UDK 666.4 doi: 10.20998/2220-4784.2020.06.02

G. V. LISACHUK, M. V. VED, R. V. KRYVOBOK, A. V. ZAKHAROV, V. V. VOLOSHCHUK, M. S. MAISTAT

DEVELOPMENT TECHNOLOGY OF ELECTRICAL CONDUCTANCE CERAMICS

The article considers the influence of the technological parameters of the composite ceramics production on the specific volume resistivity of the composition and, consequently, on the protective properties against the effects of electromagnetic radiation. The technological parameters included the preparation method, the averaging time of the raw materials, both the pressing and second calcination pressure. Based on the complex of studies carried out, the following technological parameters of production were established: duration of grinding – 60 minutes; the moisture content of the press powder is 6.2%; pressing pressure – 25 MPa; first calcination temperature – 1060 °C; temperature of the second calcination – 1060 °C. The developed technology can be applicated at enterprises that produce ceramic tiles according to high-speed calcination. The resulting material can to protect biological and technical objects from the action of electromagnetic radiation. Further research at selecting a glaze coating for the developed ceramics is aimed.

Keywords: electrical conductance ceramics, composite ceramics, technological parameters, duration of grinding, moisture content of the press powder, pressing pressure, calcination temperature, volume resistivity, flexural strength, water absorption.

Г. В. ЛІСАЧУК, М. В. ВЕДЬ, Р. В. КРИВОБОК, А. В. ЗАХАРОВ, В. В. ВОЛОЩУК, М. С. МАЙСТАТ

ВІДПРАЦЮВАННЯ ТЕХНОЛОГІЇ ЕЛЕКТРОПРОВІДНОЇ КЕРАМІКИ

У статті розглянуто вплив зміни технологічних параметрів виробництва композиційної кераміки на питомий об'ємний опір композиції а також на захисні властивості від впливу електромагнітного випромінювання. До технологічних параметрів було віднесено спосіб приготування, час усереднення сировинних матеріалів, тиск пресування і другого випалу. На підставі проведеного комплексу досліджень встановлено наступні технологічні параметри виробництва: тривалість помелу – 60 хв.; вологість прес-порошку – 6,2%; тиск пресування – 25 МПа; температура першого випалу – 1060 ° С; температура другого випалу – 1060 °С. Розроблена технологія може бути використана на підприємствах, які випускають керамічну плитку зі швидкісним режимом випалу. Отриманий матеріал може бути використано для захисту біологічних і технічних об'єктів від дії електромагнітного випромінювання. Подальші дослідження спрямовані на підбір глазурованого покриття для розробленої кераміки.

Ключові слова: електропровідна кераміка, композитна кераміка, технологічні параметри, тривалість помелу, вологість прес-порошку, тиск пресування, температура випалу, об'ємна стійкість, міцність на згин, водопоглинання.

Г. В. ЛИСАЧУК, М. В. ВЕДЬ, Р. В. КРИВОБОК, А. В. ЗАХАРОВ, В. В. ВОЛОЩУК, Н. С. МАЙСТАТ

ОТРАБОТКА ТЕХНОЛОГИИ ЭЛЕКТРОПРОВОДЯЩЕЙ КЕРАМИКИ

В статье рассмотрено влияние изменения технологических параметров производства композиционной керамики на удельное объемное сопротивление композиции и, следовательно, на защитные свойства от воздействия электромагнитного излучения. К технологическим параметрам было отнесено способ приготовления, время усреднения сырьевых материалов, давление прессования и второго обжига. На основании проведенного комплекса исследований установлено следующие технологические параметры производства: длительность помола – 60 мин.; влажность пресс порошка – 6,2 %; давление прессования – 25 МПа; температура первого обжига – 1060 °С; температура второго обжига – 1060 °С. Разработанная технология может быть использована на предприятиях, которые выпускающих керамическую плитку по скоростному режиму обжига. Полученный материал может быть использован для защиты биологических и технических объектов от действия электромагнитного излучения. Дальнейшие исследования направлены на подбор глазурного покрытия для разработанной керамики.

Ключевые слова: электропроводящая керамика, композиционная керамика, технологические параметры, продолжительность помола, температура обжига, объемная устойчивость, прочность на изгиб, водопоглощение.

Introduction.

Human life takes place in conditions of increased concentration of electromagnetic radiation (EMR) of industrial, medical, research equipment, television and radio stations, satellite and cellular communications, and many others. EMR can cause certain functional disturbances in the human body – in some cases irreversible: increased fatigue, central nervous system disorder, clouding of the lens of the eye, etc. In addition, these emissions have an adverse effect on the technical condition of electronic systems, up to and including their disabling. Therefore, the development of materials that effectively protect biological and technical objects from the EMR effect is an urgent problem.

One of the directions of creating materials that protect against the EMR is the introduction of electrical conductance additives into the dielectric matrix. It was preliminarily established [1] that silicon carbide should be used as an electrical conductance additive, and a ceramic mass for the production of facing tiles should be used as a dielectric matrix.

It is known that radio-absorbing materials (RAM) are structural dielectrics that effectively absorb the electromagnetic energy of radio waves [2, 3].

According to the classification, radio-absorbing materials can be magnetic and non-magnetic. In turn, non-magnetic radio-absorbing materials are subdivided into gradient, interference and combined [4].

The general statement of the problem and its connection with important scientific or practical tasks.

It is known that the volume resistivity of electrical conductance ceramics obtained by the composite method depends mainly on the type of electrical conductance additive (conductor, semiconductor). An important role in the regulation of conductivity is played by the nature of the distribution of the additive in the volume of the dielectric matrix (uniformity, optimal grain size, the presence of contacts between electrical conductance particles).

The distribution of the electrical conductance additive in volume is primarily influenced by the technological parameters of production: the preparation method, the time of raw materials averaging, the pressing pressure, the temperature and duration of the first and second calcination. By changing the technological parameters of the composite ceramics production, it is possible to influence the volume resistivity of the composition and, consequently, the protective properties against the effect of EMR [5–7].

Therefore, the task was set to study the influence of technological parameters of production: preparation method, averaging time of raw materials, pressing and second calcination pressure on the following properties of electrical conductance ceramics: volume resistivity – lg ρ_v, flexural strength – σ_{fl} and water absorption – W.

Experimental part.

The process of grinding the components of the dielectric matrix and the electrical conductance filler is one of the most critical stages in the technology of electrical conductance ceramics, since the conductivity and physical and mechanical properties of the composition depend on the homogeneity of the mixture [6–8]. The authors found that the duration of grinding the raw components significantly affects the volume resistivity of the composition. The influence of grinding duration in the range of 20 – 70 min on the volume resistivity and physical and mechanical properties of composite ceramics was investigated.

The technological scheme (Fig. 1) for the preparation of samples provides wet joint grinding as the optimal method for homogenizing the initial components. Then the slip is dehydrated to obtain a press powder, semi-dry pressing, drying and calcination.

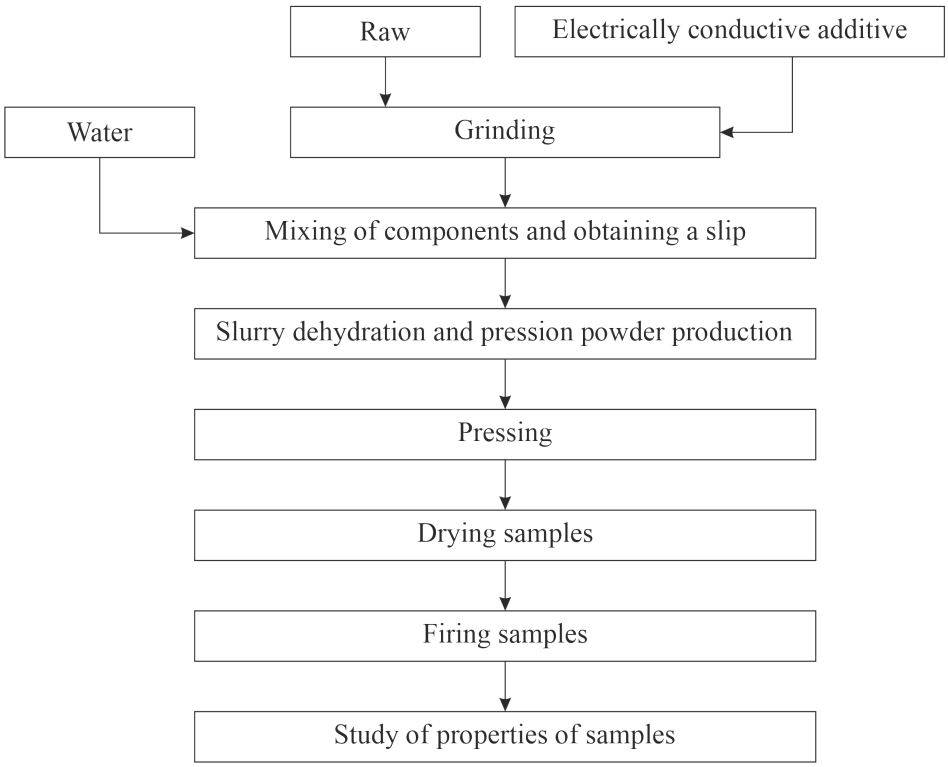

Fig. 1 Sample preparation scheme using slip method

A preliminary developed composition of electrical conductance ceramics [9], in which silicon carbide acted as an electrical conductance filler, was used in the study.

The technological parameters of the preparation of the samples under study were:

- grinding of the raw components – from 20 to 70 minutes with a step of 10 minutes;
- the moisture content in the press powder – 6.2%, the calcination temperature – 1060 °C;
- the calcination duration – 30 minutes.

Fig. 2 shows a graphic interpretation the results of the study of the grinding time effect.

As one can see from Fig. 2 the most optimal grinding time, from the point of view of obtaining the minimum value of specific volume resistivity, water absorption and maximum value of flexural strength, is 60 minutes.

As follows from the literature data [6], the moment of the highest homogeneity of the mixture coincides with the moment of volume resistivity growth, i.e. with an inflection in the dependence of volume resistivity on the duration of grinding.

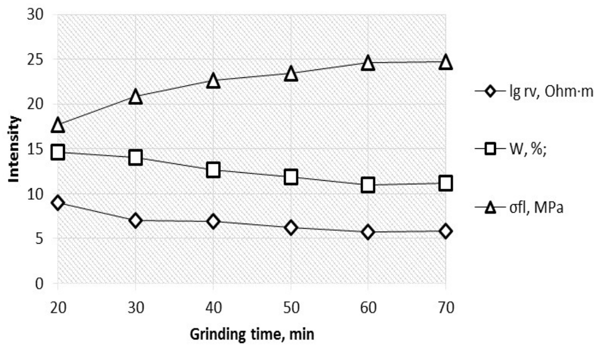

Fig. 2. A graphical interpretation the results of the study of the grinding time effect.

An increase in the duration of grinding over 60 min has practically no effect on the properties under study. Therefore, 60 minutes was chosen as the optimal grinding time. It can be stated that the values of other investigated properties such as water absorption and flexural strength are within the permissible limits of GOST 6141-91. The decrease in the volume resistivity and water absorption and the increase in the flexural strength with an increase in the grinding duration are explained by a more uniform distribution of silicon carbide over the volume of the ceramic mass.

In particular, during minimum grinding time, silicon carbide particles form small conglomerates of uneven grain size, and with a maximum grinding time, silicon carbide particles form a contact structure, due to which there is a decrease in the volume resistivity and improvement of physical and mechanical properties.

The pressing pressure, as well as the mass concentration of silicon carbide, determines the volume resistivity and the physic-mechanical characteristics of the compositions [6, 7, 10]. The pressing process of electrical conductance ceramic composite materials is one of the most important technological stages. Currently, tiles for interior wall cladding are made in a semi-dry way from press powder with a moisture content of 6 – 8 % at a specific pressure of 10 – 20 MPa.

The study of the pressing pressure influence on the volume resistivity, water absorption and flexural strength was carried out in the range of 5 – 35 MPa.

The preparation of the samples was carried out according to the scheme given above, the calcination temperature of the samples under study was 1060 °C, and the duration was 30 minutes.

The dependence of the volume resistivity and physical and mechanical properties of composite ceramics on the pressing pressure is shown in Fig. 3.

It is known [6, 10] that during dynamic or static pressing of electrical conductance mixtures, particles of dispersed electrical conductance filler (in our case, silicon carbide) approach each other. This improves the contacting conditions and reduces the transition resistance between them, which explains the decrease in the volume resistivity of the studied ceramics with increasing pressing pressure.

This makes it possible to obtain a composition with a minimum content of an electrical conductance additive characterized by a stable electrical conductivity with.

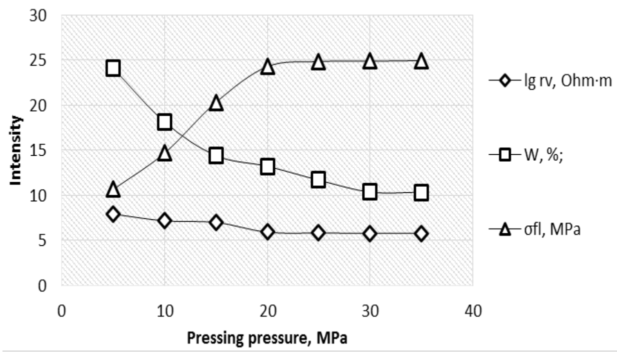

Fig. 3. Dependence of volume resistivity, water absorption and flexural strength of composite ceramics on pressing pressure

As one can see from Fig. 3, with an increase in the pressing pressure, there is a decrease both in the volume resistivity and in water absorption with a simultaneous increase in the flexural strength of the composition. A decrease in the volume resistivity is due to a decrease in the contact resistance between the particles of the electrical conductance additive as well as an increase in the contact area of the silicon carbide particles.

At pressing pressure above 25 MPa, the change in volume resistivity, flexural strength and water absorption of the composition occurs insignificantly, therefore, the pressing pressure equal to 25 MPa should be considered optimal.

Ceramic tiles for interior wall cladding are produced using the double-calcination technology. It is known [11–14] that silicon carbide, when exposed to high temperatures, undergoes oxidation producing quartz, as a result an increase in the volume resistivity of the composition occurs, and, therefore, the protective properties decreasing.

Therefore, further studies were carried out, revealing the effect of the second calcination on the volume resistivity and physical and mechanical properties of composite ceramics.

For the study, samples were taken after the first calcination, and the second calcination was carried out according to the speed mode at a temperature of 1060 °C during 30 minutes.

The properties of the specimens after the first and second calcination are shown in Table 1.

Table 1 – Properties of specimens after the first and second calcination

	Volume resistivity, Ohm·m		Water absorption, %	Flexural strength, MPa
	ρ_v	lg ρ_v		
First	$5.77 \cdot 10^5$	5.76	11	25
Second	$8.84 \cdot 10^5$	5.95		

Table 2 – Technological parameters for the production of electrically conductive ceramics

Parameter	Value
Method of preparation	Slip
Mixing duration, min	60
Press powder moisture, %	6,2
Pressing pressure, MPa	25
First calcination temperature, ºC	1060
Second calcination temperature, ºC	
First calcination time, min	30
Second calcination time, min	

Based on the complex studies carried out, the technological parameters of the electrical conductance ceramics production were established, the values of which are given in Table 2.

Conclusions and perspectives of future investigations in this direction

Human life takes place in conditions of high concentration of electromagnetic radiation and can cause certain functional disorders in the human body. Therefore, the development of materials that effectively protect biological and technical objects from the effects of electromagnetic radiation is an urgent task.

The technological parameters of the electrical conductance ceramics production were established: duration of grinding – 60 min; moisture content of the press powder – 6.2 %; pressing pressure – 25 MPa; temperature of the first calcination – 1060 °C; temperature of the second calcination – 1060 °C.

The developed technology can be used at enterprises producing ceramic tiles according to the high-speed calcination mode. Such ceramics can be used to protect biological and technical objects from the action of electromagnetic radiation.

Further research is aimed at selecting a glaze coating for the developed ceramics.

Список літератури

1. Лисачук Г.В., Кривобок Р.В., Лисачук Л.Н., Щукина Л.П., Федоренко Е.Ю., Емаева О.А. Влияние магнитных и немагнитных добавок на свойства облицовочной керамики // Вісник НТУ «ХПІ». – Х.: 2005. – № 51. – С. 168–173.
2. Lisachuk G., Krivobok R., Zakharov A., Prospects for creations of radio-absorbing ceramic materials, Conference for young scientist in ceramics SM–2013, 2013, 64-65.
3. Lisachuk G.V., Krivobok R.V., PItak Ya.M., Perspektivi stvorennya radiopoglinayuchih materIaliv v Ukrayini Conference Informatssyns tehnologiyi: nauka, tehnika, tehnologiya, osvita, zdorov’ya, 2013, Ch. II, 257.
4. Lisachuk G., Krivobok R., Zakharov A., Optimization of the compositions area of radiotransparent ceramic in the SrO-Al2O3-SiO2 system Przegląd Elektrotechniczny, 93 (2017), nr 3, 79-82.
5. Ковнеристый Ю.К., Лазарева И.Ю., Раваев А.А. Материалы, поглощающие СВЧ-излучения. – М.: Наука, 1982. – 165 с.
6. Автономов И.В., Горелов В.П., Пугачев Г.А. Шлакощелочной резистивный материал. – Новосибирск: Институт теплофизики СО АН СССР, 1989. – 110 с.
7. Горелов В.П., Пугачев Г.А. Резистивные композиционные материалы и мощные резисторы на их основе. – Новосибирск: Наука, 1987. – 216 с.
8. Тимохова М.И. Прессуемость керамических пресс-порошков в зависимости от способа их приготовления // Стекло и керамика. 2004. – №4. – С. 18–20.
9. Патент 18322 Україна, МПК С 04 В 33/00. Напівпровідна керамічна маса: Г.В. Лісачук, Р.В. Кривобок, Ю.Д. Трусова, Л.О. Бєлостоцька, Л.В. Павлова, Л.П. Щукіна; НТУ «ХПІ». – № 200603365; Заявл. 28.03.06; Опубл. 15.11.06, Бюл. № 11. 4 с.
10. Андреева Н.А., Орданьян С.С. Роль дисперсности компонентов и давления прессования при реализации свойств электротехнического фарфора // Огнеупоры и техническая керамика. 2003. – №6. – С. 17–21.
11. Гнесин Г.Г. Карбидокремниевые материалы. – М.: Металлургия, 1977. – 216 с.
12. Карбид кремния / С.А. Добролеж, С.М. Зубкова, В.А. Кравец и др. – К.: Гос–ное из–во техн. лит–ры УССР, 1963. – 316 с.
13. Францевич И.Н. Карбид кремния. – К.: Наукова думка, 1966. – 360 с.
14. Конструкционные карбидокремниевые материалы / В.В. Карлин, Г.С. Олейник, В.И. Островерхов; Под ред. А.П. Гаршина. – Л.: Машиностр., 1975. – 152 с.

References (transliterated)

1. Lisachuk G.V., Krivobok R.V., Lisachuk L.N., Shhukina L.P., Fedorenko E.Ju., Emaeva O.A. Vlijanie magnitnyh i nemagnitnyh dobavok na svojstva oblicovochnoj keramiki // Visnik NTU «KhPI». – Kh.:, 2005. – № 51, – pp. 168–173.
2. Lisachuk G., Krivobok R., Zakharov A., Prospects for creations of radio-absorbing ceramic materials, Conference for young scientist in ceramics SM–2013, 2013, 64-65.

3. Lisachuk G.V., Krivobok R.V., PItak Ya.M., Perspektivi stvorennya radiopoglinayuchih materIaliv v Ukrayini Conference Informatssyns tehnologiyi: nauka, tehnika, tehnologiya, osvita, zdorov'ya, 2013, Ch. II, 257.
4. Lisachuk G., Krivobok R., Zakharov A., Optimization of the compositions area of radiotransparent ceramic in the SrO-Al2O3-SiO2 system Przegląd Elektrotechniczny, 93 (2017). – Bjul. 3, pp. 79–82.
5. Kovneristyj Ju.K., Lazareva I.Ju., Ravaev A.A. Materialy, pogloshhajushhie SVCh-izluchenija. – M.: Nauka, 1982. – 165 p.
6. Avtonomov I.V., Gorelov V.P., Pugachev G.A. Shlakoshhelochnoj rezistivnyj material. – Novosibirsk: Ins. teplofiziki, 1989. 110 p.
7. Gorelov V.P., Pugachev G.A. Rezistivnye kompozicionnye materialy i moshhnye rezistory na ih osnove. – Novosibirsk: Nauka, 1987. – 216 p.
8. Timohova M.I. Pressuemost' keramicheskih press-poroshkov v zavisimosti ot sposoba ih prigotovlenija // Steklo i keramika. 2004. – Bjul. 4, – pp. 18–20.
9. Patent 18322 Ukraïna, MPK S 04 V 33/00. Napivprovidna keramichna masa: G.V. Lisachuk, R.V. Krivobok, Ju.D. Trusova, L.O. Bєlostoc'ka, L.V. Pavlova, L.P. Shhukina; NTU «KhPI». № 200603365; Zajavl. 28.03.06; Opubl. 15.11.06, Bjul. № 11. – 4 p.
10. Andreeva N.A., Ordan'jan S.S. Rol' dispersnosti komponentov i davlenija pressovanija pri realizacii svojstv jelektrotehnicheskogo farfora // Ogneupory i tehnicheskaja keramika. 2003. – Bjul. 6, – pp. 17–21.
11. Gnesin G.G. Karbidokremnievye materialy. – M.: Metallurgija, 1977. – 216 p.
12. Karbid kremnija / S.A. Dobrolezh, S.M. Zubkova, V.A. Kravec i dr. – K.: Gosudarstvennoe izdatel'stvo tehnicheskoj literatury USSR, 1963. – 316 p.
13. Francevich I.N. Karbid kremnija. K.: Naukova dumka,1966. – 360p.
14. Konstrukcionnye karbidokremnievye materialy / V.V. Karlin, G.S. Olejnik, V.I. Ostroverhov; Pod red. A.P. Garshina. – L.: Mashinostr., 1975. – 152 p.

Надійшла (received) 19.10.2020

Відомості про авторів / Сведения об авторах / About the Authors

Лісачук Георгій Вікторович (Лисачук Георгий Викторович, Lisachuk George Viktorovych) – професор кафедри Технології кераміки, вогнетривів, скла та емалей, Національний технічний університет «Харківський політехнічний інститут», м. Харків, Україна;
ORCID: http://orcid.org/0000-0002-7157-9115
e-mail: lisachuk@kpi.kharkov.ua

Ведь Марина Віталіївна (Ведь Марина Витальевна, Ved Maryna Vitaliivna) – професор кафедри кафедри загальної та неорганічної хімії, Національний технічний університет «Харківський політехнічний інститут», м. Харків, Україна;
ORCID: http://orcid.org/0000-0001-5719-6284
e-mail: vmv@kpi.kharkov.ua

Кривобок Руслан Вікторович (Кривобок Руслан Викторович, Kryvobok Ruslan Viktorovych) – старший науковий співробітник Науково-дослідної частини, Національний технічний університет «Харківський політехнічний інститут», м. Харків, Україна;
ORCID: http://orcid.org/0000-0002-2334-4434
e-mail: krivobok491@gmail.com

Захаров Артем Вячеславович (Захаров Артем Вячеславович, Zakharov Artem Viacheslavovych) – старший науковий співробітник Науково-дослідної частини, Національний технічний університет «Харківський політехнічний інститут», м. Харків, Україна;
ORCID: http://orcid.org/0000-0002-0120-8263
e-mail: zakharovartem106@gmail.com

Волощук Валентина Василівна (Волощук Валентина Васильевна, Voloshchuk Valentyna Vasylivna) – аспірант кафедри Технології кераміки, вогнетривів, скла та емалей, Національний технічний університет «Харківський політехнічний інститут», м. Харків, Україна;
ORCID: http://orcid.org/0000-0003-2120-3088
e-mail: valenty93vol@gmail.com

Майстат Микита Сергійович (Майстат Никита Сергеевич, Maistat Mykyta Serhiiovych) – аспірант кафедри Технології кераміки, вогнетривів, скла та емалей, Національний технічний університет «Харківський політехнічний інститут», м. Харків, Україна;
ORCID: http://orcid.org/0000-0002-1875-3946
e-mail: aichemict777@gmail.com