Enhancement of micalex composition for improving its electric insulation characteristics

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Abstract. Creation of materials with improved electric insulation properties is an urgent problem, and micalex is one of the promising materials for developing such compositions. Mica is a good insulator and “mica + glass” composition has considerable mechanical strength, therefore, micalex can be considered as a promising construction and electric insulation material. Objectives of the paper: To obtain micalex composition with improved electric insulation characteristics. Task: Studying the mechanism of interaction between components of the “mica + glass + volcanic cinder” composite and nature of changes in the electric insulation characteristics of micalex with addition of volcanic cinder. Objects of studies were samples of composite micalex material with addition of different amounts of volcanic cinder and with different types of mica as filling material. Methods of investigation. Studies were performed using present-day methods of physical and chemical analysis: X-ray phase analysis and infrared spectroscopy technique. Eclectic and physical characteristics were determined using standard procedures. Results of study: Development of micalex of new composition having sufficient mechanical strength and enhanced electric insulation characteristics owing to addition of volcanic cinder.

1. Introduction
Development of energy, electric engineering, aerospace and transport industries, growth of electricity and heat production by nuclear power plants necessitate development of new and enhancement of the existing electric insulation materials. Such materials shall combine high dielectric properties, mechanical strength, thermal and chemical endurance with economic efficiency of their production and use and shall meet all those requirements. Mica has high electric insulation properties [1-7]. Micalex is a composite material based on the potash mica of muscovite KAl₂[AlSi₃O₁₀](OH)₂ that can be used both as construction and electric insulation material [8-10]. It is produced by hot pressing of the mixture of finely crystalline mica and finely dispersed low-melting glass [11-13]. Micalex is a hard, dense material; it is not water absorbing, it is chemically stable, resistant to temperature (up to 800°C) and to its violent fluctuations; it is a good insulator, it allows mechanical treatment, particularly, cutting and polishing [14-17]. Micalex is used as inserts in the blowout chambers of...
electric locomotives and in the transient terminal blocks of the floor-mounted electric furnaces, in the electrovacuum machinery for manufacture of high-power tube holders, combs for inductance coils, wiring plates, etc.

For improving the dielectric properties of micalex, different additives are introduced into its composition. Products of volcanic origin, particularly, volcanic cinders as additives are of interest. Volcanic cinder is a mixture of dust and sand with particles less than 2 mm that was formed during natural (in natural conditions) magma disintegration. Volcanic cinder is formed during diffusion of liquid or solid lava of different composition. Depending on the size of particles, force of eruption and wind speed the volcanic cinder settles on the ground surface as powerful layers as, for example, in Magadan deposits whose thickness is as high as 20 meters. Cinder reserves in the deposits at the Khasyn and Chitar rivers of the Magadan region are estimated at 3 million m3.

In addition to the existing deposits of volcanic cinder, volcanoes of the Earth annually erupt on the average up to $3 \times 10^9$ tons of volcanic cinder. Therefore, large-scale application of volcanic cinder in the micalex production may do good for mankind thanks to economically efficient utilization (owing to simplicity of its production [18]) of particles hazardous for respiratory system of a human being.

2. Methods and materials
Samples were studied using X-ray phase analysis and an infrared spectroscopy technique. Eclectic and physical characteristics were determined using known standard techniques. Objects of studies were samples of composite micalex material with different share of volcanic cinder and different types of mica as filling material [19, 20].

3. Results and discussion
For enhancing the electric insulation properties the “mica + glass + volcanic cinder” composition was developed. Glass in this composition is a matrix, mica and volcanic cinder are used as reinforcing components.

X-ray phase analysis of volcanic cinder showed that from the standpoint of the structure it represents an amorphous mass with low degree of crystallization. Tempered cinder has high degree of crystallization (solidification) which is confirmed by obvious reflexive actions on the background of amorphous ring. A diffractogram of “mica + glass + volcanic cinder” composite material is a set of reflexive actions characteristic of potash mica of muscovite since volcanic cinder and glass have no clearly defined reflexes. Occurrence of new reflective actions was not observed.
Figure 1 shows IR-spectra of micalex composite material with addition of different amounts of volcanic cinder (5, 10, 15 %). For interpretation of the composite material spectra the IR-spectra of its components were taken: glass 203, grinded muscovite, tempered and non tempered volcanic cinder [21, 22]. IR-spectrum of micalex is mainly an overlapping spectrum of glass, mica and volcanic cinder. IR-spectrum of micalex in the KBr region is represented by double maximum with frequencies of 480 cm\(^{-1}\) and 535 cm\(^{-1}\) typical of Si-O-Si vibrations. NaCl spectrum in the region of spectral prisms has intensive bands with maxima of 720 cm\(^{-1}\) and 760 cm\(^{-1}\). A band with maximum of 850 cm\(^{-1}\) corresponds to librational vibrations of OH. A wide intensive band at a frequency of 1000 cm\(^{-1}\) is typical of Si-O vibrations. A weak absorption band at 1400 cm\(^{-1}\) corresponds to B-O-B vibrations. A band at a frequency of 3640 cm\(^{-1}\) is typical of that for structural OH groups.

There are no well-marked differences in the IR-spectra of tempered and non-tempered cinder. Glass 203 spectrum is represented by a system of wide bands at 465 cm\(^{-1}\), 1000 cm\(^{-1}\) that are typical of deformation and valence vibrations of silicon-oxygen bonds. Deformation vibrations of B-O-B group are represented by 740 cm\(^{-1}\) band, and valence vibrations are represented by 1400 cm\(^{-1}\) band.

Mechanical and dielectric characteristics of micalex of different composition are given in Table 1. With addition of 5% of non-tempered volcanic cinder, the specific volumetric electric impedance of micalex is twice as high as that of micalex with 60% of muscovite and 40% of low-melting glass 203. Tangent of the angle of dielectric losses is minimum and comparable to the value of micalex with common composition (without addition of volcanic cinder). Tangent of the angle of dielectric losses is an important characteristic of dielectric that reflects the change in the dielectric state and losses in it. In the ideal dielectric the angle tangent of dielectric losses equals zero. The value 4·10\(^{-3}\) is low for that indicator and thus evidences high quality of dielectric material. Electric strength of micalex with 5% content of non-tempered volcanic cinder in its composition is comparable to values of electric strength of micalex without the additive.

With growth of cinder content from 5% to 15% the bending strength reduces by 25.5%. Specific volumetric electric impedance reduces in this case by the order of six. Tangent of dielectric losses angle does not change significantly. There is a tendency towards micalex density reduction and to
water absorption increase. This dependence is explained by the fact that with the growing amount of volcanic cinder in the micalex composition the non-homogeneity of the “mica - low melting glass” boundary increases that contributes to higher composite porosity; density lowers and water absorption increases, accordingly.

Regularities of changes in the properties of “phlogopite+glass+non tempered volcanic cinder” composite material vs cinder content are the same. It is advisable to mention even higher reduction of bending strength and specific insulation resistance with growth in the volcanic cinder content. Presence of 10% of volcanic cinder in the composite mass reduces bending strength by 20%, and specific insulation resistance reduces by the order of six.

Introduction of 5% of preliminarily tempered volcanic cinder ensures higher mechanical strength and better dielectric characteristics. Electric strength in this case grows considerably (by 45%) as compared to average electric strength of micalex without addition of volcanic cinder. Specific insulation resistance grows 2.7 times. Tangent of dielectric losses angle does not practically change and remains low. Density, water absorption and bending strength change negligibly as compared to micalex values without addition of volcanic cinder.

**Table 1.** Mechanical and dielectric characteristics of micalex of different composition.

| Micalex composition                        | Amount of addition by mass, % | Bending strength, Mpa | Specific insulation resistance, Ohm-m | Tangent of dielectric losses angle | Electric strength, MW/m | Water absorption, % | Density, kg/m³ |
|---------------------------------------------|--------------------------------|-----------------------|---------------------------------------|-----------------------------------|------------------------|---------------------|------------------|
| Muscovite (60), glass 203 (40)              | 70-140                         | 10⁶-10¹²              | 0.003-0.010                           | 12-20                             | 0.050                  | 3000                |
| Non tempered cinder (5), muscovite (60)     | 102                            | 2.0·10¹²              | 0.004                                 | 7                                 | 0.020                  | 2760                |
| glass 203 (35)                              |                                |                       |                                       |                                   |                        |                     |
| Non tempered cinder (10), muscovite (60)    | 96                             | 2.2·10¹⁰              | 0.014                                 | 13                                | 0.232                  | 2660                |
| glass 203 (30)                              |                                |                       |                                       |                                   |                        |                     |
| Non tempered cinder (15), muscovite (60)    | 76                             | 10⁷                   | 0.004                                 | 4                                 | 1.759                  | 2520                |
| glass 203 (25)                              |                                |                       |                                       |                                   |                        |                     |
| Non tempered cinder (5), muscovite (60)     | 102                            | 2.4·10¹²              | 0.006                                 | 3                                 | 0.041                  | 2730                |
| glass 203 (35)                              |                                |                       |                                       |                                   |                        |                     |
| Non tempered cinder (10), muscovite (60)    | 82                             | 10⁷                   | 0.014                                 | 5                                 | 0.183                  | 2670                |
| glass 203 (30)                              |                                |                       |                                       |                                   |                        |                     |
| Non tempered cinder (5), muscovite (60)     | 80                             | 2.7·10¹²              | 0.006                                 | 29                                | 0.071                  | 2700                |
| glass 203 (35)                              |                                |                       |                                       |                                   |                        |                     |

Mechanical properties of some compositions were additionally subjected to high-temperature tests. Bending strength of “muscovite+glass+non tempered volcanic cinder” composition at 400°C is 58.1 Mpa, or 23.6% lower than that parameter at a room temperature.
sample with 10% addition of non-tempered cinder at heating up to 400°C reduces by 10.9% and at that temperature it is equal to 73.1 Mpa, whereas bending strength of “glass+mica” composition at heating up to 400°C reduces by 33% and equals 67.9 MPa. Those results proved higher heat resistance of composition with mica and phlogopite as a filler.

4. Conclusion
Technology for manufacture of micalex with enhanced electric insulation properties owing to addition of volcanic cinder has been developed. Experimental studies have shown that addition of 5% of non-tempered volcanic cinder enhances the electric insulation properties of the composite. It was found out that with the increase in percentage of volcanic cinder content in the composite the mechanical strength and dielectric properties degrade. Causes of this tendency have been identified.

Micalex samples with addition of different percent of volcanic cinder to the mass were studied using X-Ray analysis and IR-spectroscopy.

It was found out that addition of 5% of tempered volcanic cinder into micalex composition notably enhances dielectric properties of the composite. Mechanical characteristics of such a sample do not practically change.

Mechanical properties of some composites with the use of different types of mica (mucrovite and phlogopite in particular) were additionally subjected to high-temperature tests. Results of tests evidenced higher heat resistance of composites with presence of mica and phlogopite.

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