Research Group

InfoMine

Marketing services in field of mineral resources,
metallurgy and chemical industry

Mica (Muscovite) Market Research in the CIS

Demo

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Internet: www.infomine.ru
e-mail: info@infomine.ru

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Annotation

The report is devoted to investigation of current standing of market of muscovite mica in the CIS and forecast of the market development. The report consists of 7 Sections, contains 105 pages, including 19 Figures, 41 Tables and Appendices. This work is desk study. As information sources, we used data of Rosstat, Inter-State Committee on Statistics of CIS countries, Federal Customs Service of Russia, official domestic railage statistic of JSC RZhD (former Ministry of Railway Transport of Russia), sectoral (industrial) and regional press, annual and quarterly reports of companies, as well as data from web-sites of company-producers and consumers of muscovite.

The first Section of the report presents brief characteristics of world market of mica, including data on mining muscovite in various countries in 2001–2006, structure of consumption of muscovite in USA and dynamics of prices on the product for the latest 7 years, as well as prices on mica in some countries in 2007.

The second Section is devoted to description of the main properties of mica-muscovite and analysis of resources base of muscovite in CIS countries. The Section considers regional structure of distribution of mica reserves in Russia, data on reserves of the greatest deposits, as well as requirements, imposed on quality of the resources.

The third Section is devoted to analysis of mining muscovite in CIS countries, including statistical data on production of muscovite in Russia in 1999–2006, description of muscovite-containing ore dressing process, characteristics of mica-processing production. In addition, brief characteristics of company-producers of muscovite is presented.

The fourth Section presents description of current standing of leading company-producers of muscovite in Russia, including data on range of their products, volumes and destinations of supplies for the latest several years, and plans on further development of the production. Besides, new projects on mining of muscovite in Russia are presented.

The fifth Section is devoted to analysis of foreign trade of CIS countries in muscovite, including statistics of the foreign trade transactions in bulk and in money terms, regional structure of export and import of muscovite, data on volumes and destinations of the supplies of the main exporters and importers.

The sixth Section presents analysis of consumption of muscovite in Russia, including supply-demand balance of muscovite in 1999–2006, sectoral and regional pattern of consumption of muscovite, description of current standing of the greatest company-consumers of muscovite.

The seventh, final Section of the report presents forecast of development of muscovite market in Russia up to 2010. Appendices present State Standards (GOST) on some of grade muscovite, prices on muscovite of some Russian companies, as well as contact information on company-producers of muscovite in CIS countries.

Introduction

A group of minerals having perfect basal cleavage and capable of splitting into thin laminas is called mica. Chemically they contain complex silicate of aluminium and alkalies with hydroxyl. They crystallize in monoclinic system. Some varieties may contain iron, magnesium, lithium and rearely fluorine, barium, manganese and vandium. There are seven important mica minerals:

- Muscovite or potassium mica $H_2KAl_3(SiO_4)_3$
- Paragonite or sodium mica $H_2NaAl_3(SiO_4)_3$
- Lepidolite or lithium mica K Li $Al(OH, F)_2Al(SiO_4)_3$
- Phlogopite or magnesium mica $H_2KMg_3Al(SiO_4)_3$
- Biotite or magnesium iron mica $(H_2K)(Mg, Fe)_3Al(SiO_4)_3$
- Zinnwaldite or lithium iron mica $Li_2K_2Fe_2Al_4Si_7O_{24}$
- Lepidomelane or iron mica $(H, K)_2(Fe, Al)_4(SiO_4)_5$

Muscovite is the commonest of all and whenever the word mica is used it is understood to mean muscovite.

Muscovite, known also as white or potassium mica is a mineral of mica group, having chemical composition, emphasized by formula $KAl_2[AlSi_3O_{10}] (OH)_2$. "Muscovite" - the name comes from the word Muscovy, the old name of Russia commonly used in West Europe, because muscovite was imported to the West through Moscow and was known as Muscovy-glass (vitrum Muscoviticum), as it was used in Russia for windows. It occurs as scaly crystals, sheet-grain flaky aggregates which are sometimes shell-shaped.

Sericite - small flakes of muscovite, having a silky luster.

Fuxite - Cr-muscovite is bright emerald-green in color. Muscovite in thin cleavage sheets ranges from colorless though grey to dark-grey, often with a yellowish or greenish shade. It has a vitreous luster, and its luster is pearly on cleavage plains. It has quite perfect cleavage. Hardness: 2-3. Streak: white.

Muscovite mica belongs to group 37 of philosilicates, having layered or thin-sheet structure. Muscovite mica is among commercially important micas used in a number of industries.

Mica's value is based on several of its unique physical properties. The crystalline structure of mica forms layers that can be split or delaminated into thin sheets. These sheets are chemically inert, dielectric, elastic, flexible, hydrophilic, insulating, lightweight, platy, reflective, refractive, resilient, and transparent to opaque. Mica is stable when exposed to electricity, light, moisture, and extreme temperatures. Based on its abundance and superior electrical properties, muscovite is the principal mica used by industry.

Owing to the aforementioned exceptional properties, muscovite mica is used as insulation material in high-voltage and high-power electrical machines, condensers and radio tubes, in electronic instruments, water columns, and high-duty boilers, in peepholes of industrial furnaces with high temperatures, and in other industrial products and instruments.

MECHANICAL, PHYSICAL AND OTHER PROPERTIES of MUSCOVITE MICA:

Dielectric Constant	6.5 to 8.7 (20° C- 1 MHZ)
Volume Resistivity	2×10^{13} to 1×10^{17} at 20°C (Ohm-cm)
Color	Brown, Green
Moh's Hardness	2.8 to 3.2
Subcategory	Muscovite
Thermal Conductivity	16×10^{-4} (W/M K 20 C)
Specific Heat	0.207
Shore Hardness	80 to 150
Optic Axial Angle (°)	50 to 75
Dielectric Strength	Clear Ruby 3000 to 6000 (Volts/Mil)
Power Factor (1/0)	.0001 - .0004
Max. Coefficient of Expansion	0.000036 (per°C)
Modulus of Elasticity	About 25×10^{6} (lb/in^2)
Water of Constitution	4.5 %600 to 800 %
Max. Temperature	600

Sheet micas are produced from raw materials extracted in mining operations. Sheet mica is resistant and completely inert to chemical agents, solvents, acids, alkalis, mineral oils, and salts and is virtually unaffected by corrosion. Mica has a high compressive strength, good elasticity, and a high modulus of elasticity

Mica is found in pegmatites intruding mica schists. It is found to occur in book form in the pegmatites. The mode of formation of mica which is found in the form of small flakes to big slabs cleavable into the fine laminae is still the subject of active research.

1. Review of world market of mica

Worldwide volume of consumption of *sheet mica* (muscovite, phlogopite, vermiculite), according to US Geological Survey (USGS) is around around 5.2 kt per year; the consumption of other kinds of mica (including ground, crushed and scrap) is around 300 kt. World reserves and resources of mica have not yeat been estimated.

In 2006, according to estimate of USGS, world production of crushed mica and scrap decreased almost 5% year-on-year to 280 kt (Table 1). World production of sheet mica in latest years remains stable, around 5.2 kt per year (Table 2).

Table 1. World production of mica (crushed and scrap) in 2001-2006, kt

Country	2001	2002	2003	2004	2005	2006
Argentina	2.1	1.8	1.9	2.2	2.2	n.a.
Brazil	4.0	4.0	5.0	5.0	5.0	4.0
India	2.4	3.5	2.6	3.7	3.7	3.0
Iran	3.3	2.8	5.5	7.0	7.0	n.a.
Spain	2.5	2.5	2.5	2.5	2.5	n.a.
Canada	17.5	17.5	17.5	17.5	17.5	18.0
South Korea	109.3	29.9	33.6	59.2	50.0	40.0
Malaysia	4.1	3.7	3.6	3.5	3.6	n.a.
Norway	2.5	2.6	2.6	2.6	2.7	n.a.
Russia	100.0	100.0	100.0	100.0	100.0	100.0
USA	97.8	81.1	78.6	99.2	78.1	93.0
Taiwan	9.7	6.6	3.2	3.0	8.6	n.a.
France	10.0	10.0	10.0	10.0	10.0	10.0
Other	2.8	3.0	4.4	3.6	3.1	15.0
Total:	**368.0**	**269.0**	**271.0**	**319.0**	**294.0**	**280.0**

Note: n.a. – data are not available
Source: USGS

Table 2. World production of sheet mica in 2001-2006, t

Country	2001	2002	2003	2004	2005	2006
India	3500	3500	3500	3500	3500	3500
Russia	1500	1500	1500	1500	1500	1500
Other	200	200	200	200	200	200
Total:	**5200**	**5200**	**5200**	**5200**	**5200**	**5200**

Source: USGS

Notice that data of USGS on production of mica, including muscovite, in Russia are considerably underestimated. According to estimate of «InfoMine» volume of mining muscovite in Russia in 2006 was 3.1 kt.

In volumes of production of crushed mica, USA is one of leading producers in the world. From data of USGS, in 2006 volume of production of crushed mica and scrap in the country increased by 19% y-o-y to 93 kt. Production of crushed mica in USA is conducted by 8 companies, owning 10 mining enterprises, located in 5 states. Above 40% of crushed mica and scrap are produced in North Carolina. Mica production in the country chiefly comes from Spruce Pine, Franklin-Sylva and Shelby Hickory districts of North Carolina. Production is mostly that of scrap mica. It is obtained during the mining of felspar and quartz. For blocks, splittings (chipped) and condenser films, the USA depends solely upon imports (from Canada, India, China, Brazil).

Ground mica in USA is produced by 8 companies, owning 14 milling enterprises in 5 states. 9 enterprises produce dry-ground mica and other – wet-ground mica. Total volume of production of ground mica in USA in 2005 was 120 kt, and in 2006 decreased to 100 kt.

The main end-use of ***dry-ground mica*** in USA is production of binders (putty, plasters, grout, etc.) for finishing surfaces (mica is used as filler). From data of USGS, in USA for for this purpose, around 52% of dry-ground mica are consumed. Around 12% of dry-ground mica are used as filler in paint-and-varnish industry, 4% in production of drill mud, around 3% as filler for plastics, 1% as filler for industrial rubber articles. Also the product is used in manufacture of solf roofing materials and decorative finishing materials (stucco, ceramic tile, wallpaper, etc.).

Wet-ground mica is used, mainly, as filler in production of «pearl» paints for motor industry, as well as in cosmetics production.

Sheet mica is produced as accompanying product at 2 mining enterprises. Total volume of the production is up to 1 tpy.

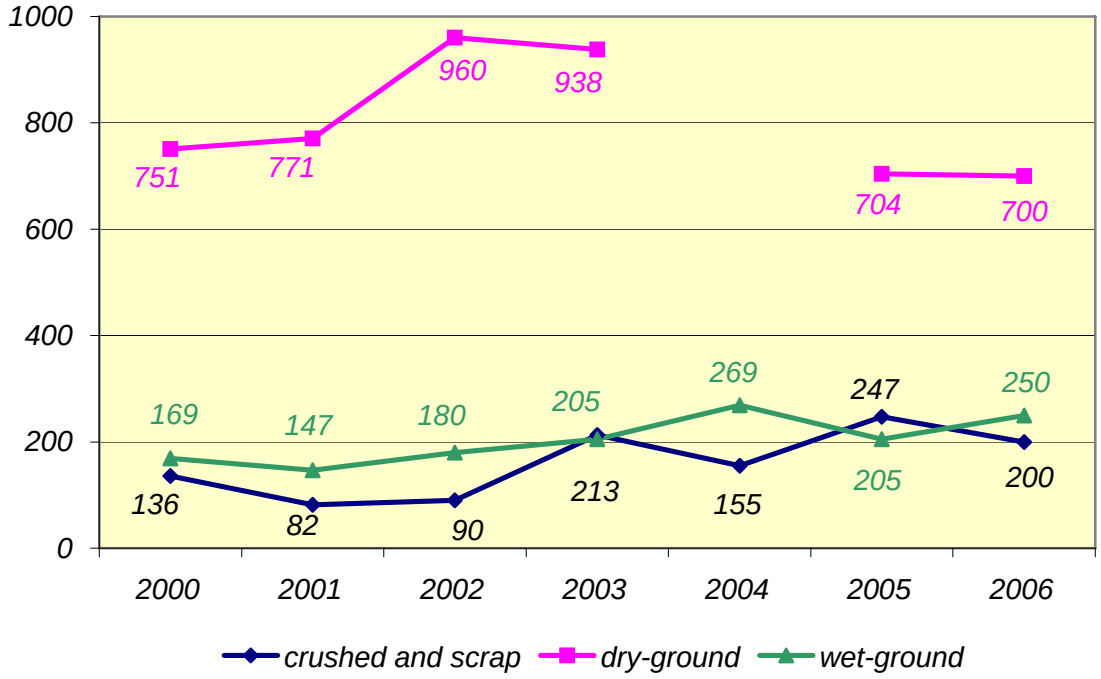
Sheet mica is used mainly in electronic and electrical industries. Mica is invaluable in the electrical industry because of its unique combination of physical, chemical and thermal properties, low power loss factor, dielectric constant and dielectric strength. Key end-use of the mica is production of electrical insulators for electronics. Total consumption of sheet mica in USA in 2005 was 1.1 t versus 1.8 t in 2004.

Production and further use of ***chipped mica*** (muscovite and phlogopite) in USA is conducted by 9 companies in 7 states. Total volume of consumption of the product is around 560 t per year. Practically the whole volume of chipped mica is used in production mica-filled products, used in electrical industry for insulation. Pattern of chipped mica consumption in the end-use in USA is as follows: around 13% for production of flexible electro-insulating plates, around 33% for manufactured moulded plates, 39% as insulating segments/plates (mainly phologopite).

Production of ***mica paper*** from mica scrap in USA is conducted by 3 companies. The product finds the same applications as chipped mica.

Average ***prices on*** mica at USA market, in latest years remain stable at a level around 700 $/t (EXW) for dry-ground mica and 200-250 $/t for , wet-ground, crushed and scrap mica. Dynamics of average prices on the products in USA in 2000-2006 is presented in Figure 1.

Figure 1. Dynamics of average prices on crushed and ground mica in USA in 2000-2006, $/t

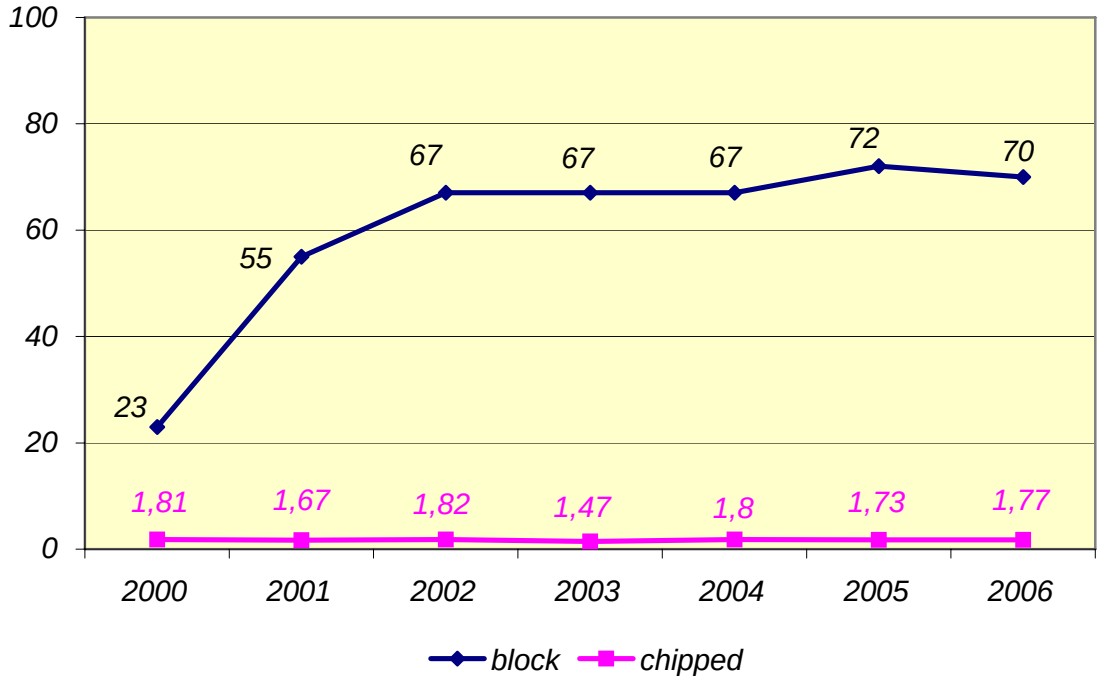


Source: USGS

From data of USGS, demand for sheet mica in USA in 2006 slightly increased compared with 2005. The country demand for sheet mica is practically completely satisfied by imports, which grew 33% y-o-y in 2006 to 48 kt. The bulk of the imports of mica belonged to Canada (43% of the total imports), China (24%), India (23%), Russia, etc. Own production of sheet mica in USA is up to 1 t per year. Notice that previously large volumes of sheet mica also came to the market from strategic reserves (Reserve store of National Defence), but the reserves of muscovite were completely exhausted in 2004, and reserves of chipped phlogopite were over in 2005. Prices on the products are expected to increase owing to shortage at the market (share of high-grade mica in the USA imports is low).

Average prices on sheet mica (block mica) in USA from 2000 to 2006 grew above 3 times to above 70 $/kg. At the same time, average prices on chipped mica were more stable and fluctuated in range 1.47-1.82 $/kg. Dynamics of average prices on the product in USA in 2000-2006 is presented in Figure 2.

Figure 2. Dynamics of average prices on sheet mica in USA in 2000-2006, $/kg



Source: USGS

Notice that prices on sheet mica in USA vary in wide range: from below 1 $/kg for low-grade products to above 2000 $/kg for highest-grade mica.

Prices on mica in some countries as of the beginning of 2007 are presented in Table 3.

Table 3. Prices on mica in some countries as of January 2007, $/t

Country-producer	Product	Delivary terms	Price, $/t*
India	micronized, 325 mesh	CIF Europe	300–545
	wet-ground	FOB India	500–1000
	dry-ground	FOB India	200–430
USA	dry-ground	EXW	210–400
	wet-ground	EXW	535–1300
	micronized	EXW	535–930
	flake	EXW	250–480

** - the prices were stable for the latest 2 years*
Source: BIKI, Industrial Minerals

2. Reserves and deposits of mica in the CIS

2.1. Resources base of Russia

2.1.1. Deposits of sheet muscovite

Muscovite is layered alumosilicate of mica group (sub-group of dioctahedral micas) of ideal formula KAl_2 $[AlSi_3O_{10}](OH)_2$, corresdponding chemistry: K_2O – 11.8%, Al_2O_3 – 38.5%, SiO_2 – 45.2%, H_2O – 4.5%. Natural muscovite always contains isomorphic impurities of other components. For instance, in deposits of sheet muscovite, it contains up to: 1.2% Na_2O, 1.0% CaO, 3.3% $FeO+Fe_2O_3$, 1.6% MgO, 1.0% TiO_2, 0.3% F. So formula of the real mineral from these objects is as follows:

$$(K_{>0,75}\ Na_{<0,10}\ Ca_{<0,10})_{1-x}\ (Al_{>1,6}\ Mg_{<0,3}\ Fe_{<0,15})_{2+y}\ (Al_{1-z}\ Si_{3+z}\ O_{10})\ [OH_{2-0,0n}\ F_{o,on}]_{2,00},$$

where x and $y < 0.1$, $z < 0.2$, $n < 9$.

Higher contents of mafic elements (isomorphic to aluminium) worsen commercial properties of muscovite.

Muscovite is widespread in various types of rocks and, according to estimates of specialists, is the main concentrator of aluminium in upper earth crust (17% of total aluminium). However, commercial grade occurrences of large-crystal kinds of the mineral are rather rare.

Russia has hysrorical priority in mining and use of sheet muscovite, name of which originates from Moscow – “musca vitrum” – Moscow glass; muscovite sheet was used in windows, mirrors, etc.

Mica is found in pegmatites intruding mica schists. It is found to occur in book form in the pegmatites. The mode of formation of mica which is found in the form of small flakes to big slabs cleavable into the fine laminate is still the subject of active research. One thing has been clearly established is the degree of presence or absence of orthoclase felspar indicates the possibility of finding mica in the pegmatite is indicative of the presence of more mica. This establishes that mica forms at the expense of orthoclase/microcline felspar.

The presence of tourmaline crystals and decomposed felspar in the pegmatites shows the possibility of finding good quantity of mica.

Mica pegmatite consists of quartz core with felspar on the sides adjoining the country rock, mica-schists. In the quartz and felspar zones, which usually form the core, the formation of mica is sparsely found and also the flakes are not big in size.

Mica pegmatites have been found to occur in various shapes and sizes mostly occuring as lenses. They may occur as parallel veins, pipes or in massive form. It is difficult to ascertain when the vein will pinch out and hence the mining of mica is regarded as quite speculative. Also, the abrupt decrease in degree of mineralization and disappearence of mica from the working face is quite common. Pipe mica veins have been worked upto a maximum depth of 200 meters.

Sheet muscovite is mined from granite pegmatites exclusively, and only from two formations of the pegmatites: specifically muscowite and rare-metal-muscovite, occurring in metamorphic complexes of amphibolite facies of metamorphism. Mica-bearing bodies occur as zones in pegmatoid granites or, more often, as veins of complex shape in metamorphic strata, usually in gneises. Metasomatic and migmatization processes played impotant role in origination of both pegmatites and commercial-scale mica bodies.

Plate and thick-plate crystals of muscovite – the main source of large high-grade mica (up to 1.5 m crystals) – are confined to block and pegmatite zones of plagioclase-microcline composition. In lesser differentiated pegmatites, muscovite (up to 15 cm in size of crystals) usually occurs in association with quartz; this association is confined mainly to plagioclase zones.

In plagioclase pegmatites of specific parts of some deposits of Mamsky district (Mochikitsky, Dovgokitsky, Kolotovsky), the main type of commercial mica is muscovite over buitite (partially replacing biotite metasomatically). Close intergrowth with biotite lowers quality of muscovite; this is aggravated by effect of deformation dislocations (these pegmatites are the oldest in the territory).

Prospecting of mica is still a matter of trial and error as no scientific method has so far been evolved for determining with certainty the occurrence of paying mica pegmatite. All the discoveries of mica-pegmatites so far are thanks to that devoted band of labourers who go in the field with chisel and hammer from vein to vein to find out paying pegmatite veins. Mines are developed following the veins.

The Room and Pillar method is adopted in mining. The mica obtained from the mine is called crude mica. Reserves of sheet muscovite are calculated in “crude mica”, to which all crystals with total surface area of at least 4 cm^2 refer; crude mica content is measured in kg/m^3. Crude mica is recovered manually. It requires a little dressing to remove associated pegmatite dirt as well as defective portions such as buckled, wrinkled and wavy mica. They are rifted away with sickel.

Book-mica, split into a size at least covering an area of 2x 1½ and about 1/8 inch thick is called block mica. Block mica split into thin films of thickness 0.004-0.0012 inch is called mica-film and less than 0.0012 inch thick as splitting. The labourers engaged in mica mines and factories where mica is hand-dressed are experts in dressing the crude mica into block, films and splittings. They do it by visual aid only. During the course of processing a considerable portion of mica goes waste. It is termed as scrap mica.

For commercial purposes, mica is graded according to the quality e.g. superfine, clear, stained, fairly stained, good stained, heavily stained and densely stained; and according to sizes as given below.

The quality of mica for commercial purposes depends largely on the amount of staining, air inclusions, the degree of flatness, and the colour. The staining is caused by mineral inclusions which occur intergrown with muscovite or between cleavage planes. The most common minerals which occur as inclusions are biotite, quartz, magnetite, hematite, garnet, plagioclase, apatite, clay minerals and the alteration products of biotite and iron oxides.

Muscovite which does not split up into even cleavage has a lower market value. It can be sold only as scrap mica. Such mica is called buckled mica. Buckling effect in mica results from post-pegmatite movement.

Other features possessed by muscovite, which greatly lower its value are A-structure and wedge-structure. Such structures originated at the time of crystallization. A-structure refers to cleavage imperfections called reeves or ridges that intersect at an angle of about 60º. This feature results from the twinning phenomenon. Crystals with A-structure which are thicker at one end than at the other are said to possess a wedge-structure.

The presence of A or wedge structure greatly reduces the yield of sheet mica. Normally most of the muscovite in an individual body is of one habit; it either does or does not possess these structures.

For further processing (into mica articles), only mica with effective (valuable) area of ≥4 cm^2 is suitable only, it is named "commercial crude mica, i.e. crude mica without defects – crossing mineral inclusions, fractures, obvious wedging, etc. Share of commercial crude mica in total crude mica ranges 20-60%, depending on the defective portion in the crude mica, commonly 30-40%. In minimal size of crystals (in cm^2), it is subdivided into 4 sizes (R_4, R_{25}, R_{50}, R_{100}), each of which, in turn, is broken into 2 sorts. To the 1st sorts, only plate crystals with at least 40% of effective area from both sides refer. The most valuable is such mica of size above 50 cm^2 (R_{50} I), and, especially, above 100 cm^2 (R_{100} I), because it is the only resources, suitable for obtaining plate for crucial application (including in defence industry). Reserves of such resources are very scarce, and demand for R_{100} I mica always much in excess of supply. So veins, containing above 30 kg/m^3 crude mica at yield of $R_{100+50} \geq 12\%$, including I sort ≥ 2% (all % – of crude mica as 100%) refer to objects of high-grade resources, attracting special interest in exploration and mining processes.

Commercial crude mica is processed (by splitting cutting, chipping, forging, etc.) to avoid all undesirable defects for use as semiproduct in manufacture of specific article. Nomenclature of the semiproducts is defined in GOST 10698-80 «Mica. Types, grades and the main parameters». Requirements, imposed on the semiproducts for specific designation (in size, quality of surface, degree of staining, etc.) are determined by series of GOSTs (13750-88 – plates for instrucment-making industry, 18096-87 – plates for electronic instruments, 7134-82 – Mica for capacitors, 13751-86 with amendment № 1 – Mica for inspection windows of industrial furnaces and household appliances, 13752-86 with amendment № 1 – Mica for water columns of high-pressure boilers, 13753–86 – Mica for brush carriers of electric motors, 3028-78 with amendment № 1, 2, 3 – Mica chipped), as well as by many intra-sector industrial Specifications (TU). Final yield of muscovite into sheet articles is not more than 10% of crude mica, and even lower commonly.

Wastes of mica at various technological stages are taken into account as scrap mica and used mainly being crushed and milled, both in electrical industry and in other uses (fine (small-size) muscovite). Besides, in latest 10 years, owing to very weak demand for small-size crude mica, practically the whole volume of mica of

sizes R_4 and II sort R_{25} is used in production micaceous laminate materials, where only mica scrap was applied previously.

In the course of mining sheet mica, from the same veins, also small-size muscovite and quartz-feldspar resources (quartz, microcline, microcline pegmatite) can be extracted as accompanying products (by-product mining).

Location of reserves and mining muscovite

Total balance reserves of muscovite in Russia are around 860 kt, including 433 kt in categories $B+C_1$ (balance demonstrated reserves and 425 kt in category C_2 (inferred reserves). In addition around 160 kt muscovite refer to outbalance reserves . Of reserves in categories $B+C_1$, mining enterprises manage 50 kt, or 11%, and 384 kt, or around 90%, are in Gosrezerv (State Stock of Reserves, registered in GKZ (State Committee on Reserves) (rest), are 242 kt, or around 55% from reserves, registered in categories $B+C_1$.

Location of balance reserves in the territory of Russia is presented in Table 4.

The main reserves of sheet muscovite, same to its mining, belong to Siberian District, where the greatest in Russia and in the world Mamsko-Chuisky muscovite-bearing territory is located (Irkutsk region). Registered reserves of sheet muscovite in the territory are 668 kt in categories $B+C_1+C_2$, including in categories $B+C_1$ (balance demonstrated reserves) 352 kt, or around 80% of the reserves of these categories in Russia.

In Northwestern Federal District, within which 5 muscovite-bearing territories (ore districts) are located: Jona, Strel'ninsky, Ramozero-Keivsky (Murmansk region), Chupa-Loukhi and Kemsky-Belomorsky (Karelia), around 16% of Russian muscovite reserves in all categories (175 kt, including in category $B+C_1$ – 70.0 kt) are available.

Rather small reserves of muscovite (11.4 kt in categories $B+C_1$ and 5.3 kt in category C_2) are available in deposits of Urals and Krasnoyarsk krai. These deposits are not planned for involving in mining owing to heavy mining conditions at low grade of mica.