.

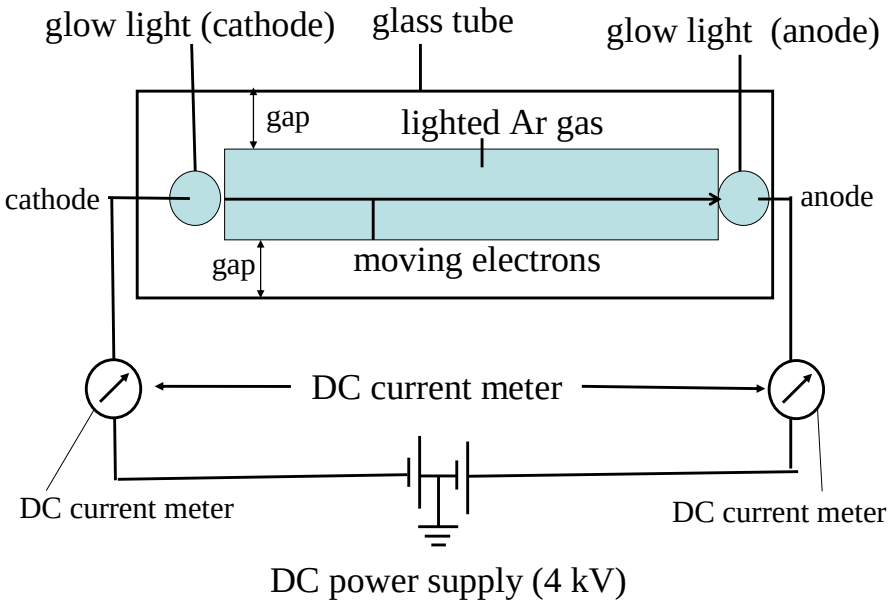


Figure 17 Lighted glass tube which cathode and anode are formed by volume of glow lights on metal needle electrodes

Then, we have set the needle electrodes at the both ends in a vacuum-sealed glass tube that contain Ar gas pressure at 930 Pa (7 Torr). The DC voltage at 4 kV applies to the needle electrodes at the both ends of the glass tube. The Ar gas space between the volumes of the glow lights on the needle electrodes emits the brilliant sky-blue light as shown in Figure 17. The DC current meters at the electrodes surely indicate the flow of the electrons between electrodes. As the needle electrodes sets in the vacuum at less than 10^{-2} Pa (=10^{-4} Torr), the volume of the glow light disappears from the glass tube and the DC current meters do not detect the electron current. The observed results surely indicate the formation of the cathode and anode in the Ar gas space by the volumes of the glow light in the Ar gas. The electrons from the needle cathode move on in the Ar gas space to the anode electrode. The diameter of the lighted column in the glass tube is narrower than the inner diameter of the glass tube, indicating the moving electrons do not randomly scatter in the whole volume of the Ar gas space. Consequently, there is the gap between lighted column and inner wall of the glass tube. The details of the formation of the gap will describe in latter of this report. Here we have concentrated to the formation of the volume of the sky-blue light between cathode and anode at the both ends in the vacuum-sealed glass tube.

The results in Figure 17 surely indicate that the volume of the glow light on the cathode supplies the electrons into the Ar gas space, and that the volume of the glow light on the anode collects the electrons

from the Ar gas space. It should note that in the Ar gas space, the electrons flow from the cathode and the anode collects the electrons from the vacuum. The DC current meters at the both ends of the vacuum-sealed glass tube show us the same amount of the DC electric currents. The inside of the volumes of the glow lights is electrically connected with the moving electrons between the needle metal electrodes without the electric resistance. The evidence of no electric resistance between cathode and anode will be proof with the constant voltage between the cathode and anode with the different electric current. Thus, we have found the formation of the internal DC electric circuit in the Ar gas space by the volume of the glow lights at the both ends of the vacuum-sealed glass tube. We may study the DC electric currents in the Ar gas space as a function of the applied DC voltages to the needle electrodes.

Electrons move on in superconductive vacuum between cathode and anode

The amount of the detected DC current at the needle electrodes is characteristically changed with the applied DC voltages to the needle metal electrodes. Figure 18 shows the detected DC current as a function of the DC applied voltages. As the voltages on the needle metal electrodes are gradually increased from the DC 100 volt, the vacuum-sealed glass tube does not have the glow lights until the applied voltages below 1.0 kV. Consequently, the DC current meters do not show the electron current in the vacuum-sealed glass tube. The Ar gas space between the electrodes is the electric insulator as shown in Figure 11.

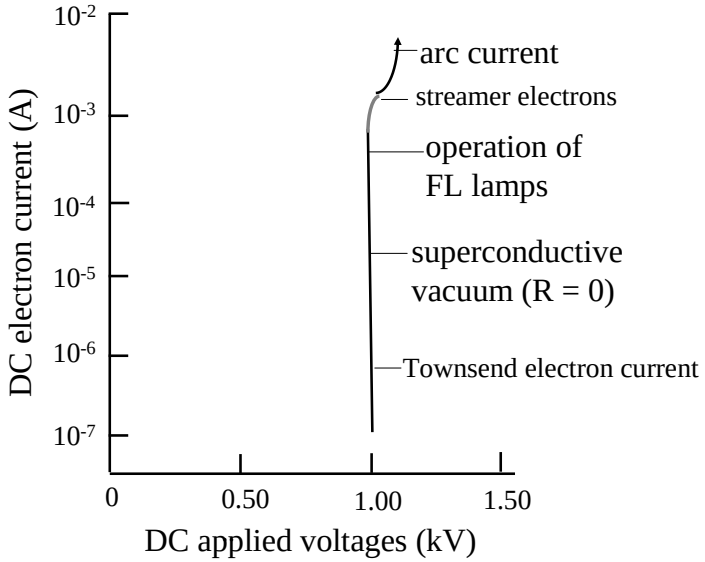


Figure 18 DC electric current between volume of glow lights on needle electrodes in vacuum-sealed glass tube that contains Ar atoms at pressure of 930 Pa (7 Torr).

The vacuum-sealed glass tubes suddenly have the volume of the glow lights at the both ends in the vacuum-sealed glass tube by the application of above DC 1.0 kV. Accordingly, the vacuum-seal glass tube lights up with the sky blue lights. We have observed the curious results with the application of the DC voltages above1 kV. As the applied voltages to the needle electrodes slowly increase to 10 kV from 1 kV, the needle electrodes hold the constant DC 1.0 kV between the needle electrodes. Whereas the DC current meters at the needle electrodes vertically increase with the applied voltages to the needle electrodes as shown in Figure 18. The size of the volume of the glow light on the needle electrodes does not change with the applied DC voltages.

The FL lamps are a kind of the vacuum-sealed glass tube that contains the Ar gas at 930 Pa (7 Torr) and Hg atoms at 0.1 Pa (= 1 x 10^{-3} Torr). We may change the naming of the glass tubes to the FL lamps that have the phosphor screen on the inside wall of the FL lamps. Then, we have found a confusion in the analysis of the moving electrons in the Ar gas space in the FL lamps. The confusion comes from the vacuum conditions in the unlighted FL lamps and in the lighted FL lamps. As shown in Figure 11, the vacuum between Ar atoms in the unlighted FL lamps fills up with the negative electric field. On the other hand, the vacuum between Ar atoms in the lighted FL lamps surely changes to the superconductive vacuum as shown in Figure 18. The details are below:

The vertical increase in the DC currents at the constant voltage at 1.0 kV in Figure 18 is a direct evidence of the existence of the superconductive vacuum in the Ar gas space between Ar atoms in the lighted FL lamps. In the superconductive vacuum, as already mentioned, the moving electrons do not have the electric resistance (R), so that there is no voltage drop by the V = RI = 0.

The results in Figure 18 had already obtained by J. S. Townsend on 1903, but he could not analyze the curve as the superconductive vacuum between Ar atoms. He gave the name as the Townsend electric current, as indicate in Figure 18. We have found that the Townsend electric current is the direct evidence of the electric current in the superconductive vacuum between the floating Ar atoms. The results shown in Figure 18 had used in the practical DC voltage regulation tubes before the development of the solid-state voltage regulation devices. The study on the voltage regulation tubes did not find the superconductive vacuum in the Ar gas space. They only paid their attention to the practical device. We have found that the FL lamps light up by the moving electrons in the superconductive vacuum between Ar atoms. Figure 19 illustrates the moving electrons in the superconductive vacuum in the lighted FL lamps.

The uniformly lighting of the FL lamps is limited by the electron flows in the vertical range in Figure 18. In the current range at above the 5 x 10^{-4} A, the electrons gather up to the electron beam in the Ar gas space. Finally, the electrons flow changes to the arc current, like as the thunder lightings. The practical FL lamps should be operated in the moving electrons below 3 x 10^{-4} A, corresponding to the 1.9 x 10^{15} electrons per second {= 3 x 10^{-4} Coulomb per second x (1.9 x 10^{-19} Coulomb)$^{-1}$}.

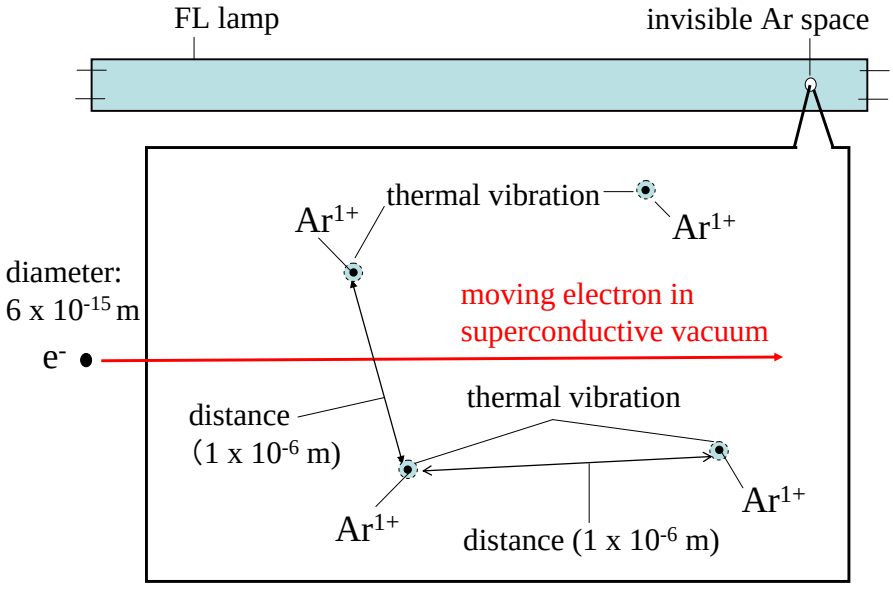


Figure 19 Schematic illustration of superconductive vacuum for moving electrons in Ar gas space of lighted FL lamp with Ar gas pressure at 930 Pa (7 Torr)

The volume of the glow lights contains Ar, Ar^{1+}, Ar* and free electrons (e-). Only Ar* emits the sky-blue light and others are invisible by the naked eyes. As describe latter in this report, the ratio of the Ar^{1+} and Ar* is around 62 to 1 with the operation conditions of the FL lamps under 1 kV DC voltage at the electrodes. We must figure out how the electrons in the volume of the glow light get out from the volume of the glow light. The negative electric field inside of the volume of the glow light is completely neutralized by the presence of the large numbers of Ar^{1+}. The weight of Ar^{1+} and Ar* is 1.7 x 10^{-27} kg. The weight of electron is 9.1 x 10^{-31} kg. Under the given F_{DC}, the moving particles in the volume of the glow lights are the electrons that have the 10^4 times faster of the speed. By the analysis of Figure 17, we have inferred that the cathode needle metal electrode supplies the electrons into the volume of the glow light and the anode electrode collects arrived electron. The external DC electric circuit consumes the electric power of W_{DC}. This conclusion is not our goal as the ideal FL lamps.

External DC electric power consumption of FL lamps to be $W_{DC} = 0$

With a curiosity of the formation of the volume of the glow lights on the needle electrode, we made the flowing experiments. The surface of the needle electrodes are covered with the thin glass layer less than 10^{-3} m. The thin glass layer on the needle electrodes is the electric insulator. The thin glass layer on the needle electrode cut off the electron flow from the needle electrodes to the volume of the glow lights. Figure 20 illustrates the experimental configuration of the needle electrodes that are covered with the thin glass layers of around 1 x 10^{-3} m thickness. We have obtained the volumes of the glow light on the thin glass layer on the both negative and positive electrodes by the application of voltages above 1.0 kV. Figure 20 respectively illustrates the volume of the glow lights in the Ar gas space on the cathode metal electrode (A) and anode metal electrode (B) in the vacuum-sealed glass tubes. The DC current meters indicate no electric current from the needle metal electrodes. The volume of the glow lights on the thin glass layer has the same size

with the needle electrodes as shown in Figure 16. The experimental results definitely indicate that the electric field from the needle electrodes penetrates through the thin glass layer. Consequently, the volumes of the glow lights are formed on the thin glass layer, without the electrons from the needle electrode. The finding of the formation of the volume of the glow lights on the glass insulator layers, which cover on the needle metal electrode, steps in the new lighting mechanisms of the FL lamps.

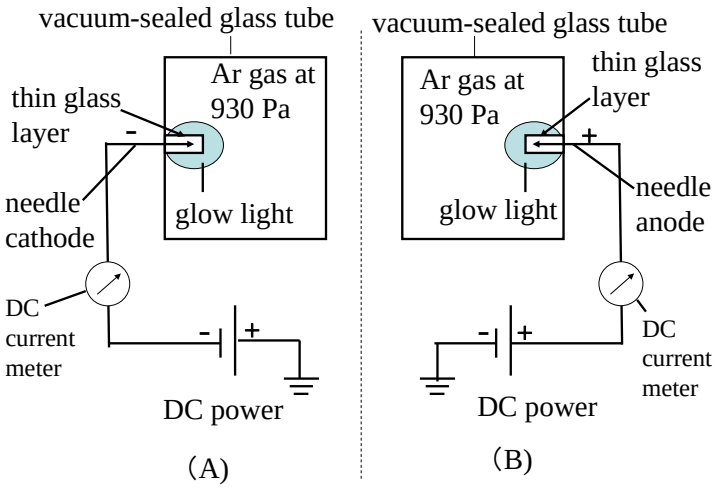


Figure 20 Illustration of volume of glow light on thin glass layer on needle electrodes. Experiments are made with the DC voltage at 2 kV

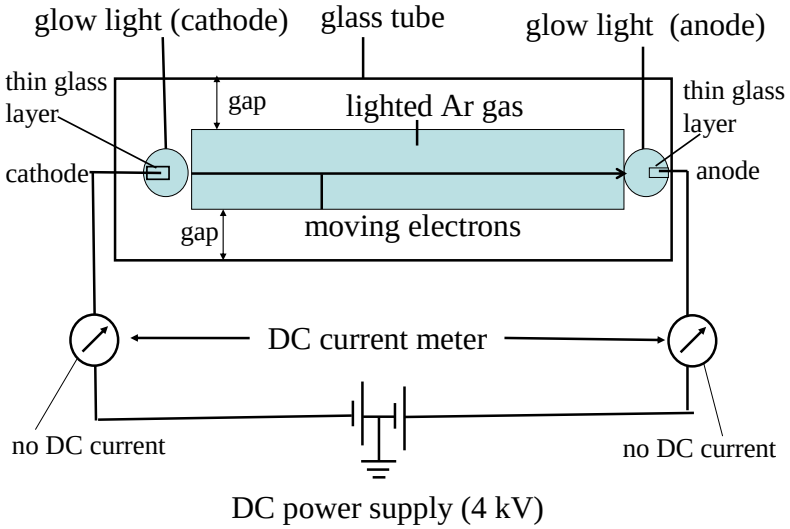


Figure 21 Lighted FL lamp which cathode and anode are formed by volume of glow lights on thin glass layers on metal needle electrodes

Then we have a question as whether the volume of the glow lights on thin glass layers work as the cathode and anode of the internal DC electric circuit in the Ar gas in the vacuum-sealed glass tube. We set the new needle electrodes at the both ends of the vacuum sealed glass tube. The Ar gas pressure is 930 Pa (= 7 Torr). The threshold voltage for the formation of the volume of the glow lights is the same that is DC 1 kV. The

following experiments are made with the DC 4 kV to the needle electrodes of the vacuum sealed glass tube. Figure 21 illustrates the lighted glass tube by the cathode and anode of the volumes of the glow lights on the thin glass layers on the needle metal electrodes. The DC current meters at the both electrodes show no electric current. The external DC electric circuit does not have the electric current. However, the tested glass tube lights up with the Ar*, indicating that the internal DC electric circuit is surely formed by the volume of the glow lights without the electron flow from the needle metal electrodes. Accordingly, the electric power consumption of the external DC driving circuit is zero; $W_{DC} = 0$. The vacuum-sealed glass tubes emit the light without the electric power consumption of the external DC driving circuit. This is a moment that we have found the new lighting mechanism of the lighting FL lamps with the zero electric power consumption; $W_{DC} = 0$.

We cannot directly detect the DC current between the cathode and anode of the internal DC driving circuit. We have the same light intensities with the needle electrodes with and without the thin glass layer. The observed results surely indicate that the conditions of the volumes of the glow lights on the polarized glass layer do not change with the needle electrodes covered with the thin glass layer. The DC current between the cathode and anode in the internal DC driving circuit likes as the DC electric current shown in Figure 18. The maximum DC current in the lighted glass tube is 4×10^{-4} A. The DC current at above 4×10^{-4} A, the lighted glass tubes have the arc discharge current via the streamer beam current.

Now we must find out a way of the breaking out of the negative electric field between the Ar atoms that float in the vacuum in the volume of the glow lights. The volume of the glow light contains many Ar^{1+}, free electron (e-), excited Ar atoms (Ar*), and Ar atoms (Ar). We may calculate the numbers of the Ar^{1+} to Ar* in the volume of the glow light. The details of the formation mechanisms of Ar^{1+} and Ar* will be described in next section. The ratio of Ar^{1+} to Ar* is 62 to 1 (= 1000 V x 16^{-1} V) because the constant voltages in Figure 18. The majority in the volume of the glow light is Ar^{1+}. The negative electric field in the volume of the glow light disappears by the presence of the large amount of the Ar^{1+}. The electrons in the volume of the glow light are accelerated by the electric field F_{DC} between the cathode and anode of the internal DC electric circuit. The accelerated electrons under the F_{DC} may step out from the volume of the glow light to the nearby Ar gas space. The stepped electrons to the nearby Ar gas space may ionize the Ar atoms. The presence of the ionized Ar^{1+} at nearby the volume of the glow light instantly neutralizes the negative electric field. The neutralization of the negative electric field propagates to the entire vacuum in the vacuum-sealed glass tube with the moving speed of the electrons of 10^8 m per seconds. The ionization of the Ar atoms accompanies the Ar* that emit the sky-blue light. Therefore, the vacuum-sealed glass tube in the length at 1.0 m instantly lights up within 10^{-8} seconds, after the formation of the cathode and anode of the internal DC electric circuit in the Ar gas space. Thus we have found a new way that the entire Ar gases in the vacuum-sealed glass tube light up by the formation of the volumes of the glow lights at the both ends, without the power consumption of the external DC electric circuit, $W_{DC} = 0$. The vacuum-sealed glass tubes are the same with the FL lamps that have the phosphor screen on the inner glass wall.

We have found a distinguished advantage of the lighted FL lamps over other incandescent lamps. The FL lamps are light up with the zero power consumption of the external electric circuit, without any sacrifice of

the lighting conditions of the internal DC electric circuit. The moving electrons in the lighted FL lamps do not have the electric resistance (R) caused by the thermal perturbation from the neighbor Ar atoms that thermally vibrate at the floating position. Consequently, the moving electrons in the lighted FL lamp do not have the Joule Heat ($I^2R = 0$). We must know the more details of the lighting mechanisms by the moving electrons in the Ar gas space in the FL lamps.

Lighting mechanisms of Ar atoms by moving electrons in FL lamps

As described above, the electrons in the lighted FL lamps move on in the superconductive vacuum between Ar atoms. The moving electrons do not have the electric resistance caused by the thermal perturbation from the thermally vibrating Ar atoms at the floating positions. The moving electrons under the F_{DC} of the internal DC electric circuit may have the chance to meet the floating Ar atoms. Then the moving electrons may influence on the orbital electron in the upper most electron shell of the Ar atoms. This means that the FL lamps never emit the radioactive ray in the operation. The FL lamps are the safe as the lighting source in the operation. Figure 22 illustrates the difference of the approaching electron to the Ar atom with the kinetic energies of the moving electron. As the moving electron has the kinetic energy below 10 kV, the approaching electron to the Ar atom receive the strong Coulomb's repulsion from the orbital electrons in the upper most electron shell $^3p_6$. The moving electron cannot get in the $^3p_6$ shell of the Ar atoms. But the repulsed electron gives some amount of the kinetic energy to an orbital electron in $^3p_6$. This is the conditions of the moving electrons in the Ar gas space in the lighted FL lamps. As the moving electron has the kinetic energy higher than MeV, the electron may penetrate into the orbital shells of the Ar atom. This is the high energy physics that radiate the radioactive rays. We are studying on the lighted FL lamps with the electrons that have the kinetic energy less than 10 kV.

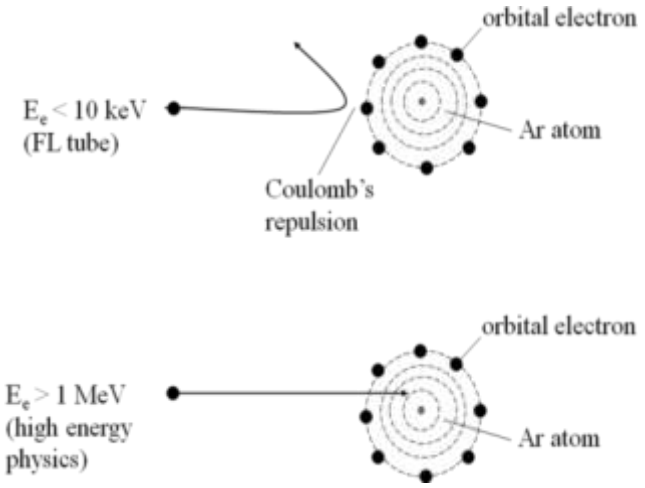


Figure 22, Schematic illustration of approaching electron to Ar atom with different kinetic energies below 10 k eV and higher than 1 mV.

Figure 23 illustrates the orbital electrons in the Ar atom (A) which fill up the electrons in $^1s_2$, $^2s_2$, $^2p_6$, $^3s_2$, and $^3p_6$ orbital shells, and (B) ionized Ar^{1+} by removal of one electron from the most upper $^3p_6$ orbital shell to the vacuum. Only one electron in the $^3p_6$ orbital shell involves in the (a) ionization, (b) excitation, and (c) recombination of Ar^{1+} and (d) free electron in the superconductive vacuum.

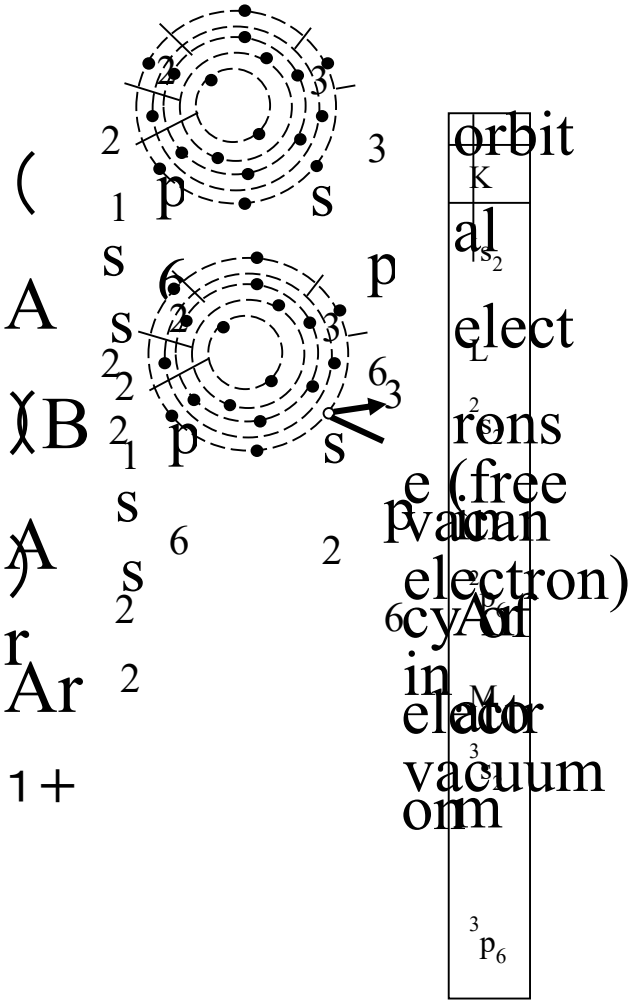


Figure 23 Orbital electrons in Ar atoms (A) and ionized Ar^{1+} by removal of one electron from $^3p_5$ orbital shell (B)

The electron in the $^3p_6$ orbital shell involves in the reduction of the kinetic energy of the moving electrons in the superconductive vacuum. Figure 24 illustrates the approaching electron in the different kinetic energy. As the approaching electrons have the kinetic energy higher than 15.7 eV, the Coulomb's repulsion results in the ionized Ar^{1+}. The moving electron loses the kinetic energy of 15.7 eV by each Coulomb's repulsion. This means the attenuation of the kinetic energy of the moving electrons by the Coulomb's repulsion. In the lighted FL lamps, the heat source is only ionization of Ar atoms in the positive column. The positive column is defined as "the volume of the moving electrons in the Ar gas space". The heat source is caused by the change in the entropy of the Ar toms. The temperature of the Ar gas space increases with the high Ar gas pressures. The temperatures of the positive column determine the amount of the evaporated Hg atoms from the Hg droplets on the phosphor screen in the lighted FL lamps.

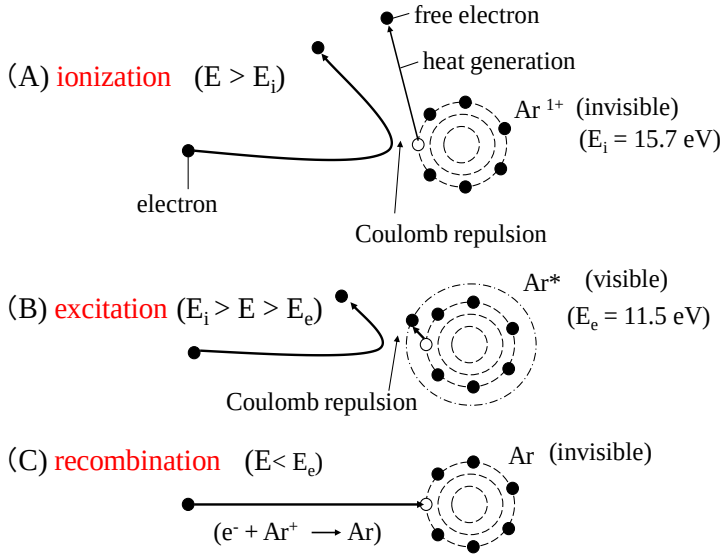


Figure 24 Schematic illustrations of ionization, excitation, and recombination of electron and Ar^{1+} by approaching electrons that have different kinetic energy in lighted FL lamps

As the moving electrons have attenuated to the kinetic energies between 15.6 eV and 11.5 eV, the moving electrons may excite the Ar atoms (Ar*) in the positive column. Ar* emits a photon within 10^{-6} sec after the excitation. As the scattered electron has the kinetic energy smaller than 11.4 eV, the moving electrons recombine with the Ar^{1+} and the Ar^{1+} returns to Ar atoms. Thus, the lighted FL lamp reserves the Ar atoms in the operation, promising the operation life longer than 10^6 hours. The operation life of 10^6 hours corresponds to the operation life longer than 100 years with 24 hours per day (> 24 hours x 365 days x 100 years = 8.8 x 10^5 hours). In reality, the Ar gas spaces of the commercial HCFL lamps at the present time are heavily contaminated with the residual gases at the pressure more than 10 Pa (> 0.1 Torr) [1]. The residual gasses in the lighted FL lamps determine the operation life. The reservation of the Ar atoms in the operation of the lighted FL lamps is another advantage over other incandescent lamps such as LED lamps and W-filament lamps.

Calculations of numbers of Ar^{1+} and Ar* $(m^3, s)^{-1}$ in lighted FL lamps

The great advantage of the lighted FL lamps is the numbers of the generations of Ar^{1+} and Ar* by one moving electron in the superconductive vacuum. As the moving electron meets to the Ar atom, the moving electron scatters from the electric field F_{DC}. The scattering is by the Coulomb's repulsion from the electric field of the orbital electrons, F_{orb}, in the $^3d_6$ shell of Ar atom. The moving electron that has the Coulomb's repulsion from the Ar atoms scatters from the F_{DC} in the region $F_{DC} < F_{orb}$. The scattered electron takes again the F_{DC} where $F_{DC} \geq F_{orb}$. The moving electron attenuates the kinetic energy by each Coulomb's collision. The attenuation of the kinetic energy of the moving electrons results in the ionization of the Ar atom (Ar^{1+}). The returned electron in the $F_{DC} > F_{orb}$ meets other Ar atom and generates Ar^{1+}. Figure 25 illustrates the moving electron in the superconductive vacuum with the ionization of two Ar atoms in the superconductive vacuum.

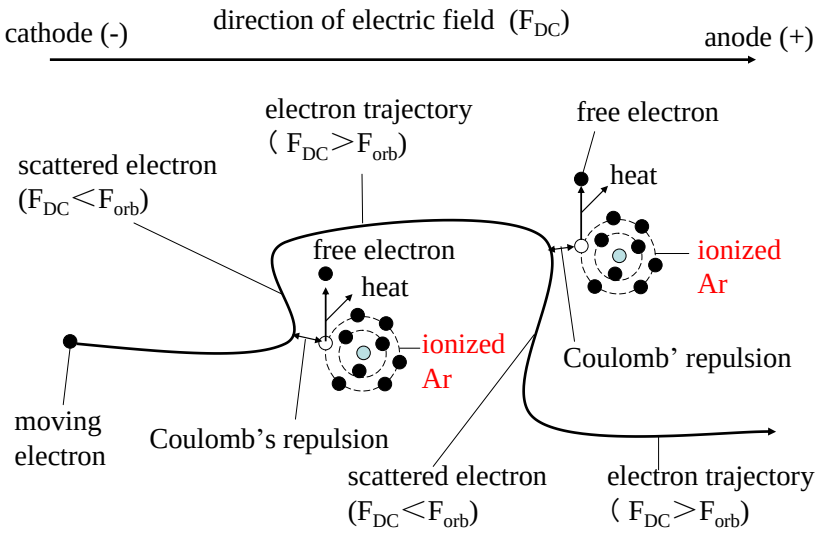


Figure 25 Schematic explanation of moving electron under electric field F_{DC} and change of trajectory by Coulomb's repulsion from two Ar atoms. Each Coulomb's repulsion generates Ar^{1+} and free electron in Ar gas space

The moving electron in the superconductive vacuum continually meets the floating Ar atoms in the superconductive vacuum until the kinetic energy of the moving electron attenuates to 15.7 eV. The large numbers of the Ar atoms in the lighted FL lamps are ionized by the moving electron. For the calculation of the Ar^{1+} and Ar*, we must take the results in Figure 18. The voltage at the cathode and anode in the internal DC electric circuit is constant at 1 kV with the different application voltages. Considering the results, we may calculation of the numbers of Ar^{1+} and Ar*. The simple calculation of the numbers of the generated Ar^{1+} by one moving electron gives 62 Ar $^{1+}$ {= 1000 V x (16 V)$^{-1}$} per one moving electron. After the generation of 62 Ar^{1+}, the moving electron may excite one Ar atom; Ar*. The ratio of the numbers of Ar^{1+} to Ar* is given by 62 to 1. After the excitation of the Ar*, the moving electron has the kinetic energy smaller than 11.4 eV.

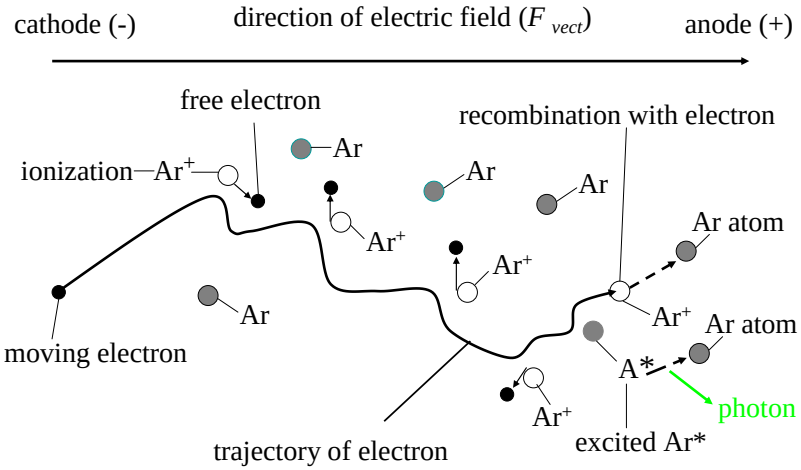


Figure 26 Schematic illustration of moving trajectory of given electron in superconductive vacuum,

generating many Ar^{1+}, one Ar* and then return to Ar atom.

Then the moving electron recombines with the Ar^{1+}, and Ar^{1+} returns to Ar atom. The specified electron from the cathode disappears from the Ar gas space before reaching to the anode. Figure 26 schematically illustrates the attenuation of the kinetic energy of the specified moving electron in the superconductive vacuum in the lighted FL lamp and disappearance of the electron from the cathode in the Ar gas space.

This is the specified electron from the cathode. In reality is complicated. As shown in Figures 17, the collected numbers of the electrons by the anode coincide with the numbers from the cathode. This means the moving electron from the cathode never disappear and never increase in the Ar gas space. Statistically, the electrons from the cathode never disappear in the Ar gas space in the lighted FL lamps. The anode collects the same numbers of the electron from the cathode. We must solve this problem in the calculation of the Ar^{1+} and Ar*.

By the referring to the results in Figures 17, it can statistically say that the same numbers (62) of the free electrons are also generated in the Ar gas space by the formation of Ar^{1+}. The newly generated 62 electrons also move on in the superconductive vacuum under the F_{DC}. The newly generated electrons are under the F_{DC}. The generated electrons also ionize and excite the Ar atoms. Finally the electrons also disappear from the Ar gas space before reach to the anode.

If one pays his attention to the specified electron from the cathode, he surely obtains the results in Figure 26. However, the electron from the cathode mixes up with the generated 62 free electrons in the Ar gas space. Some free electrons may recombine with the Ar^{1+} and disappear from the Ar gas space in the lighted FL lamp.

The ionization and excitation of the Ar atoms in the lighted FL lamps should be considered as the statistical results of the mixture of the injected electrons and generated free electrons. As shown in Figure 17, the numbers of the injected electrons from the cathode coincide with the numbers of the electrons collected by the anode. Therefore, we may take the moving electron from the cathode to the anode as the statistical results of the moving electrons in the lighted FL lamps. We do not take the specified electron from the cathode for the generation of the Ar^{1+} and Ar* in the lighted FL lamps.

As already calculated, the FL lamps (T-10) contain 1.4×10^{15} Ar atoms per lamp that is given by 2×10^{18} Ar atoms per m^3. For the statistical calculations of the formation of Ar^{1+} and Ar*, we take the numbers of 2×10^{18}Ar atoms per m^3 in the Ar gas space. We also consider the numbers of the electrons from the cathode that are 1.9×10^{15} electrons per second $\{= 3 \times 10^{-4}A \times 1.6 \times 10^{-19}$ Coulomb$\}$. The statistical results are given by the combinations of the numbers of Ar atoms and moving electrons.

Since Ar atoms distribute in the Ar gas space with the separation distance of 1×10^{-6} m, the average numbers of the collisions of the moving electron in one direction are given by 1×10^{6} times $\{= (1 \times 10^{-6}\ m)^{-1}\}$. The numbers of the collisions in unit volume (m^3) are given by 1×10^{18} per m^3 $\{= (1 \times 10^{6}\ m)^3$. The generated

Ar^{1+} in the FL lamp is calculated as 1 x 10^{18} Ar^{1+} $(m^3, s)^{-1}$.

The numbers of the excited Ar* in the FL lamp are calculated as below: The moving electron should attenuate the kinetic energy to 16 eV from 1000 eV by the scatterings. It requires 62 scatterings {= 1000 eV x $(16\ eV)^{-1}$}. Then the moving electron may excite one Ar atom (Ar*). The ratio of the Ar^{1+} to the Ar* in the 1 m^3 Ar gas space is 62 to 1. The estimated numbers of the Ar* are ~1 x 10^{16} $(m^3, s)^{-1}$ {= 1 x 10^{18} x 62^{-1} $(m^3, s)^{-1}$}. The FL lamps do not use the Ar* as the lighting source. The origin of the lighting source is the excited Hg atoms (Hg*). The numbers of the Hg* is calculated from the numbers of Ar^{1+}.

Astronomical quantum efficiency of 10^{13} visible photons $(m^3, s)^{-1}$ in lighted FL lamp

The FL lamps use the excited Hg atoms (Hg*) as the origin of the light source. The excited Hg* emits the strong ultraviolet lights at 254 nm and/or 187 nm. The numbers of Hg* atoms determines the feature of the FL lamps. For the excitation of the Hg atoms, the Hg atoms should be vaporized in the Ar gas space in the positive column. However, there is no report on the heat source in the FL lamp. It has described in the previous Chapter, the heat source in the lighted FL lamps is only ionization of the Ar atoms. The ionization of the Ar atoms releases the heat by the change in the entropy of the Ar atoms.

The Ar gas pressure of the commercial HCFL lamp (T-10) is 930 Pa (7 Torr). The numbers of the Ar atoms at 930 Pa (7 Torr) are 2 x 10^{18} per m^3. The pressure of the vaporized Hg atoms at 40°C is 0.67 Pa (5 x 10^{-3} Torr) that is 7 x 10^{-4} times of the Ar gas pressure {= 0.67 Pa x $(930\ Pa)^{-1}$}. The numbers of the vaporized Hg atoms in the HCFL lamp is calculated as 1.4 x 10^{15} Hg atoms $(m^3)^{-1}$ (= 2 x 10^{18} Ar atoms x 7 x 10^{-4}). For the excitation of one Hg atom, the moving electron must have the 63 scatterings by the Coulomb's repulsions before the excitation of the Hg atom. The estimated numbers of the Hg* in the Ar gas space at 40°C is 2 x 10^{13} Hg* $(m^3, s)^{-1}$ (= 1.4 x 10^{15} x 63^{-1}).

The calculated 2 x10^{13} Hg* $(m^3, s)^{-1}$ are the quantum efficiency η_q of the Hg* by one moving electron in the lighted FL lamps. The total Hg* in the FL lamps are given by the multiplication of the numbers of the moving electrons. The moving electrons in the internal DC electric circuit are 3 x 10^{-4} A that contain 2 x 10^{15} electrons per second {= 3 x 10^{-4} A x $(1.6 \times 10^{-19}\ Coulomb)^{-1}$}. The numbers of the generated Hg* in the FL lamp are 4 x 10^{28} UV photons $(m^3, s)^{-1}$ (= 2 x 10^{13} Hg* x 2 x 10^{15} electrons per second). Since the inner volume of the 40W-HCFL lamp is 7 x 10^{-4} m^3, the commercial 40W-HCFL lamp must emits 2.8 x 10^{25} UV photons per second {= 4 x 10^{28} $(m^3, s)^{-1}$ x 7 x 10^{-4}}. As described latter, the volume of the positive column is a half of the inner volume of the glass tube of the 40W-HCFL lamps. The commercial 40W-HCFL lamps emit 1.4 x 10^{25} photons per second (= 2.8 x 10^{25} x 2^{-1}). The phosphor screen on the inside wall of the FL lamps transduces the UV photons to the photons in the visible spectral wavelengths with the η_q ≈1.0. Therefore, each commercial 40W-HCFL lamp may emit 1.4 x 10^{25} visible photons per second. Human eyes have adjusted for 5 million years to the daytime scenery under the slightly overcastting sky that is given by the around 10^{25} visible photons $(m^2, s)^{-1}$. The commercial 40W-HCFL lamp may comfortably eliminates the 1 m^2 room with the daytime scenery under the slightly overcastting sky. The calculated results coincide with the illumination level by the practical 40W-HCFL lamps. We have theoretically and experimentally confirmed the performance of the lighted 40W-HCFL lamps with the astronomical quantum

efficiency $\eta_q = 2 \times 10^{13}$ visible photons per second by one moving electron. The remained subject is the reduction of the electric power consumption of the external driving circuit.

Development coil-EEFL lamps as most advanced illumination source

As described in previous section, the lighted FL lamps actually operate with the internal DC electric circuit that the cathode and anode are formed with the volumes of the glow lights in the Ar gas. The volumes of the glow light are formed by the electric field from the needle electrodes of the external driving circuit, without the electron flow. The use of the needle electrodes is not convenient for the mass production of the FL lamps. We must find out a new way that forms the volumes of the glow lights, rather than needle electrodes.

Development of coil-EEFL lamps on polarized phosphor particles

We have carefully studied the details of the preparation of the phosphor particles [4]. The phosphor particles are polycrystalline particles in the sizes at around 5×10^{-6} m. By the control of (a) the temperature profile in the production furnace and (b) heating program of the crucibles in the furnace, we have the well crystallized phosphor particles. Figure 27 shows, as an example, the photograph of the phosphor particles under the electron microscope (x 3000). Each polycrystalline particle contains many growing axes that make the sharp edge lines and points on the surfaces of the particles. Furthermore, the practical phosphor particles are the good piezoelectric crystals that easily deform to the polarized particles under the electric field. The sharp edge lines and points on the polarized phosphor particles may work as the sharp points like as the needle electrodes.

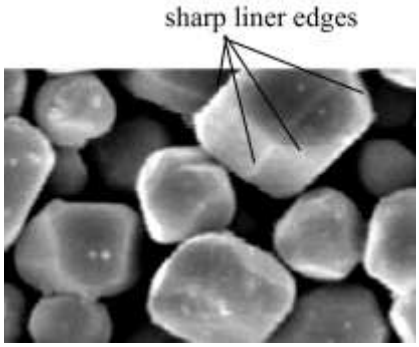


Figure 27 Photograph of phosphor particles under scanning electron microscope (x 3000)

With the expectation, the both ends of the outer glass wall of the FL lamp are covered with the lead wire (1×10^{-3} m diameter).The lead wire is covered with the plastic layer (1×10^{-3} m thickness).Thus, we have the coil-external electrodes; e.g., coil-EE. The coil-EEFL lamp brilliantly lights up under the external DC electric circuit at the voltage above 1 kV. The lighting mechanisms of the coil-EEFL lamps are the same with the volumes of the glow lights on the needle electrodes. Figure 28 shows, as an example, the photograph of the lighted coil-EEFL lamp (1×10^{-2} m diameter) operated with the DC external electric circuit at 2 kV. The experiments of the coil-EEFL lamp use the commercial CCFL lamps in the out diameter 1×10^{-2} m (T-4). Even though the external DC driving circuit of the coil-EEFL lamp has no electric current, $W_{DC} = 0$, the converted coil-EEFL lamps brilliantly light up with the higher illuminance (lm, m^{-2}) than the

original CCFL lamp. Thus, we have developed a prototype of the coil-EEFL lamp as the new lighting source with $W_{DC} = 0$. We may use the piezoelectric transformer as the DC power source of the coil-EEFL lamps.

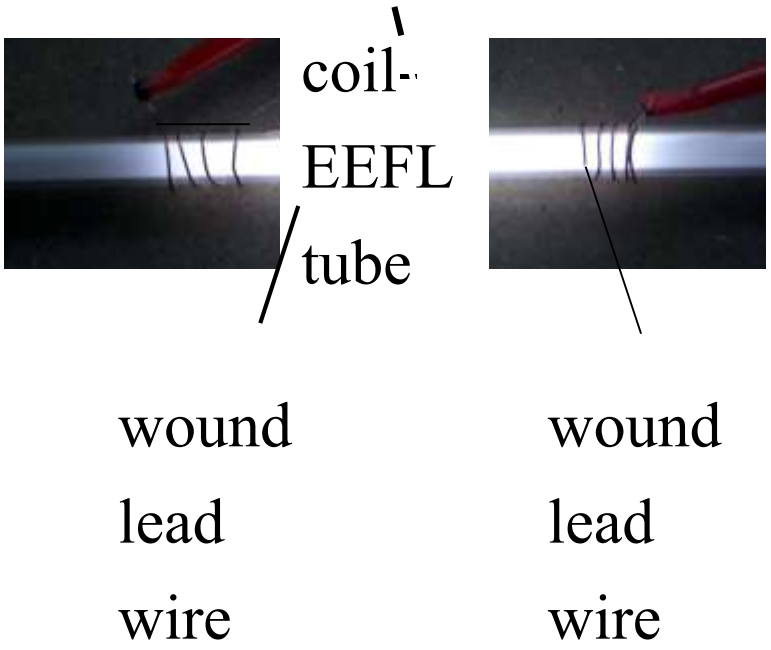


Figure 28 Photopicture of lighted coil-EEFL lamp under DC voltage at 2 kV

Then, we have produced the coil-EEFL lamps for the characterization of the coil-EEFL lamps. It should be noted that if you produce the phosphor screen of the coil-EEFL lamps with the commercial PL phosphor powder, you will produce a very poor quality of the light from the phosphor screen as shown in Figure 29(above). For the study of the reliable coil-EEFL lamps, you should make the phosphor screen with the improved phosphor powder as shown in Figure 29 (below). This is because the improved phosphor powders completely remove the electric charges of the SBE on the phosphor particles.

PL phosphor powder

improved phosphor powder

Figure 29 coil-EEF lamps that phosphor screen is made with commercial PL phosphor powder (above) and improved phosphor powder (below).

Furthermore, you need a new screening technology for the preparation of the coil-EEFL lamps. The phosphor screen in the coil-EEFL lamps should be the thin screen as possible, as shown in Figure 30 (A). If the coil-EEFL lamps are made with the thick phosphor screen as shown in Figure 30 (B), the coil-EEFL lamps have the dim light. This is because the phosphor particles efficiently absorb the electric field from the EEs. This is an important concern for the study on the coil-EEFL lamps.

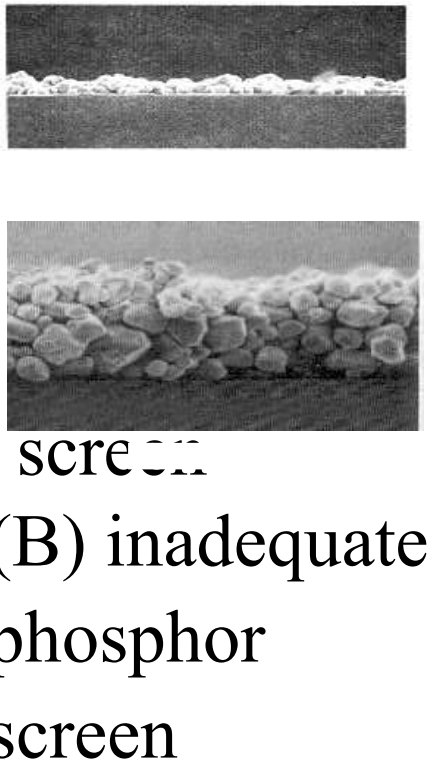


Figure 30 Cross-section of phosphor screen in coil-EEFL lamp (A) and in commercial HCFL lamp (B). Photograph are obtained with scanning electron microscope (x 1000)

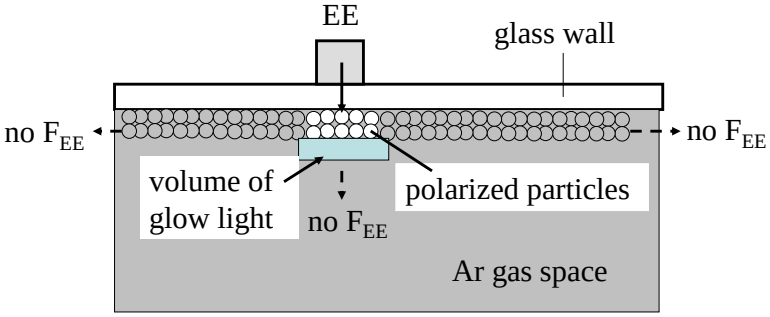


Figure 31 Illustration of polarized phosphor particles in screen by electric field from external electrode and formation of volume of glow lights as internal cathode (or anode) in Ar gas space

Figure 31 illustrates the formation mechanisms of the volume of the glow light on the polarized phosphor particles in the lighted coil-EEFL lamp. The electric field from the EE on the glass wall polarizes only phosphor particles (o) in a few layers by the vertical electric field, F_{EE}. The F_{EE} does not extend to horizontal direction in the phosphor screen. The depth of the volume of the glow light on the polarized phosphor screen is about 3 x 10^{-3} m that is the same size of the volume of the glow light on the needle electrodes. The depth of the volume of the glow lights determines the optimized diameter of the coil-EEFL lamps. The optimum of the inner diameter of the coil-EEFL lamps is within1.0 x 10^{-2} m {= (3 x 2 + 4) x 10^{-3} m},

although the coil-EEFL lamps light up with any diameters. It has believed that in the Ar gas space, the lighted coil-EEFL lamp has only the electric field F_{DC} by the cathode and anode of the internal DC electric circuit. However, there is another electric field in the Ar gas space. That is the vertical electric field from the phosphor screens, F_{phos}. The F_{phos} has the vertical electric field against to the horizontal F_{DC}. The approaching electrons to the phosphor screen receive the Coulomb's repulsion from the phosphor screen by the vertical F_{phos}. The repulsed electrons must move on in the superconductive vacuum where $F_{DC} > F_{phos}$. Therefore, the optimized coil-EEFL lamps have the limitation of the diameter of the FL lamps.

Diameters of FL lamps determined by vertical F_{phos}

The limitation of the diameters is not only the coil-EEFL lamps. The commercial HCFL lamps use the 4G electron sources that are the large volumes of the heated corona lights [12]. The HCFL lamps also have a limitation with the diameters of the glass tubes with the F_{phos}. The limitation of the HCFL lamps has not studied as the science for more than 80 years. With this reason, we may clarify the diameters of the lighted FL lamps that are determined by the F_{phos}. The limitation of the diameters of the lighted FL lamps is caused by the deep gap between the positive column and phosphor screen. The details are below:

The commercial FL lamps have used the PL phosphor particles in the screen. The concept of the use of the PL phosphor particles comes from the fact that the phosphor screen transduces the UV lights from the positive column to the visible lights. According to the recent study, the surfaces of the commercial PL phosphor particles are heavily contaminated by the electric insulators [15]. The contamination level of the phosphor screens is only studied by the voltage dependence, VD, curves of the cathodoluminescence, CL, as a function of the applied voltages. The threshold voltage of the VD curves of the PL phosphor screen is 2,000 V that is caused by the surface-bounded-electrons (SBE) on the phosphor particles [4]. The SBE generates the negative electric field (F_{phos}) in the vertical direction against the phosphor screen. The approaching electrons to the phosphor screen receive the strong Coulomb's repulsion from F_{phos}. The repulsed electrons only move on in the Ar gas space in which $F_{DC} > F_{phos}$. The volume of the $F_{DC} > F_{phos}$ in the Ar gas space has called as the positive column. The positive column is not right naming. The positive column has the mixture of the Ar^{1+} and free electrons with the same numbers. The electric charge of Ar^{1+} and electron are the same as 1.6×10^{-9} Coulomb. The large difference is the mass. The mass of the Ar^{1+} is 1.7×10^{-27} kg and the mass of the electrons is 9.1×10^{-31} kg. Under the constant F_{DC}, the moving speed of the electrons is 10^3 time faster as compared with moving speed of the Ar^{1+}. Under the given $F_{DC,}$ only electrons move on in the superconductive vacuum in the positive column. However, we accept the naming of the positive column in this report.

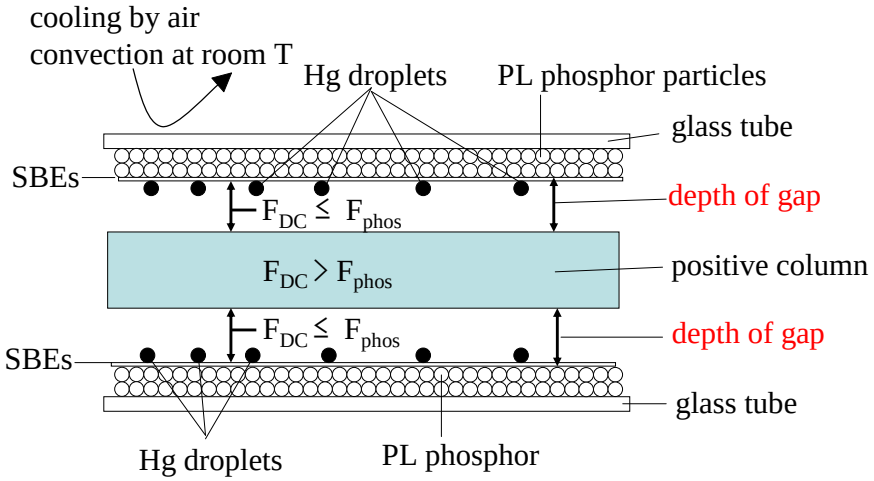


Figure 32 Schematic illustration of cross-section of FL lamp, partially. Electrons only move on in Ar gas space where $F_{DC} > F_{phos}$. Commercial phosphor screen is heavily contaminated with insulators; generating deep gap of $F_{DC} < F_{phos}$.

The electrons never move on in the entire volume of the Ar gas space of the lighted FL lamps. The electrons move on in the superconductive vacuum between Ar atoms in the positive column. Figure 32 schematically illustrates the formation of the positive column where $F_{DC} > F_{phos}$ in the Ar as space. Naturally, there is the deep gap between the positive column and phosphor screen. The existence of the deep gaps in the lighted FL lamps has overlooked in the past study on the FL lamps with the opaque phosphor screens. The gap in the lighted FL lamps is the invisible by the naked eyes. The depths of the gap are determined by the $F_{DC} < F_{phos}$; the deep gap by the large F_{phos}. The depth of the gap of the commercial 40W-HCFL lamps is around 4×10^{-3} m. Therefore, the diameter of the positive column is 2.2×10^{-2} m $\{= (3.0 - 0.8) \times 10^{-2}\}$. If you consider the inner diameters of the FL lamp and diameter of the positive column, the difference is the small. However, when you consider the volumes of total Ar gas (V_{Ar}) and the volume of the positive column (V_{posi}), you may find the serious problems with the depths of the gap on the performances of the lighted FL lamps. The V_{Ar} and V_{posi} in the FL lamp are calculated by ($\pi r^2 l$) where r is the inner radius of the FL lamp; r = 0.5 d of the inner diameter d.

The ratios of the (V_{posi} /V_{Ar}) are calculated as a function of the outer diameters of the FL lamps with l = 1.0 m long. The parameters are the depths of the gaps; e.g., 0.1, 0.3, 1.0, 2.0, 3.0 and 4.0 ($\times 10^{-3}$ m), respectively. Figure 33 shows the calculated results. The results are solely determined by the F_{phos} and are not changed with the Ar gas pressures [6]. At glance of Figure 33, the V_{posi} of the commercial HCFL lamps in the outer diameter of 3.2×10^{-2} m (T-10) is 60 % of the V_{Ar}. The moving electrons involve in only 60 % of the Ar gas space. Other 40 % of the Ar gas is in the gap in which the moving electrons never step in. The Ar gases in the gap negatively acts as the performance of the lighted FL lamps. The negative actions of the Ar gases in the gap are caused by (i) the thermal insulation between the positive column and phosphor screen, and (ii) optical absorption of the UV lights by the unexcited Hg atoms before reaching to the phosphor screen of the lighted FL lamps.

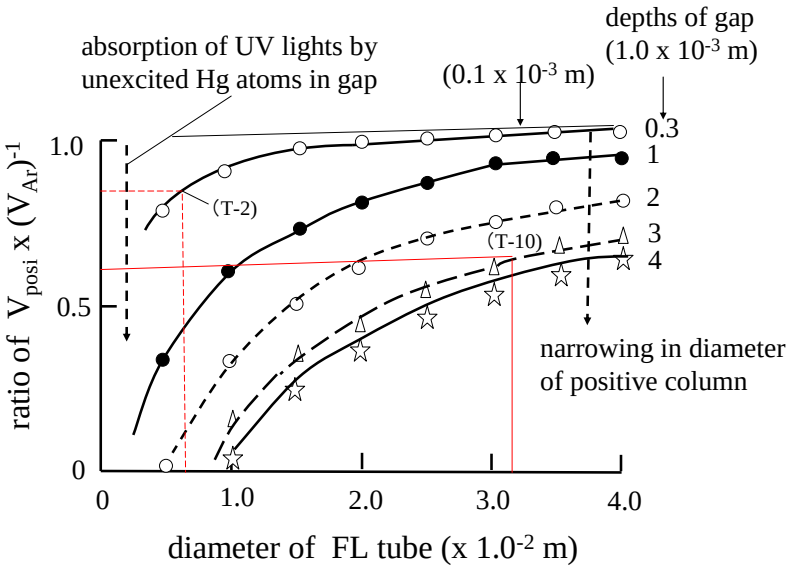


Figure 33 Curves of (V_{posi} x V_{Ar}^{-1}) of FL lamps as a function of outer diameters of FL lamps. Parameter is depth of gap in FL lamps

Thermal insulation of positive column by Ar gas in gap

The heat conductance of the Ar atoms at 1 atmosphere is 3.9 x 10^{-5} cal (deg, sec, deg at 0°C). The Ar gas at 930 Pa is 3.9 x 10^{-7} cal (deg, sec, deg) that is good thermal insulator. The heat source in the lighted HCFL lamp is only ionization of the Ar atoms in the positive column. The Ar gas in the positive column in the commercial 40W-HCFL lamp heats up to around 40°C that can be detected by the infrared thermometer [6]. The origin of the light in the lighted FL lamp is the UV lights from the excited Hg* in the positive column. The numbers of the evaporated Hg atoms in the positive column is not simply determined by the temperature of the positive column. In the unlighted FL lamps, the Hg droplets on the phosphor screen are at the room temperature. As shown in Figure 32, the Hg droplets on the phosphor screen should heat up from the heated positive column. We cannot expect the heat conductance and thermal convection of the Ar gas in the gap. The Ar gas in the gap is the good thermal insulator. The Hg droplets on the phosphor screen only heat up by the thermal radiation from the positive column. The Hg droplets slowly heat up to the equilibrium temperature. Consequently, the light intensities of the FL lamps slowly increase after turn-on the electric power of the external AC driving circuit to the FL lamps, giving rise to the build-up curve of the light intensity as a function of the lighting times. The detected build-up curve is fast with the shallow gap and is a very slow with the deep gap of the FL lamps. The saturation levels of the build-up curves also differ with the depths of the gap.

Figure 34 shows, as the examples, two build-up curves of the FL lamps with the ratios of (V_{posi} x V_{Ar}^{-1}) = 0.9 and 0.6, respectively. The results of the build-up curves clearly inform us the remarkably change with the depth of the gaps. The (V_{posi} x V_{Ar}^{-1}) = 0.9 has the 2 x 10^{-4} m depth of the gap, and (V_{posi} x V_{Ar}^{-1}) = 0.6 has the 3 x 10^{-3} m depth. We may roughly, but clearly, evaluate the depths of the gaps from the measurements of the build-up curves of the lighted FL lamps.

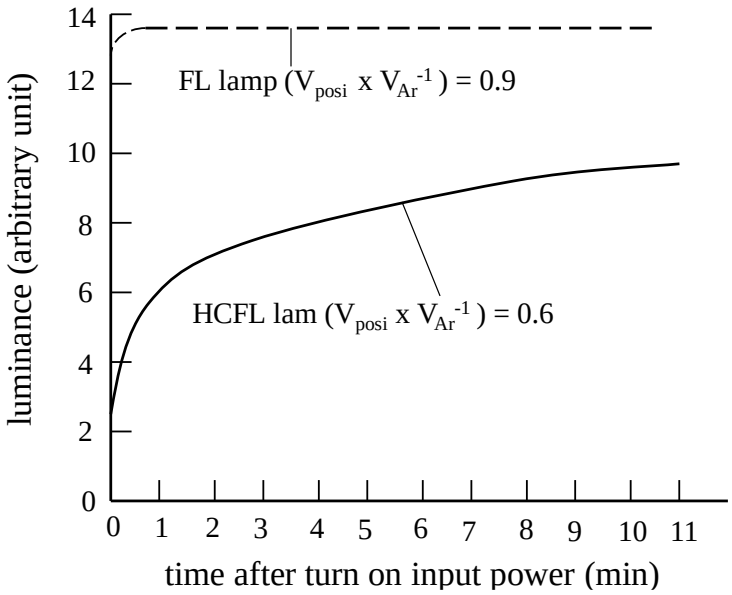


Figure 34 Build-up curves of light of FL lamp having (V_{posi} x V_{Ar}^{-1}) = 0.8 and Commercial HCFL lamp that has (V_{posi} x V_{Ar}^{-1}) = 0.6

Large temperature difference between positive column and phosphor screen

As illustrated in Figure 32, the Hg droplets in the unlighted FL lamps are on the phosphor screen. The heat source is the positive column. The temperatures of the positive column are determined by the numbers of the ionized Ar atoms in the lighted FL lamps. The Ar gas in the gap is a good thermal insulator. The Hg droplets on the phosphor screen do not heat up by the thermal circulation. The Hg droplets are heated by the thermal radiation from the positive column. Here arises a problem. The outer glass wall of the FL lamps is cooled by the thermal convection of the cool air at the room temperature (22ºC). The equilibrium temperature at the outer glass wall of the lighted HCFL lamps is around 30ºC. We can precisely determine the temperatures of the positive column in the lighted HCFL lamps by the use of the infrared thermometer (e.g., a commercial Venter 350), even though the HCFL lamps have the opaque phosphor screen. The positive column in the commercial HCFL lamps heats up to around 40ºC. However, the determined equilibrium temperature at the outer glass wall of the commercial 40W-HCFL lamps is below 30ºC that depend on the room temperatures. We can determine the temperature at the outer glass wall of the lighted HCFL lamps by the attachment of the point of the thermocouple. The temperature difference between positive column and outer glass wall enhances with the high temperatures of the positive column. The deep gap contains the unexcited Hg atoms that optically absorb the UV lights from the positive column. The optical absorption is the resonance absorption of the UV lights that the transitions terminate to the grand state of $^6s_0$. The resonance absorption of the UV lights by the unexcited Hg atoms in the gap makes the operation temperature of the positive column at 40ºC. If the FL lamps have a shallow gap between positive column and outer glass wall, the light from the FL lamps goes up with the temperatures of the positive column. The limitation of the high temperature of the FL lamps is the safety of the operation of the FL lamps. More details are below.

Optical absorption of UV lights by Hg atoms in gap

Origins of the lights of the FL lamps are the UV lights at 254 nm and 185 nm from excited Hg*. The UV lights are respectively assigned as the electron transitions between excited $^3p_1$ and $^1p_1$ to the grand state $^6s_0$ respectively. The unexcited Hg atoms fill up the electrons in the grand state $^6s_0$. Therefore, the unexcited Hg atoms in the gap efficiently absorb the UV lights at 254 nm and 185 nm before reaching to the phosphor screen. The optical absorption by the unexcited Hg atoms in the gap is made by the resonance absorption from the grand state $^6s_0$. The amount of the resonance absorption of the UV lights in the gap changes with the depths of the gap. Ideal FL lamps must produce with the shallow gap as possible. The target of the depth of the gap in the FL lamps is 1 x 10^{-4} m hopefully.

The coil-EEFL lamps utilize the volumes of the glow light that the thickness is around 3 x10^{-3} m. The optimal outer diameter of the coil-EEFL lamps is around 1.0 x 10^{-2} m. The commercial 40W HCFL lamps are produced with the outer diameter of 3.2 x 10^{-2} m. As referencing of Figure 33, the volume of positive column (V_{posi}) of the FL lamps is sensitively changed by the depths of the gaps and by the inner diameters of the FL lamps. Table 1 gives percent of the V_{posi} in the lighted FL lamps with different depths of the gap in the outer diameters of the FL lamps of 1.0 x 10^{-2} m and 3.0 x 10^{-2} m, respectively.

Table 1 Percent of V_{posi} in FL lamps with different depths of gap of FL lamps in diameters of 1.0 x 10^{-2} m and 3.0 x 10^{-3} m

depths of gap (x 10^{-3} m)	3	2	1	0.3
V_{posi} (%) with 1.0 x 10^{-2} m	14 %	30 %	60 %	90 %
V_{posi} (%) with 3.0 x 10^{-2} m	62 %	71 %	91 %	99 %

The outer diameters of the commercial HCFL lamps are empirically determined as 3.2 x 10^{-2} m (T-10). The phosphor screens of the HCFL lamps are made with the PL phosphor powders that the surfaces of the phosphor particles are heavily contaminated by the surface treatment of the phosphor particles. The pine holes and clumped phosphor particles in the screens are reduced by the adhesion of the electric insulator, like as SiO_2 microclusters. The SiO_2microclusters have the surface-bound-electrons (SBE) that give the deep gaps. The phosphor screens in the commercial HCFL lamps usually have the deep gaps. We take the gap of 3 x 10^{-3} m in the following calculations. According to the results in the table 1, the V_{posi} is only 60% of the total Ar gas in the HCFL lamps. The 40 % of the Ar gas is in the gap. We may calculate the UV lights that reach on the phosphor screen.

The unexcited Hg atoms in the 40 % Ar gas in the gap absorb the UV lights from the positive column, so that the Ar gas space in the gap works as the optical filter for the UV lights from the positive column. The gap absorbs 24 % (0.6 x 0.4 = 0.24.) of the emitted UV lights in the positive column. The UV lights that penetrate through the gap corresponds to 36 % (= 60 % - 24 %) of the total evaporated Hg atoms in the Ar gas space in the lighted HCFL lamp. The phosphor screen transduces the UV lights to the visible lightsthat correspond to 36 % of the evaporated Hg atoms in the HCFL lamps. If the commercial HCFL lamps are produced by the advanced phosphor powders, the light output from the HCFL lamps will go up to more than double (e.g. 72 %). However, the numbers of the Ar^{1+} (forming C_{Ar}) in the positive column also

increase. The electrodes of the external AC driving circuit pick up the double AC induced current from the C_{Ar}. So far as the HCFL lamps are operated with the external AC driving circuit, the reduction of the depth of the gap is not the attractive subject. On the contrary, the coil-EEFL lamps are operated with the external DC electric circuit with the $W_{DC} = 0$. Therefore, the reduction of the depth of the gap is an attractive subject of the coil-EEFL lamps.

The diameter of the developed coil-EEFL lamps is restricted by the thickness of the volume of the glow lights on the polarized phosphor particles in the screen. The thickness of the volume of the glow light is around 3×10^{-3} m. Total thickness is around 6×10^{-3} m. The thickness of the glass tubes is around 1×10^{-3} m. The optimal inner diameter of the coil-EEFL lamps is given by $(6 + 2) \times 10^{-3}$ m $= 8 \times 10^{-3}$ m. The practical coil-EEFL lamps can be produced with the outer diameters less than 1.3×10^{-2} m (< T-4).

The phosphor screens of the coil-EEFL lamps cannot produce by the commercial PL phosphor powders. The coil-EEFL lamps require the shallow depth of the gap as possible. The clean surface of the phosphor particles is essential requirement. The cleanness of the phosphor particles is only determined by the measurements of the VD curves of the CL. So far as the phosphor particles have the clean surface physically and chemically, the VD curve of the phosphor screen in a few layers has the threshold voltage at 110 volt. However, as the phosphor screen is made with the low voltage CL phosphor, the moving electrons take the surface conduction on the phosphor screen [1]. The phosphor screens in the coil-EEFL lamps require the special arrangements of the low voltage CL phosphor particles and the PL phosphor particles at side by side on the top layer of the phosphor screen [15].

For the preparation of the coil-EEFL lamps, you must control of (1) the thickness of the phosphor screen less than a few layers as shown Figure 30. (2) The production furnace of the coil-EEFL lamps should have the uniform temperature profile. Because the glass tubes are a good thermal insulator, the heaters in the furnace should be covered with the heat scatters for the uniformity of the temperature profile of the furnace. (3) You cannot use the established pumping facilities of the commercial FL lamps, because the inside of the vacuum systems is heavily contaminated with the oil-vapor of the rotary pump. You must use the oil-less rotary pump for the production of the coil-EEFL lamps.

Lighted coil-EEFL lamps in vacuum-sealed sheath tube

The coil-EEFL lamps must have the very shallow gap between positive column and phosphor screen, hopefully 1×10^{-4} m. We have an interesting of the heat of the Hg droplets on the phosphor screen. Fortunately, we have the 10 CCFL lamps in the outer diameter 3×10^{-3} m from a FL store. Each CCFL lamp contains the Ar gas pressures at 6.7×10^{3} Pa (= 50 Torr). The estimated depth of the gap is 3×10^{-4} m from the build-up curve, As the CCFL lamps convert to the coil-EEFL lamps, the converted coil-EEFL lamps are operated with the external DC driving circuit. The applied voltage to the coil-EEFL lamps is 3kV. The individual coil-EEFL lamps light up with the same illuminance (1200 lm, m^{-2}) with the $W_{DC} = 0$. The bottom line in Figure 35 shows the measurement results. Then, the EEs of the 10 coil-EEFL lamps are arranged with the parallel connection in the room. The curve of the coil-EEFL lamps in air in Figure 35 is the measured results of the illuminance. The illuminance does not linearly increase with the numbers of the

parallel connections. The outer glass wall of the coil-EEFL lamps are cooled with the thermal convention of the air in the room.

When the coil-EEFL lamps in the parallel connection set in the vacuum-shield sheath tube as shown in Figure 36, the cooling of the outer glass wall of the coil-EEFL lamps has prevented by the vacuum pressure at around 600 Pa (= ~ 5 Torr). The illuminance of the coil-EEFL lamps linearly increases with the numbers of the parallel connection as shown in Figure 35. We have found the lighting device that the coil-EEFL lamps should set in a vacuum-sealed flat container or in the vacuum-sealed glass tube.

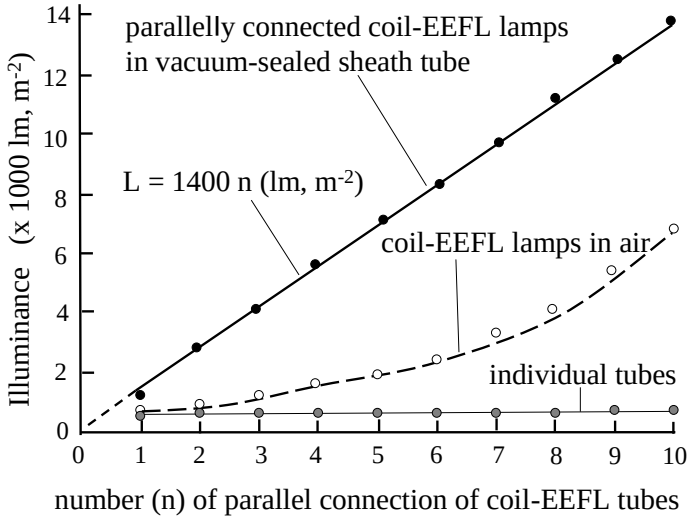
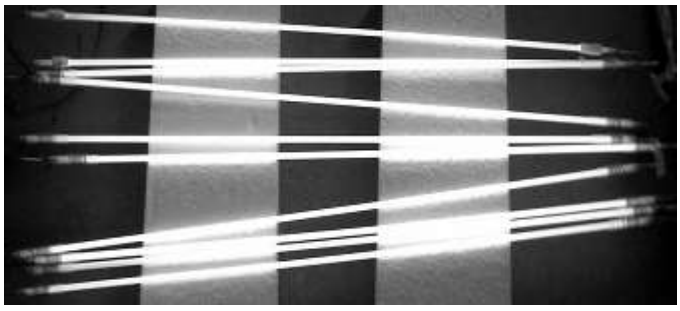
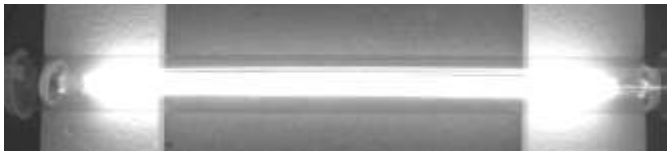


Figure 35 Illuminance (lm, m^{-2}) curves of individual coil-EEFL lamps, coil-EEFL lamps with parallel connection in air, and coil-EEFL lamps in parallel connection in vacuum-sealed sheath tube



(A) 10 parallel connection of coil-EEFL lamps under DC 3kV



(B) 10 coil-EEFL lamps in a vacuum-sealed sheath tube

Figure 36 Photopictures of individuals of lighted 10 coil-EEFL lamps in parallel connection under operation of external DC electric circuit with 3 kV (A) and lighted 10 coil-EEFL lamp set in vacuum-sealed sheath tube (B)

Figure 36 shows photographs of the individuals of the lighting coil-EEFL lamps in parallel connection in air (A) and 10 coil-EEFL lamps set in a vacuum-sealed glass tube (B). The results in Figure 36 definitely inform us that the coil-EEFL lamps should be operated with the parallel connection of the required numbers for the illumination purpose of the rooms and offices.The coil-EEFL lamps in the parallel connection set in the vacuum-sealed container. With this way, you may brilliantly illuminate the required roomsand offices with the coil-EEFL lamps with the electric power consumption W_{DC} =0.With W_{DC} =0, the coil-EEFL lamps in the parallel connection may operate with the combination of the solar cells and the electric battery in each home, without the distribution power networks from the electric power generators and home. With this way, the electric power consumption on the world may reduce to nearly zero. If it is so, the pollution level in air from the electric power generators on the world may reduces to the target level (more than 31 %) of the Paris Agreement of the United Nation on 2016.

Appendixes

Coil-EEFL lamps with Ne and Xe

In early study on the FL lamps, the neon tubes had studied as the lighting lamp. Because the Ne atoms release a small amount of the heat by the ionization energy, the FL tube with Ne gas did not absorb the attention as the lamp. We have found that the small volume of the Ne atoms on the polarized phosphor particles also ionized with the electric field from the EEs on the outer glass tube. We may have the cathode and anode of the internal DC electric power generator in the Ne gas space without the heat of the Ne atoms.

We also know that the Xe atoms in gas phase also emit the UV light at 172 nm and 142 nm. The phosphor

screen may transduce the vacuum UV lights to the lights in the visible spectral wavelengths. With this reason, the coil-EEFL lamps may be produced with the combination of Ne gas and Xe gas, In this case, the concentrations of the Xe gas in the Ne gas can be simply controlled by the pressures of the Xe gas without the heating of the Xe.

The melting temperature of Xe is -112°C, and boiling temperature is -107°C.Xe at room temperature is always gas phase. In this case, the lighted FL lamps do not require the heat-up for the Xe atoms. The FL lamps can be produced with the mixture of the gases of the Ne and Xe. The emitted UV lights from the excited Xe* by the moving electrons is the wavelength at 172 nm in the vacuum UV range. The preferable phosphor screens for the FL lamps by the mixture of Ne and Xe gases are produced with (a) $BaMgAl_{10}O_{17}$:Euas the blue light, (b) Zn_2SiO_4:Mn as the green light, and Y_2O_2S:Eu as the red light. The plasma display panel (PDP) uses (Y, Ga)BO_3:Eu phosphor as the red lights. However, the control of the sizes and surface conditions of the(Y, Ga)BO_3:Eu phosphor is a very hard. We recommend the use of the Y_2O_2S:Eu red phosphor powder that each phosphor particles have the sharp points and sharp edges. The study of the coil-EEFL lamps by the combination of Ne and Xe gases is underway.

Safety of Hg atoms with FL lamps

Here is an action against the production of the FL lamps on the world with the use of the Minesota disease in Japan. The Japanese Government had ordered the termination of the production of the FL lamps in Japan on 2014 with the antipollution of the Hg by using the Minamata disease. Their action lacks the basics of the biological science. The living matters on the Earth do not directly take the metallic atom (e.g. Hg droplets) in the body. The necessary metallic atoms for the disease should be in the organic compounds. The Minamata disease is caused by the uncontrolled drain of the organic compound of the methane mercury (CH_4Hg) solution from the chemical factory to the sea water to Minamata Bay. If the Japanese Government had controlled the drain of the organic CH_4Hg solution to the sea water from the starting of the chemical factory, the Minamata disease never happened in the poor fishing villages at Minamata Bay. But the Japanese Government did not it. There is no report from the industrialized countries in USA and Europe about the disease of the organic CH_4Hg solution from the similar and larger chemical factories that use the CH_4Hg catalysis. This is because the Governments in the USA and Europe well control the drain of the organic CH_4Hg solution to the rivers. Only Japanese Government has the responsibility on the Minamata disease with no control of the drain of the organic CH_4Hg solution to the Minamata Bay. It is clear that the Minamata disease has responded on the Japanese Government by the out control of the drain of the organic CH_4Hg solution from the factory. The Minamata disease is a limited small area in Japan. The Japanese Government cannot control the production of the FL lamps using the Minamata disease. The human society has used the Hg droplets as the useful material for more than 2000 years. But there was no report of the Hg disease like as the Minesota disease.

We have found the scientific reason why Minamata disease occurs at the villages at Minamata Bay. The Minamata disease was limited in the small fishing villages at Minamata Bay, and was not the residents in the Minamata City. Why the Minamata disease was limited in the fishing villages? The disease by the catalytic CH_4Hg solution in the fishing village occurs with the organic cycles in the living body on the Earth. As a large amount of the organic CH_4Hg solution discharges to the seawater in the Bay, the organic

CH_4Hg float in the sea water. The bacteria in the sea water first takes the floating organic CH_4Hg compounds in to the cell of the bacteria. The bacteria never directly take the Hg atoms from the sea water. As the small fishes in the sea eat the contaminated bacteria, the organic Hg selectively concentrates in the brain and innards of the small fish. The meats of the small fish are not contaminated with the organic Hg. When the mother in the fishing villages eats the small fishes without removal of the head and innards of the fishes, her body is contaminated, but the mother does not have the serious trouble in the daily activity. When the mother is pregnant, the fetus in early stage selectively receives the contaminated organic Hg from the mother. The brain of the fetus is seriously damaged by the received organic Hg, like as case of the Ziga Virus. The serious Minamata disease is limited as the new born babies. The residents in Minamata city, who eat the meets of the large fishes with the removal of the head and innards, never have the Minamata disease. If the Japanese Government controls the drain of the organic CH_4Hgsolution from the factory at early stage, the Minamata disease never happened in the small fishing villages in Japan. The regulation of the FL lamps by the Japanese Government using the Minamata disease is unacceptable as the biological science.

As described above, it can say that the productions of the advanced coil-EEFL lamps are safe from the Minamata disease. The coil-EEFL lamps are the necessary illumination source for the green energy project with the electric power consumption $W_{DC} = 0$, without scarifying the illuminance (lm, m^2). The production of the coil-EEFL lamps surely contributes to the Green Energy project of the United Nation by the reduction of the polluted materials in air from the electric power generators on the world more than 30 % from the present level.

CONCLUSION

We have briefly studied the established incandescent lamps from the basics that are the arrangements of the atoms in the vacuum. The electrons move on in the bounding shell of the metal. Naturally, moving electrons have the electric resistance caused by the thermal perturbation from the neighbor atoms. The W-filament lamps use the heated metal at the high temperatures by the Joule Heat. The LED lamps use the recombinations of the injected electrons in the luminescence centers, giving rise to the η_q (quantum efficiency) less than 1.0. Furthermore, the injected electrons that move on in the narrow vacuum between atoms at the lattice sites inevitably have the electric resistance caused by the thermal perturbation from lattice sites. As the illumination source, the LED lamps must inject, at least, more than 10^{25} electrons $(m^2, s)^{-1}$ for the illumination purpose. The injection of the large numbers of the electrons to the LED lamps generates the very high temperatures of the LED lamps. On the other hand, the electrons in the FL lamps move on in the superconductive vacuum between Ar atoms that float in the vacuum, resulting in the astronomical quantum efficiency of $\eta_q = 10^{13}$ visible photons $(m^3, s)^{-1}$.

The superiority as the FL lamps has obscured in the study on the FL lamps for more than 80 years with the wrong assignments of (i) the vacuum between Ar atoms that float in the wide vacuum, (ii) electron sources in Ar gas space, (iii) AC power consumption, W_{act}, of the external AC driving circuit as the generation energy of the lights, and (iv) lighting mechanisms of the Hg atoms in the Ar gas, (v) the coexistence of the disparity of the external driving circuit and internal DC driving circuit in the lighted FL lamps, and (vi) the existence of the capacitor, C_{Ar}, in the lighted FL lamps. After the clarification of all of them, we have developed a prototype of the coil-EEFL lamps that the power consumption of the external DC driving circuit is zero; $W_{DC} = 0$. The cathode and anode of the internal DC electric circuit are formed in the Ar gas

space with the volume of the glow lights on the sharp edges and points of the polarized phosphor particles. The phosphor particles are polarized by the electric field from the EE on the outer glass wall of the coil-EEFL lamp. The maximum electron current between the cathode and anode of the internal DC electric circuit is 3 x 10^{-4} A, corresponding to the numbers of 10^{15} electrons. The generated photons in the coil-EEFL lamps are 10^{28} visible photons (m^3, s)$^{-1}$. The fundamental mechanisms of the coil-EEFL lamps have studied in this report for the mass production of the coil-EEFL lamps by someone else. The author is 85 years old with the cancer that propagates all body. He hopes someone continue this project for the contribution to Green Energy Project by UN in a near future.

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