ISSN 2079-5459 (print)
ISSN 2413-4295 (online)

УДК 666. 1.031 doi:10.20998/2413-4295.2021.02.13

ІНТЕГРАЦІЯ НОВІТНІХ ТЕХНОЛОГІЙ У ВИРОБНИЦТВІ АРХІТЕКТУРНО-БУДІВЕЛЬНОГО ФЛОАТ-СКЛА

Л. Л. БРАГІНА[1*], С. М. ЯЇЦЬКИЙ[2], Д. В. ПЕТРОВ[1], О. Є. СТАРОЛАТ[1]

[1]кафедра технології кераміки, вогнетривів, скла та емалей, Національний технічний університет «Харківський політехнічний інститут», м. Харків, УКРАЇНА
[2]ТОВ «Лисичанський скляний завод», м. Лисичанськ, УКРАЇНА
[*]e-mail: bragina_l@ukr.net

АНОТАЦІЯ *Проаналізовано сучасний стан технологій виробництва скляних виробів, що використовуються в архітектурно-будівельній галузі, типи енергозберігаючих флоат-стекол та їх роль у якості освітлення будівель. Показано актуальність використання low-E стекол, зокрема у склопакетах. Розглянуто інноваційні тенденції у виробництві листового архітектурно-будівельного флоат-скла із застосуванням сучасних технологій та обладнання, зокрема, на ПАТ «Лисичанський склозавод «Пролетарій». Встановлено, що суттєвим недоліком більш енергоефективних І-стекол, які мають широкий діапазон колірних характеристик, є недостатня механічна міцність м'яких покриттів, що наносять магнетронним вакуумним напиленням. Показано, що технологія виготовлення низькоемісійних І-стекол з такими покриттями не дозволяє здійснювати їх гартування зі збереженням всіх необхідних експлуатаційних параметрів. Наведено фізико-хімічні властивості і експлуатаційні характеристики великогабаритних стекол з срібними, сонцезахисними м'якими покриттями, ламіновані, плоскі та радіусні загартовані стекла, а також сфери їх застосування. Досліджено принципи зміцнення м'яких магнетронних покриттів для одержання низькоемісійних Double Low-E стекол та склад, комбінації шарів й технологічні параметри нанесення багатошарових нанопокриттів загальною товщиною до 140 нм, що дозволяє гартувати І-скло з цими покриттями. Проаналізовано технологічні параметри отримання низькоемісійних І-стекол з варіативними покриттями, які регулюють спектральні та експлуатаційні показники даних скловиробів за міждержавними стандартами ГОСТ EN 673–2016 й ГОСТ EN 410–2014. Розглянуто технологічні методики гартування листового скла із нанесеними низькоемісійними покриттями шляхом створення спеціальних їх складів та оптимізації процесів магнетронного нанесення, а також основні закономірності розташування шарів плівкової системи Si_3N_4 / NiCr / Si_3N_4 для витримування термічної обробки стекол системи R_2O–RO–SiO_2. Запропоновано принципи корегування їх спектральних й механічних характеристик в залежності від концентрації та співвідношення компонентів тонкоплівкового наношару, що сприятиме створенню варіаційного ряду флоат-стекол з необхідним рівнем відбиття в інфрачервоному спектрі.*
Ключові слова: *флоат-скло; Low-E покриття; безпечні стекла; технології магнетронного напилення; гартування скла; спектральні характеристики; архітектурно-будівельна галузь; інфрачервоний спектр*

INTEGRATION OF MODERN TECHNOLOGY FOR ARCHITECTURAL-BUILDING GLASS PRODUCTION

L. BRAGINA[1*], S. YAITSKY[2], D. PETROV[1], O.STAROLAT[1]

[1]Department of ceramic, refractories, glass and enamels technology, National Technical University "Kharkiv Polytechnic Institute", Kharkiv, UKRAINE
[2]LLC "Lysychansk glass factory", Lysychansk, UKRAINE

ABSTRACT *The current state of technologies for the production of glass products used in the architectural and construction industry, types of the energy-saving float-glasses and their role in the lighting quality of the buildings was analyzed. The relevance of the use of Low-E glass, in particular in the glass units, is shown. Innovative trends in the production of sheet architectural and construction float glass with the use of modern technologies and equipment, in particular, at PJSC "Lysychansk glass factory "Proletary ", considered. It is established that a significant disadvantage of more energy-efficient I-glasses, which have a wide range of color characteristics, is the insufficient mechanical strength of soft coatings applied by magnetron vacuum spraying. It is shown that the technology of manufacturing low-emission I-glasses with such coatings does not allow them to be hardened while maintaining all the necessary operating parameters. Physicochemical properties and operational characteristics of large-sized glasses with silver, sunscreen soft coating, laminated, flat and radial tempered glasses, as well as their areas of application are presented. The principles of strengthening soft magnetron coatings for low-emission Double Low-E glasses and composition, layer combinations and technological parameters of multilayer nanocoatings with a total thickness of up to 140 nm, which allows to harden I-glass with these coatings, investigated. The technological parameters of obtaining low-emission I-glasses with variable coatings, which regulate the spectral and operational indicators of these glassware according to the interstate standards GOST EN 673-2016 and GOST EN 410-2014, are analyzed. Technological methods of the sheet glass with low-emission coatings hardening by creating of the special compositions and optimizing magnetron sputtering processes optimizing, as well as the basic regularities of the arrangement of the film layers of the Si_3N_4 / NiCr / Si_3N_4 film for the heat treatment withstanding of the glasses in the R_2O – RO – SiO_2 system are considered. The principles of adjusting their spectral and mechanical characteristics depending on the*

concentration and ratio of the components of the thin-film nanolayer, which will contribute to the creation of a variation series of float glasses with the required level of reflection in the infrared spectrum, are proposed.
***Keywords**: float glass; Low-E coatings; safety glasses; magnetron sputtering technology; glass hardening; spectral characteristics; architectural and construction industry; infrared spectrum*

Introduction

Giving of the fundamentally new performance characteristics to the architectural and construction polished glass through the use of scientific achievements advances and advanced technologies has contributed to a significant expansion of its application [1,2]. Providing high light, heat and sound insulation of premises, almost absolute environmental friendliness, a significant reduction in lighting costs, a significant speed of construction, as well as a significant improvement in the strength of glassware in combination with giving them different shapes, - all these factors have led to a new level urban ideas about the role of glass [3,4].

Energy-efficient windows have become extremely popular, and their widespread use in Europe has grown significantly in recent decades.

Window structures of double glass appeared, which opened new opportunities in architectural construction [5]. In the 90s of the last century, thanks to advances in float glass technology, an alternative to them were the so-called low-emission glass including with special coatings [6]. Light-protective glasses change the spectral properties of the light that passes through them, create a more comfortable, compared to colorless glass, lighting and provides high clarity of perception of objects and do not cause eye fatigue. Such glass significantly reduces the flow of heat into buildings and protects against the destructive effects of ultraviolet rays [7].

Light-protective float glass is widely used for lighting buildings, where there is a problem of reducing the brightness of lighting, there is a need for one-sided inspection of the premises during the day and special requirements for interior parameters, as well as for facade and interior design of administrative, public and residential premises. furniture, etc. When using low-emission glass in double-glazed windows filling the interglazed space with inert gas leads to an additional increase in heat transfer resistance by 7 - 10%, while in the case of ordinary double-glazed windows this measure does not create the desired effect.

Low-E glasses include hardening safety glass, which is used mainly in multi-storey offices and other public buildings to ensure strict safety standards. There are two types of low-E glasses: the first type is painted in bulk with metal oxides in bronze, gray, blue and other colors. These components provide the absorption of solar thermal radiation and reduce transmission in the visible part of the spectrum, thereby achieving the desired effect. The second type includes glasses with special coatings that provide a similar effect [8]. The disadvantage of light-protective glasses, colored in bulk, is a fairly significant cost due to the use of very expensive and scarce, especially in Ukraine, dyes, as well as the complexity of the cooking process of this type of glass [9]. Thus, to obtain glasses colored with compounds of manganese, chromium, copper, an oxidizing medium is required, while sulfide selenium glasses and "copper ruby" require a reducing or neutral atmosphere. n addition, the peculiarity of cooking colored glass is associated with low thermal conductivity of glass, which greatly limits the possibilities of the manufacturing modern methods widespread use such sheet glass [9]. [10]. Low-emission glasses with special coatings only a few tens of nanometers thick, making them completely transparent to the human eye, have presented serious competition to the first type of glass [11].

The goal of the work

The main purpose of the work was to analyze the innovative trends of low-emission glass integrated technologies and their problems, as well as to develop ways of the significantly improve this product in Ukraine.

The main results and their discussion

Recently, the volume of production of laminated glasses with special films and inorganic nanocoatings has increased significantly. They are able to have the same functional characteristics as the above low-emission glasses, that is they can be energy-saving, sun-proof, etc.

The use of inorganic coatings has significant advantages over laminating films due to their significant durability. Typically, laminated glass is a triplex made by gluing glass plates with a special polymer film PVB under conditions of significant pressure and high temperature. The hardened, reflective, energy-saving float glasses with silk-screen printing or color printing are used as initial. Bonding glass does not increase the mechanical strength of the components of the triplex, but due to the formed layers in the whole product as a whole increases the resistance to fracture. In addition, triplex belongs to a safe group of glasses due to the fact that when it is destroyed, the fragments do not fly away, but remain on the film [12].

Modern safety glasses include flat and curved hardened glasses. The first of them is an indispensable material for the building industry during the closing of high-rise buildings, offices and banks, mansard windows, greenhouses, subway cars, passenger trains, trams, passenger transport; with the prepared details of the side-by-side technology (folding shelves for refrigerators and ovens), spare parts of furniture; decorative glassware with a color digital signet [13].

Among the glasses with non-vacuum coatings should be noted silver mirrors and glasses with color photo printing, which are widely used in solving the design of various rooms [12]. The advantages of digital color printing on glass consist of a wide range of colors;

ISSN 2079-5459 (print)
ISSN 2413-4295 (online)

at the same time thanks to the further heat treatment glassware has all advantages of the tempered glass: the increased durability, resistance to any mechanical damages, ultraviolet radiation, influence of such aggressive environments, as atmospheric precipitations, chemical reagents.

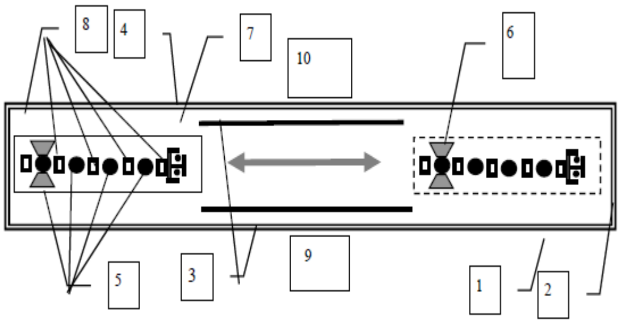
However, the greatest attention is paid to glasses that are integrated with functional coatings. This type includes low-emission glass [14]. Today, two types of low-emission coated glasses are produced: the so-called I-glass (Double Low-E) with a soft coating applied by magnetron in vacuum, and K-glass (Low-E) with a hard metal oxide coating applied directly on the surface of the still hot glass in the production process by pyrolysis. These glasses differ mainly in the values of the coefficient of emissivity, hardness and technology of their production.

I-glass has high energy-saving properties. It successfully reflects infrared radiation and partly - ultraviolet, its heat transfer coefficient does not exceed 0.1. The service life of such glass is unlimited, but provided that adequate protection against abrasive effects due to insufficient hardness of the coating. Therefore, I-glasses are used in double-glazed windows with a layer sprayed inside these products, but their use for single glazing is virtually excluded.

K-glasses with non-vacuum coatings, which are characterized by special strength and are called solid, are devoid of this disadvantage. These glasses have become widespread due to the neutral color, ease of processing and high thermal insulation properties. They can be subjected to hardening, painting [13], used in the manufacture of multilayer and single glazing systems. The disadvantage of such glasses, from the point of view of the architectural industry, is the impossibility of varying their color shade. Therefore, special Low-E float glasses need special attention.

The main feature of low-emission float glass is the high values of light transmission and transparency, which is due to the high absorption index in the infrared zone (800–2000 nm) and the coefficient of thermal insulation. In this work, to obtain such glasses with a "soft" coating on the surface of the finished float glass after cooling by cathodic sputtering in an electromagnetic field under vacuum on a magnetron installation GC-254H (fig. 1) was coated with metal-containing layers, alternating with dielectric (oxides of BiO_x, TiO_2, ZnO, etc.). Their choice depended on the required characteristics of these properties.

For preliminary calculations of the coatings composition used a coating designer, the action of which is based on the software of modeling the spectrum of SCOUT. We calculated the coordinates x, y, z of the desired color (fig. 2), which the program converted to L *, A *, B *, RGB coordinates (red, green, blue), and the allowable values of the transmission coefficients in certain spectral ranges. Thanks to the software, a preview of the change in the optical model and spectral characteristics in the process of calculating the thickness of the individual layers of the coating carried out. To characterize the spectrum, the dominant wavelength was calculated, which reflects the position of pure spectral colors in the x – y plane (from 380 to 700 nm) relative to white and facilitates the choice of spectrum. Light transmission and reflection coefficients, sunlight transmission and reflection coefficients, color rendering index were calculated according to color coordinates.



1 – vacuum chamber, 2 – doors, 3 – glass, 4 – carriage, 5 – MRS, 6 – streams of atomized atoms, 7 – ion source, 8 – anodes, 9 – light source, 10 – optical registration system

Fig. 1 – Vacuum installation for magnetron SPUTTERING of the coatings

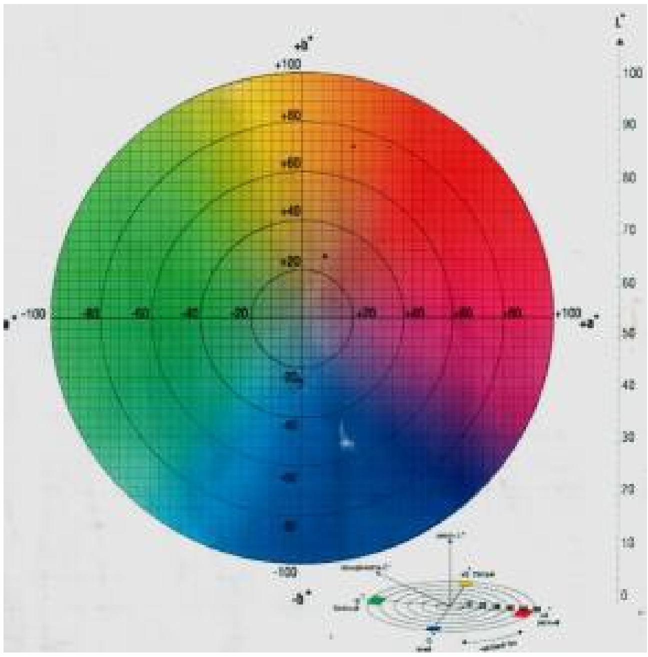
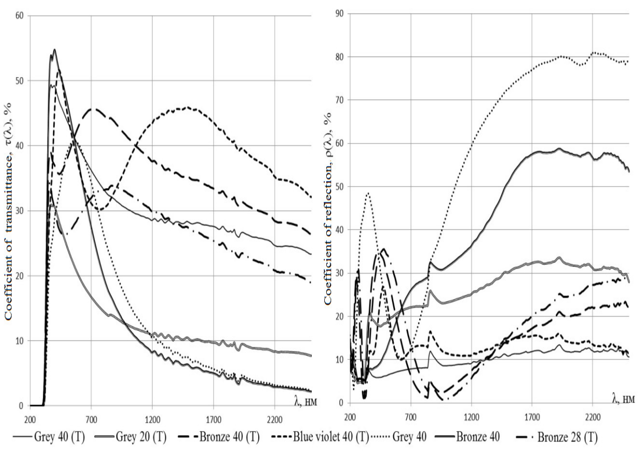


Fig. 2 – Color coordinates to calculate the properties of the optical coating

However, oxide components, which are typical components of the low-emission glasses nanocoating, are subject to destruction during heat treatment at the hardening. However, the nitride components are resistant to quenching temperatures. Therefore, it was proposed to replace the composition of the multifunctional coating components to simultaneously preserve the color and spectral properties with the possibility of hardening. SnO_2 in the adhesion layers was replaced by silicon nitride Si_3N_4 and silicon nitride doped with aluminum Si_3N_4:Al (SiAl). They, like SnO_2, correct the color characteristics of the glass well, but, having much greater strength, provide a significant strengthening of the "soft" coating at a very small thickness (up to 140 nm). Their application to the glass was carried out by magnetron cathodic sputtering of targets containing silicon. In particular, a target with a content of from 80 to 95 wt.% Si and from 5 to 20 wt.% Al was used to apply the SiAl adhesive layer. For a similar purpose, the Cr darkening layer was replaced with a thinner NiCr layer. All this allowed to obtain low-emission float glasses with reinforced soft coatings, resistant to external influences, which are subject to hardening. The thickness of the barrier layer in them is from 5 to 50 nm, preferably from 10 to 30 nm. This allowed to achieve low values of surface resistance (4 Ohm) and satisfactory flexibility. In addition, the coating due to the barrier layer of the specified thickness reliably protected the glass in a humid atmosphere.

For the variation of color characteristics, a system of arrangement of I-glass coating layers with different values of the required spectral characteristics was developed (Fig. 3).



a b

Fig. 3 – Features of transmission (a) and visibility (b) of created glasses

According to the results of testing for gritting, the glasses correspond the standards of annealing R 43.

During the tests for mechanical strength through the abrasion, it was found that the composition of the coating changing allowed to increase this parameter from 200 to 1000 abrasions. Technological parameters for the creating of low-energy I-glasses with variable coatings, which regulate spectral and exploitation indicators, made it possible to obtain multifunctional low-energy float glasses in accordance with the international standards GOST EN 410–2014 and GOST EN 673-2016. They have been successfully implemented at the LLC "Lysychansk Glass Factory" and in the architectural and construction industry.

Conclusions

Thus, the analysis of innovative trends in integrated technologies of low-emission float glasses showed the relevance of their use in architecture and construction and the advantages of I-glass with so-called soft magnetron coatings over K-glasses with hard pyrolysis coatings.

Replacement of oxide components of magnetron multilayer nanocoatings with nitride, as well as development of technological parameters of their application allowed to significantly increase the mechanical strength of coatings, provide the necessary spectral and color characteristics of finished glass products and carry out the hardening process.

The implementation of these results at Lysychansky Glass Factory LLC has led to the production of products at the level of the best world analogues, which are successfully used in the architectural and construction industry.

Список літератури

1. Holand W., Beall G. *Glass Ceramic Technology*. New Jersey: JohnWiley & Sons, 2012. 360 p.
2. Jelle B. P, Kalnaes S. E., Tan Gao. Low-Emissivity Materials for Building Applications: A State of the Art Review and Future Research Perspectives. *Energy and Buildings*. 2015. № 3. P. 96–106. doi: 10.1016/j.enbuild.2015.03.024
3. Carter B. C., Norton M. G. *Ceramic Materials. Science and Engineering*. Springer, 2013. 775 p.
4. F. Bos, C. Louter. Structural Glass in Architecture, *Encyclopedia of Glass Science, Technology, History, and Culture*, Chapter 9.1. 01 February 2021. doi: 10.1002/9781118801017.ch9.1
5. Shelby J. E. *Introduction to Glass Science and Technology*. Second Edition. Cambrige: The Royal Society of Chemistry, 2005. 224 p.
6. Mohelnikova J. Window Glass Coatings. *Green Energy and Technol.* 2011. № 33. P. 913-934.
7. Брагина Л. Л., Яицкий С. Н., Машкин В. В. Архитектурно-строительные стекла с низкоэмиссионными энергосберегающими покрытиями. *Вісник НТУ «ХПІ»*. 2014. № 16. С. 165-173.
8. Ящишин Й. М. *Технологія скла у трьох частинах. Ч. ІІІ.* Львів: Видавництво «Растр-7», 2011. 149 с.
9. Hartmann P., Jedamzik R., Reichel S., Schreder B. Optical glass and glass ceramic historical aspects and recent developments: A Schott view. *Applied Optics*. 2010. Vol. 49, No. 16. P. D 157–D 176. doi: 10.1364/AO.49.00D157.
10. Петров Д. В., Брагіна Л. Л., Петрова А. М. Проблеми технології варки оптичного скла на етапах гомогенізації

ISSN 2079-5459 (print)
ISSN 2413-4295 (online)

та освітлення. *Питання хімії і хімічної технології*. 2020. № 5. С. 68-72. doi: 10.32434/0321-4095-2020-132-5-68-72.
11. Bull S. J. Elastic properties of multilayer oxide coatings on float glass. *Vacuum*. 2015. № 114. P. 150–157. doi: 10.1016/j.vacuum.2014.12.012.
12. Kleideiter G. Function and Production of Coating on Architectural Glass. Basics and overview. *Leybold optics*. 2010.
13. Петров В. Н., Петров Д. В., Брагина Л. Л., Філоненко С. В. Особливості формування оптичних скловиробів складної конфігурації. *Вісник НТУ «ХПІ». Серія: Хімія, хімічна технологія та екологія*. 2016. № 22 (1194). С. 136-139.
14. Немилов С. В. *Оптическое материаловедение: Оптическое стекло: Учебное пособие*. СПб: СПбГУ ИТМО. 2011. 175 с.

References (transliterated)

1. Holand W., Beall G. *Glass Ceramic Technology*. New Jersey: JohnWiley & Sons, 2012. 360 p.
2. Jelle B. P, Kalnaes S. E., Tan Gao. Low-Emissivity Materials for Building Applications: A State of the Art Review and Future Research Perspectives. *Energy and Buildings,* 2015, no. 3, pp. 96–106, doi: 10.1016/j.enbuild.2015.03.024
3. Carter B. C., Norton M. G. *Ceramic Materials. Science and Engineering*. Springer, 2013. 775 p.
4. Bos F., Louter C. Structural Glass in Architecture, *Encyclopedia of Glass Science, Technology, History, and Culture*, Chapter 9.1. 01 February 2021. doi: 10.1002/9781118801017.ch9.1
5. Shelby J. E. *Introduction to Glass Science and Technology.* Second Edition. Cambrige. The Royal Society of Chemistry, 2005. 224 p.
6. Mohelnikova J. Window Glass Coatings. *Green Energy and Technol.,* 2011, no. 33, pp. 913-934.
7. Bragina L. L., Yaittskii S.N., Mashkin V. V. Arhitekturno-stroitel'nye stekla s nizkojemissionnymi jenergosberegajushhimi pokrytijami [Architectural and building glass with low-emission energy-saving coatings]. *Bulleten of NTU "KhPI"*, 2014, no. 16, pp. 165-173.
8. Yashhy`shy`n J. M. *Texnologiya skla u tr`ox chasty`nax.* [*Glass technology in three parts*]. *Part III*, Lviv. Raster-7 Publishing House, 2011, 149 p.
9. Hartmann P., Jedamzik R., Reichel S., Schreder B. Optical glass and glass ceramic historical aspects and recent developments: A Schott view. *Applied Optics,* 2010. Vol. 49, no. 16, pp. D 157–D 176. doi: 10.1364/AO.49.00D157.
10. Petrov D. V., Bragina L. L., Petrova A. M. Problemy` texnologiyi varky` opty`chnogo skla na etapax gomogenizaciyi ta osvitlennya [Problems of optical glass cooking technology at the stages of homogenization and lighting]. *Py`tannya ximiyi i ximichnoyi texnologiyi* [*Questions of chemistry and chemical technology*], 2020, no. 5, pp. 68-72, doi: 10.32434/0321-4095-2020-132-5-68-72.
11. Bull S. J. Elastic properties of multilayer oxide coatings on float glass. *Vacuum,* 2015, no. 114, pp. 150–157, doi: 10.1016/j.vacuum.2014.12.012.
12. Kleideiter G. Function and Production of Coating on Architectural Glass. Basics and overview. *Leybold optics,* 2010.
13. Petrov V. N., Petrov D. V., Bragina L. L., Filonenko S. V. Osobly`vosti formuvannya opty`chny`x sklovy`robiv skladnoyi konfiguraciyi [Features of Optical Products of Complex Configuration Forming]. *Visny`k NTU «XPI». Seriya: Ximiya, ximichna texnologiya ta ekologiya* [*Bulletin of NTU "KhPI". Series: Chemistry, chemical technology and environment*], 2016, no. 22, pp. 136-139.
14. Nemilov, S. V. *Opticheskoe materialovedenie: Opticheskoe steklo: uchebn. posobie*. [*Optical material science: optical glass*], SPb: SPbU ITMO, 2011, 175 p.

Відомості про авторів (About authors)

Liudmyla Bragina – Dr. Sci., professor, Department of ceramic, refractories, glass and enamels technology, National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine; ORCID: 0000-0002-4029-0941; e-mail: bragina_l@ukr.net.

Брагіна Людмила Лазарівна – доктор технічних наук, професор, Національний технічний університет «Харківський політехнічний інститут», кафедра технології кераміки, вогнетривів, скла та емалей; м. Харків, Україна; ORCID : 0000-0002-4029-0941; e-mail: bragina_l@ukr.net.

Serhiy Yaitsky – General Director of Lysychansk Glass Plant LLC; Lugansk region, Lysychansk; ORCID : 0000-0003-2525-1773; Ukraine; e-mail: tehnolog183@gmail.com

Яїцький Сергій Миколайович – генеральний директор ТОВ «Лисичанський скляний завод»; Луганська область, м. Лисичанськ, Україна; ORCID : 0000-0003-2525-1773; e-mail: tehnolog183@gmail.com.

Dmytro Petrov – Ph. D., Department of ceramic, refractories, glass and enamels technology, National Technical University "Kharkiv Polytechnic Institute", Kharkiv, Ukraine; ORCID: 0000-0001-7571-8592; e-mail: petrovdmitry@ukr.net.

Петров Дмитро Вікторович – кандидат технічних наук, Національний технічний університет «Харківський політехнічний інститут», кафедра технології кераміки, вогнетривів, скла та емалей; м. Харків, Україна; ORCID: 0000-0001-7571-8592; e-mail: petrovdmitry@ukr.net.

Olena Starolat – Researcher; National Technical University "Kharkiv Polytechnic Institute"; Department of Ceramics, Refractories, Glass and Enamels; Kharkiv; Ukraine; ORCID: 0000-0003-2742-2628; e-mail: le_star@ukr.net

Старолат Олена Євгенівна – науковий співробітник; Національний технічний університет «Харківський політехнічний інститут», кафедра технології кераміки, вогнетривів, скла та емалей; м. Харків, Україна; ORCID: 0000-0003-2742-2628; e-mail: le_star@ukr.net

Please cite this article as:

Bragina L., Yaitsky S., Petrov D., Starolat O. Integration of modern technology for architectural-building glass production. *Bulletin of the National Technical University "KhPI". Series: New solutions in modern technology*. - Kharkiv: NTU "KhPI", 2021, no. 2 (8), pp. 90–95, doi:10.20998/2413-4295.2021.02.13.

Будь ласка, посилайтесь на цю статтю наступним чином:

Брагіна Л. Л., Яїцький С. Н., Петров Д. В., Старолат О. Є. Інтеграція новітніх технологій у виробництві архітектурно-будівельного флоат-скла. *Вісник Національного технічного університету «ХПІ». Серія: Нові рішення в сучасних технологіях*. – Харків: НТУ «ХПІ». 2021. № 2 (8). С. 90–95. doi:10.20998/2413-4295.2021.02.13.

Пожалуйста, ссылайтесь на эту статью следующим образом:

Брагина Л. Л., Яицкий С. Н., Петров Д. В., Старолат Е. Е. Интеграция технологий в производстве архитектурно-строительного стекла. *Вестник Национального технического университета «ХПИ». Серия: Новые решения в современных технологиях*. – Харьков: НТУ « ХПИ». 2021. № 2 (8). С. 90–95. doi:10.20998/2413-4295.2021.02.13.

АННОТАЦИЯ *Проанализировано современное состояние технологий производства стеклянных изделий, используемых в архитектурно-строительной отрасли. Показана актуальность использования low-E стекол, в частности в стеклопакетах. Рассмотрены инновационные тенденции в производстве листового архитектурно-строительного флоат-стекла с применением современных технологий и оборудования, в частности, на ОАО « Лисичанский стеклозавод «Пролетарий». Установлено, что существенным недостатком энергоэффективных Е-стекол, которые имеют широкий диапазон цветовых характеристик, является недостаточная механическая прочность мягких покрытий, наносимых магнетронным вакуумным напылением. Показано, что технология изготовления Е-стекол с такими покрытиями не позволяет осуществлять их закалку с сохранением всех необходимых эксплуатационных параметров. Приведены физико-химические свойства и эксплуатационные характеристики крупногабаритных стекол с серебряными, солнцезащитными мягкими покрытиями, ламинированных, плоских и радиусных закаленных стекол, а также сферы их применения. Исследованы принципы упрочнения мягких магнетронных покрытий для получения низкоэмиссионных Double Low-E стекол, их состав, комбинации слоев и технологические параметры нанесения многослойных нанопокрытий общей толщиной до 140 нм, что позволило закалять Е-стекло с ними. Проанализированы технологические параметры получения низкоэмиссионных Е-стекол с вариативными покрытиями, которые регулируют спектральные и эксплуатационные показатели данных стеклоизделий в соответствии с межгосударственными стандартами ГОСТ EN 673-2016 и ГОСТ EN 410-2014. Рассмотрены технологические методики закалки листового стекла с нанесенными низкоэмиссионное покрытиями путем создания специальных составов и оптимизации процессов магнетронного нанесения. Рассмотрены основные закономерности расположения слоев пленочной системы* Si_3N_4 / $NiCr$ / Si_3N_4 *для выдерживания термической обработки стекол системы* R_2O-RO-SiO_2 *и предложены принципы корректировки их спектральных и механических характеристик в зависимости от концентрации и соотношения компонентов тонкопленочного покрытия, что будет способствовать созданию вариационного ряда флоат-стекол с необходимым уровнем отражения в инфракрасном спектре.*

Ключевые слова: *флоат-стекло; Low-E покрытия; безопасные стекла; технологии магнетронного напыления; закалка стекла; спектральные характеристики; строительная отрасль; инфракрасный диапазон*

Received 02.05.2021