Journal of Engineering and Applied Sciences 11 (6): 1218-1222, 2016
ISSN: 1816-949X

Fluorescent Lamp Environmental State Improvement

Albert Abbyasovich Ashryatov and Andrey Mikhailovich Kokinov
National Research Mordvinian State University, B. Khmelnitskogo Str.39, Saransk, Russia

Abstract: The study is dedicated to the increase of fluorescent lamp environmental state. The existing methods of fluorescent lamp environmental state improvement, their advantages and disadvantages are analyzed. It was proposed to introduce mercury into a lamp in a bound state in the form of titanium mercuride placed in a capsule which is welded to one of the leg inputs without an exhaust tube and with a mounted electrode. The manufacturing process of environmentally improved fluorescent lamps was studied. The shortcomings of the current technological process were determined. The elimination of these shortcomings required the improvement of fluorescent lamp mercury formation (mercury vapor release from titanium mercuride in a sealed off lamp volume) on a test device. The feature of the scheme is the fluorescent lamp DC supply which is more than two times greater than the nominal current discharge and the electrode performing the cathode role operates in the mode of two cathode spots. Besides, the device to monitor the purity of fluorescent lamp filling after their sealing off on a pumping machine. The method of mercury vapor presence control in a sealed off fluorescent lamp is described. In order to improve the environmental state of fluorescent lamp production process the thermal decomposition of titanium mercuride in a capsule is proposed to perform after the production seasoning of finished fluorescent lamps, during which the manifestation of lamp latent defects takes place.

Key words: Environmentally improved fluorescent lamps, mercury, the introduction of mercury into a lamp, mercury formation process, titanium mercuride, capsule mercury dispenser, the process of fluorescent lamp manufacture

INTRODUCTION

The share of Fluorescent Lamps (FL) accounts for about 80% of all light energy generated by all light sources in the commercial sector and about 13% in the residential sector (Anonymous, 2016). This is related to the fact that FL have high technical and operational parameters: high luminous efficiency, the possibility of varying by spectral characteristics, long service life (Ayzenberg, 2006).

A significant shortcoming of FL is that they use liquid mercury and there is a serious environmental problem associated with FL production, transportation, storage, operation and disposal (Selezneva, 2014). The specifics of the existing domestic technology and the lack of advanced and reliable tools and methods for mercury introduction causes its increased (2-4 times) content in a FL of T12 type (30÷60 mg, instead of sufficient 10÷15 mg), the most part of which of which is sucked by air pumps and poisons the production facilities and environment.

The problems are not limited to FL production environment. After the use of these lamps, the excess of unspent mercury is dissipated in air, soil and water after their disintegration. Thus, the development of FL with improved environmental properties is one of the most urgent tasks. The introduction of such FL allows to improve the conditions of production significantly and reduce its harmful impact on the environment.

This problem is solved in different ways according to the world practice. So for these purposes the researchers (Bayneva and Bainev, 2012) provide the devices which allow the precise dosing of liquid mercury in FL volume. The leading FL producers introduce the regulation of the minimum required amount of mercury for all FL types including the Compact FL (CFL) (Ashryatov, 2009). For example, the company Philips (Fluorescent, 2016) regulates 1.4 mg for most types of FL with the tube diameter of 16 mm. Taking this into account it is advisable to reconsider the use of light output enriched by separate mercury isotopes in order to obtain the maximum possible output of modern FL designs (Ashryatov *et al*., 2011, 2012).

Many studies such as (Ashryatov and Fedorenko, 2015) are devoted to the solution of this problem by the means of liquid mercury pouring in a sealed vial which is heated by High-Frequency Current (HFC) or discharge current after LL sealing off. After this it is depressurized

Corresponding Author: Albert Abbyasovich Ashryatov, National Research Mordvinian State University, B. Khmelnitskogo Str. 39, Saransk, Russia

and mercury falls into a lamp volume. One way to solve this problem is to develop the methods for the minimum required amount of mercury dosing into a lamp so as to eliminate pure mercury from the technological process (Fedorenko *et al*., 2009). For this purpose, they use ampoule, capsule methods, the screens coated with hetero mercury dispenser, amalgams, etc.

For several reasons, amalgam FL which are more environmentally friendly as compared to conventional FL (Mikaeva *et al*., 2012) are not widely distributed. A number of studies (Kado *et al*., 2008) suggests to apply an intermetallic mercury compound with a number of metals such as titanium and other metals as the powder on a metal strip which will be used subsequently as a FL element shielding an electrode. In (Egoyan *et al*., 1990; Corazza *et al*., 2011) an intermetallic mercury compound with such metal as titanium, for example to place in a capsule in the form of a rod which is fixed inside a lamp and after its ealing off the capsule is heated by the discharge current or HFC (High Frequency Current). Thus, mercury is evaporated from the capsule in volume and moves into a lamp volume, i.e., the mercury formation takes place.

The use of screens coated with a hetero mercury dispenser in environmentally improved FL is constrained by their higher cost and the complexity of the installation as compared with a capsular dispenser. Besides, in this case the screen heating to activate a hetero mercury dispenser is performed by High Frequency Current (HFC) which leads to the deterioration of ecological process in terms of microwave radiation (Ilyin, 1983).

A common drawback of the considered FL mercury formation techniques is that there is a complete decomposition of a mercury source and a lamp holds the amount of metallic mercury which is much greater than the amount necessary for the normal operation of a lamp.

The most rational way of FL mercury formation was proposed by the researchers (Tumasyan *et al*., 1984). The decrease of mercury pollution probability during production, storage, transportation and operation by maintaining a minimum amount of metallic mercury in a lamp is achieved by the fact that the thermal decomposition of the mercury source is carried out partially. For this a metal capsule with an intermetallic compound of mercury-titanium mercuride is welded to one of the inputs of a mounted leg which is welded in a FL. The release of mercury in a lamp volume occurs after its sealing off a pumping device during a capsule heating to 900°C, approximately.

The mercury formation in a lamp is carried out by two stages: in the technological cycle of manufacturing, after the sealing off operation in the minimum amount by partial thermal decomposition of a mercury source at the short-term supply of rated voltage to a lamp until the luminous flux obtaining and during the entire period of operation by a continuous slow supply of mercury from the source under the action of the current flowing through it (Tumasyan *et al*., 1984).

This method of mercury formation dramatically reduces the probability of mercury contamination during all stages of FL production. During FL combustion mercury is absorbed by a luminiferous layer. Continuous slow delivery of metallic mercury in a working volume from a source compensates mercury loss due to sorption during the entire period of FL operation. Thus, the metered amount of mercury is maintained almost a constant one in the technological cycle of FL manufacture and during the entire period of their operation.

MATERIALS AND METHODS

Experimental studies of ecologically improved fluorescent lamp operation terms: The method of mercury introduction proposed by Tumasyan (1984) was implemented at OJSC “SELZ” for the production of Environmentally Enhanced FL (EEFL) of LB 20-E type. Capsule welding operations to the leg without an exhaust tube and FL mercury formation using a test device were introduced in the technological process of common FL manufacture. However, a low product yield was obtained during EEFL production which required the determination of causes and technological process improvement. The low efficiency of the initial scheme (Tumasyan *et al*., 1984) in terms mercury formation is explained by the alternating current flow through a lamp with the frequency of 50 Hz, so the capsule heating occurs only during one half-cycle that is when an electrode with a capsule is used as an anode.

Another FL mercury formation scheme using Pulse Ignitor (PI) was developed to improve training device efficiency (Ayzenberg, 2006). The scheme of this PI is based on the principle of pulse transformer series connection. Therefore, PI supply is performed only by the alternating current of industrial frequency. On this basis the inductive ballast 1I 65/220 is used as the ballast, limiting the FL discharge current. Using 220 V voltage supply this inductive ballast provides the following magnitude of the discharge current: 0.85 A. A bridge rectifier scheme is applied at PI output for FL supply with direct (rectified) current. Each arm of the bridge consists of a diode assembly designed for 2 A current at least and the reverse voltage of 6000 V. The discharge current flows through a FL during FL mercury formation. This current is two and a half times above the nominal one. An electrode

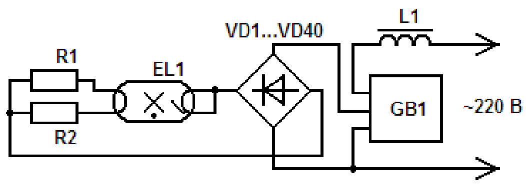

Fig. 1: Scheme for EEFL mercury formation of LB20-E type with DC; EL1: FL of LB20-E type; R1, R2: PEV-10 resistor with 30 ohms; VD1: VD40-semiconductor diodes of KD203 V type; L1: inductive ballast of 1I65/220 type; GB1: pulse ignitor of ISU 100-150 type DNaT-220-B-UHL2

acting as a cathode, should work in two cathode spot mode. This is achieved by using two separating resistors with 30-ohm resistance (Fig. 1).

During the debugging of environmentally enhanced FL production the study of operational production release showed a large number of rejected lamps after the pumping device due to the lack of glow in the Tesla machine. At that as the studies of defective lamps showed, their vast majority is structurally fit but without mercury. This suggests that a part of the lamps on the pumping machine has no separation of mercury from the Capsule Mercury Dispenser (CMD) and the mercury release takes place in the major part of FL, i.e., FL which passed the control on the unit Tesla have mercury “traces”. On the one hand, this degrades the ecological situartion of technological process and on the other hand the amount of mercury in the fluorescent lamp will be less than necessary during the operation of such a lamp because of its leaving from the discharge. This lamp with a low mercury content will have the dramatical fall of luminous power (“dim lamp”) long before the end of its service life (Ashryatov and Fedorenko, 2015).

In order to complete this technological process of EEFL production the complex of works on the following studies was performed:

- The properties of mercury capsule dispenser
- Various parameters of EEFL production technological process making an impact on MCD
- The modes of various design electrode operation in EEFL with MCD

The capsule mercury dispensers used in the production of environmentally improved fluorescent lamps have titanium mercuride decomposition temperature of 900°C at the mercury content of 10-14 mg. Such a high temperature of decomposition leads to certain difficulties during mercury formation (mercury release from a vial in a lamp volume) of ready FL on a line.

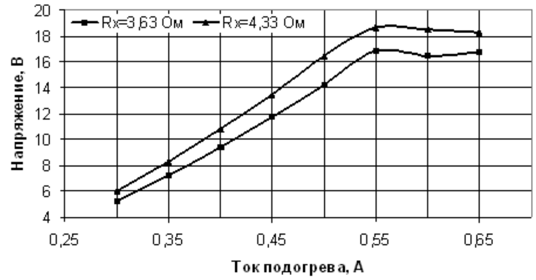

Fig. 2: Typical current-voltage characteristics of the electrodes with different cold resistance in FL, filled with argon

The determination of a capsule temperature at which the release of mercury from it was carried out using an experimental EEFL, an exhaust tube of which was purified from phosphor. It allowed to measure the electrode and the capsule temperature during the simulation process of EEFL processing modes by an optical micropyrometer WIMP-015M. The use of an infrared image converter, included in a micropyrometer set allows to measure the temperature in the range of 400-800°C.

An indirect assessment of an assembly and an oxydated machine required electrode cold Resistance (Rx) measurement in respect of studied lamps. This cold resistance is equal to 4.23 ohms with the range of ±5%. In order to assess the state of the lamp internal environment, i.e., the presence of mercury vapor, the current-voltage characteristics were determined on exhaust tube electrodes (without capsules) of EEFL ends.

The method of mercury presence determination in a lamp volume is as follows. The typical Current-Voltage Characteristic (CVC) of an emitter electrode is shown on Fig. 2 which has a linearly increasing portion and which depends on electrode temperature and ionization processes the point corresponding to the heating current of 0.55 a characterizes the discharge inception voltage near the electrode and which depends on the temperature of the electrode and the ionization processes in electrode space (Ashryatov, 2003). Since, all studied FL have the same electrode structure, the electrode temperature changes equally with current increase. So, the charge voltage appearance depends on the gas filling a lamp. It is known that mercury ionization potential (10.39 eV) is significantly lower than the argon ionization potential (15.78 eV), filling FL. Therefore, if a lamp has mercury vapors, the discharge around an electrode occurs at a lower voltage on the current-voltage characteristics than during pure argon lamp filling (Fig. 3). Thus, the measured CVC showed the absence of mercury vapor in the experimental tubes.

The study of temperature distribution on an electrode and a capsule surface during the thermal

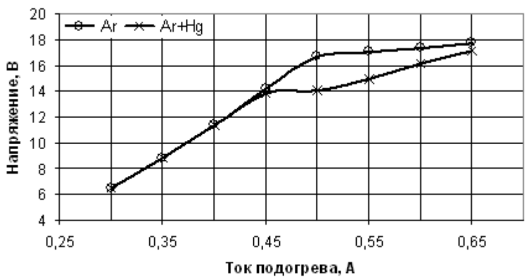

Fig. 3: Electrode current-voltage characteristics with R_x = 4.26 Ohms in FL, filled with argon (Ar) and argon mercury compound (Ar+Hg); Voltage-voltage/current heating-heating current

vacuum processing of EEFL electrodes allowed to adjust the thermal vacuum processing mode of existing electrodes in order to avoid the decomposition of MCD on the pumping machine.

RESULTS AND DISCUSSION

Developed technological process of ecologically improved fluorescent lamps: In order to improve the ecological status of fluorescent lamp production technological process the thermal decomposition of MCD is offered to be produced until the luminous flux achievement after the technological seasoning of lamps, during which the manifestation of lamp latent defects takes place. In this case, almost all lamps rejected for some reason will be mercury-free and their processing does not require the operation of a special expensive installation for mercury removal from defective fluorescent lamps (Ashryatov *et al*., 1997).

However, there are certain difficulties of several operation control during EEFL manufacture in this case. For example, the purity control of FL filling after its sealing off on a pumping machine by a traditional method (the visual perception of a fluorescent lamp phosphor glow which is caused by the excitation in the volume of a high-frequency discharge lamp within mercury vapor by Tesla device). This is related to the fact that in these lamps do not have mercury vapors and inert gas glow (not a mercury vapor) takes place. This gas does not radiate electromagnetic waves in the ultraviolet area of the spectrum and accordingly does not excite the luminiferous layer on the inner surface of a bulb tube. At that the intensity of the inert gas glow is significantly lower than the discharge glow in mercury vapors as the latter case requires a smaller electric field intensity for a discharge excitation due to the Penning mixture appearance.

The intensity of the inert gas emission in a tube is such that the (normal) illumination, existing on an assembly line, the difference in the brightness of a glowing and a non-glowing lamp is below the threshold contrast (Gutorov, 1983). The increase of the inert gas luminescence intensity by increasing the value of the excitation voltage is not possible, since Tesla existing devices operate at full capacity in terms of an allowable scattering of a high-frequency electromagnetic radiation in the environment.

Therefore, the technique of content quality evaluation for EEFL without mercury vapor which allows to reject lamps and reduce the number of suitable lamps which are rejected accidentally (Ashryatov *et al*., 1997). The control of fluorescent lamp filling is performed after its exit from a pumping device during the excitation moment of an electric discharge by Tesla device measuring a lamp luminescence brightness by a photosensor. It is converted into an electrical signal, compared in a comparator with the predetermined limits and the control of a fluorescent lamp filling is performed and in the case of a need the rejection of lamps is performed by supplying a signal on an actuator which removes a defective lamp from a process chain. Thus, in this case, the filling control is performed by a tracking system (not manually) which distinguishes easily a glowing lamp from a non-glowing one.

This offer allows not only to increase a product yield from a line but also to improve the environmental friendliness of the technological process, since the fluorescent lamps, produced from a pumping machine will be virtually without free mercury until a training operation (almost final one) in the amount. And in the case of their failure the surrounding will not be infected with mercury vapors. And the appearance of brightly glowing lamp during the operation of environmental lamp filling control will demonstrate the violation of lamp electrode thermal vacuum processing using a pumping machine which leads to the release of mercury from MCD and accordingly to the infringement of technological process ecology and the increase of “dim” lamp appearance probability among consumers.

Summary: Thus, during the development of environmentally improved FL the complex of research works was performed which allowed to determine an optimal structure of a capsule dispenser and thermal vacuum processing mode of electrodes using a pumping device, to develop an original way of a lamp filling purity control after its sealing off, to create the mercury formation scheme for FL.

CONCLUSION

The results presented in the section can be summarized as follows. The production technology of environmentally superior FL is improved based on the basis of mercury capsule dispenser with titanium mercuride. The technology of EEFL production was proposed excluding the mercury formation of lamps during their production. Mercury formation is performed after the technological seasoning of finished products.

ACKNOWLEDGEMENTS

Researchers are grateful to process engineers of chief technologist department at OJSC “SELZ” who were directly involved in this work performance.

REFERENCES

Anonymous, 2015. Fluorescent lamps. http://www.xnn.ru/lyuminesczentnyie-svetilniki.

Ashpyatov, A.A., V.A. Duhonkin, V.L. Mizonov, V.I. Melyakin and A.V. Simonov, 1997. The method of fluorescent lamp production. Patent No. 2094893 of Russian Federation, October 27, 1997.

Ashryatov, A.A. and A.S. Fedorenko, 2015. Calculation and Design of Fluorescent Lamps: The Textbook for High Schools. 3rd Edn., Publishing House SVMO, Saransk, Russia, Pages: 412.

Ashryatov, A.A., 2003. The study of near-electrode plasma during the starting period of the fluorescent lamp with a mercury dispenser. Proceedings of the 5th International Conference of Lighting Equipment: Light and Progress, September 2-5, 2003, Interregional Light Equipment Community, St. Petersburg, Russia, pp: 141-143.

Ashryatov, A.A., 2009. Research into characteristics of compact fluorescent lamps with built-in electronic ballast. Light Eng., 17: 34-36.

Ashryatov, A.A., S.A. Mikaeva and A.S. Fedorenko, 2011. About the possibility of further luminous efficacy increase among low pressure fluorescent lamps. Lighting Equip., 5: 15-19.

Ashryatov, A.A., S.A. Mikaeva and A.S. Fedorenko, 2012. On further increasing the luminous efficacy of low pressure fluorescent lamps. Light Eng., 20: 93-98.

Ayzenberg, Y.B., 2006. Reference Book on Lighting Equipment. 3rd Edn., Znak Publ., Moscow, Russia, Pages: 972.

Bayneva, I. and V. Bainev, 2012. Mercury dosing device in discharge light sources. Photonics, 1: 36-39.

Corazza, A., V. Massaro and A. Gallitonotta, 2011. The method of mercury separation. Patent No. 2411603 of Russian Federation, February 2, 2011.

Egoyan, V.V., A.K. Pagutyan, L.R. Grigoryan and S.I. Galoyan, 1990. The method of a fluorescent lamp manufacture. A.S. No. 1599913 USSR, Bulletin No. 38, October 15, 1990.

Fedorenko, A.S., A.A. Dourdan, E.A. Karasev and A.A. Ashryatov, 2009. Research on environmental performance of fluorescent lamp improvement. Proceedings of the Russian Lighting Equipment Online Conference, June 3-16, 2009, Lighting Equipment Company, Russia, pp: 264-265.

Gutorov, M.M., 1983. Basics of Lighting Equipment and Light Sources: The Textbook for High Schools. 2nd Edn., Energoatomisdat, Moscow, Russia, Pages: 384.

Ilyin, S.K., A.M. Kokinov, L.E. Petrovsky and N.N. Shcherbakova, 1983. Hetero mercury dispenser for fluorescent lamps. Lighting Equip., 4: 19-21.

Koda, A., A. Koradza, A. Gallitonotta, V. Massaro, M. Porro and L. Toya, 2008. Compounds for mercury dispensing and the method of their preparation. Patent No. 2339114 of Russian Federation, November 20, 2008.

Mikaeva, S.A., A.S. Mikaeva, A.A. Ashryatov and O.Y. Kovalenko, 2012. Amalgam lamps in water disinfection devices. Autom. Mod. Technol., 9: 10-15.

Selezneva, A., 2014. Mercury: Danger for a man. The factors of mercury danger. http://fb.ru/article/160913/rtut-opasnost-dlya-cheloveka-chem-opasna-rtut.

Tumasyan, B.A., V.V. Egoyan and A.K. Pagutyan, 1984 1984. Fluorescent lamp and the method of its manufacture. A.S. No. 1120429 USSR, Bulletin No. 39.