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Operation of FL Lamps with ±3G Electron Sources in Ar Gas Space as a Most Clean Energy Light Source

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Abstract: *FL lamps are operated with coexistence of disparate external and internal electric circuits. External electric circuit works as a help of formation of internal electric circuit in Ar gas space of FL lamp, with no electron flow. FL lamp actually lights up with moving electrons from cathode to anode of internal electric circuit formed in Ar gas space. The cathode and anode are assigned as either one of (a) the volumes of glow light (±3G) on phosphor particles or (b) heated corona light (±4G) on the metal electrodes. The developed coil-EEFL lamps use the (±3G) volume without heat. Adequate outer diameter of the coil-EEFL lamps is within 1.0 x 10^{-2} m with Ar gas pressures higher than 7 x 10^{4} Pa (> 50 Torr). The developed coil-EEFL lamps light up under AC and/or DC driving circuits. Under the AC driving circuit, capacitor C_{phos} involve in W_{AC} that is lower than 0.1 W_{AC} of the established HCFL lamps that involve the C_{Ar}. Under the external DC driving circuit, both of C_{phos} and C_{Ar} do not involve in the power consumption. Consequently, W_{DC} = 0. The operation life is longer than 10^{6} hours. The Coil-EEFL lamps surely contribute to the urgent project of COP of UN with reduction of generated electric power consumption more than 30 % on the world.*

Keywords: *Green Energy, cathode and anode, quantum efficiency, power consumption, operation life*

1. Introduction

Recently our planet Earth faces a serious problem with worming up by air pollution. Our life activities use the illumination lamps as the necessaries of life. The illumination of the lamps use the electricity generated at the electric power generators on the world. According to the report of COP 21 (Conference of particles 21), illumination by lamps consumes more than 31 % of totally generating electric powers on the world. Major illumination lamps are the incandescent lamps. Therefore, the reduction of the electric power consumption of the incandescent lamps is a very important subject in our life activity. For the reduction of the electric power consumption of the illumination lamps, at first, we must clarify the word of the incandescent lamp.

If you refer the Webster Dictionary, the incandescent lamps is defined as the W-filament lamp. After the assignment of the W-filament lamps on early 1900s, the fluorescent (FL) lamp and LED lamps have developed. FL and LED lamps light up with moving electrons in materials. The original word of candescence comes from ancient Greek that means light from fire flame. According to the original definition, incandescent lamps include lighting lamps by moving electrons in solids and/or gases that are no use of fire flame. Here we identify FL lamps and LED lamps as the incandescent lamps. Then we must know which incandescent lamp may significantly reduce the electric power energy by lighting with the daytime scenery that is given by illuminace (300 lm, m^{-2}) or luminance (300 cd, m^{-2}), corresponding to 10^{25} visible photons per m^2 per second [1]. For the evaluation of the incandescent lamps, someone use the luminous efficiency (lm, W^{-1}) that is for the colorimetry. We cannot use the luminous efficiency for the evaluation of the incandescent lamps.

Electron is quantum. Therefore, figure of merit of incandescent lamps is given by quantum efficiency (η_q) that is given by the numbers of the generated visible photons per one moving electron in the given incandescent lamp. We cannot calculate the η_q of the W-filament (metal) lamp, because the W-filament lamp emits the lights in a wide spectral wavelength from the ultraviolet to infrared lights. The LED lamps by the solid compounds have η_q < 1.0. This is because visible one photon from the LED lamp is generated by recombination of a pair of electron and hole at luminescence centers in junction in the LED lamps. Furthermore, the moving electron in solids unavoidably loses some amount of the kinetic energy before the recombination at the luminescent centers by the Joule Heat

(I^2R), where I is electric current in the LED lamps and R is electric resistance of the solids. R is caused with the thermal perturbation from the thermally vibrating atoms at lattice sites. We may calculate the required electric current in the LED lamp for illumination of the room in unit size (m^2). The calculation shows 2×10^6 A {10^{25} photons x (1.6×10^{-19} coulomb)}, because 1A electric current is given by 1.6×10^{-19} coulomb per second. The LED lamps are operated with DC 2.8 V, so that the power consumption (W_{LED}) is calculated as 5.6×10^6 watt (= 2×10^6 A x 2. 8 V) for the illumination of $1m^2$ room. Here is a large limitation of the numbers of the injected electrons into the LED lamps. The luminescence centers in the junction are the impurity in the LED lamps. The luminescence centers diffuse out from the junction at above the threshold temperature at 70°C. The operation temperature is determined by (I^2R). The stability of the luminescent centers determines the maximum amount of the injected electric current in the LED lamps. One may allow us to say that the LED lamp is not energy saving incandescent lamps, even if someone claims it.

It is a very hard to find out the η_q of the FL lamps from the publication of the past studies of FL lamps. This is because the HCFL lamps have developed without the clarifications of the moving electrons in the vacuum space between floating Ar atoms at the Ar gas pressure at 930 Pa (= 7 Torr). The vacuum space between Ar atoms in FL lamps quite differs from the vacuum space at the pressure less than 10^{-5} Pa (10^{-5} Torr), like as cathode ray tube (CRT) and vacuum radio tube (VRT). The developers of the FL lamps did not clarify the vacuum conditions of the FL lamps. The main purpose of the studies on the FL lamps was the development on the commercial HCFL lamps for last 90 years, by try and error approach based on the concept of the discharge lamps. FL lamp is not discharge lamp. By the concept of the discharge lamp, the established FL lamps do not light up with the moving electrons. Recently, we have deeply studied the lighting mechanisms of the FL lamps with the moving electron in the electric insulating vacuum and in the neutralized vacuum space between floating Ar atoms per second [1, 2, 3, 4]. Then, we have found that the electrons in the lighted FL lamp move on in a superconductive vacuum space (R = 0) between floating Ar atoms in vacuum at above room temperature. This is a great advantage, but it requires the statistical calculations. We have statistically calculated the astronomical $\eta_q = 10^{12}$ visible photons (m^2, s)$^{-1}$ by one moving electron [1, 2, 3]. The numbers of the moving electrons in the vacuum in the commercial HCFL lamp in outer diameter at 9.5×10^{-2} m with 1.0 m long are 10^{13} electrons, corresponding to 4×10^{-4} A. The HCFL lamp continuously emits 10^{25} visible photons (m^2, s)$^{-1}$ (= $10^{12} \times 10^{13}$), like as the daytime scenery. The astronomical η_q of the FL lamp is a great advantage over other incandescent lamps. But the calculated results have hidden in the past study of the FL lamps with the concept of the gas discharge lamps.

Continuous illumination of rooms is necessary condition for the protection of the eyes and nerves in brain of human. This is because human have daytime activity for more than 5 million yeas under the illumination of the slightly overcastted sky with thin clouds. Naked eyes of human adjust to daytime sceneries that continuously generate 10^{25} visible photons (m^2, s)$^{-1}$; corresponding to luminance (300 cd, m^{-2}) or illuminance (300 lm, m^{-2}). The LED lamps discontinuously emit the light. Therefore, the eyes and brain will damage for the illuminated rooms under the LED lamps. With above calculations, we may select the FL lamps as the unrivaled candidate for (a) protection of the nerves in the human brain, and (b) the significant reduction of the electric power consumption to the contribution to the Green Energy Project of UN.

2. TECHNOLOGIES OF DEVELOPED HCFL LAMPS FOR LAST 90 YEARS

The excellent properties of the HCFL lamps have been concealed with the erroneous concepts of the lighting mechanisms for past 90 years. The typical error is the thermoelectron emissions of the heated BaO particles as the hotcathode (HC) FL lamps. The heated BaO particles never emit the thermoelectrons in to the Ar gas space at 930 Pa (= 7 Torr) [1, 2, 3]. According to the extensive study on CRTs, the Ba atoms on the heated BaO particles steadily emit thermoelectrons into vacuum at the pressure less than 10^{-5} Pa (< 10^{-7} Torr). The heated Ba atoms in the vacuum at the pressures higher than 10^{-2} Pa (10^{-4} Torr) instantly change to BaO or Ba compounds by the chemical reactions with the residual gases. The BaO and Ba compounds never emit the thermoelectrons in to the vacuum. Therefore, the HCFL lamps never use the thermoelectron emission from the heated BaO particles on the W-filament coils. The heated BaO particles at the nearby heated bear spot of the W-filament coils work as an important role of the formation of the volumes of the heated corona light on the W-filament coils at the both ends [4]. The volumes of the corona light on the W-filament coils form the ±4G electrodes of the internal DC diving circuit of the HCFL lamps. The lights from the HCFL lamps are generated with the moving electrons from -4G electrode (cathode) to +4G electrode (anode) of the internal DC driving circuit. We must explain why the HCFL lamps require the ±4G electrodes. The answer is a very simple. The vacuum space between floating Ar atoms in FL lamps fills up with the negative electric field of the electrons in the $^3p_6$ orbital shell of Ar atoms, as illustrated in Figure 1 [1]. The electrons from the metal electrode cannot step in the vacuum between Ar atoms. The difficulty of the lighting mechanisms had already found on 1903.

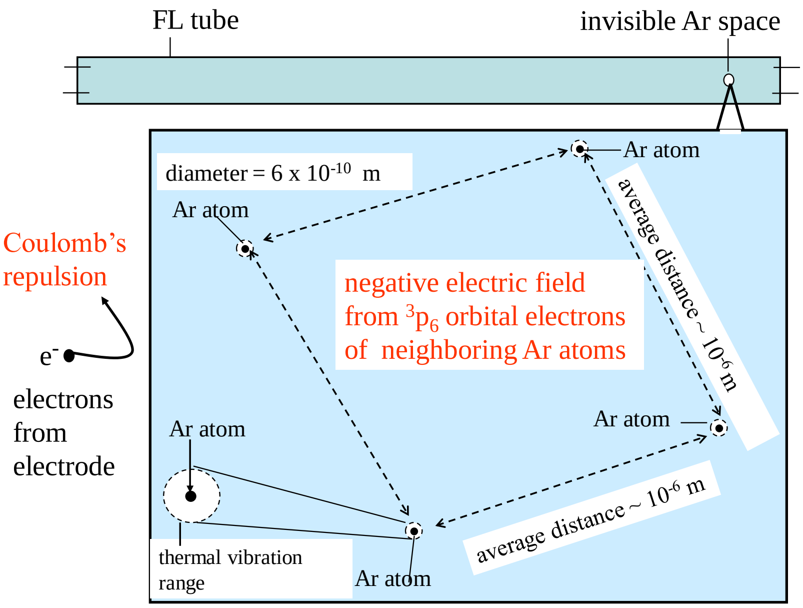


Figure1. *Schematic illustration of vacuum space between floating Ar atoms in commercial HCFL lamp that has Ar gas pressure at 931 Pa (7 Torr)*

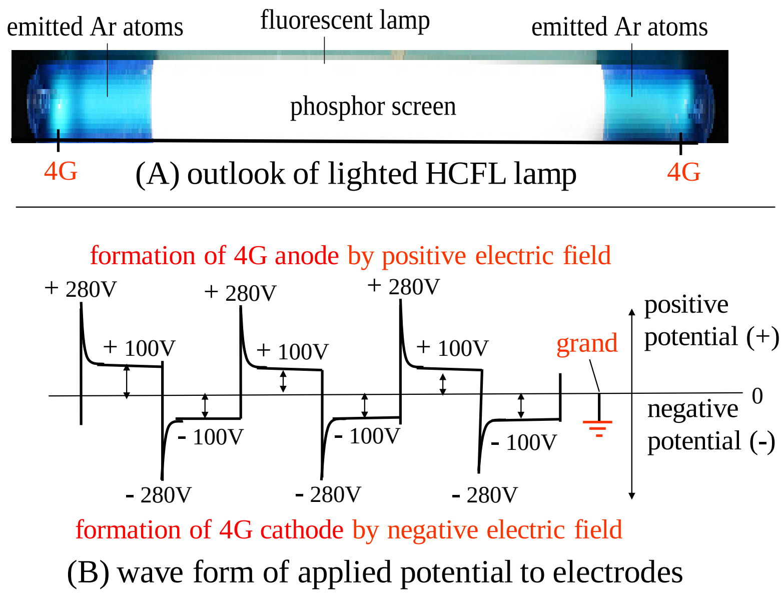
First lighting glass tube that has metal electrodes at the both ends is called as the Geissler tubes that are operated with the high frequencies on 1859. After 44 years later from Geissler, John Sealy Townsend had reported on 1903 that as the vacuum pressure is below 10^{-3} Pa (< 10^{-5} Torr), the needle metal cathode electrode, having a few ten volts, continuously emits electrons in to the vacuum and the anode metal electrode collects the electrons from the vacuum. This has called as the field emission of the electron in to vacuum from the needle electrode. As the Ar gas pressures higher than 10^{-1} Pa (> 10^{-3} Torr), however, the needle electrode does not emit the electrons to the Ar gas space under the potential below 0.95 kV. Townsend did not give the reason. We know the reason that the vacuum space between Ar atoms fills up with the negative electric field from the electrons in the $^3p_6$ orbital shell of Ar atoms, as illustrated in Figure 1 [1, 4]. Townsend had found that the negative electric field between Ar atoms suddenly breaks out by the formation of the volumes of the glow lights (i.e. ±3G electron sources) of the Ar atoms. After formation of the ±3G volume of the electrodes, the electrons from the needle cathode continuously step in the neutralized vacuum between Ar atoms. After the formation of the ±3G electrodes, the needle cathode vertically emits the electrons against 1.0 kV with the different applied voltages. He did not explain the reason. The Townsend results give us the real lighting mechanisms in the Ar gas space in FL lamp.

However, after the Townsend report for more 80 years, the scientists and engineers who had studied the FL lamps never paid their attention to the formation of the ±3G electrodes in the Ar gas space. They paid their attention to the Geissler tube with the change of the name as the *vacuum discharge lamps*. The FL lamps never light up with the discharge of the electricity. The FL lamps light up the excitation of Ar (and Hg) atoms by the moving electrons between cathode and anode formed in Ar gas space. The developers of the FL lamps, however, had taken the discharge of the electricity. They had believed that the lights of the FL lamps are generated by the discharge of the electricity in the glass tube. The Ar atoms under the electric field from the metal electrodes at both sides of the Geissler tubes brilliantly emit the sky-blue lights with any Ar gas pressures. Then they had developed the commercial HCFL lamps [5, 6, 7, 8, 9, 10].

Electrons in FL lamps only move from cathode to anode in vacuum between Ar atoms. In the past study, the developers of the HCFL lamps never consider the anode in the lighted HCFL lamps. This is because the lights are generated by the discharge of the electrons in the HCFL lamps. We know that the lights from the HCFL lamps are only generated with the excitation of the Ar atoms (Ar*) by the moving electrons. The electrons only move on in the vacuum under the electric field between cathode and anode of the internal DC electric circuit. For the moving electrons, the HCFL lamps must have the anode as the correction of the arrived electrons. However, we cannot find the anode in the established HCFL lamps [5, 6, 7, 8, 9]. The study on the lighting mechanisms of the HCFL lamps has not completed in the last 70 years. Why the scientists and engineers had developed the HCFL lamp? Without the assignment of the anode, they had developed the practical HCFL lamps that brilliantly emit the visible white light.

The next serious mistake is the formation of the electric circuits. We have found that the HCFL lamps are operated with the coexistence of the disparities of the external AC driving circuit and internal DC driving circuit [1, 2, 3]. The electrodes of the W-filament coils with the BaO particles are only closed with the induced voltages from the capacitor C_{FL}. Under the AC electric field between W-filament coils at the both ends, the C_{FL} is only formed by the voltage changes that are caused by the synchronously displacing electrons in the $^3p_6$ orbital electron shell in Ar^{1+} [1]. The W-filament coil electrodes never close with the moving electrons in the Ar gas space. The electrons in the HCFL lamps only move on in the internal DC electric circuit that the cathode and anode are formed with the ±4G volumes of the corona lights [1, 4].

In general, the HCFL lamps brilliantly light up under the AC driving circuit that has AC 100 V with 50 (or 60) Hz. Figure 2 (A) shows the photopicture of the lighted HCFL lamp. Figure 2 (B) shows the waveform at the electrodes of the lighted HCFL lamp. The negative and positive potentials of the waveforms are respectively given by the potential against to grand (Earth) that has zero voltage, as shown in Figure 2 (B). In the past study, the lighting mechanisms of the HCFL lamps under the AC driving circuit never analyzed with the science.



Figurer2. *Photopicture of lighting HCFL lamp and AC waveform of driving circuit [4]*

By referring the waveform shown in Figure 2 (B), it is clear that for a half cycle (1 x 10^{-2} second), the HCFL lamp has only cathode or anode. For the formation of the electric circuit for each half cycle, the cathode and anode should be coexistence during each half cycle. However, no one has the question on the fundamental point for the formation of the electric circuit for the half cycle of the AC driving circuit. This is because they took the Geissler concept of the discharge lamp. The advance science informs us that for the formation of the electric circuit in the vacuum at any gas pressures, the cathode and anode must coexist for each half cycle.

Recently, we have found the coexistence of the external AC riving circuit and internal DC electric circuit [1]. The external AC driving circuit is only active with the existence of the capacitance C_{FL}. The internal DC electric circuit is formed by the cathode and anode in each half cycle (10 ms) [4]. The internal DC driving circuit is formed by the heated volumes of the corona light that are assigned as the

±4G electron sources [4]. The electric field from the W-filament coil electrodes of the external AC driving circuit helps the formation of the cathode and anode of the internal DC driving circuit. Figure 3 illustrates the coexistence of the cathode and anode for one cycle (10 ms) under 50 Hz in the HCFL lamp. Then, the electrons continuously move from the cathode to the anode of the internal DC driving circuit. We have solved the pending question of the operation of the HCFL lamps. The solution of the HCFL lamps is not our main subject. The main subject is the generation of the ±3G electron sources. Anyway, we clarify the ±4G electron sources, for a good understand of the formation of the ±4G electron sources.

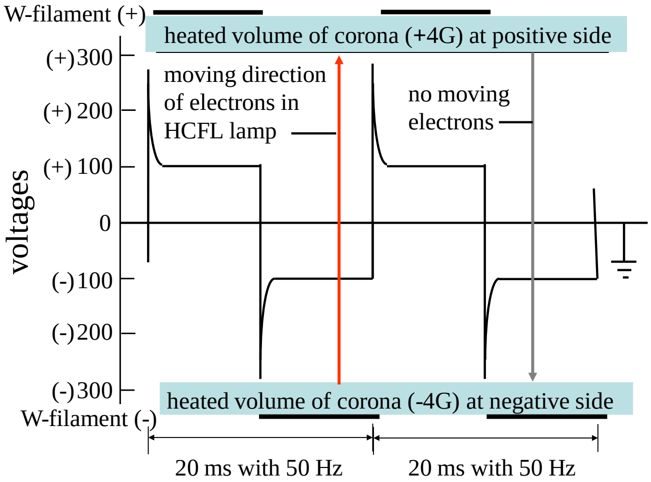


Figure3. *Formation of 4G volumes of corona light (sky blue) on positive and negative W-filament coils of HCFL lamp. Lights are generated by moving electrons in internal DC driving circuit which is formed with ±4G volumes in Ar gas space*

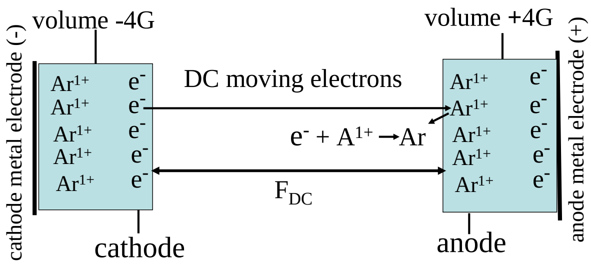


Figure4. *Schematic illustration of distribution of Ar^{1+} and e^- in volumes of corona light (4Gs) and moving direction of electrons between cathode and anode. Arrived electron recombines with Ar^{1+} and returns to Ar atom*

Figure 4 illustrates the details, with the atomic levels, of the internal DC driving circuit. The electric field from the W-filament coils at both ends of the HCFL lamp ionizes the Ar atoms in the heated volumes of the ±4G. The ionized 4G volumes contain electron (e^-), ionized Ar atom (Ar^{1+}), and excited Ar atoms (Ar*). Only Ar*, which does not have electric charge, uniformly distributed in the 4G volume. We can monitor the presence of the heated ±4G volumes with the lighted Ar*.

The e^- and Ar^{1+} are the electrically charged particles. They are not uniformly distributed in the ±4G volumes. Following are the details of the working mechanisms of the -4G volumes. The electric field from the negative metal electrode (-) attracts the Ar^{1+}, but the negative metal electrode does not take out the Ar^{1+} from the -4G volume. The attracted Ar^{1+} stays in the surface volume of the -4G volume, as illustrated in Figure 4. The e^- in the 4G volume repulses from the negative electrode. The repulsed e^- distributes far from the negative electrode in the -4G volume, as illustrated in Figure 4. The electrons that distribute at the far distance in the -4G volume (Σe^-) form the real cathode of the -4G volume. Similarly, the positive electric field at opposite side (i.e., positive (+) metal electrode attracts the electrons in front of the positive electrode, and repulsed Ar^{1+} distribute far from the positive electrode in the +4G volume. The (ΣAr^{1+}) act as the real cathode of the +4G volume. Thus, the internal cathode and anode are respectively formed in the Ar gas space in the HCFL lamps. They are completely isolated by the electron flow from the external AC driving circuit.

The negative vacuum space of the Ar atoms in the ±4G volumes are neutralized by the presence of Ar^{1+}. The electrons in the ±4G volumes smoothly move on in the vacuum space between Ar atoms under the electric field (F_{FL}) between the cathode and anode. The step-out electron to the nearby Ar gas space may ionize the Ar atom. Thus, the negative vacuum space between Ar atoms, as shown in Figure 1, instantly neutralizes by the step-out electrons with the moving speed of the electrons. Total insulating vacuum in the HCFL lamps is instantly neutralized with generated Ar^{1+} by the moving speed of the electrons form the -4G cathode to the +4G anode. As the power source of the external AC driving circuit turns off, the neutralized vacuum space in the lighted HCFL lamps instantly changes to negative electric field. Thus, the HCFL lamps light up with the formation of the ±4G volume of the corona light at around heated W-filament coils.

In the past, the developers of the commercialized HCFL lamps never found out the formation of the coexistence of the cathode and anode in the internal DC driving circuit in the Ar gas space for more than 70 years. This is because they took the concept of the discharged electrons in the Geissler tube. The AC driving circuit at the W-filament coil electrodes is never closed with the discharged electrons. The AC driving circuit with the W-filament coils of the HCFL lamps is only closed with the induced voltages from the capacitor, C_{FL}, formed with the synchronous displacement of the orbital electrons in $^3p_6$ shell of Ar^{1+} [1, 2, 3]. Then, they have erroneously assigned the generated lights with the energy detected AC voltage of the capacitor, C_{FL}, at the W-filament electrodes. The determined AC power consumption at the W-filament electrodes does not relate with the generation of the lighting energy of the HCFL lamps. This is the false story.

As described above, we have totally revised lighting mechanisms of the established 40W-HCFL lamps. Under the AC driving circuit, the 40W-HCFL lamp forms the heated ±4G volumes of the corona light on the heated W-filament coils at the both ends [1, 4].

As the summary of ±4G electrodes, we have found that the HCFL lamps light up with the moving electrons between the heated ±4G volumes of the corona light. It is said again that the negative electric field in the vacuum between Ar atoms is neutralized by the positive potential of the ionized Ar atoms (Ar^{1+}) that are generated by the moving electrons from the -4G cathode to the +4G anode. We have confirmed the results by Townsend. Then we have calculated the moving electrons with the statistical considerations. The electrons from the -4G cathode move on in the superconductive vacuum (R = 0) at above the room temperature, giving rise to the astronomical quantum efficiency, $\eta_q = 10^{12}$ visible photons per second by one moving electron in HCFL lamps [1, 2, 3].

The operation life of the HCFL lamps has determined by the cut-off of the heated W-filament coil at either side by the evaporation of W-atoms. The average operation life of the HCFL lamps is around 500 hours under the operation at 50 Hz. The operation life extends to around 10^4 hours under the operation at 30 kHz. The remained subjects of the HCFL lamps are (a) the formation of the volume of the corona lights at the room temperature for the extension of the operation life, and (b) reduction of the electric power consumption of the external AC driving circuits; hopefully zero power consumption of the external electric circuit of the FL lamps.

3. INVENTION OF COIL-EEFL LAMPS WITH ±3G VOLUMES OF GLOW LIGHTS

Townsend has shown us the volume of the glow light of Ar atoms on the needle electrode at room temperature acts as the cathode (e.g., electron supplier) in the glass tube on 1903. Recently, we have studied the formation of the volume the glow lights on the needle metal electrodes in Ar gas at the pressures higher than 665 Pa (> 5 Torr). The negative and positive needle electrodes separately set in the vacuum sealed glass tubes. We have obtained the similar results by Townsend [1]. The needle electrodes in the glass tubes, which separately have the positive and negative potentials, are suddenly covered up with the volume of the glow lights at 1.0 kV at the room temperature. The thickness of the volume of the glow lights on the needle electrodes is around 1×10^{-3} m. The size of the volumes of the glow light, here after ±3G volume, does not change with (a) Ar gas pressures up to 1.3×10^4 Pa (100 Torr), and (b) applied ± DC voltages up to 10 kV, that we have studied.

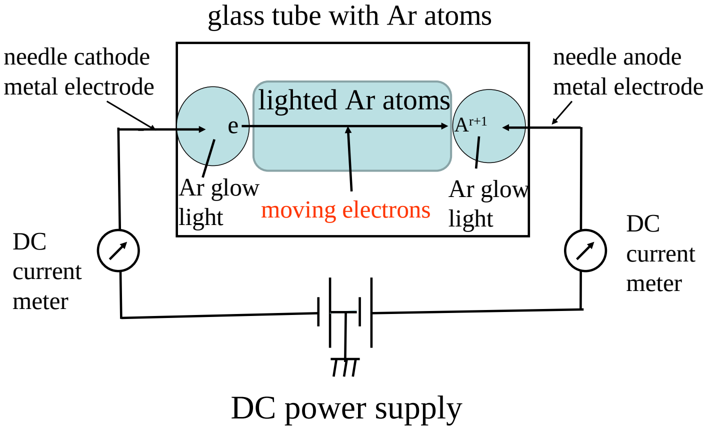


Figure5. *Experimental configuration of flow of electrons between ±3G on needle electrodes that separately have negative and positive potentials above 1.0 kV.*

Then, the needle electrodes separately set at the both ends of one glass tube that contains the Ar gas pressure at 930 Pa (= 7 Torr), as illustrated in Figure 5. We know the HCFL lamps are operated with moving electrons from the negative cathode and positive anode of the internal DC driving circuit, as shown in Figures 2, 3 and 4. The testing glass tube in Figure 5 is operated with the DC driving circuit. We have found that the volumes of the glow light are separately formed in the Ar gas space on the needle cathode (above -1.0 kV) and the needle anode (above +1.0 kV) against the grand (V = 0) at the room temperature. We have assigned the volumes of the glow lights on the needle electrodes as ±3G electrodes of the internal DC driving circuit that forms in the Ar gas space at the pressures above 133 Pa (= 1 Torr). By the measurement of the infrared thermometer, the temperature of the ±3G electrodes is around 30°C that probably generated by the ionization of the Ar atoms by the electric field from the needle electrodes by the change in entropy. The Ar atoms in the volume of the ±3G electrodes emit sky-blue lights that are generated by the excited Ar* as illustrated in Figure 5, The tested glass tube brilliantly lights up under the DC ± voltages above 1.1 kV by the moving electrons from the -3G cathode to +3G anode at the both ends. The moving electrons in the Ar gas generate the ionization of the Ar atoms, generating Ar^{1+} and electrons, and the sky-blue lights from the excited Ar atoms (Ar*). The results in Figure 5 surely indicated that the ±3G volumes in the glass tubes work as the cathode and anode at around room temperatures. We have the DC current meters (1 mA maximum) to the needle electrodes at both ends, as illustrated in Figure 5. The electric current linearly increases with the applied voltages to the needle electrodes, like as the Townsend report. The DC current meters at the both sides show the same amount of the DC electric currents, indicating the external DC electric driving circuit is activated with the electron flow (currents) in the Ar gas space. The measured results show us that the needle electrodes and ±3G electron source are electrically connected each other.

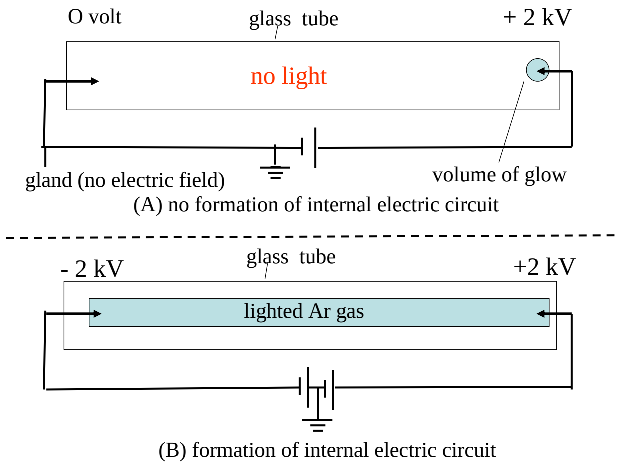


Figure 6 As you apply positive potential to needle electrode at one side and electrode at other side has grand potential (V=0), glass tube never light up by DC driving circuit, as illustrated in Figure 6 (A). For lighting, needle electrodes at both sides respectively have negative and positive potentials, as illustrated in Figure 6 (B).

We have many troubles with the production engineers of the FL lamps, especially Asian countries. They have made the experiments that use their HCFL and/or CCFL lamps for the study on the ±3G electrons sources. They claimed my experimental results are the false story. In reality, they do not understand the formation mechanisms of the ±3G and ±4G electron sources in their HCFL and CCFL lamps. It should note that the test vacuum glass tube never lights up with the application of the positive DC voltage at 2.0 kV to one electrode and other electrode has the grand potential as illustrated in Figure 6 (A). The vacuum glass tube only lights up with the negative and positive DC voltages at ± 2 kV to the needle electrodes, as illustrated in Figure 6 (B). The results of Figure 6 (B) are similar with the ±4G volume of the corona lights in the HCFL lamps as shown in Figures 2, 3, and 4.

We back to our studies. The tested glass tube also lights up under the AC driving circuit. In this case, you may apply the AC voltages at the needle electrodes above 1.0 kV with AC frequencies higher than 10 kHz. The AC driving circuit must have the AC voltages higher than 1.0 kV, as shown in Figures 2 and 3. Under the AC driving circuit, the needle electrodes at the both ends mainly pick up the voltages from the large capacitor C_{FL}, like as the case of the HCFL lamps. Under the application of the DC electric circuit, the needle electrodes never pick up the induced AC voltages from the C_{FL}. With this reason, we recommend that at first, the experiments of the ±3G volumes are made with the DC driving circuits, for the avoidance of the confusions in the analysis of the observed results.

The formation of the ±3G volumes does not require the heating part, promising the extension of the operation life of the FL lamps to longer than 10^6 hours, corresponding to 100 years with lighting for 24 hours per day [= 24 x 365 x 10^2 hours). Here arises a limitation of the FL tubes. The thickness of the ±3G volumes on the needle electrodes is around 3 x 10^{-3} m. The thickness of the ±3G volume on the needle electrodes does not change with (a) the applied voltages above 1.0 kV to 10 kV, and (b) Ar gas pressures up to 1.3 x 10^4 Pa (= 10^2 Torr). The study on the needle electrodes should be made with the glass tube in the inner diameter at 5 x 10^{-3} m. We must solve a most important item that is the power consumption of the external DC driving circuit to W_{DC} = 0.

With a curiosity, the needle electrodes are covered with the frit glass layer in the thickness at around 1 x 10^{-6} m for cutoff of the electron flow between needle electrodes and the ±3G volumes. The frit glass is a good electric insulator. The needle electrodes covered with the frit glass layer set in the vacuum sealed glass tubes in the diameter of 1 x 10^{-2} m with 0.5 m long. The experiments are made with the glass tubes, without the phosphor screen, for the observation of the lighted conditions of the Ar atoms. The vacuum sealed glass tube only contains Ar gas pressure at 665 Pa (= 5 Torr). Then, we separately apply DC voltage at ± 2 kV against the grand (V = 0) to the needle electrodes as shown in Figure 7. The attached DC current meters do not show the electric current, indicating that the frit glass layer on the needle electrode surely cuts off the electron flow between the volumes of the ±3G and needle electrodes. Surprisingly, the test glass tube brilliantly lights up with the sky-blue light between the volumes of the ±3G electrodes. The results certainly indicate that the formation of the ±3G volumes only requests the electric field from the needle electrodes.

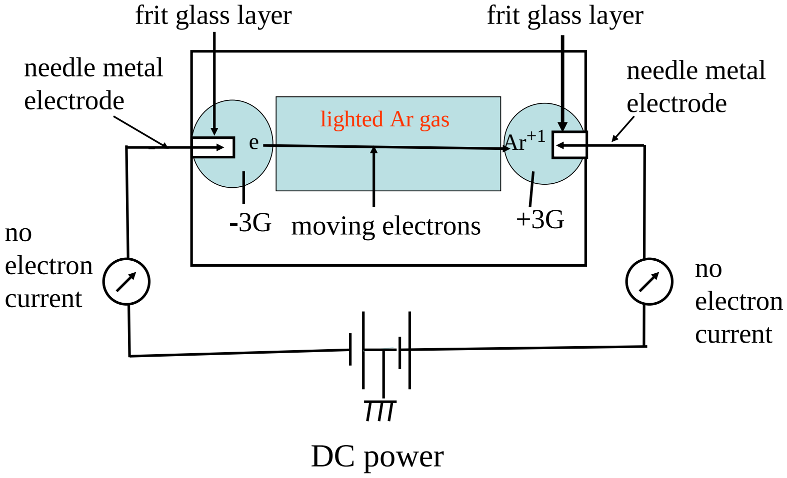


Figure 7 Explanation of moving electrons between volume of 3G (glow light) as cathode and anode of internal DC electric circuit formed in Ar gas space

4. FUNDAMENTALS OF LIGHTING MECHANISMS OF COIL-EEFL LAMPS

We have found that the ±3G volumes in the Ar gas space form on the phosphor particles in the screen on the inner glass wall of the FL lamp by the electric field from the external electrodes on the outer glass wall. The clue of the formation of the ±3G volumes is caused with the characteristic properties of the phosphor particles.

We have extensively studied the electric properties of the phosphor particles in the screens in the past years for more than 70 years, including of the production process of the phosphor powders [11]. The phosphor powder contains the crystallized tiny phosphor particles in the sizes around 5×10^{-6} m. We cannot use the commercial instruments for the determination of the distribution of the particle sizes. We had the handmade instruments for the determination of the phosphor particles in the sizes at around 5×10^{-6} m by the microscope determination. If you use the commercial instruments for the determination of the phosphor particles, you never obtain the following information. The best practical phosphor particles distribute with a log-normal distribution that forms the densely packed phosphor screen. The shape of each particle is determined with the control of the production conditions of the phosphor powders. The best particles for the application to the vacuum devices are polycrystals that have many glowing axis, generating the sharp edge lines and points less than 10^{-8} m. The practical phosphor particles are the piezoelectric particles. The deformed phosphor particles may generate the strong electric fields from glowing edges and sharp points to the Ar gas space, like as the needle electrodes. The studies of the practical phosphor particles suggest us followings. The phosphor particles deform the crystal structure under the electric field from metal electrodes on the outer glass wall of the glass tube. The ±3G volumes may form on the phosphor particles with the strong electric field from the deformed phosphor particles. If you use the commercial phosphor powders for the FL lamps, the sizes of the phosphor particles do not distribute with the log-normal distribution. They are the mixtures of the plural log-normal distributions. The ±3G electron sources only form on the phosphor particles with the controlled production conditions.

Next subject is the optimal outer diameter for the coil-EEFL lamps. Since the thickness of the formed ±3G volumes on the phosphor particles is 3×10^{-3} m, total thickness of the ±3G volumes in the FL lamps is 6×10^{-3} m. The total thickness of the glass tube is around 2×10^{-3} m. Therefore the optimal outer diameter of the FL lamp for the coil-EEFL lamp is around 1×10^{-2} m.

For the initial study on the coil-EEFL lamps, we may modify the commercial HCFL or CCFL lamps to a coil-EEFL lamp. It is a very hard to find the adequate HCFL lamp in the outer diameter of 1×10^{-2} m on the market of the FL lamp. Fortunately, we have the CCFL lamps in the outer diameter 3×10^{-3} m from a friend.

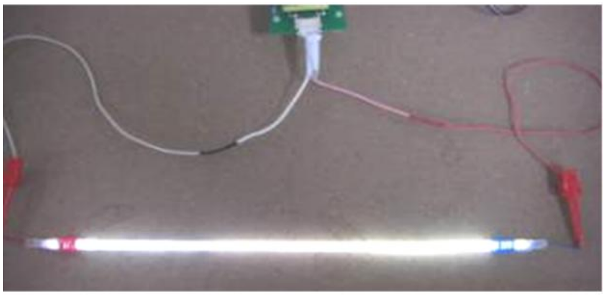


Figure8. *Lighted coil-EEFL lamps under AC driving circuit with 2kV, 30 kHz and/or DC driving circuit with ± 2kV against grand (V = 0)*

Then, we set the lead wire on the outer glass wall that is external electrode (EE) on the outer glass wall of the CCFL lamp. Thus, we have had a prototype of the coil-EEFL lamp in our hands by the modified from the CCFL lamp. At first, we have applied the AC voltage at 2kV, 30 kHz to the coil-EEFL lamp. The coil-EEFL lamp brilliantly lights up as shown in Figure 8. The AC power consumption, W_{act}, is less than one tenth of the CCFL lamp. This is because the EE electrodes never pick up the power consumption of the C_{FL}. But, the EE electrodes on the outer glass tube picks up the power consumption of the C_{phos} that is formed with the periodically polarized phosphor particles under the EE electrodes on the outer glass wall of the coil-EEFL lamp. Then, we change the driving circuit to the DC driving circuit that respectively supply ± 2.0 kV to the coil-EEs. The coil-EEFL lamp also light up with the similar brightness with the AC driving circuit. The power consumption of W_{DC} of the

DC riving circuit is zero; $W_{DC} = 0$, because the DC driving circuit never picks up the C_{phos}. Here, we have developed an ultimate coil-EEFL lamp as the energy saving of the incandescent lamp with the $W_{DC} = 0$.

It should note that the tested coil-EEFL lamps shown in Figure 8 is not optimized coil-EEFL lamp. The optimized coil-EEFL lamps should be made with (a) the outer diameter at 1 $x10^{-2}$ m with Ar gas pressures higher than 7 x 10^3 Pa (> 50 Torr). (b) The numbers of the phosphor layers in the phosphor screen is less than 5 layers. And (3) the special arrangements of the color phosphor particles on the screen [12]. This is a most important point for the preparation of the coil-EEFL lamps. If you convert the commercial 40W-HCFL lamps to the coil-EEFL lamps, the converted coil-EEFL lamps light up with the low illuminance (lm. m^{-2}) or luminance (cd, m^{-2}), about a half light intensities. You must carefully learn the conditions of the adequate FL lamps with the reference [11, 12]. Otherwise, you do not obtain the similar results shown in Figure 8.

The result shown in Figure 8 inform us that the FL lamps may produce without the inside electrodes of the FL lamp. The production process of the coil-EEFL lamp looks like a very simple by no use of the inside electrodes in the FL lamp. This may revolutionary advantage in the production of the FL lamps. The subject of the optimizations of the coil-EEFL lamps remains for the subjects of the application research, not for the subject of the production engineers. We have described the fundamental research subjects.

The coil-EEFL lamps in the outer diameter at around 1.0 x 10^{-2} m linearly increase the illuminance (lm, m^{-2}) with the Ar gas pressures up to 10^4 Pa (= 70 Torr). This is because the DC and AC driving circuits never pick up the large capacitor C_{FL} caused by the Ar^{1+} in the lighted FL lamps. If you operate the coil-EEFL lamps in diameter of 1.0 x 10^{-2} m with the AC driving circuit, the W_{AC} of the coil-EEFL lamps is less than one tenth of the W_{AC} of the HCFL lamps, because of the involvement of the C_{phos}. If you operate the coil-EEFL lamps with the DC driving circuit, the $W_{DC} = 0$. If you have an interest of the development of the coil-EEFL lamps, it is a better way to know at the first the theoretical details of the formation of the coil-EEFL lamps.

The EEFL lamps have the metal electrodes on the outer glass wall of the FL lamps. We can use either one of (a) the cylinder electrodes or (b) the coil electrodes that are on the outer glass wall. The cylinder electrodes may have a trouble in the operation with the breakout of the vacuum of the cylinder FL lamp. The vacuum break is caused with the arc discharge of the trapped air babbles between glass wall and inside of the metal cylinder. For the avoidance of the generation of the vacuum break, we recommend the use of the lead wires on the outer glass wall that is the coil-EEFL lamp. The lead wire should be covered with the plastic layer in thickness less than 1 x 10^{-3} m (= 1 mm). The numbers of the lead wire on the outer glass wall may have 3 to 5 turns. Then the lead-coil wires strongly push down on the glass wall by the application of the thermally shrinking plastic tube.

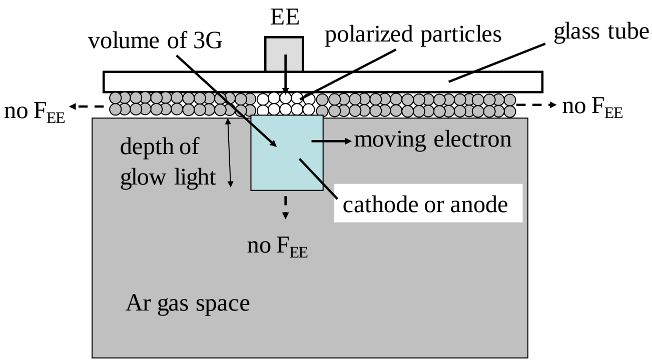


Figure9. *Schematic explanations of formation mechanisms of volume of glow light (3G) by electric field F_{EF} from polarized phosphor particles on inner glass wall. Phosphor particles are polarized under electric field of external electrode (EE) on outer glass wall.*

Followings are the fundamental results of the formation mechanisms of the coil-EEFL lamps. Figure 9 illustrates the formation mechanisms of the 3G volume of the glow light on the polarized phosphor particles on the inner glass wall, which are under the electric field (F_{EE}) of the EE on the outer glass wall of the FL lamp. So far as the EE has the negative potential higher than -1.5 kV against the grand, the formed 3G volume with 3 x 10^{-3} m thickness works as the cathode of the internal DC electric circuit. As the EE at other side of the FL lamp has the positive potential higher than +1.5 kV against the grand, the formed 3G volume on the phosphor particles works as the anode of the internal DC electric circuit. Thus, the cathode and anode of the internal DC driving circuit of the coil-EEFL lamp are formed in Ar gas space without the electron flow from the external AC (or DC) driving circuit. The developed coil-EEFL lamps are operated with the moving electrons from the cathode to the anode that are formed under the electric field, F_{EE}, of the external driving circuit. The finding is an invention in the study on the FL lamps. Even though the experiments are made with the coil-EEFL lamps in the outer diameter of 3×10^{-3} m, the results are applicable to the coil-EEFL lamps in any diameters.

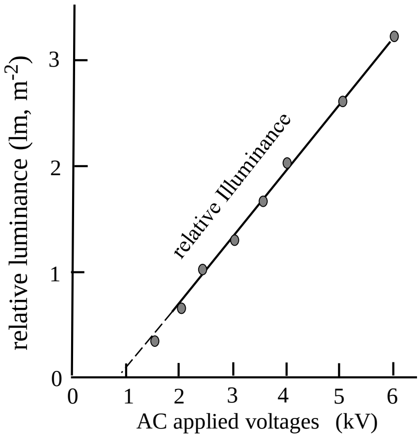


Figure10. *Relative luminance of coil-EEFL lamps as a function of AC applied voltages to EF electrodes*

Figure 10 shows the relative luminance of the coil-EEFL lamp as a function of the AC voltages on the coil-EE up to 6 KV. The luminance of the coil-EEFL lamp linearly increases with the applied voltages above AC 1.5 kV. The similar results are also obtained with the DC ± voltages to the EE of the coil-EEFL lamp.

The FL lamps use the visible lights from the phosphor screen that converts the ultraviolet (UV) lights to the white lights. The origin of the lights in the FL lamps is assigned as the excited Hg atoms (Hg*) in the Ar gas space. The Hg droplets in the small sizes are on the phosphor screen. The evaporation of the Hg atoms from the droplets are made with the heating of the droplets. Here is a problem. The heat source is the ionization of the Ar atoms in the positive column by the change of the entropy. There is a gap between the positive column and the phosphor screen. The gap is a good thermal insulator. The depth of the gap in the commercial 40W-HCFL lamps is higher than 3×10^{-3} m. The Hg droplets on the phosphor screen only heat up by the thermal radiation from the positive column. And the temperature of the heated phosphor screen is controlled by the thermal convection of the room air. If the FL lamps set in a vacuum sealed sheath glass tube, the temperature of the Hg droplets on the phosphor screen should be equal to the temperature of the positive column. Figure 11 shows the experimental results by the coil-EEFL lamps in the diameter of 3×10^{-3} m. The results are applicable to the FL lamps in different diameters.

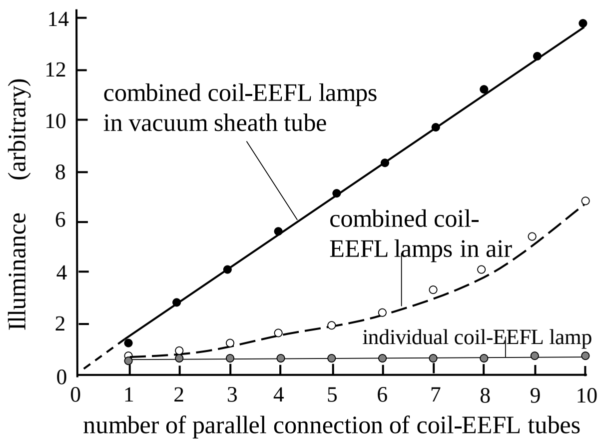


Figure11. *Luminance of individual coil-EEFL lamps, bound coil-EEFL lamps in air and bound coil-EEFL lamps in a vacuum sealed sheath tube in a few Pa.*

The individual coil-EEFL lamps in 3 x 10^{-3} m diameter emit the equal luminance as shown in the bottom line in Figure 11. As the 10 coil-EEFL lamps are parallel connection in the air, the luminance of the bound coil-EEFL lamps do not linearly increase as shown in dash line in Figure 11. As 10 bound coil-EEFL lamps by the parallel connection set in the vacuum sealed sheath tube, the luminance of the coil-EEFL lamps linearly increases with the numbers of the connected coil-EEFL lamps. The evaporated Hg atoms are optimized by the setting of the FL lamps in the vacuum sealed sheath tube. The experimental results shown in Figure 11 inform us an important massage. All FL lamps must set in the vacuum-sealed sheath tube for the optimization of the light intensity.

Figure 12 show the photopicture of commercialized compact HCFL lamp. From the described as the coil-EEFL lamps and the results in Figure 11, we like to make an advice to the producers of the commercial compact HCFL lamps. If the compact HCFL lamps convert to the coil-EEFL lamps, and if the converted coil-EEFL lamps are operated with the AC voltages above 2 kV with 30 kHz, the power consumption W_{AC} goes down to a few watt with the life longer than 10^6 hours. If the converted coil compact FL lamps are operated with the DC driving circuit with the output voltages above ± 2 kV, the power consumption will be $W_{DC} = 0$. The illuminance (lm, m^{-2}) will significantly increase with the Ar gas pressure to 9000 Pa (70 Torr). Then, the compact coil FL lamps set in the vacuum sealed sheath tube, you may have the ultimate incandescent lamps. The LED lamps cannot compete with the compact coil-EEFL lamp in the vacuum-sealed sheath tube. If you need our help, please contact us.

Figure12. *Commercial compact HCFL lamps as candidate of coil-EEFL lamp with $W_{DC} = 0$ and operation life longer than 10^6 hours*

Figure13. *Lighting of four coil-EEFL lamps under DC driving circuit with ± 2 kV. Above 2 FL tubes take from the scrap yard, and below 2 FL tubes are store*

The photograph in Figure 13 shows the direct evidence of the operation life of the commercial 40W-HCFL lamps. Four coil-EEFL lamps converted from the HCFL lamps. They are (a) life terminated HCFL lamps from the scrap yard (above two lamps), and (b) the HCFL lamps from the stores. Four converted FL lamps are operated with the DC driving circuit that the supply ± 2 kV that is giving $W_{DC} = 0$. The photopicture clearly shows that operation life of the coil-EEFL lamps is longer than 10^6 hours.

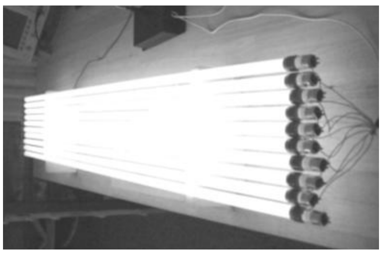


Figure14. *Photograph of lighted 10 coil-EEFL lamps in parallel connection under one driving deriving circuit with AC voltage at 3 kV with 50 Hz with total W_{AC} = 80 watt. If 10 coil-EEFL lamps in parallel connection are operated with ± DC voltages at 3 kV, $W_{DC} = 0$.*

The illumination of the large rooms and large hall can be illuminated with the coil-EEFL lamps that are parallel conection. We just convert 10 commercial 40W-HCFL lamps to the coil-EEFL lamps. The converted FL lamps are connected with the parallel connection. Then, the 10 converted coil-EEFL lamps are operated with the single DC power supply with the output of the ± 3kV. The W_{DC} of 10 coil-EEFL lamps is zero. Figure 14 shows the photopicture of the lighted 10 coil-EEFL lamps. By the optimization of the coil-EEFL lamps, the invented coil-EEFL lamps may greatly contribute to the reduction of the electric power consumption on the world.

5. Conclusions

We have found that the FL lamps are operated with the coexistence of the disparity of the external driving circuit and internal DC driving circuit. The lights of the FL lamps are generated by the moving electrons in the internal DC driving circuit. The cathode and the anode in the established HCFL lamps are formed with the heated volume of the corona lights (e.g., ± 4G electron sources) in the Ar gas space. The demerit of the ± 4G electron sources are the short operation life at around 10^4 hours.

Then, we have studied the Townsend's results that form the volume of the glow lights (i.e., ± 3G electron sources) on the needle electrodes in the Ar gas space. After the studies of the Townsend's results, we have found that the ±3G electron sources are formed on the thin frit glass layer that covers the needle metal electrodes. The results lead us to the development of the prototype of the coil-EEFL lamps.

The coil-EEFL lamps respectively form the cathode and anode of the internal DC electric circuit in the Ar gas space under the help of the electric field of the external metal electrodes on the glass wall, eliminating the metal electrodes in the FL lamp, promising the simple production of the FL lamps. There is no electron flow between the disparities of the internal and external electric circuits. Fundamentally, the lights are solely generated with the moving electrons between cathode and anode of the internal DC electric circuit formed in the Ar gas space. The coil-EEFL lamps can be operated with either AC driving circuit with the applied voltage above 1.5 kV with 20 kHz. In this case, the AC driving circuit picks up the induced voltage of C_{phos} that are generated by the periodical deformation of the phosphor particles under the EE on the outer glass tube. The value of the C_{phos} is less than 0.01 of C_{Ar}. If the coil-EEFL lamps are operated with the external DC driving circuit with the voltages higher than ± 1.5 kV, the coil-EEFL lamps brilliantly light up with the W_{DC} is zero. The brightness of the coil-EEFL lamps linearly increases with the ± applied voltages. The brightness of the given coil-EEFL lamps also increase with the Ar gas pressures up to 10^3 Pa (= 75 Torr).

We have found that the electrons from the cathode move on in the superconductive vacuum between Ar atoms, giving rise to the astronomical quantum efficiency, $\eta_q = 10^{13}$ visible photons $(m^3, s)^{-1}$ with no power consumption of the external DC driving circuit; $W_{DC} = 0$. The coil-EEFL lamps are also operated with the external AC driving circuit. In this case, the EE electrodes pick up the induced electric voltages of the capacitor C_{phos} that are periodically polarized phosphor particles under the electric field from the EE on the outer glass wall. The C_{phos} does not relate with the Ar gas pressures. If the coil-EEFL lamps in the parallel connection set in the vacuum sealed sheath tube, the brightness of the coil-EEFL lamps linearly increase in the numbers of the coil-EEFL lamps. There is no consumption of the Ar atoms and Hg atoms in the operation of the coil-EEFL lamp, promising the operation life longer than 10^6 hours.

Here arises a difficulty for the production of the coil-EEFL lamps. For the production of the advanced coil-EEFL lamps, we cannot use the existing production facilities for the FL lamps, and commercial phosphor powders. The main reasons are: (i) the inside of the established FL production facilities are heavily contaminated with the pumping oils. (ii) The polluted materials in the air of the working room. (iii) The FL glass tubes are a good thermal insulator, so that the existing degassing furnaces for the FL production have the inadequate temperature profiles. The heating furnaces should be uniformly heating of the entire FL glass tubes. And (iv) the trajectory of the moving electrons in the Ar gas space are severely influenced with the improper distribution of the electric charges on the phosphor screens. Those are not for the advanced research subjects. Those are the application research subject and it is not the engineering subjects.

In this report, we have clarified the fundamental mechanisms of the coil-EEFL lamps. Finally, we may suggest some idea that the commercial compact HCFL lamps, using around 1×10^{-2} m diameter, can smoothly modify to the compact coil-EEFL lamps. The modified compact coil-EEFL lamps are operated with the AC driving circuit that have higher than 2 kV, 30 kHz, you may instantly have the incandescent lamp that has the high quality over the LED lamp. If the compact coil-EEFL lamp sets in the vacuum sheath tube, the modified compact coil-EEFL lamps will be the incandescent lamp without the competitor.

The developed coil-EEFL lamps may also change the operation condition of the green houses in the agricultures in the desert areas and cold areas with the combination of the solar panel and batteries. We have believed that the developed coil-EEFL lamps surely contribute to the green energy project COP (Conference of the Particles) on the world after the clarification of the applied research laboratories by someone else.

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