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An Invention of Coil-EEFL Lamps Operated with WDC = 0 for a Great Contribution to Green Energy Project of UN

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ABSTRACT

The reduction of the electric power consumption of the illumination lamps is an urgent subject for the green Energy project by UN. The invented coil-EEFL lamps are miraculously operated with zero electric power Consumption of the DC driving circuit, with the high luminance (> 300 lm, m-2). The coil-EEFL lamps May operate with the power supply from the combination of the solar cells and batteries, without the Distribution lines from electric power generators on the world. The invented coil-EEFL lamps may respond On the requirement of the Paris Agreement and COP 23 of the UN project that is the reduction of the air Pollution, more than 40 %, on the Earth from the electric power generators on the world.

Keywords: *Green Energy, FL Lamps, Power Consumption, Superconductive Vacuum in FL lamps, Phosphor Screen.*

INTRODUCTION

The reduction of the polluted air on the Earth is an urgent subject for the reduction of the worming up the air atmosphere by the polluted gases, mainly CO2 and small particles in micron sizes. The Paris Agreement of UN on 2016 gives us an urgent target that should reduce the pollution level in air more than 40 % from the present level. However, no one gives us a suggestion how reduces the large amount of the polluted gases in the air on the Earth as soon as possible, without a sacrifice of our daily activity. We suppose automobiles and light sources on the world inevitably release the large amount of the polluted gases (e.g., CO2) and tiny carbon particles (e.g., PM 2.5) in the air atmosphere on the Earth. The largest sources of the air pollution attribute to (i) automobiles and (ii) light sources in the dark. The automobiles are shifting to the electric cars (e.g., EV). However, the driving of the EVs consumes electricity generated at the electric power generators on the world. The shifting of the automobile to the EV does not reduce the total pollution level 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 coil-EEFL lamps as the incandescent lamp. The word of the candescent comes from the ancient Greek that means the lights generated by burning of organic compounds with oxygen in air. Incandescent lamps use moving electrons in metals, solids, and gases for the generation of the light. Incandescent lamps consume the electricity for the generation of the lights. According to the report of COP (Conference of particles, 2015) of the UN, the electric power consumption of the incandescent lamps on the world is around 31 % of the totally generated electric powers on the world. If one considers the electric power consumption by the distribution network on the grand, the operation of the commercial incandescent lamps will reduce the consumption of the electricity more than 40 %.

The typical incandescent lamps in our life are (a) tungsten (W) filament light bulbs, (b) LED lamps and (c) fluorescent (FL) lamps. All of them are operated with the AC electric driving circuits that consume the active AC electric power, Wact. If we can reduce the Wact of the incandescent lamps to Wact ≈ 0, the results will be a real reduction of the air pollution from the electric power generators on the world. We have studied the incandescent lamps from the basics of the lighting mechanisms [1, 2, 3] for the selection of a candidate. Fortunately we have invented the coil=EEFL lamps that consume the electricity, WDC = 0 with the high illuminance (> 300 lm. m-3).

A BRIEF SUMMARY OF ESTABLISHED INCANDESCENT LAMPS

After finding of the atoms and electrons, the lights in the incandescent lamps become the popular lighting sources. The incandescent lamps generate the lights (visible photons) by the moving electrons in materials, instead of the heat by the chemical reaction. We must know which incandescent lamp consumes less Wact in the operation. The materials are made with the atoms that float in vacuum with the given separation distance. The atoms in the materials are actually bounded with the electrons in the uppermost electric shells (s, p, d, and f shells) of the atoms. The bonding conditions of the electrons of the atoms make the different materials.

W-filament Lamps

The metals are formed with the metallic bound with the electrons in either one of s, p, d, and f shells in which the electron shell has vacancy of electrons. Accordingly, the electrons in the metals move on in the inside of the bonding shell of the metal atoms. No vacuum space between metal atoms at lattice sites involves in the moving electrons in metal. The moving electrons in the metals inevitably generate the Joule Heat that is given by I2R. Where I is electric current, and R is electric resistance. The R is determined by the thermal perturbation of the moving electrons from the thermally vibrating atoms at lattice sites. The typical metal lamp is made by tungsten (W) filament in the vacuum-sealed glass bulb. The lights are generated from the heated W-filament to the temperatures higher than 900oC. The lighting source of the W-filament lamp is the heated metal that is similar with the lights from the Sun. With this reason, the performance of the W-filament lamps is evaluated with the heated temperatures of the metal filaments by the Joule Heat. We cannot calculate the quantum efficiency (ηq) that is given by the number of the generated visible photons per one moving electron in the lamp. One may allow us to have a conclusion that the W-filament lamps do not contribute to the Green Energy Project.

LED Lamps

The lighting mechanisms of the LED lamps quite differ from the metal-filament lamps. The difference comes from the bonding of the atoms. The LED lamps use the solids that are the compounds formed by the atoms. The compounds, like as III-V compounds, are made by the covalent bounding. The covalent bonding does not have the vacancy in the bounding electric shell of the atoms. The electron in the covalent bounding cannot move on in the bonding electron shell. The pure III-V compounds are the electric insulators.

The story is changed with the impure compounds. As the compound contains a very small amount of the impurity (like as IV-atoms), each impurity atom in the III-V compound has one extra electron in the bonding shell of the impurity atom. The diameter of the electron is 5.6 x 10-15 m. The extra electrons in the impure atoms stay in the narrow vacuum space between atoms at the lattice sites that have the separation distance at around 10-10 m. As the impure III-V compound has the metal electrodes at the both ends, the extra electrons in the compound may move on in the narrow vacuum space (10-10 m) between atoms at lattice sites. The vacuum space in 10-10 m is a wide space for the electron in the diameter of 10-15 m. This is n-type III-V semiconductor. Thus the impure compound becomes as the electrically conductive compound. The impure compound is called as n-type compound. As the III-V compounds contain the small amount of other impurity (II-atoms), the bonding shell of the impurity atoms in the III-V compound has an empty of the electron in the upper shell in the bounding atoms. But the empty electric shell is local area. The electrons cannot move the III-V compound. The impurity may pick up the electron from the vacuum space between atoms at lattice sites. The compounds that have the empty of the bounding electrons at the local area are called as p-type semiconductor. The n-type and p-type semiconductors are the electric conductors, but the moving electrons in the both semiconductors do not generate the light.

The LED lamps utilize the luminescence centers in the narrow junction layer between n-type and p-type semiconductors. The luminescence centers in the junction act as the recombination centers of the captured electrons and holes. The recombinations of the electrons and holes at the recombination centers generate the visible photons. The colors of the generated lights change with the kinds of the recombination centers. Thus the LED lamps generate the visible photons from the luminescence centers. The generation mechanisms of the lights from the LED lamps totally differ from that of the W-filament lamps.

Here arises a problem in the operation of the LED lamps. The moving electrons in the narrow vacuum space between atoms in the LED lamps receive the thermal perturbation from the atoms at the lattice sites. Thermal perturbation gives the electric resistance (R) to the moving electrons. Consequently, the moving electrons in the LED lamps unavoidably have R, generating the Joule Heat (I2R). Here arises a problem in the operation of the LED lamps. The stability of the luminescence centers (impurities) in the junction has a threshold temperature at 70°C [4]. We may calculate the numbers of the emitted photons from the LED lamps per second. The numbers of the emitted photons are less than the numbers of the injected electrons into the LED lamp (ηq < 1.0). The reported ηq is around 0.5 [4]. The LED lamp generates one photon by injection of two pairs of the electrons and holes. Furthermore, the threshold temperature of the luminescence centers determines the maximum number of the moving electrons.

The required photon numbers for the illuminated room is 1025 photons (s, m2)-1. The calculated numbers of the injected electrons into the LED lamp on the 1 m2 dais is 3.2 x 106 A (= 1.6 x 10-19 Coulomb x 1 x 1025 x 2). The applied voltage to the LED lamps is 2.8 V. The calculated Wact of the LED lamps is 9 x 106 watt (= 2.8 V x 3.2 x 106 A).

The study on the LED lamps leads us to a conclusion that the LED lamps are definitely not the energy saving lamps to the Green Energy Project of the UN.

FL Lamps

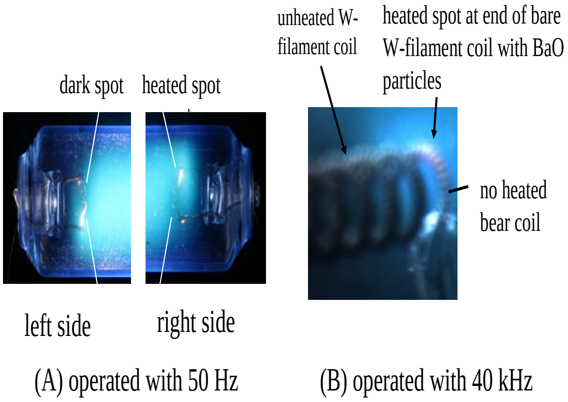
The commercial HCFL lamps have the long developing history for nearly 90 years since the original patent on 1928 [5]. The studies for 90 years have summarized in many Hand Books and published papers. The typical summaries are the references in [6, 7, 8, 9]. After 1980, there is no report on the new technology in the HCFL lamps. We have a very hard time for the communications with the scientists and engineers who have learned the technologies of the FL lamps in the established text books. If you just lean the text books, your brain is similar with a computer. You never involve in the development of the science in your life. We must review the established technologies of the FL lamps with the science.

Although the FL lamps have not studied with the modern science, the developed hotcathode FL (HCFL) lamps light up with the excellent brightness over other incandescent lamps. The brightness of the FL lamps should be evaluated with the illuminance (lm, m-2) (= lux) or luminance (cd, m-2). The FL lamp never evaluate with the luminous efficiency (lm, W) that is for the only study on the colorimetry.

The illuminance (lm, m-2) of the most popular commercial 40W-HCFL lamps can be determined by the use of the Ulbricht Sphere. It should note that the inside of the Ulbricht Sphere in the many laboratories on the world has modified with the wrong ways. You must remove all modified goods in the Ulbricht Sphere. Then, you may measure the real illuminance (lm, m-2) of the commercial HCFL lamp. The determined illuminance (lm, m-2) of the commercial 40W-HCFL lamps is around 300 (lm, m-2) that is equivalent with the daytime scenery under the slightly overcastting sky [10]. The commercial 40W-HCFL lamp has a capability for the illumination of the furniture in 1m2 room with the daytime scenery. The commercial 40W-HCFL lamps already have the adequate illuminance over other incandescent lamps. However, we cannot theoretically calculate the advanced illuminance of the HCFL lamps.

The largest mistake in the evaluation of the HCFL lamps is the electric power consumption. The commercial HCFL lamps are operated with the alternating current (AC) in the electric driving circuit. The AC electric power consumption of the AC driving circuit should be given by the total AC power consumption that is the Wact of the AC driving circuit. We have found that the Wact of the commercial 40W-HCFL lamps is higher than 80 watt [1, 2, 3], depending on the producers. However, the electric power consumption of the commercial 40W-HCFL lamps is given by the Wact = 40 watt [6, 7, 8]. This is a fundamental mistake in the study on the AC power consumption of the lighted FL lamps. The developers of the HCFL lamps give the Wact = 40 watt for the claiming of the energy saving light source. We wonder no one makes the correction of the erroneous Wact = 40 watt for 90 years. The determined Wact = 40 watt at the electrodes does not relate with the generation energy of the lights from the FL lamps.

The mistake comes from the thermoelectron emission from the heated BaO particles into the Ar gas space of the HCFL lamps. The drilled study of the thermoelectron emission from the heated BaO layers on the cathode metal electrode has studied in the development of the CRT and radio vacuum tubes. The heated BaO particles steadily emit the thermoelectrons in the vacuum pressures less than 10-3 Pa (< 10-5 Torr). The thermoelectron emission instantly damages under the operation in the vacuum pressures higher than 10-1 Pa (> 10-3 Torr). The Ar gas pressures of the FL lamps of the 40W-HCFL lamps are around 930 Pa (7 Torr). Furthermore, the commercial FL lamps always contain the residual gases higher than 10 Pa (> 0.1 Torr). The residual gases chemically react with the BaO particles. It can say that the heated BaO particles on the W-filament coils in the HCFL lamps never emit the thermoelectrons into the Ar gas space.



(A) operated with 50 Hz (B) operated with 40 kHz

Figure1. *Photographs of working W-filament coils of HCFL lamp with 50Hz (left) and with 40 kHz (right).*

Figure 1 shows the photographs of the BaO particles on and in the W-filament coils with the operation of 50 Hz (A) and 40 kHz (B). You may see that the only bear W-filament spot at the one side coil is selectively heated in the working W-filament coils. The large areas of the W-filament coils do not heat up in the operating HCFL lamps. The temperature of the heated bear spot of the W-filament coils remarkably changes with the operation frequencies of the HCFL lamps. The temperature is low with the operation by 40 kHz.

Figure 2 shows the areas of (a) the densely packed BaO particles and (b) bare W-filament coil at the end in the W-filament coil. (A) is unheated W-filament coil and (B) is the operating W-filament coil under the AC frequency at 40 kHz. Under the operation of the FL lamps, the heated area of the W-filament coil selectively limits in the tiny area of the bare W-filament with the BaO particles. The photograph in Figure 2 (B) undoubtedly shows the heated tiny spot at one end of the working W-filament coils. The large unheated areas with the packed BaO particles and the bare coil at the end of the W-filament coil do not heat up in the lighted FL lamp. From the results in Figures 1 and 2, the HCFL lamps do not operated with the thermoelectrons from the heated BaO particles on the W-filament coils. The operation of the thermoelectrons in the HCFL lamps is illusion in your brain.

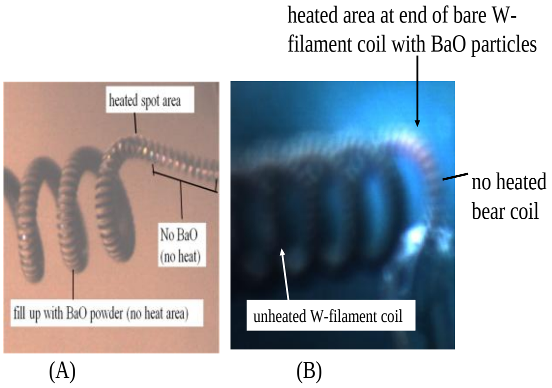


Figure2. *Photographs of unheated Ba O on W-filament coil (A) and working W-filament coil under 40 kHz.*

As the conclusion of Chapter 2, it may say that the commercial HCFL lamps have an advantage with the illuminance (300 lm, m-2) over other incandescent lamps. However, many technologies involved in the commercial FL lamps base on the hypotheses without the clarification by the advanced science. A large room remains for the study on the FL lamp. By the clarification of the hypotheses, the commercial FL lamps will become an unrivaled lamp. According to the conclusion, we have studied the details of the involved technologies of the FL lamps with the science. The details are below:

REVISED ELECTRON SOURCE OF FL LAMPS

The electron source (cathode) and electron receiver (anode) are essential necessity for the operation of the FL lamps. We must find out the cathode and anode in the lighted FL lamps. The difficulty of the finding of the cathode and anode in the FL lamps comes from that the Ar gas space in the unlighted FL lamps is the electric insulator. The metal electrodes at the both sides of the FL lamps cannot inject the electrons into the insulating Ar gas space. The established concepts by the study on solid-state physics cannot apply to the generation of the lights of the Ar gas in the FL lamps.

Actual Electron Sources of Commercial FL Lamps

Figure 3 shows photograph of the lighted FL lamp without the phosphor screen. The FL lamp is operated with the AC driving circuit at 30 kHz. If the heated BaO particles (cathode) emit the thermoelectrons, the electrons straightly move from the BaO particles on the W-filament coil to the W-filament electrode (anode) for each half cycle. From the observation of the photograph in Figure 3, we cannot observe the light by the direct emission from the W-filament coils. The observation of the photograph in Figure 3 informs us that the FL lamp never lights up with the thermoelectron emission from the heated BaO particles on the W-filament coils.

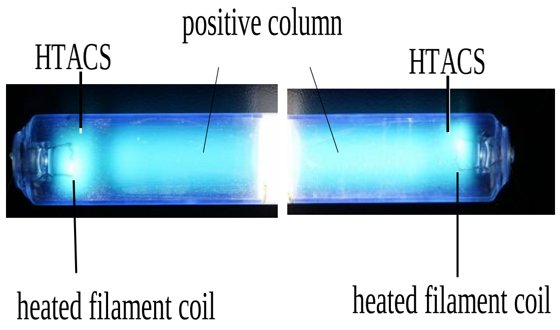


Figure3. *Photograph of lighted FL lamp without phosphor screen.*

The electrons in the lighting FL lamps must move in the vacuum between Ar atoms. But the vacuum between Ar atoms in the unlighted FL lamps fills up with the negative electric field from the electrons in the upper electron shell of Ar atoms. For the confirmation of the negative electric field between Ar atoms, you may measure the absorption spectrum of the unlighted Ar gas by the optical spectrometer in the high resolution. The obtained absorption spectrum of Ar atoms consists with the sharp lines, not the bands. The sharp absorption lines indicate that individual Ar atoms in the Ar gas space float in the vacuum without the interaction with the neighbor Ar atoms [1, 2, 3]. Furthermore, the intrinsic absorption lines in the spectrum split into many sub-lines by the Stark Effect. The Stark Effect is the direct evidence that the vacuum space between floating Ar atoms in the unlighted HCFL lamps fills up with the negative electric field from the orbital electrons of the neighbor Ar atoms. The electrons from the heated BaO particles on the W-filament coil cannot step in the negative electric field of the vacuum.

The photograph in Figure 3 indicates the followings. The W-filament coils at the both sides of the lighted FL lamp are covered with the large volume of the lighted Ar atoms. The lighted volume is assigned as the volume of the corona lights. The lighted volumes of the corona on the W-filament coils at the both ends are assigned as the real electron source (cathode) and electron correction source (anode).

The study on the electrodes in the lighted FL lamps encounters a difficulty with the operation with 50 Hz. The W-filament coils require the heat circuit at the starting time. If the FL lamps are operated with the frequency higher than 20 kHz, the FL lamps can operate without the heat circuit of the W-filament coils. With this reason, we have studied the details of the operation of the HCFL lamps under 30 kHz.

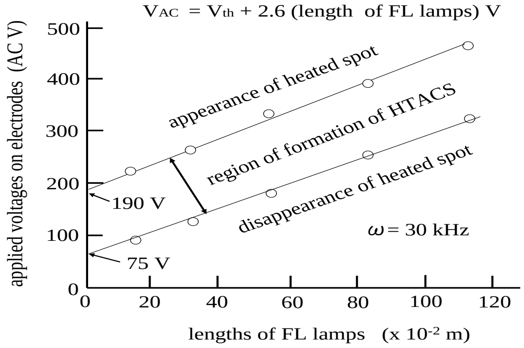


Figure4. *Experimental results of appearance and disappearance voltages of HTACS of FL lamps with different lengths under application of 30 KHz*

The operation of the commercial HCFL lamps requires two applied voltages, appearance and disappearance voltages, for the lights from the FL lamps, as shown in Figure 4. The appearance voltage is for the start of the lighting of the HCFL lamps. After lighting, the high applied voltage reduces to the voltages between appearance and disappearance voltage. The disappearance voltage is the light-off voltage of the lighted HCFL lamps. The appearance and disappearance voltages changes with the lengths of the HCFL lamps. The change comes from the constant strength of the electric field on the W-filament coils. After the formation of the volume of the corona, the ionization of the Ar atoms generates the heat in the volume of the corona light by the change in the entropy. The heated Ar atoms in the volume of the corona reduce the generation voltage of the corona to the above disappearance voltage. The volume of the corona at around W-filament coils attribute to the high temperature Ar corona space (HTACS) [11, 12]. The HTACS is the real electron sources (cathode and anode) in the lighted HCFL lamps.

The formation of the HTACS on the W-filament coil at the room temperature that corresponds to the appearance voltage requires the very high electric field from the W-filament coil. The generation voltage of the HTACS can slightly reduce by the application of the BaO particles on and in the W-filament coils. The required voltage for the generation of the HTACS is significantly changed with the quality of the polarized BaO particles, rather than the amount of the BaO particles. The favorable BaO particles are the well crystallized polycrystalline particles. The well crystallized BaO particles have many sharp edges and points less than 10-6 m that generate the high electric field. Consequently, the well crystallized tiny BaO particles on the W-filament coil give the low ionization potential of Ar atoms. It is not the amount of the BaO particles on the W-filament coil. The formation voltage of the HTACS depends on the quality of the BaO particles.

The electric field from the W-filament coils ionizes the Ar atoms (Ar1+ and free electrons), excited Ar atoms (Ar*), and Ar atoms. Only Ar* emits the sky-blue lights that are visible by the naked eyes. Others are invisible by the naked eyes. The major factor of the formation of the HTACS is the formation of the invisible Ar1+. The formation of the Ar1+ generates the heat in the volume of the HTACS by the change of the entropy. However, we use the sky-blue light as the monitor of the formation of the HTACS at around the W-filament coils. The W-filament coils at the both ends also form the vector electric field (Fvect) over the Ar gas space in the FL lamps. In the past study on the HCFL lamps, the formation mechanisms of the HTACS overlooked with the monitor of the visible glow lights. The role of the HTACS in the lighted HCFL lamps is below:

Fortunately, the negative electric field in the volume of the HTACS is perfectly neutralized by the presence of Ar1+. The volume of the HTACS is under the Fvect. The electrons in the HTACS smoothly move on in the neutralized vacuum space between Ar atoms in the HTACS. The electrons in the volume of the HTACS step out from the volume of the HTACS to the nearby Ar gas space. The stepped out electrons instantly neutralize the negative electric field in the nearby Ar gas space. The negative electric field in the entire Ar gas space of the FL lamp is neutralized by the moving speed of the electrons (108 m per minute) from the cathode to the anode of the HTACS.

The operation conditions of the practical HTACS have empirically found. If the FL lamps are operated with the appearance DC voltage, the FL lamps continuously light up under the DC operation with WDC = 0. But the operation life of the lighted FL lamps is shorter than 100 hours. The short operation life of the FL lamps is caused by the continuous evaporation of the W-atoms from the heated bear spot in the W-filament coil.

For the long operation life, the HCFL lamps are operated with the AC voltage of 50 Hz. The HTACS on the W-filament is formed by the half cycle of the applied AC voltage. The subsequent half cycle, the cathode and anode inversely change the positions. The bear spot in the W-filament coil is irradiated with the streamer electrons beam from the HTACS as the W-filament coil has the positive potential. The heated bear spot heats up the Ar gases in the HTACS with a high temperature under the appearance voltage in Figure 4, resulting in the short operation life. The operation voltage of the heated HTACS by the heated bear spot can be reduced to the low AC voltage that gives the disappearance voltage in Figure 4. However, temperature of the heated bear spot rapidly cools down to the below the disappearance voltage in Figure 4. The heated bear spot in the W-filament coil must hold the temperature above the disappearance temperature for the half AC cycle. If the temperature of the bear spots in the W-filament coil decreases to a low temperature at the disappearance voltage in Figure 4, the HCFL lamp does not continuously light up for the next half cycle. Consequently, the HCFL lamps do not operated with the applied voltage below the appearance voltage in Figure 4.

Under the operation of the appearance voltages, the Ar atoms in the HTACS must be heated to the required temperature for the continuous ionization from the electric field from the W-filament coil. The cooling problem for the unheated half cycle has solved by the aid of the heated BaO particles at around the heated bear spot. As shown in Figures 1 and 2, the small bear spot at one side of the W-filament coil has the small amount of the BaO particles that have the large heat capacitance. The heated BaO particles hold the given temperature for the holding of the HTACS as the W-filament coil has the negative potential. The HTACS are continuously heated by the temperature of the combinations of the bear spot and small amount of the BaO particles. Then, the FL lamps with the HTACS can be operated with the slightly above disappearance voltages with 50 Hz.

Formation of HTACS with Different Ways

If you make the volume of the HTACS in the Ar gas space at the room temperature with other ways, you may have a single operation voltage for the given HCFL lamps that have the W-filament coils with the BaO particles. The volume of the HTACS is physically the same with the volume of the glow light. The glow light can make at room temperature. The difference is the size of the glow light. The diameter of the glow light is around 3 x 10-3 m. The volume of the glow light also contains Ar1+, free electrons, Ar*, and Ar atoms. We may generate the volume of the glow light at any place of the FL lamps.

The test FL lamp should have the electrodes at the both ends that hold the AC voltage above the disappearance voltage in Figure 4. The most convenient equipment for the generation of the glow light is the Tesla coil. As the AC voltage at 200 V applies to the unlighted FL lamp in the 0.6 m length, the lamp does not light up. We slowly approach the Tesla coil to the unlighted FL lamp. As the weak spark from the Tesla coil in air reaches on the outer glass wall of the unlighted FL lamp, the FL lamp instantly lights up with the normal illuminance. Naturally, the FL lamps continuously light up after the removal of the Teslar coils. The FL lamp light up with any position of the Tesla coil on the FL lamps. Figure 5 illustrates the experimental configuration.

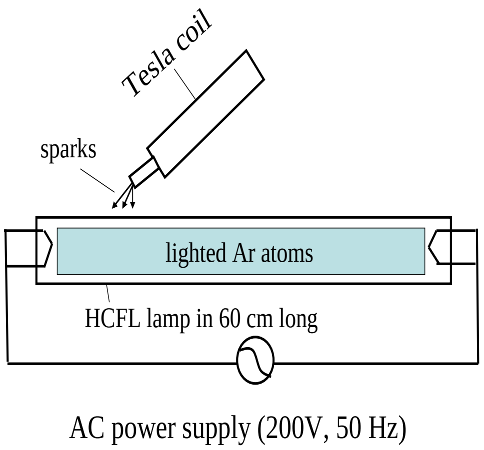


Figure5. *Illustration of experimental arrangement of Teslar coil on FL lamp in 60 cm long under 200 V with 50 Hz*

There is another way for lighting of the HCFL lamps with the normal illuminance. The HCFL lamp must have the phosphor screen. The electrodes of the unlighted HCFL lamp in 0.6 m length have the AC 200 V with 30 kHz. Then the electric lead wire puts on the outer glass wall at near the electrodes of the FL lamp. As the electric lead wire has the AC (or DC) voltage higher than 2 kV, the volume of the glow light instantly generates on the polarized phosphor screen under the electric field from the lead wire. Then the HCFL lamp instantly lights up with the normal illuminance.

Discovery of Coexistence of Disparity of External and Internal Electric Circuits in Operation of FL Lamps

From the experiments in Figure 5, it can say that the FL lamps light up without injection of the electrons from the metal electrodes at the both ends of the FL lamp. The lights of the HCFL lamps start by the formation of the volume of the HTACS that are corona or glow lights under the electric field from the electrodes at outside of the HCFL lamps. The HTACS are not generated by the electron flow from the metal electrodes. The lights of the FL lamps are generated by the moving electrons between volumes of the HTACS formed at both ends of the HCFL lamps. The formed HTACS at the both ends of the FL lamps actually act as the cathode and anode of the internal DC electric circuit. The formation of the internal DC electric circuit is a new concept in the study on the lighted FL lamps.

The metal electrodes at the both ends never inject the electrons into the Ar gas space. The metal electrodes at the both ends of the HCFL lamps pick up the induced AC current from the capacitor CAr formed in the lighted FL lamps. The electrodes do not pick up the electron flow from the Ar gas. Consequently, the HCFL lamps are actually operated with the coexistence of the disparity of the external AC driving circuit and internal DC electric circuit [13], as illustrated in Figure 6.

The lights from the HCFL lamps are generated by the moving electrons in the internal DC electric circuit. The metal electrodes at the both sides of the FL lamps never activated by the moving electrons in the Ar gas in the lighted FL lamps. The external AC driving circuit is activated with the induced AC current, so that the power consumption of the external AC driving circuit, Wact, does not involve in the generation of the lights of the HCFL lamps. In the past for 90 years, the Wact relates with the generation energy of the light of the FL lamps [6, 7, 8].

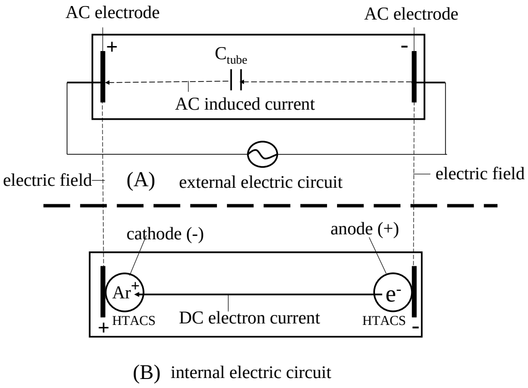


Figure6.*Illustration of coexistence of external AC driving circuit (A) and internal DC electric circuit (B) in operation of lighted FL lamp*

The formation of the capacitor CAr is a new concept in the study of the FL lamps. The formation of the capacitor (C) is well studied with the solids. The solid capacitors are made with the synchronous deformation of the crystal structure under the AC electric field between the electrodes. The solid capacitor breaks down with the arc current in the inside of the solid. The electrodes on the solid capacitor never inject the electrons into the solid capacitor. The solid capacitor is only active as the electrodes pick up the induced electric current.

The similar concept may apply to the formation of the CAr in the lighted FL lamps. The electrodes of the FL lamps are only active so far as the electrodes of the AC external electric circuit picks up the AC induced current. The external electric circuit breaks down as the electrodes pick up the arc current from the Ar gas space in the lighted FL lamps.

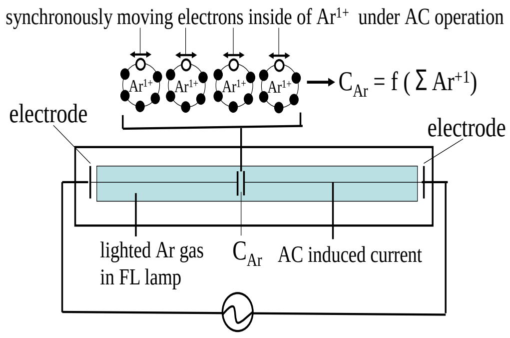


Figure7.*Schematic illustration of formation of C_{Ar} and AC induced current at electrodes under AC driving circuit*

A question arises to the formation mechanisms of the CAr in the lighted FL lamps. The positions of the Ar atoms in the Ar gas do not change with the electric field from the electrodes. As the floating Ar atoms in the vacuum are ionized, each Ar1+ has one empty electron in the upper most orbital shell. Each floating Ar1+ has the moving space of one electron in the upper shell. The electron in each Ar1+ may synchronously move on in the orbital shell of the Ar1+ under the AC electric field from the electrodes. The metal electrodes at the both ends of the lighted FL lamps pick up the synchronous displacement of the electrons. Therefore, the CAr is given by the function of ΣAr1+. Figure 7 schematically illustrates the mechanisms of the formation of the CAr in the Ar gas in the lighted FL lamp. The calculated capacitance of the commercial 40W-HCFL lamps (Ar gas pressure at 930 Pa ≈ 7 Torr) is around 80 μF. The capacitance of the CAr changes with the diameter of the positive column, not the volume of the FL lamps. The moving electrons never step out from the positive column. Therefore, the generation of Ar1+ limits in the positive column in the lighted FL lamps.

The determination of the capacitance of the CAr leads us to important information in the study on the lighted FL lamps. So far as the HCFL lamp is operated under the DC voltage, the WDC is zero in the lighted HCFL lamp. However, the HCFL lamp under the DC operation has an extremely short operation life (< 100 hours). The short operation life is caused by the continuous evaporation of W-atoms from the bear spot of the W-filament coil. So far as the FL lamps that do not use the HTACS as the electron sources, the FL lamps may have the long operation life. We have found a new electron source that is the volume of the glow light in the Ar gas.

New Electrodes Formed on Phosphor Screen in Fl Lamps

The glow light is the same with the corona light, except for the size of the volumes. The size of the volume of the glow light is around 3 x 10-3 m that is one tenth of the HTACS. The size of the glow light does not change with the applied voltages and Ar gas pressures. Then, we have made the volumes of the glow light on the phosphor screen with the electrodes on the outer glass wall of the FL lamps. The setting electrodes respectively have the DC positive and negative potentials. The generated glow lights at the different positions on the phosphor screen in the FL lamps respectively may act as the cathode and anode of the internal DC electric circuit. With the expectation, we have made the experimental FL lamps.

The similar concept may apply to the formation of the CAr in the lighted FL lamps. The electrodes of the FL lamps are only active so far as the electrodes of the AC external electric circuit picks up the AC induced current. The external electric circuit breaks down as the electrodes pick up the arc current from the Ar gas space in the lighted FL lamps.

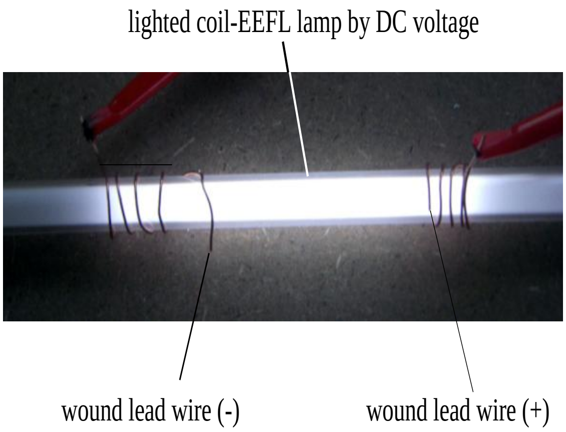


Figure8. *Photograph of lighted coil-EEFL lamps under DC driving circuit*

Figure 8 shows the photograph of the prototype of the lighted FL lamp with the lead wires on the outer wall of the FL lamp. We have named the lighted FL lamp as the external electrode FL lamp; simplified as coil-EEFL lamp. There is the threshold DC voltage for the operation that is higher than 1.0 kV. The coil-EEFL lamp in Figure 8 is operated with the DC voltage at 4 kV. The coil-EEFL lamp in Figure 8 uses the commercial CCFL lamps in the outer diameter 0.03m. The coil-EEFL lamp brilliantly light up with the zero power consumption WDC = 0 of the external DC driving circuit. The illuminance of the coil-EEFL lamp (400 lm, m-2), that is the higher than the original CCFL lamp (300 lm, m-2). Hence, we have invented the coil-EEFL lamp that consume the electric power WDC = 0 with the high illuminance (400 lm. m2).

MOVING ELECTRONS IN SUPERCONDUCTIVE VACUUM BETWEEN AR ATOMS IN LIGHTED FL LAMPS

Now we know the electrons only move from the cathode to anode of the internal DC driving circuit in the lighted FL lamp. The moving electrons in the external driving circuit do not involve in the lighting of the FL lamps. The Ar atoms in the FL lamps float in the vacuum with the large separation distance of 10-6 m. In the solids, the electrons move on in the very narrow vacuum space (10-9 m) between atoms at the lattice sites. The moving conditions of the electrons in the lighted FL lamps quite differ from the moving electrons in the solids and metals. We will find the superiority of the moving electrons in the FL lamps.

We like know about the amount of the electric current in the internal DC electric circuit in the lighted FL lamps. However, we cannot set the electric current meter in the inside of the lighted FL lamp. We must have the experimental device for the study on the amount of the moving electrons between the cathode and anode of the internal DC electric circuit. We have a handmade device shown in Figure 9 for the study on the electric current from the volume of the glow light (cathode) to the plate anode in the internal electric circuit. The sharp needle electrode sets in the Ar gas space at 930 Pa (= 7 Torr). In the lighted experimental device, the needle electrode is covered with the volume of the glow light as the needle electrode has the negative potential higher than 1.0 kV. We set the small and thin metal plate electrode as the anode in the device for the collection of all arrived electrons. The amount of the DC currents is respectively determined by the DC current meters as illustrated in Figure 9.

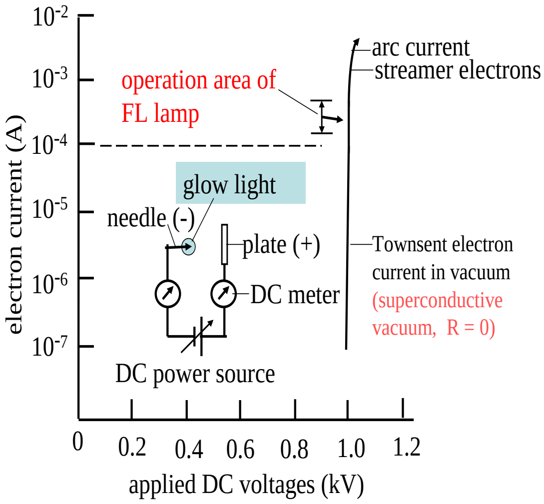


Figure9. *DC electric current between volume of glow light and plate electrode in Ar gas at 930 Pa (7 Torr)*

As the voltages on the needle electrodes are gradually increased from the DC 100 volt, the vacuum-sealed glass tube does not have the glow lights until the applied voltages to 0.98 kV. Consequently, the DC current meters do not show the electric current by the electrons. Before the formation of the light, the vacuum between Ar atoms fills up with the negative field, The Ar gas space is the electric insulator. By the application of the DC 1.0 kV, the needle electrode is suddenly covered with the volume of the glow lights. Accordingly, the Ar gas in the vacuum-seal glass tube lights up with the sky blue lights between the needle cathode and plate metal anode. The electrons surely move from the cathode to the anode. The DC current meters at cathode and anode indicate the same DC current. Then, we have observed the curious results with the application of the DC voltages above 1 kV.

As the applied voltages between the needle cathode and plate anode slowly increase to 8 kV from 1 kV, the electrodes hold the constant DC voltage at 1.0 kV. The DC current meters vertically increase with the applied voltages. The size of the volume of the glow light on the needle electrodes does not change with the applied DC voltages. We obtain the same size of the glow lights on the needle cathode. The vertical increase in the DC electric current in Figure 9 gives us the distinguished vacuum conditions of the Ar gas space of the lighted FL lamp. The electrons move on in the vacuum between Ar atoms in the lighted FL lamps without the electric resistance R, resulting in RI = 0. The measurement results in Figure 9 show the superconductive vacuum for the moving electrons in the Ar gas space. We have the superconductive vacuum at above the room temperature. This is the distinguished advantage with the Ar gas. The moving electrons in the internal DC electric circuit of the lighted FL lamps do not have the electric resistance. This is a significant advantage of the FL lamps over the solid lamps. The electrons in the solid lamps never move on in the superconductive vacuum.

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 name of the handmade test tube in Figure 9 to the FL lamps that have the phosphor screen on the inside wall of the FL lamps. Then, we have clarified the confusion in the analysis of the moving electrons in the Ar gas space in the FL lamps. The confusion comes from the Joule Heat (I2R = 0). We do not consider the Joule Heat for the moving electrons in the Ar gas space of the lighted FL lamps.

The results in Figure 9 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 named as the Townsend electric current, as shown in Figure 9. We have found the direct evidence of the superconductive vacuum between the floating Ar atoms in lighted FL lamps. The results shown in Figure 9 had also 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 with the moving electrons in the superconductive vacuum between Ar atoms.

The vertical voltage range is limited with the DC current at below 3 x 10-4 A. 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. The gathered electrons form the streamer electric current. Finally, the electron flow changes to the arc current, like as the thunder lightings. The practical FL lamps is operated in the moving electrons below 3 x 10-4 A, corresponding to the numbers of the electrons that are 1.9 x 1015 electrons per second {= 3 x 10-4 Coulomb per second x (1.9 x 10-19 Coulomb)-1}. Now we know the numbers of the moving electrons in the lighted FL lamps.

The volume of the glow lights contains Ar, Ar1+, Ar* and free electrons (e-). Only Ar* emits the sky-blue light and others are invisible by the naked eyes. We must figure out how the electrons in the volume of the glow light get out from the volume of the glow light to the entire volume of the Ar gas in the FL lamp. The mechanisms are the same with the electrons in the volume of the HTACS.

The weight of Ar1+ and Ar* are 1.7 x 10-27 kg. The weight of electron is 9.1 x 10-31 kg. Under the given FDC, the moving particles in the volume of the glow lights are the electrons that have the 104 times faster of the speed over Ar1+ and Ar*. The electrons are the major moving particles in the vacuum in the Ar gas space in the lighted FL lamps. The characteristic properties of the lighted FL lamps are determined by the moving electrons from the cathode to the anode in the internal DC electric circuit.

QUANTUM EFFICIENCY HQ = 1013 VISIBLE PHOTONS PER SECOND

Another figure of the merit of the incandescent lamps is the quantum efficiency (ηq) that is given by the numbers of the emitted visible photons by one moving electron in the lighted FL lamp. For the calculation of ηq, we must know the numbers of Ar atoms in the FL lamps.

We may calculate the numbers of the Ar atoms in unit volume (m3) of the FL lamp that contains the Ar gas pressure at 930 Pa (7 Torr). We take 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 m3 {= πr2 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 103 (= 8.32 x 300 oK). P/(RT) = 4 x 10-6 {= (1 x 10-2) x (2.5 x 103)-1}. The mole of the Ar gas in the FL lamp 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 atoms in FL lamp is calculated by the Avogadro's number (6 x 1023 per mole). The numbers of the Ar atoms in the FL lamp are calculated as 1.7 x 1015 Ar atoms (= 6 x 1023 x 2.8 x 10-9 mole).

The separation distance of the Ar atoms in the FL lamps is calculated by the unit volume (m3). The numbers of the Ar atoms per 1 m3 are 2 x 1018 atoms per m3 {= 1.7 x 1015 x (7 x 10-4 m3)-1}. The Ar atoms arranged on one side of 1 m3 are 1.2 x 106 Ar atoms per meter (= (2 x 1018 m-3)1/3. The rounded average separation distance between Ar atoms on the side of the cube is 1 x 10-6 m {= 1 m x (1.2 x 106)-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, as compared with the moving electrons in the solids (10-9 m vacuum space). The wide vacuum space at 1µm between Ar atoms gives the superconductive vacuum as shown in Figure 9.

The analysis of the moving electrons in the vacuum between Ar atoms is an important factor for the study on the FL lamps. The size of the Ar atoms is 4 x 1010 m (= 4 Å). Each Ar atom in FL lamps isolates from neighbor Ar atoms. The calculations inform us that the 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 x 10-9 m (8 nm). Consequently, the moving electrons in the wide vacuum space do not receive the thermal perturbation from the thermally vibrating Ar atoms at the floating position. Consequently, the moving electrons in the vacuum in the FL lamps do not have the electric resistance R. The calculated results are very important information for the support of the superconductive vacuum in the lighted FL lamps.

Then, we may calculate the numbers of Ar1+, and A* by one moving electron in the superconductive vacuum. As the moving electron meets to an Ar atom, the moving electron scatters from the electric field FDC. The scattering is made by the Coulomb's repulsion from the electric field of the orbital electrons, Forb, in the 3d6 shell of Ar atom. The moving electron scatters from the FDC in the region FDC < Forb. The scattered electron takes again the FDC where FDC ≥ Forb. 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 (Ar1+). The returned electron in the FDC > Forb meets other Ar atom and generates Ar1+.

The results in Figure 9 show that the voltage at the cathode and anode in the internal DC electric circuit of the lighted FL lamp is a constant at 1 kV with the different applied voltages. Considering 1 kV, we may calculate the numbers of Ar1+ and Ar*. The moving electron in the superconductive vacuum continually meets the floating Ar atoms until the kinetic energy of the moving electron attenuates to 15.7 eV from 1000 eV. The simple calculation of the numbers of the generated Ar1+ by one moving electron gives 62 Ar 1+ {= 1000 V x (16 V)-1} per one moving electron. After the generation of 62 Ar1+, the moving electron may excite one Ar atom; Ar*. The ratio of the numbers of Ar1+ 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. Then the moving electron recombines with the Ar1+, and Ar1+ returns to Ar atom. The specified moving electron from the cathode disappears from the Ar gas space.

The running distance is 6.2 x 10-5 m. The specified electron from the cathode disappears with 6 x 10-5 m, before reaching to the anode. As shown in Figure 9, 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. We must take the statistical consideration of the moving electrons. Statistically, the electrons from the cathode never disappear in the Ar gas space in the lighted FL lamps. Under the conclusion described above, we may calculate the average numbers of the Ar1+ and Ar* in the lighted FL lamp by one moving electron.

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. 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 Ar1+ and Ar* in the lighted FL lamps.

For the statistical calculations of the formation of Ar1+ and Ar*, we take the numbers of 2 x 1018 Ar atoms per m3 in the Ar gas space. We also consider the numbers of the electrons from the cathode that are 1.9 x 1015 electrons per second {= 3 x 10-4 A x 1.6 x 10-19 Coulomb}. The statistical results are given by the combinations of the average numbers of Ar atoms and moving electrons.

Since Ar atoms distribute in the Ar gas space with the separation distance of 1 x 10-6 m, the average numbers of the collisions of the moving electron in one direction are given by 1 x 106 times {= (1 x 10-6 m)-1}. The numbers of the collisions in unit volume (m3) are given by 1 x 1018 per m3 {= (1 x 106 m)3. The generated Ar1+ in the FL lamp is calculated as 1 x 1018 Ar1+ (m3, s)-1 as the statistical results.

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 numbers of the Ar1+ to the Ar* in the 1 m3 Ar gas space is 62 to 1. The estimated numbers of the Ar* are ~1 x 1016 (m3, s)-1 {= 1 x 1018 x 62-1 (m3, 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 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 from the droplets on the phosphor screen. However, there is no report on the heat source in the FL lamp. The heat source in the lighted FL lamps is only ionization of the Ar atoms by the moving electrons in the positive column. The ionization of the Ar atoms releases the heat by the change in the entropy of the Ar atoms.

The pressure of the vaporized Hg atoms at 40oC 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 FL lamp is calculated as 1.4 x 1015 Hg atoms (m3)-1 (= 2 x 1018 Ar atoms x 7 x 10-4). For the excitation of one Hg atom, the moving electron must have the 63 scatterings with the Ar atoms by the Coulomb's repulsions before the excitation of the Hg atom. The estimated numbers of the Hg* in the Ar gas space at 40oC is calculated as 2 x 1013 Hg* (m3, s)-1 (= 1.4 x 1015 x 63-1). The phosphor screen transduces the UV lights to the visible lights with ηq ≈ 1.0. Therefore, the FL lamp has the ηq = 2 x1013 visible photons per second.

The numbers of the emitted visible photons from the FL lamps are given by the multiplication of the numbers of the moving electrons with the ηq. The moving electrons in the internal DC electric circuit are 3 x 10-4 A that contain 2 x 1015 electrons per second {= 3 x 10-4 A x (1.6 x 10-19 Coulomb)-1}. The numbers of the generated visible photons from the lighted FL lamp are 4 x 1028 UV photons (m3, s)-1 (= 2 x 1013 Hg* x 2 x 1015 electrons per second).

We may confirm the calculated numbers of the visible photons from the commercial HCFL lamp per second. Since the inner volume of the 40W-HCFL lamp is 7 x 10-4 m3, the commercial 40W-HCFL lamp must emits 2.8 x 1025 visible photons per second {= 4 x 1028 (m3, 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 40W-HCFL lamp. The commercial 40W-HCFL lamps may emit 1.4 x 1025 visible photons per second (= 2.8 x 1025 x 2-1). Human eyes have adjusted for 5 million years to the daytime scenery under the slightly overcastting sky that is given by around 1025 visible photons (m2, s)-1. The commercial 40W-HCFL lamp may comfortably illuminates the 1 m2 room with the daytime scenery under the slightly overcastting sky. The commercial 40W-HCFL lamp illuminates the furniture in 1 m2 room with the daytime scenery..

We have theoretically and experimentally confirmed the performance of the lighted commercial 40W-HCFL lamps. The superiority is the astronomical quantum efficiency ηq = 2 x 1013 visible photons per second with one moving electron. The superconductive vacuum in the lighted FL lamps provides the superior advantage of the FL lamps over other incandescent lamps. The calculated results are applicable to the coil-EEFL lamps. The invented coil-EEFL lamps have the zero electric power consumption (WDC = 0) of the external driving circuit. The remained problems of the coil-EEFL lamps are the production of the practical coil-EEFL lamps. For the production of the reliable coil-EEFL lamps, we cannot use the established production facilities and handling of the facilities for the production of the established HCFL lamps. You must use the most advanced vacuum technologies and phosphor powders for the preparation of the coil-EEFL lamps. Those are the subjects of the application research laboratories. The projects of the application research remain for the future study. We may show the fundamentals that are influence in the production of the coil-EEFL lamps.

DIFFICULTIES OF PRODUCTION OF COIL-EEFL LAMPS

The fundamentals of the coil-EEFL lamps have been clarified. The cathode and anode of the coil-EEFL lamps are formed with the volumes of the glow light on the polarized phosphor particles in the phosphor screen. You may prepare the phosphor screens with the commercial phosphor powders. However you will produce the poor quality as the phosphor screen for the practical coil-EEFL lamps. The poor quality of the produced coil-EEFL lamps come from the deep gap in the lighted FL lamps with the commercial PL phosphor screens. The established phosphor screens generate the deep gap (deeper than 3 x 10-3 m) between positive column and phosphor screen. The commercial HCFL lamps have optimized by the gap deeper than 3x 10-3 m. They could not find the presence of the deep gap in the HCFL lamps. Here is the reason that the commercial HCFL lamps are produced with the outer diameter wider than 2.5 x 10-2 m (T-8). The operation life is 104 hours maximum under the operation frequency with 40 kHz. Under the operation with the frequency at 50 Hz, the life of the HCFL lamps is less than 500 hours.

In the case of the coil-EEFL lamps, the cathode and anode are formed with the volumes of the glow light. The depth of the volume of the glow light on the phosphor screen is 3 x 10-3 m. If the coil-EEFL lamps are made with the outer diameter narrower than 1.6 x 10-2 m, the produced coil-EEFL lamps do not emit the lights. This is because the vacuum between the Ar atoms in the wider gap fill up with the negative field. Consequently, the electrons from the cathode cannot step in the gap. If the phosphor screen of the coil-EEFL lamps is made with the commercial phosphor powders, the coil-EEFL lamps do not emit the light. The coil-EEFL lamps only emit the lights with the gap shallower than 3 x 10-4 m. If the coil-EEFL lamps are produced with the adequate phosphor screen, the coil-EEFL lamps in the outer diameters narrower than 9 x 10-3 m emit the light. Furthermore, the operation life of the emitted coil-EEFL lamps is longer than 106 hours.

As described above, the first consideration for the preparation of the coil-EEFL lamps is the selection of the phosphor powder

Depths of Gap between Positive Column and Phosphor Screen

The depth of the volume of the glow light determines the inner diameter of the coil-EEFL lamps. In the past for 90 years, the scientists did not find the presence of the gap in the lighted HCFL lamps [6, 7, 8]. This is serious problems in the development of the FL lamps.

Considering of the thickness of the glass (total 2 x 10-3 m), a preferable outer diameter of the coil-EEFL lamps is given by 8 x 10-3 m {= (3 x 2) x 10-3 m + 2 x 10-3 m}. The diameter of the glass tubes of 9.5 x 10-3 m (T-3) is the maximum diameter for the coil-EEFL lamps. If you take the wider glass tube, the coil-EEFL lamps surely have the same problems with the commercial HCFL lamp.

The outer diameter of the commercial HCFL lamps has empirically determined for the optimization of the output of the light from the phosphor screen. The empirically determined outer diameter for the commercial HCFL lamps is wider than 2.5 x 10-2 m (> T-8). The moving electrons in the Ar gas space never step in the gap. Unexcited Hg atoms in the gap optically absorb the UV lights generated in the positive column before reaching to the phosphor screen of the FL lamp. The volume of the gap in the 40W-HCFL lamp is calculated about 50 % of the total inner volume of the HCFL lamps [14]. The numbers of the Hg atoms in the positive column is the half of the evaporated Hg atoms from the Hg droplets. Then, 50 % of the generated UV light in the positive column is absorbed by the unexcited Hg atoms in the gap before reaching to the phosphor screen. We may calculate the reached UV lights to the phosphor screen. It corresponds to only 25 % of the evaporated Hg atoms in the HCFL lamp.

We cannot take the commercial phosphor powders for the coil-EEFL lamps. The volume of the positive column in the coil-EEFL lamps should be more than 90 % of the inner volume of the FL lamp. The goal can be made with the shallower gap between positive column and phosphor screen. The coil-EEFL lamps should have the gap shallower than 3 x 10-4 m. The Hg atoms in the gap absorb only 10% UV lights from the positive column. The 90 % of the UV lights reach on the phosphor screen, giving rise to the high illuminance (lm, m-2).

Quality of Phosphor Particle for Coil-EEFL Lamps

Next consideration is the generation of the volume of the glow lights on the phosphor screen. It is well known that the volume of the glow lights smoothly forms on the sharp point of the needle metal. It has empirically found that the volume of the glow lights also form on the polarized phosphor particles, as shown in Figure 8. For the formation of the Ar glow light in the Ar gas space, the phosphor particles must have polarized under the electric field from the EE on the outer glass wall. The individual phosphor particles in the screen must have the sharp points and sharp edges for the supply the strong electric field to the Ar gas space.

However, the phosphor particles in the commercial phosphor powders are composed with the various shapes with a wide distribution of the particle sizes. Furthermore, the surface of individual particles is heavily contaminated with the surface treatment with the electric insulators, such as SiO2. The electric insulators on the surface of each particle shield the phosphor particles. The formation of the cathode and anode of the coil-EEFL lamps utilize the electric field from the polarized phosphor particles. Therefore, the shape of individual phosphor particles is the important consideration for the optimization of the coil-EEFL lamps.

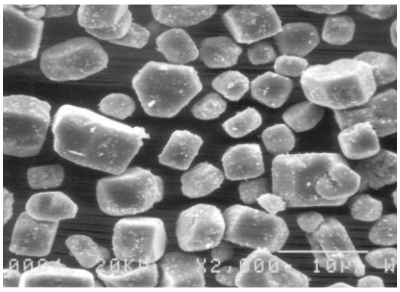


Figure10. *Photograph of scanning electron microscope (x 2000) of phosphor particles for coil-EEFL lamps.*

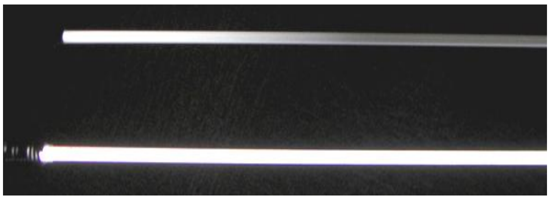
The phosphor particles are the polycrystals and are not the single crystal. The polycrystals have the many growing axes, giving rise to many growing edges and sharp points less than 1 x 10-6 m on the surface of each phosphor particle. The edges and sharp points on the polarized phosphor particles provide the strong electric field to the Ar atoms. We have developed the special phosphor particles by the control of the growing process of the phosphor particles in the heated crucibles in the furnace. More details, we have controlled (a) the production recipe of the row material and fluxes, (b) the removal of air babbles from the heating mixtures in crucible by the heat program of the furnace, and (c) heating program of the crucibles for the growth of the well shaped polycrystalline particles in the crucible. The controls of those factors are important for the preparation of the phosphor particles [15, 16, 17]. Figure 10 show the photograph of the scanning electron microscope (x 2000) of the improved phosphor particles for the coil-EEFL lamps.

It should be note that the commercial phosphor powders are the mixture of the rounded particles and thin plate particles with the wide distribution of the particle sizes. The commercial phosphor particles do not provide the strong electric field to the Ar gas atoms. Furthermore, the surfaces of the commercial phosphor particles are deliberately contaminated with the tiny particles

(< 1 x 10-6 m) of the SiO2 gel that is the electric insulators. Consequently, the surface of all phosphor particles is covered with the strong negative electric field, ~ 2 kV. The commercial phosphor powders are the inadequate phosphor powder for the phosphor screen of the coil-EEFL lamps.

For instance, the strong negative electric field on the phosphor screen under the FDC pushes the moving electrons to the center volume of the Ar gas space. Consequently, the light intensities of the coil-EEFL lamps significantly reduce with the distance from the cathode. Figure 11 shows photographs of the pushing results of the moving electrons to the center volume of the Ar gas space (above), and the uniform lighting with the improved phosphor screen (below). Never use the commercial FL phosphor powder for the preparation of the coil-EEFL lamps.

phosphor screen by commercial phosphor powder



phosphor screen by improved phosphor powder

Figure11. *Photographs of lighting phosphor screens of FL lamps with the different phosphor screens. Above is made with the commercial phosphor powder and below is the improved phosphor powder.*

Depth of Gap by Phosphor Particles in Screen

Another serious problem is the depth of the gap between positive column and phosphor screen. The mass of the moving electron is 9.1 x 10-31 kg with negative charge of 1.6 x 10-19 Coulomb. The moving electrons that have the light weight are strongly repulsed from the negative electric field on the commercial phosphor screen. The repulsed electrons only move on in the Ar gas space in which the FDC ≥ Fphos, where Fphos is the vertical electric field from the phosphor screen. The volume of the moving electrons in the Ar gas space is called as the positive column.

The diameter of the positive column is smaller than the inner diameter of the glass tube of the FL lamp. There is the gap between positive column and inner wall of the glass tube. The Ar atoms in the gap are good thermal insulator with the Ar gas pressure at 930 Pa (= 7 Torr).

As the phosphor screens are made with the commercial phosphor powder, the phosphor particles in the screen surely have the negative electric charges. The direct evidence of the electric charge on the phosphor screens can be determined by the threshold voltage (Vth) of the voltage dependence (VD) curve of the CL. The Vth of the commercial phosphor screen is 2 kV. If the phosphor screen is made with the phosphor particles in the thickness less than 3 layers of the low voltage CL phosphor particles, the phosphor particles in the screen do not have the electric charge, giving rise to the Vth = 110 V [15, 16, 17]. The Vth of the CD curves shifts to the high volts with the increase in the thickness of the phosphor screens. Finally, the Vth reaches to 2,000 V that is the equivalent with the contaminated CL phosphor screen. Therefore, you must establish the adequate screening technology of the phosphor slurry for the thin thickness, before the start of the study of the coil-EEFL lamps.

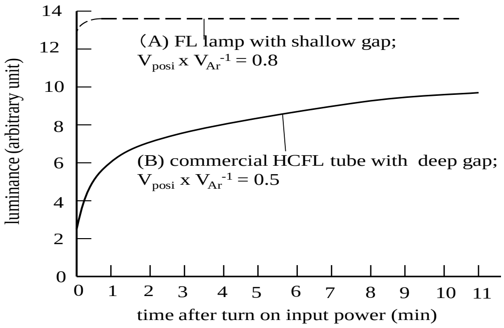


Figure12. *Build-up curves of FL lamps with different depth of gaps. (A) is shallow gap and (B) is deep gap.*

Another difficulty in the study on the coil-EEFL lamps is evaporation of the Hg atoms from the Hg droplets on the phosphor screen. The origin of the light source of the FL lamps is the excited Hg*, instead with the Ar*. With the unlighted FL lamps, the Hg droplets are on the phosphor screen. The heat source of the Hg droplets on the phosphor screen is only ionization of the Ar atoms. The formation of the Ar1+ is only made by the moving electrons in the positive column. The Ar gas in the gap is the good thermal insulator. We cannot expect the heat conductance and heat convection in the gap. The Hg droplets on the phosphor screen only heat up with the thermal radiation from the positive column. Accordingly, the light intensities of the FL lamps increase with the running times of the FL lamps after start of the lighting. The increase in the light intensity with the running time is called as the build-up curve of the FL lamps. Figure 12 shows two build-up curves with the different depths. The depths of the gap are given by the ratios of the volume of the positive column (Vposi) and the inner volume of the FL lamp (VAr). The shallow depth of the gap is given by the large ratio of (Vposi/VAr). The coil-EEFL lamps require the shallow gap as possible. The curve with shallow gap in Figure 12 is acceptable for the coil-EEFL lamps. The curve with deep gap is for the commercial 40W-HCFL lamp that has the gap deeper than 3 x 10-3 m. The saturation of the light intensities of the FL lamps occurs with the long running time with the deep gap. We cannot take the phosphor screens that are prepared with the present screening technology of the commercial HCFL lamps. You must find the proper screening technologies of the phosphor screens for the study on the coil-EEFL lamps [15. 16].

Unacceptable of Pumping Technologies of HCFL Lamps

The preparation of the coil-EEFL lamps encounters a great difficulty with the pumping technologies of the HCFL lamps. The produced FL lamps always contain a large amount of the residual gases in the produced HCFL lamps, higher than 1 Pa (10-2 Torr). The acceptable pressure of the residual gases in the coil-EEFL lamps is a low than 10-5 Pa (10-7 Torr).

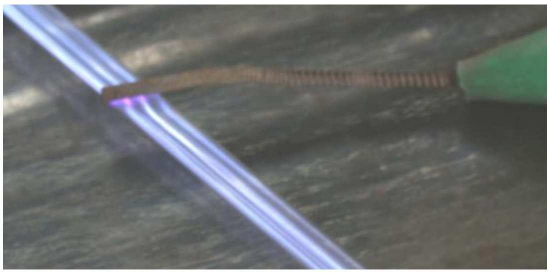


Figure13. *Photograph of lights from vacuum sealed glass tubes under Teslar Coil*

The test of the residual gases should make the vacuum sealed glass tubes, before the production of the FL lamps. Figure 13 shows photograph of the lights of the residual gases in the vacuum-sealed glass tubes of the outer diameter 3.2 x 10-3 m (T-1). The glass tubes on the pumping facilities do not have the lights under the examination by the Tesla Coil. After seal-off of the testing glass tubes from the pumping facility, all tested glass tubes emit the brilliant lights under the Tesla Coil. The lights are caused by the residual gases. They are water (H_2O), air (N_2 and O_2), carbon dioxide (CO_2), sulfur (S), methane (CH_4) and hydrocarbons of methane series (CH_n). The residual gases in the FL lamps are polymerized in the lighted FL lamps. Especially, CH_n are polymerized to the high n-number. The sealed-off FL lamps experience of the aging process that is the lighting of the FL lamps. By the aging process, the surface of the phosphor particles adsorbs the residual gases, resulting in the low brightness of the FL lamps. If you wish the study on the coil-EEFL lamps, you must find a way how do remove the residual gases in the vacuum-sealed glass tube, without the aging process. Then, you make a reliable coil-EEFL lamp.

Side by Side Arrangement of CL and PL Phosphor Particle on Top Layer of Phosphor Screen

A most difficulty for the development of the coil-EEFL lamps is the preparations of the adequate phosphor screens. The main condition of the moving electrons in the Ar gas is determined by the FDC. The moving electrons are sensitively influenced by the vertical electric fields from the phosphor screen, Fphos. The depth of the gap is determined by the large Fphos. There is no report on this subject for past 90 years. We have studied the fundamentals of the moving electrons on the phosphor screens, by using thin and electric conductive indium-tin oxide (ITO) film. The generated conditions in front of the phosphor screen are (i) grand potential, (ii) positive 100 V, and (iii) negative 110V.

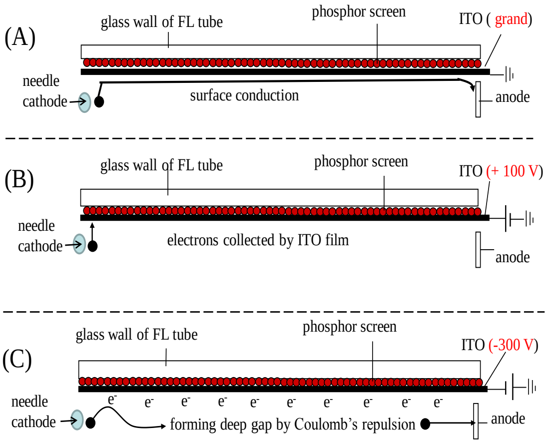


Figure14. *Experimental configurations for study on movement of electrons on different electric potentials on phosphor screens, Electric potentials on surface of the phosphor screen have changed with electric conductive indium-tin-oxide (ITO) film.*

Figure 14 shows the experimental configurations. For the study on the different electric potential on the phosphor screens, we have respectively applied the DC voltages to the ITO film; e.g., grand (A), +100V (B), and -300V (C). In the vacuum device, the electrons move from cathode to anode. When the ITO film has the grand that has no electric charge, the electrons from the cathode selectively move on with the surface conduction on the ITO film, as shown in Figure 14 (A). When the ITO film has the positive potential (DC = + 200 V), the ITO film corrects all the electrons from the cathode, Figure 14 (B). As the ITO film has a negative potential (DV = - 100 V), Figure 13 (C), the electrons from the cathode never reach on the ITO film. The negative electric field from the ITO film repulses all approaching electrons to the Ar gas space. The commercial phosphor particles have the negative charges by the SBE (-2000 V) [14]. From the results in Figure 14, it can say that the repulsed electrons from the SBE move on in the Ar gas space where the electric field in Fvect ≥ Fphos. Where Fvect is the horizontal electric filed formed by the cathode and anode, and Fphos is the vertical electric field from the phosphor particles in the screen.

It is now clear that the phosphor screens of the commercial HCFL lamps are produced with the PL phosphor particles. Consequently, the commercial HCFL lamps always have the deep gap wider than 3 x 10-3 m. So far as the phosphor screen is made with the low voltage CL phosphor particles, the electrons from the cathode move on the surface conduction on the CL phosphor screen in the FL lamps. The results give us the complicated mechanisms of the moving electrons in the lighted FL lamps. The complications give us an idea of the arrangement of the PL phosphor particles and low voltage CL phosphor particles for the generation of the shallow gap less than 3 x 10-4 m.

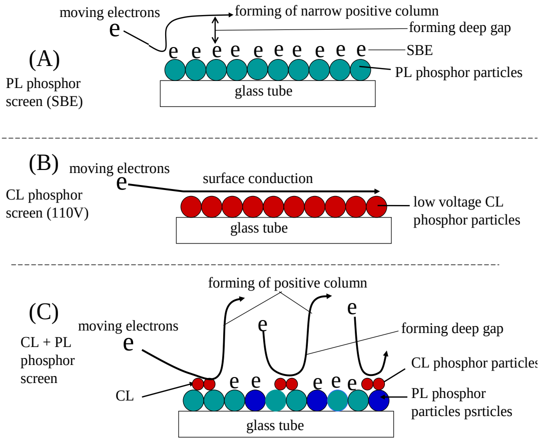


Figure15. *Traces of moving electrons on PL phosphor particles (blue and green) and low voltage CL phosphor particles (red)*

Figure 15 gives the schematic illustration of the moving electrons in the Ar gas space. (A) is the phosphor screen by the PL phosphor powder that generates the deep gap. (B) is the phosphor screen by the low voltage CL phosphor particles. The electrons move on the surface conduction on the low voltage phosphor screen. The moving electrons cannot excite Hg atoms in the Ar gas. The ideal phosphor screen for the coil-EEFL lamps are produced with the special arrangement of the PL phosphor particles and low voltage CL phosphor particles [17]. This is a new study for the development of the coil-EEFL lamps. The developments of the practical phosphor screens for the coil-EEFL lamps remain for the future study.

Parallel Connection of 10 Coil-EEFL Lamps Converted from HCFL Lamps

Even though we do not have the optimized coil-EEFL lamps in our hands, we may demonstrate the advantage of the coil-EEFL lamps that modified from the commercial 40W-HCFL lamps. The converted EEFL lamps are operated with the DC power supply with 4 kV. The modified coil-EEFL lamp has the 60 % illuminance of the original 40W-HCFL lamps. The low illuminance of the converted coil-EEFL lamps is caused by the deep gap between positive column and phosphor screen. As already mentioned, the depths of the gaps in the tested 40W-HCFL lamps can be non-destructively determined by the measurements of the build-up curve of the illuminance. The estimated depth of the tested HCFL lamps is 4 x 10-3 m. The low brightness of the converted coil-EEFL lamps is caused with the sizes of the electron sources. The electrodes of the HCFL lamps are made with the large volume of the HTACS, and the electrodes of the coil-EEFL lamps are made with the volume of the glow light. Even though the converted coil-EEFL lamps have the low brightness, we may examine the following experiments.

If you make the parallels connection of the electrodes of 10 coil-EEFL lamps, the 10 coil-EEFL lamps uniformly light up with the DC power consumption of the external DC driving circuit (WDC = 0). Figure 16 shows photograph of the lighted 10 coil-EEFL lamps with the WDC = 0. This is real advantage over the AC power consumption of the 10 HCFL lamps, Wact ≥ 800 watt. If you increase the illuminance of the coil-EEFL lamps with the narrow diameters, you may have the good illumination lamps with the coil-EEFL lamps in the parallel connection.

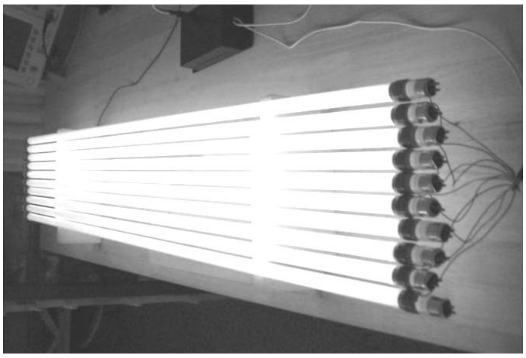


Figure16. *Photopicture of lighted 10 coil-EEFL lamps converted from commercial 40W-HCFL lamps. The* $W_{DC} = 0$.

The improved coil-EEFL lamps with the parallel connection that are operated with ΣWDC = 0 will contribute to the Green Energy Project by UN. The developed coil-EEFL lamps in the parallel connection may operate with the electric power that is the combination of the solar cells and electric butteries.

CONCLUSION

After the analysis of the incandescent lamps, we have the conclusion that the FL lamps hold the great advantage as the saving of the electric energy. Although the commercial HCFL lamps have studied for nearly 90 years, we have found that the fundamental technologies of the HCFL lamps stay at the premature technologies by the design with the erroneous concepts. We have revised them.

The Ar atoms in the FL lamps do not combine each other with the electron shell of Ar atoms. The individual Ar atoms float in the vacuum with the separation distance with 10-6 m. However, the vacuum space between Ar atoms fills up the negative electric field from the electrons in the orbital shell of the Ar atoms. The negative electric field in the vacuum takes away in the lighted FL lamps by the generation of the Ar1+ by the moving electrons from the new electron sources (volume of the corona or glow light) in the Ar gas space. Actually, the FL lamps are operated with the coexistence of the disparity of the external and internal electric circuits. There is no electron flow between two disparate electric circuits. The wide vacuum between Ar atoms in the lighted FL lamps changes to the superconductive vacuum for the moving electrons in the internal DC electric circuit. The moving electrons in the Ar gas space do not have the electric resistance R. Consequently, the moving electrons in the FL lamps have the astronomical quantum efficiency {ηq = 2 x 1013 visible photons (m3, s)-1}. The electric current of the FL lamps is 3 x 10-4 A that contains 2 x 1015 electrons per second. We may calculate 6 x 1029 visible photons (m3, s)-1 from each FL lamp. The illuminance of the FL lamps holds the unrivaled advantage over other incandescent lamps that have only ηq < 1.0.

We also find the erroneous determination of the AC electric power consumption, Wact, of the commercial HCFL lamps. The electric AC driving circuit for the commercial 40W-HCFL lamps actually consumes Wact > 80 watt. The error comes from the assignment of the AC driving circuits at the electrodes at both ends of the FL lamps. The metal electrodes at the both ends of the lighted FL lamps are closed with the induced AC current from the capacitor CAr. The CAr is formed by the synchronous displacement of the electron in orbital shell of each Ar1+ in the lighted FL lamps.

The cathode and anode of the internal DC electric circuit in the HCFL lamps are formed with the volume of the corona lights in the heated Ar gas. The operation life of the HCFL lamps is determined by the evaporation of the heated spot of the W-filament coil. The operation life of the W-filament lamp is 104 hour maximum. We have found that the cathode and anode of the internal DC electric circuit also formed by the volume of the glow lights on the polarized phosphor particles under the external coil electrodes on the outer glass wall of the FL lamps. This is the coil-EEFL lamps that have the operation life longer than 106 hours. The coil-EEFL lamps can be operated with the external DC driving circuit that give the WDC =0. The plural coil-EEFL lamps in parallel connection can be operated with one DC electric circuit, resulting in WDC = 0.

We have studied the fundamentals of the coil-EEFL lamps. The coil-EEFL lamps in the diameter narrower than 1 x 10-2 m cannot produced with the established facilities and handling of the production facilities. The problem generates the deep gap between positive column and phosphor screen. The commercial HCFL lamps have the deep gap at 4 x 10-3 m. By the arrangement of the low voltage CL phosphor particles and PL phosphor particle side by side on the top layer of the phosphor screen, the depth of the gap decrease to 3 x 10-4 m. The appropriate diameter of the coil-EEFL lamps is around 1 x 10-2 m (T-3).

The lighting panels at any sizes with the high illuminance can be made by the arrangement of the plural coil-EEFL lamps in the parallel connections, which are operated with one external DC power supply with WDC = 0. The developed coil-EEFL lamps in the vacuum-sealed container can be operated with the combination of the solar cells and electric batteries, without the ordinary networks of the electric power distribution from the electric power generators on the world. By the application of the coil-EEFL lamps to the illumination source, the electric power consumption will be down more than 40 % on the world. The coil-EEFL lamps surely contribute to the Paris Agreement and COP of UN projects.

BIOGRAPHY

The author started production of the FL lamp on 1948. On 1950, he moved to the phosphor production at a very small factory in Japan. Then he moved to USA on 1968. He studied all his life on the luminescent materials and application of phosphor screens to the lighting devices, like as the most advanced monochrome and color CRTs, and FL lamps. He has studied the properties of the luminescent materials by the hand-made equipments. He had increase the 10 times of the luminance (cd, m-2) of color CRT on 1968 to 1971 at Zenith, USA. He also developed the miniature CRT in the highest image quality in Japan on 1993 for application to the virtual reality device. The highest image quality of the color CRT had developed in Korea on 1998. He obtained the certificates of the graduation of high school, master degree in science, consultant in the applied science from Japanese Government. He worked as professor of Tianjin Technological Institute in China. He has classified as the extra-ordinary ability person from USA Government. He wrote 4 books, 5 review articles of the luminescence in professional Journals.

REFERENCES

[1] Lyuji Ozawa, [Coil-EEFL tube as supreme incandescent light source with zero electric power consumption, astronomical quantum efficiency, and long life], Global Journal of Science Frontier Research, 15, Issue 8 Version 1.0, pp 16-50, 2015.

[2] Lyuji Ozawa, [coil-EEFL Lamps as a promise Candidate fro Green Energy project of UN]. International Journal of Energy Engineering, 7(4), pp91-113, 2017, DOI: 10.5923/j.jee. 2017 0704.01

[3] Lyuji Ozawa, [A development of an Ultimate coil-EEFL lamp with WDC ≈ 0 for Green Energy Project by UN]. International Journal of Physical Science Research, Vol.1, No.1, pp1-28, 2017,

[4] Lyuji Ozawa and Tian Yakui, [Restriction of solid lighting sources in practical use], J. China Illum. Engs. Soc., 6, pp 57-64, 2011.

[5] F. Meyer, US Pat. 2,182,732 (1928).

[6] Phosphor Handbook, second edition, by William Yen, ISBN: 0849335647, CRC Press, Taylor & Francis Group, Boca Raton, London, New York, (1998).

[7] Discharge Handbook, Japanese Electric Society, (1973).

[8] J. F. Way mouth, [Electron discharge lamp], MIT Press (1971).

[9] American Vacuum Society Classics, (1) The fundamental data on electrical discharge gases, (2) Field emission and field ionization, (3) Vacuum technology and space simulation, (4) The physical basics of ultrahigh vacuum, (5) Handbook of electron tube and vacuum techniques, (6) Vacuum sealing techniques, and (7) Ionized gases, American Institute of Physics, 1993

[10] Lyuji. Ozawa, [Illuminance (lm, m^{-2}) of compact 20W-HCFL tube], Science Research, **3(3)**, pp170-179, (2015), (http//www. Science publication group.com/j/sr.

[11] Lyuji Ozawa and Yakui Tian, [A new 4G electron source for fluorescent lamp tubes], J. China Ill. Soc., 7, pp58-65, 2012.

[12] Lyuji Ozawa and Yakui Tian [New electron source and electron collection source in FL tube], Korean J. Inf. Display, 12, pp 69-74, 2011.

[13] Lyuji Ozawa and Yakui Tian, [Coexistence of disparities of external AC driving circuit and internal DC electric circuit in operation in FL tubes], J. China Ill. Soc., 6, pp19-30, 2011.

[14] Lyuji Ozawa, [Illuminance of FL tubes controlled by depth of gap between positive column and phosphor screen], Science Research, 3 (3), pp93-104, (2015), online publication, http//www. sciencepublicationgroup.com/j/sr.

[15] Lyuji Ozawa and Yakui Tian, [A breakthrough in the study on FL tubes], J. China Ill. Soc., 8, pp86-94, 2013.

[16] Lyuji Ozawa, [Ideal distribution of polycrystalline phosphor particles for application to phosphor screens in CRT], International Journal of Materials Science and Applications, 6(1): pp 6-17, 2017, online publication, http//www.science

publicationgroup.com/j/ijmsa

[17] Lyuji Ozawa, [Special arrangement of phosphor particles in screen for optimization of illuminance (lm, m^{-2}) of FL tubes, Science Research, 3 (6), pp 261-272, (2015), online publication,http// www.sciencepublicationgroup.com/j/sr.