Mineral Resources
Consultative Committee

Mineral Dossier No 15

Mica

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Preface

The Mineral Resources Consultative Committee consists of representatives of interested Government Departments, and specialist advisers. It was set up in 1967 to keep present and future requirements for minerals under review and to identify problems associated with the availability, exploitation and use of mineral resources, both inland and offshore, having regard to competing demands on land use and other relevant factors.

Widespread and increasing interest in the mineral resources of the United Kingdom has led the Committee to undertake the collation of the factual information at present available about those minerals (other than fossil fuels) which are now being worked or which might be worked in this country. The Committee has produced a series of dossiers, each of which was circulated in draft to the relevant sectors of the minerals industry. They bring together in a convenient form, in respect of each of the minerals, data which had previously been scattered and not always readily available. These dossiers are now being published for general information.

Acknowledgements

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Metric units are employed throughout this document except where otherwise stated. In most cases this has necessitated the conversion of originally non-metric data. The units and conversion factors used are as follows:

millimetres	(mm)	= inches x 25.4
metres	(m)	= feet x 0.3048
kilometres	(km)	= miles x 1.609344
hectares	(ha)	= acres x 0.404686
kilogrammes	(kg)	= pounds x 0.45359237
tonnes	(1000 kg)	= long tons x 1.01605

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Summary

Mica is the collective name for various complex hydrous aluminium silicate minerals that are characterised by a perfect basal cleavage. This cleavage enables the natural crystals to be split into very thin plates. Among the many varieties of mica, muscovite has major industrial importance and is the principal subject of this dossier.

The main classes of mica utilised for industrial purposes are sheet, scrap and flake mica. Ground mica is generally produced from scrap or flake mica. The term 'manufactured mica' is usually taken to refer to synthetic products incorporating mica such as micanite, mica paper and glass-bonded mica.

Mica commonly occurs in igneous rocks, mainly of granitic composition, and in gneissic and schistose metamorphic rocks. Commercial quantities of mica are extracted from mica-bearing pegmatites in various parts of the world. In Scotland mica pegmatites occur in the Highland Region, principally in the former counties of Inverness and Ross and Cromarty. These are small, disconnected and lenticular bodies. Although some were worked during the Second World War, their present economic potential is doubtful. While mica suitable for grinding has been produced from mica schists in the United States, attempts to start similar operations in the United Kingdom have not as yet proved successful.

The uses of mica are based upon a unique combination of physical, chemical and electrical properties. Sheet mica is mainly used by the electrical and electronic industries, although wet and dry ground mica find a wider range of industrial uses.

Owing to the geological nature of the pegmatite deposits from which sheet mica is obtained, mining is usually on a small scale and not highly mechanised.

In Britain flake mica was, until 1975, extracted as a by-product from china clay working at Lee Moor, Devon. A number of companies produce ground mica from imported waste or from domestic flake mica.

There are no materials that can totally replace mica in all its applications. However, for applications such as stove windows, sparking plugs and radio condensers, substitution is possible. Reconstituted mica has been found particularly suitable for electrical insulation. Synthetic mica is a potential substitute for natural sheet mica but to date it has been found difficult to grow large crystals economically and in substantial amounts.

Definition and nomenclature

Mica is a collective name given to a particular class of silicate minerals the most conspicuous characteristic of which is a persistent basal cleavage of the crystals or 'books'. This cleavage is responsible for the familiar flaky or platy habit of all micas. All micas crystallise in the monoclinic system but their crystal form approximates to the hexagonal system. Crystallographically, micas posses a structure in which SiO_4 tetrahedra are linked together at three of their corners so as to form a two dimensional sheet extending indefinitely. The plane of this sheet lattice is parallel to the perfect basal cleavage. One silicon ion in three within the SiO_4 tetrahedra is replaced by aluminium. The overall negative ionic charge of the tetrahedra is over compensated by various metallic cations. Potassium is usually present and the remaining cationic positions in the lattice are occupied by a variety of elements; ferrous iron, magnesium and further aluminium are the commonest but metals such as sodium and lithium are also occasionally present. Neutralisation of the excess cationic charge, and therefore of the lattice as a whole, is achieved by the presence of negatively charged hydroxyl ions either alone or partly replaced by fluorine.

Various naturally occurring forms of mica are given specific names. Examples include:

Muscovite or 'white mica'	$KAl_2(Si_3Al_{10})(OH,F)_2$
Phlogopite	$KMg_3(Si_3Al_{10})(OH,F)_2$
Biotite or 'black mica'	$K(Mg,Fe)_3(Si_3Al_{10})(OH,F)_2$
Lepidolite	$K(Li,Al)_3(Si_3Al_{10})(OH,F)_2$

Chemical formulae for the main varieties of mica are, at best, only approximations. Minor quantities of many elements may be present in micas and variations in the relative quantities of major constituents, for example magnesium and ferrous iron in biotites, may lead to a considerable variation in their mineralogical properties.

British Standard definitions for micas include those quoted in BS 2487: 1957 (Glossary of terms for stone used in building) and BS 812:1967 (Methods for the sampling and testing of mineral aggregates, sands and fillers). These are:

> Mica: A group of hydrous alumino-silicates of iron, magnesium, potassium etc characterised by a perfect cleavage enabling them to be split into thin sheets.
>
> Muscovite: Potash mica ('white mica') $KAl_3Si_3O_{10}(OH)_2$
>
> Biotite: Hydrous alumino-silicate of potassium, magnesium and iron ('black mica') $K(Mg,Fe)_3\ AlSi_3O_{10}(OH)_2$.
>
> BS 3446:1962 (Glossary of terms relating to refractory materials) contains the following definition:
>
> > Mica: A group of silicate minerals which are laminar and non-plastic.

Muscovite is the mineral of main economic value and forms the principal subject of this dossier. Phlogopite is of lesser importance although it can be substituted for muscovite in some applications. Little use is made of biotite.

Lepidolite is an ore of lithium and is not considered here. The minerals known as brittle micas, such as chloritoid, and the vermiculites have some affinity with the true micas but are again beyond the scope of this report.

There is a somewhat complex nomenclature covering the type and quality of mica in commercial use and the various stages in mica preparation.

Unmanufactured (or unworked) mica: refers to material that has not been further processed other than by simple trimming and splitting. The main classes of unmanufactured mica are sheet, scrap and flake mica.

Sheet mica: is subdivided on the basis of thickness into block, thins and films. These subdivisions are defined in BS 3564: 1962 (method for the size-grading of muscovite mica block, thins, and films) as follows:

> *Block:* Trimmed mica of which at least 95 per cent by weight has a thickness not less than 0.20 mm (0.008 in), the remainder having a thickness not less than 0.18 mm (0.007 in).
>
> *Thins:* Trimmed mica of any thickness within a specified range between 0.05 mm (0.002 in) and 0.18 mm (0.007 in).
>
> *Films:* Trimmed mica split and gauged to any specified range of thickness.

An additional category known as *splittings* is sometimes used to specify mica down to 0.025 mm (0.001 in) but not over 0.300 mm (0.012 in).

Sheet mica is also classified according to the size, or 'grade', of the sheets, by colour and by visual quality. Common sizes or grades for sheet mica range from 1 to 24 square inches (6.45 cm^2 to 154.8 cm^2). Size gradings are given in BS 3564: 1962 and parallel classifications are published by the American Society for Testing Materials (ASTM) and the Indian Standards Institute.

Muscovite mica usually possesses a body colour which is apparent in all but very thin films. This colour can vary from pinkish buff through shades of brown and green to pale yellowish green. Colour classifications vary from country to country. In the United States, for example, three commercial categories for body colour are commonly recognised. Pinkish and brown varieties are given the name *ruby mica.* Yellow and green varieties are named *green mica.* An intermediate category is *rum mica.* In other cases this threefold classification is simplified into 'ruby' and 'non-ruby' Inclusions and stained areas are ignored in classifying mica by colour.

The quality of natural muscovite sheet mica is assessed on the relative quantity of visible inclusions and structural imperfections and is determined visually. Interpretation of visual standards is somewhat subjective and may vary from one observer to another. The finest quality mica is that which is uniform in colour and free from all stains and other defects. ASTM specifications for sheet mica recognise twelve quality groups ranging from the best, *Clear,* to the poorest, *Densely Black and Red Stained.*

Scrap (or waste) mica is material that is too small in size or too poor in quality to be used as sheet mica. It may be derived from dressing operations at the mine or from trimming and fabricating at the factory. A roughly equivalent material is *flake mica* obtained from beneficiating fine-grained micaceous rocks.

Somewhat confusingly the term *sheet mica,* is sometimes applied colloquially to mica that is *manufactured* (or *worked*) to the extent that is has been split and shaped to a predetermined size. In general, however, the term manufactured (or worked) mica refers to small or thin mica flakes that have been made to adhere to each other. *Built-up mica* or *micanite* is made up of thin, partly overlapping, sheets (splittings) bound together with an organic adhesive. *Reconstituted mica* or *mica paper* is composed of fine flakes of scrap mica pressed into sheets with or without the addition of an organic binder. *Glass-bonded mica* consists of fine mica particles bonded by low melting point borate or boro-silicate glass.

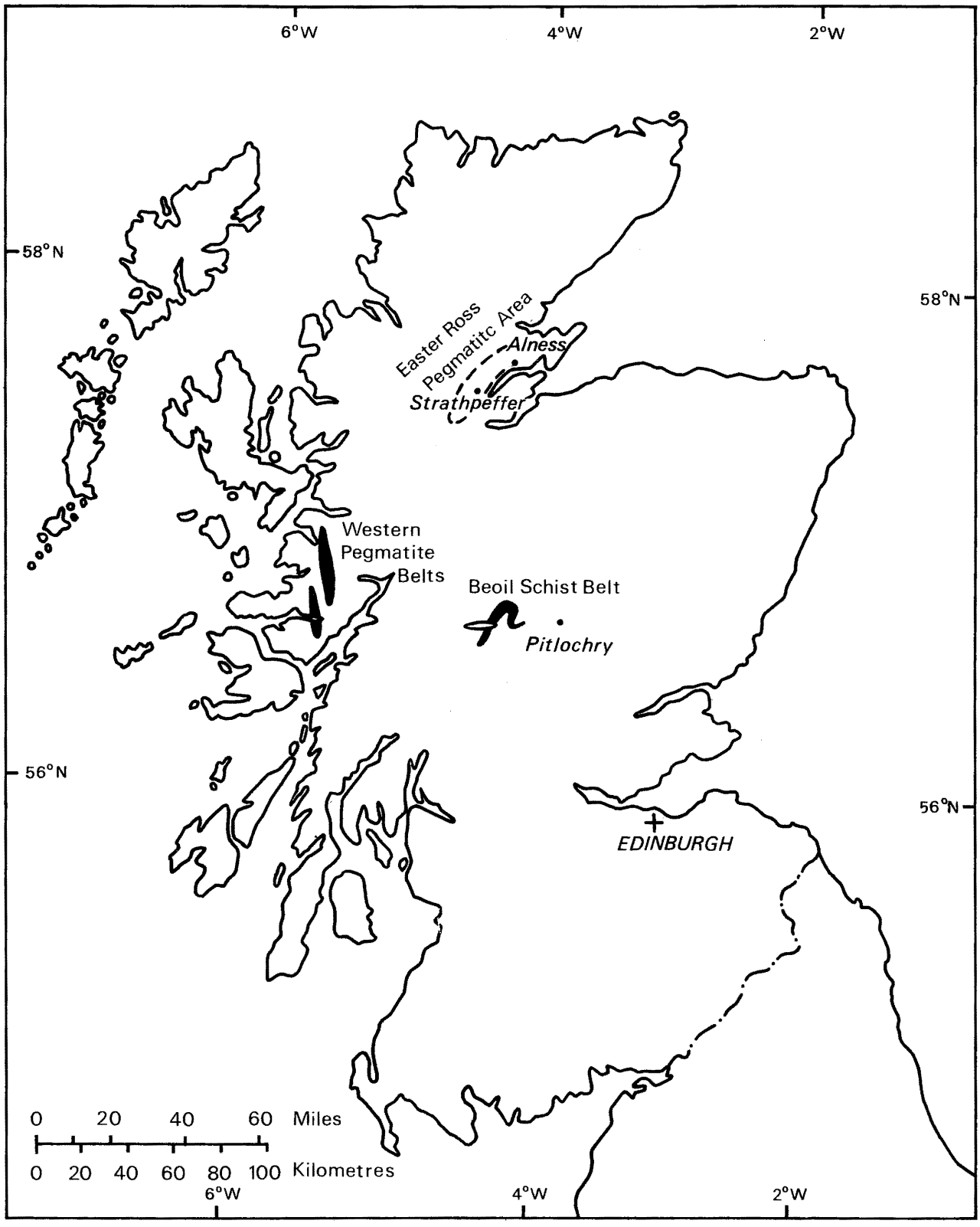
The other grade of industrial importance is *ground mica* which is manufactured by reducing waste or flake mica to powder. Although not, strictly speaking, an unworked commodity, ground mica has commonly been included with waste mica in trade classifications. Specifications for certain grades of ground mica are given in BS 1795: 1965 (Extenders for paints).

Occurrence and domestic resources

Small flakes of muscovite or biotite are common in igneous rocks, mainly those of granitic composition, and also in various gneissic and schistose metamorphic rocks. Biotite is relatively unstable chemically. As a consequence it does not usually survive the denudation of igneous or metamorphic rocks and the subsequent incorporation of the resultant detritus into sedimentary rocks. Muscovite, in contrast, is unaffected by chemical weathering and it is common as a fine-grained detrital mineral in some sedimentary rocks. Phlogopite is a rare mica and is found principally in certain magnesium-rich metamorphic limestones.

Although small flakes of biotite and muscovite occur widely in various kinds of rock, large sheets of mica are of much rarer occurrence and, in the case of muscovite at least, constitute a valuable commodity. Such large sheets are associated with the distinctive rocks known as pegmatites. These are found locally in dykes and veins as very coarse-grained differentiates from much larger masses of igneous or metamorphic rocks. Most pegmatites, and all those containing large sheets of mica, have a modified granitic composition. However, the converse is not true since only a minority of granite pegmatites contain large sheets of mica. Individual bodies of mica-bearing pegmatite rarely attain a large size and mining operations associated with them are generally on a relatively small scale.

Within the United Kingdom there are small occurrences of pegmatite containing sheet muscovite in the metamorphic rocks of the Moine Series in two areas of the northern Highlands of Scotland. A western belt extends from Knoydart southwards to Loch Shiel and Loch Sunart and there is an eastern belt in the Strathpeffer and Garve districts. When compared with commercial deposits of sheet mica in other countries these Scottish pegmatites cannot be considered as being potentially economic although there was some emergency production during the Second World War. In general, the books of mica are small and the overall size of the pegmatite bodies themselves is limited. In the western belt the majority of the pegmatite veins and lenses have thicknesses of only 3 metres or less. Almost all of the wartime productions in this area came from a single pegmatite body on Sgurr Coire nan Gobher in Knoydart, situated at an altitude of 520m north of Loch Nevis. Negligible amounts of mica were produced from other pegmatites nearby and to the south near Loch Shiel. In the Strathpeffer



Scotland, showing locations of mica deposits

and Garve districts there are a number of larger mica pegmatites 5 to 6m wide and, in some cases, over 90m long. The wartime production in this area was mainly from Little Scatwell, with trial amounts from Carn Gorm and from Braetollie, northwest of Alness. The quality of the sheet muscovite was lower than that from Knoydart. Even in wartime, production of sheet mica in Scotland did not prove to be economic; although the quality and yield (9.23 kg of mica per tonne of ore mined for the Knoydart deposit) were good, the small size and remoteness of the deposits made working costs unacceptably high.

Some of the schists that are characteristic of the metamorphic rocks of the Scottish Highlands constitute a potential source of flake mica suitable for the production of ground mica. Some interest has been aroused in the possibility of producing this commodity from the formation known as the Beoil Schist which is best developed in the Schiehallion region, west of Pitlochry. This rock contains over 40 per cent mica by weight and investigations conducted jointly by the Warren Spring Laboratory and the Institute of Geological Sciences have shown that muscovite, biotite and mixed mica concentrates can be separated from the rock. Resources are extremely large but the colour of the muscovite concentrates is poorer than that of imported waste or ground mica.

Flake mica has been produced from the Foxdale granite in the Isle of Man as a by-product from the beneficiation of a quartz-feldspar flux used in the ceramics industry. The granite contains about 10 per cent muscovite and is almost completely free from iron-bearing minerals. The reason for ending production at Foxdale was probably connected with the changing demand for the main product rather than for mica.

The only recent production in Britain was on a flake mica by-product obtained from waste sand at the china clay workings at Lee Moor near Plymouth. In general, the waste products from the china clay industry of Cornwall and Devon consist mainly of quartz but in certain cases can contain up to around 15 per cent of muscovite. The quantities of waste available are enormous but the extent to which further production of flake mica would be possible is unknown. The level of production was a function of demand, not only for china clay, but also for coarse de-slimed sand tailings which are used in the manufacture of sand lime bricks. Renewal of flake mica production would therefore depend upon an increased demand for these associated products.

Elsewhere in the United Kingdom future prospects for the production of mica are not encouraging. The Scottish occurrences of sheet mica are probably too small and too remote to offer any serious competition to the supplies of imported mica. At present demand for ground mica appears to be too low to justify the establishment of a quarrying and processing operation for flake mica alone. Production of flake mica in association with feldspar and quartz may be economic if a deposit were to be identified from which concentrates of high quality could be obtained.

The former workings for mica in Scotland and the Isle of Man were small and did not result in significant dereliction or restoration problems. The production of flake mica in Devon makes a negligible contribution to the disposal of waste material from the china clay industry.

Uses

Muscovite is the form of mica that is most in industrial demand owing to its dielectric strength, perfect basal cleavage, toughness and elasticity, chemical inertness, thermal stability up to about 500°C, and its transparency and silvery lustre. In most of these respects muscovite is superior to phlogopite and biotite but phlogopite is substituted where thermal stability up to about 850° to 1000°C is required.

Uses for sheet mica, principally as small insulating and supporting components in the electrical and electronic industries, contrast with the bulk uses for ground mica.

Electrical equipment incorporating mica components includes condensers, transformers, small heating elements, rheostats, fuses, incandescent bulbs, thermionic devices and certain types of coil. In generators it is used for commutator and armature insulation. There are also more specialised uses for mica in X-ray and acoustic equipment.

Other, non-electrical, uses for sheet mica include gauge glasses for high pressure steam boilers, furnace windows and transparent diaphragms for oxygen-breathing equipment and goggles.

Ground mica is marketed in three forms, namely dry and wet-ground and micronised. Dry-grinding is a simple and therefore relatively cheap process and is mostly used to produce material in the 16 to 100 mesh size range. Such material is used as a filler in, for example, the manufacture of rubber, plastics and insulating boards. It can also be utilised as a surface coating for asphaltic roofing materials. This surface coating is important in that it prevents the mutual adhesion of adjacent asphalt surfaces. Furthermore, as a consequence of its platy nature, mica is not appreciably absorbed by freshly made asphalt and acts therefore as a continuous weatherproof coating. Oil well drilling muds use coarser grades of dry-ground mica (16 to 40 mesh). This acts as a sealant because of its platy structure. Finer grades of dry-ground mica are used as a pigment extender in paint. Surface coatings of dry-ground mica are used as a flux coating on welding rods, on cores and moulds for metal casting, on electric cables, on concrete, tile and stucco surfaces, on wallpaper and as artificial snow on Christmas cards. Dry-ground mica is the major constituent used in the manufacture of some reconstituted mica components. Lesser uses are as an annealing agent in metal treatment and as an absorbent for explosives and disinfectants. Dry-ground mica is an effective thermal insulator but owing to its higher specific gravity is not so suitable as, for example, expanded vermiculite for cavity wall insulation.

The dry-grinding process is unsuitable for producing the finer grades of ground mica since the characteristic laminar crystalline structure of the mica flakes tends to be destroyed. Where it is desirable to retain the form of the mica flakes in finely comminuted grades, a wet grinding technique is substituted. Even finer grades of commercial mica powders retaining the laminar form can be produced by the use of steam micronizers.

Wet-ground or micronised mica is particularly important for the manufacture of paint where material in the range 160 to 325 mesh is superior to dry-ground mica as a pigment extender since it increases the resistance of the paint to weathering and contraction. A more silvery appearance can be imparted to wall-paper by the use of wet-ground rather than dry-ground mica. Although more expensive than dry-ground mica, the wet-ground or

micronised commodity is specified as a filler and mould lubricant in the manufacture of some specialised rubber and plastic products. Wet-ground mica can be used as an efficient anti-sticking, anti-friction powder between the inner tubes and casings of tyres. Certain special greases used as lubricants or soft packings require an alternative to graphite and in these cases wet-ground mica may be suitable as a substitute.

Some changing trends in the usage of mica can be identified. As a generalisation, the use of sheet mica is becoming restricted to those essential applications which make use of a combination of several of its properties which cannot collectively be matched by substitutes; where only one distinctive property of mica is required, transparency or electrical resistance for example, sheet mica is no longer used. Even in the case of applications where sheet mica has not been replaced, it is apparent that there has been a shift towards the use of lower grades and of built-up mica rather than the natural material. In the future built-up mica, made from sheet mica splittings, may itself be replaced by reconstituted mica made from scrap or flake.

At present virtually all ground mica produced is compositionally muscovite; colour and lustre being major factors in assessing the suitability of scrap and flake mica for grinding. For some applications, however, these properties are not important and heavily stained muscovite, biotite or biotite-muscovite mixtures could be used instead. The original emphasis on white ground micas was probably engendered by the demand for this material by the wallpaper industry but a decline in such demand since the Second World War may encourage a trend towards the use of coloured ground micas.

Flake mica produced from its only domestic source, namely china clay waste, has been found to be suitable only for grinding to certain grades. It is not suitable for wet grinding or for the production of the coarser dry-ground grades.

Some specifications for the use of mica are covered in British Standard and other authoritative publications. BS 4145:1962 (Glass mica boards for electrical purposes) and BS 626:1946, confirmed 1960 (Micanite for commutator separators) deal with certain uses for glass-bonded and built-up mica. BS 1795:1965 (Extenders for paints) deals with certain grades of ground mica. Other specifications covering their products are published by manufacturers of ground mica.

Technology

Mining of sheet mica is almost always a small-scale, largely unmechanised operation and can be either opencast or underground. The rather primitive method of mining is associated with the erratic nature of mica-bearing pegmatite ore bodies both vertically and laterally. In some countries, notably India, mining of mica has almost the status of a 'cottage industry'.

Drilling although often done by compressed air equipment is still frequently carried out with hand drills. This is done to avoid excessive damage to the books of mica. For the same reason any blasting that is required has to be performed with care.

Run-of-mine mica, consisting of rough crystals and lumps ranging in size up to about 0.5m across, is at first roughly sorted and hand cobbed to separate it from the waste material, usually consisting of quartz and feldspar.

The mica is then split and roughly cut to give block mica which, in turn, is further trimmed to remove ragged edges or inferior surfaces. If skilled labour is available, mica film and splittings may be produced at the mine itself but normally mica blocks are merely sorted by size (grade) and quality for despatch.

During the wartime period when sheet mica was produced in Scotland the total output of crude mica was transported from the quarries to a small factory at Pitlochry where sorting and trimming to block mica sizes were carried out.

Final processing of sheet mica involves such operations as cutting, stamping and punching.

Flake mica is recovered from various kinds of rock such as pegmatites, mica schists and granites. Workings are opencast and, although they may be larger and more systematic than workings for sheet mica, are still on a relatively small scale owing to limited demand for the product. In the United States much mica of scrap grade is produced from soft weathered rock which can be mined by hydraulic methods or by power shovels and bulldozers.

Where pegmatites are worked for flake mica alone, processing is usually simple and may consist only of crushing and screening; mica tends to be more resistant to crushing than quartz and feldspar and some is therefore concentrated in the coarser fractions. Nonetheless losses, amounting to perhaps 50 per cent of the total, may be unacceptably high and the finer grades of mica may therefore be recovered using Humphrey spirals or flotation.

In recent years by-product mica and quartz have been sold from plants set up in Europe and the USA, the prime function of which is the recovery of feldspar. At Foxdale, Isle of Man, processing of the muscovite granite consisted of crushing and grinding and then separation of the mica from the main product, a quartz-feldspar mixture, by combination of tabling and froth flotation. The mica extraction process used at Lee Moor, Devon, consisted of de-sliming waste sand graded in the range 14 to 60 mesh followed by froth flotation and screening.

Some scrap and flake mica is marketed directly but most is converted to ground mica. The *dry-grinding* process is straightforward and typically involves pre-crushing, grinding in hammer mills, grading in the 16 to 100 mesh range on vibrating screens and final bagging. The *wet-grinding* process involves a somewhat more complex flowsheet. The plant operated by Microfine Minerals and Chemicals Ltd at Derby can be cited as typical. Material destined for the wet-grinding circuit is first fed into a Lightning primary crusher where it is reduced to -$^3/_8$ in (9.3 mm). Further milling and de-laminating follows in hollow-log grinding mills after which a scalping screen passes -$^1/_8$ in (3.1 mm) grade. Oversize material is returned direct to the mill. Undersized material is passed to a rake classifier which returns the +52 mesh fraction to the mill after tabling to remove impurities, mainly quartz. Water is added to the -52 fraction to give a paste-like consistency. This is then passed through a series of rod mills. More water is added and three fractions, -150, -200 and -300 are separated in hydrocyclones. Dewatering is carried out in vacuum filters and the material is then passed on for bagging.

Micronised grades of mica are produced by treatment with steam under high pressure (200 psi). A micronising circuit is fed either directly or from a dry-grinding circuit with material of -25 grade.

Of the various kinds of manufactured mica, built-up mica or micanite is made from mica splittings. The splittings are arranged, either mechanically using air suction or by hand, so that they overlap in layers of uniform thickness. Alternate layers of mica and a cementing agent such as shellac are built up and are bonded together by the application of heat and pressure. The micanite is then further fabricated in the same way as natural block mica.

Reconstituted mica is a paper or mat made from high quality scrap. This is partially exfoliated by heating and then the mica flakes are fed as a pulp on to a modified Four drinier paper making machine. A continuous sheet of mica paper is produced which can be impregnated with a binder.

Glass-bonded mica is made from a mixture of ground mica and powdered glass. The mixture is pressed into moulds and heated to soften and anneal the glass. It is necessary to use lead borate or borosilicate glasses which have melting points at a lower temperature than that at which mica begins to break down chemically. The moulded components can be fabricated by grinding, cutting or drilling.

Price

Prices of sheet mica show a very considerable variation that depends upon size and quality. Marked fluctuations reflect irregularity in demand and also a periodic tendency, particularly by Indian producers, to stockpile better grade material.

Variations in price for different grades of sheet mica is exemplified by the prices (April 1974) for material f.o.b. Calcutta where block mica ranged from about £5 to £23 per kg and first quality splittings were priced at £0.15 to £3.2 per kg. Special sizes of particularly good quality block mica may command even higher prices in the region of £50 per kg or even more.

Prices of all varieties of mica imported into the United Kingdom have shown a tendency to rise in recent years. Some indication of this is given by HM Customs and Excise figures which refer to the mean c.i.f. value of imports from all sources. For 1971 until 1974 values per tonne are as follows:

	1971	*1972*	*1973*	*1974*
Blocks	£1,590	£1,625	£2,199	£2,299
Films and splittings	£ 576	£ 811	£ 543	£ 546
Ground	£ 39	£ 54	£ 39	£ 88
Waste	£ 33	£ 32	£ 38	£ 50

These figures are misleading in some cases. In the case of ground mica, for example, figures are for all grades imported into the country and no differentiation is possible between the cheaper grades of dry-ground mica and the more expensive wet-ground grades. The relatively depressed value of imported ground mica for 1973 does not therefore represent a fall in the intrinsic value of mica imported that year but merely indicates that greater quantities of cheaper grade material were entering the country than hitherto. Ground mica prices quoted in the journal *Industrial Minerals* are for domestically produced material and give a more direct indication of the rise of prices in this commodity in recent years. Figures for the years concerned (January in each case) are:

	1971	*1972*	*1973*	*1974*	*1975*
Dry-ground mica, ex works *£ per tonne*	45-58	48-58	47-57	53-63	90-100
Wet-ground mica, ex works *£ per tonne*	80-90	89-96	79-94	81-108	110-150

Scrap mica, the c.i.f. price of which according to *Industrial Minerals* had remained stable at £23 to £26 per tonne since at least 1968, had started to rise in price by the end of 1973 and reached £55 to £65 by January 1975. This movement is broadly confirmed by the corresponding figures from HM Customs and Excise.

Overseas trade

The United Kingdom is dependent on imported supplies of mica, which for the past 25 years have been valued at around £2 million per annum, reaching £2.4 million in 1974. Exports and re-exports of mica have tended to increase during this period from about £0.4 million to £1.1 million in 1974. Trade in mica has a small adverse effect on the balance of payments, the difference between imports and exports amounting to about £1.3 million in 1974, higher than previous years.

Since 1970, both imports and exports have been recorded under the headings and code numbers of the United Kingdom Tariff and Overseas Trade Classification. In 1974 these were as follows:

Mica, including splittings; mica waste –

Blocks, films and splittings –

2526 0002	Blocks
2526 0130	Films and splittings

Other –

2526 0283	Ground
2526 0408	Other

Worked mica and articles of mica, including bonded mica splittings on a support of paper or fabric (for example, micanite and micafolium) –

6815 0070	Sheets or splittings of mica
6815 0202	Plates, sheets or strips made from mica splittings or powder, whether or not on a support
6815 0330	Other

These detailed trade descriptions represent an expansion of the information available previously. From 1970 to 1973 only one heading (6815 0017) described worked mica, and the distinction between ground and other forms of unworked mica has been made only since 1971, one heading (2526 0276: Other, including waste) applying in 1970. Prior to 1970 information was only available by descriptions of the Standard International Trade Classification (Revised) and although re-exports were distinguished from exports, the same descriptions were not used for each, restricting comparability of the data.

There has been no clear trend in the supply of mica to the United Kingdom since 1950 (see Table 1), the total tonnage imported having fluctuated, reaching a peak of 15,102 tonnes in 1971. Imports in 1974, of 8,535 tonnes, were of similar magnitude to quantities imported in the early 1950's. Imports of films and splittings have tended to fall in recent years both in tonnage and as a proportion of mica imported. In the period 1950-1954, films and splittings comprised nearly 30 per cent of imported supplies, compared with only 7 per cent since 1970. Conversely, there has been an increased supply of ground and waste mica which formed nearly 90 per cent of the tonnage imported since 1970, but only just over 60 per cent from 1950-1954. Imports of mica since 1971 are shown in Table 2 by the detailed descriptions of the United Kingdom Tariff and Overseas Classification and by countries of consignment. For many years India was the principal source, but changes in Indian export policy have led to a rapid decline. In 1974 1,367 tonnes of mica were imported from India, 16 per cent of total imports, compared with 4,451 tonnes or 30 per cent in 1971. The decline is virtually all in waste mica, reflecting the fact that India is now encouraging local production of ground mica and the nascent industry is protected by maintaining the price of exported raw material at a deliberately high level. Ground mica has been imported from India for the last 2 years. In 1974 China, France and the Republic of South Africa together supplied 60 per cent of United Kingdom imports, (China alone supplying about 25 per cent), largely replacing the traditional Indian sources.

Ground mica, produced in the United Kingdom partly from imported material and partly from domestic flake production, is exported in significant quantities, and there is also a small amount of other unworked mica and of worked mica exported. Exports of mica (including re-exports) since 1950 are shown in Table 3. The fluctuations in the tonnage reflect those in the amount of material imported, (Table 1), since most mica exported is of foreign origin. Actual re-exports of imported mica (Table 4) were only recorded up to and including 1969; these data describe material transhipped through United Kingdom ports without further processing. The high tonnages shown as re-exports of ground and waste mica in the years 1965-1968 may include mica ground in the United Kingdom from imported material which in other years would have been classed as domestic exports.

Exports of mica by detailed descriptions and countries of consignment for the past 4 years are shown in Table 5. These figures include re-exports, and it can be assumed that the small quantities of mica blocks, films and splittings are in fact re-exports. Of the 282 tonnes of worked mica exported in 1974 sheets or splittings amounted to 118 tonnes, and plates, sheets or strips made from mica splittings or powder to 44 tonnes. The remaining 120 tonnes consisted of articles and other forms of mica. Exports are mostly to European countries. With increasing world consumption there appears to be some scope for increasing exports, particularly of ground mica. The development of indigenous Scottish mica resources as well as a renewal of production from china clay waste may be possible in this context.

Table 1 Imports of mica 1950-1974

	Blocks	*Films and splittings*	*Ground and waste*	*Worked mica*	*Total (a)*	*Total value (a)*
	Tonnes					*£ cif*
1950	295	1,940	2,143	...	4,378	1,241,913
1951	566	3,753	4,341	...	8,660	2,730,647
1952	761	1,747	4,332	...	6,840	2,651,001
1953	403	804	3,328	...	4,535	1,582,285
1954	758	1,217	6,529	...	8,504	1,867,019
1955	653	1,423	4,885	...	6,961	1,655,356
1956	623	1,033	3,661	...	5,317	1,473,258
1957	683	1,210	6,216	...	8,109	1,852,007
1958	550	1,425	3,244	...	5,219	1,676,670
1959	639	1,010	3,248	...	4,897	1,544,467
1960	527	1,625	6,647	...	8,799	1,667,198
1961	551	1,576	5,435	...	7,562	1,729,840
1962	453	899	4,730	...	6,082	1,414,574
1963	442	1,225	9,893	36	11,596	1,526,512
1964	514	1,272	4,990	75	6,851	1,436,676
1965	539	1,649	11,707	97	13,992	1,778,312
1966	517	1,013	8,281	127	9,938	1,456,354
1967	235	432	8,342	150	9,159	1,295,769
1968	348	803	11,798	267	13,216	1,904,833
1969	442	976	10,493	259	12,170	2,079,340
1970	372	578	12,330	245	13,525	1,582,457
1971	195	1,142	13,535	230	15,102	1,822,338
1972	123	441	6,880	298	7,742	1,276,607
1973	222	868	8,450	372	9,912	1,921,211
1974*(p)*	214	796	7,001	524	8,535	2,427,701

Source: HM Customs and Excise

(p) Provisional

(a) Excluding imports of worked mica, if any, from 1950-1962 which were not separately recorded

Table 2 Imports of mica by countries 1971-1974

	1971	1972	1973	1974*(p)*	*Average value per tonne in 1974*
	Tonnes				*£ cif*
Blocks					
from: India	89	50	108	85	1,619
USA	58	35	53	98	2,797
Brazil	25	14	26	17	2,720
Tanzania	15	16	19	4	2,698
Madagascar	5	2	7	3	4,545
Other countries	3	6	9	7	1,360
Total	195	123	222	214	2,299
Value £ cif	310,068	199,878	488,234	491,916	
Films and splittings					
from: India	925	306	603	632	518
USA	62	75	252	94	993
Sri Lanka	36	-	-	-	-
Fed. Rep. of Germany	33	33	-	-	-
Poland	23	6	-	-	-
France	18	7	0	0	-
Madagascar	19	2	-	3	2,262
Tanzania	16	3	-	-	-
Rep. of South Africa	-	-	-	54	88
Norway	-	-	-	13	157
Other countries	10	9	13	-	-
Total	1,142	441	868	796	546
Value £ cif	657,989	357,487	470,886	434,494	
Ground mica					
from: Rep. of South Africa	616	87	125	741	86
India	-	-	39	495	63
China	-	-	-	475	51
France	489	346	820	1,057	95
Norway	63	73	14	109	155
Madagascar	-	-	-	100	120
Other countries	12	24	18	168	163
Total	1,180	530	1,016	3,145	88
Value £ cif	45,558	28,724	39,789	275,902	
Waste mica					
from: Rep. of South Africa	6,524	4,339	5,117	851	41
India	3,409	57	31	137	62
China	1,196	925	450	1,674	46
Mozambique	810	300	300	700	42
Madagascar	161	49	251	51	105
South West Africa	-	229	66	-	-
France	1	160	163	277	70
Netherlands	-	-	847	-	-
Sri Lanka	36	83	-	50	58
Morocco	-	-	165	-	-
Brazil	49	50	-	-	-
Other countries	169	158	44	116	130
Total	12,355	6,350	7,434	3,856	50
Value £ cif	413,797	204,659	284,028	193,042	
Worked mica					
from: Belgium-Luxembourg	151	222	224	359	1,141
India	28	28	27	18	10,737
Fed. Rep. of Germany	18	29	71	55	3,033
France	12	0	18	16	1,550
Switzerland	11	2	1	27	4,695
Spain	5	12	10	10	1,828
Czechoslovakia	2	3	10	14	1,195
Other countries	3	2	11	25	3,139
Total	230	298	372	524	1,969
Value £ cif	394,926	485,859	638,324	1,032,347	

Source: HM Customs and Excise
(p) Provisional

Table 3 Exports of mica 1950-1974 (a)

	Tonnes	*£ fob*		*Tonnes*	*£ fob*
1950	1,992	1,011,559	1962	3,237	579,869
1951	1,785	776,470	1963	4,084	724,398
1952	845	314,657	1964	5,319	893,702
1953	1,105	315,549	1965	5,511	944,808
1954	1,634	372,257	1966	6,202	862,403
1955	1,843	377,185	1967	4,286	815,798
1956	2,174	426,091	1968	5,356	869,339
1957	2,141	474,175	1969	6,129	1,079,675
1958	1,754	402,679	1970	5,952	827,902
1959	1,930	437,479	1971	5,571	995,983
1960	2,511	477,446	1972	6,010	906,058
1961	2,991	499,076	1973	5,849	1,228,222
			1974*(p)*	2,378	1,069,814

Source: HM Customs and Excise

(a) Exports include re-exports. Excluding exports of worked mica, if any, from 1950-1962, which were not separately recorded

(p) Provisional

Table 4 Re-exports of mica 1950-1969 (a)

	Blocks	*Films and splittings*	*Ground and waste*	*Worked mica*	*Total (b)*	*Total value (a)*
	Tonnes					*£ cif*
1950	708	718	79	...	1,505	986,284
1951	269	642	136	...	1,047	739,961
1952	79	176	68	...	323	285,466
1953	98	304	12	...	414	278,396
1954	121	277	89	...	487	316,867
1955	146	237	2	...	385	309,498
1956	145	277	10	...	432	344,965
1957	148	459	-	...	607	399,471
1958	117	299	1	...	417	336,034
1959	171	311	104	...	586	368,118
1960	138	305	56	...	499	373,314
1961	163	215	50	...	428	376,884
1962	239	131	19	...	389	431,296
1963	135	66	39	0	240	294,425
1964	121	98	27	1	247	277,323
1965	546	283	1,674	1	2,504	474,503
1966	970	325	2,337	1	3,633	476,967
1967	115	24	3,306	4	3,449	528,660
1968	92	55	4,555	10	4,712	576,053
1969	65	31	420	5	521	266,055

Source: HM Customs and Excise

(a) Re-exports not separately recorded after 1969

(b) Excluding re-exports of worked mica, if any, from 1950-1962, which were not separately recorded

Table 5 Exports of mica by countries 1971-1974 (a)

	1971	1972	1973	1974*(p)*	*Average value per tonne in 1974*
	Tonnes				*£ fob*
Blocks					
to: Fed. Rep. of Germany	7	8	6	6	1,709
Spain	4	2	1	0	-
Rep. of South Africa	4	8	5	12	1,938
Australia	2	0	0	-	-
France	1	4	1	1	4,359
Taiwan	-	5	3	-	-
China	-	-	24	-	-
Japan	0	2	7	-	-
Netherlands	1	0	3	1	1,292
United States	0	0	1	2	6,547
Switzerland	0	0	0	4	1,318
German Dem. Rep.	-	-	-	4	2,550
Portugal	0	0	0	2	2,209
Other countries	0	1	0	0	-
Total	19	30	51	32	2,499
Value £ fob	89,121	77,794	289,560	79,957	
Films and splittings					
to: Spain	20	14	8	3	2,031
France	20	7	19	24	598
Fed. Rep. of Germany	0	10	13	35	412
Rep. of South Africa	0	8	3	4	1,094
Belgium-Luxembourg	4	0	0	7	916
Austria	-	4	2	1	1,874
German Dem. Rep.	-	-	-	10	80
Irish Republic	-	-	-	9	295
Denmark	0	-	0	5	320
Taiwan	13	14	-	-	-
Switzerland	7	8	2	-	-
New Zealand	-	0	1	1	998
Netherlands	0	0	0	1	246
Other countries	16	13	13	0	-
Total	80	78	61	100	542
Value £ fob	50,793	65,360	42,873	54,184	
Ground mica					
to: Fed. Rep. of Germany	297	1,040	751	82	112
Netherlands	229	544	602	143	80
Belgium-Luxembourg	172	371	280	188	83
Sweden	146	340	371	153	74
Iran	136	263	99	15	102
Spain	88	331	226	83	89
Italy	81	255	257	11	80
France	19	120	369	55	80
Finland	94	163	210	22	101
Switzerland	-	162	201	28	84
Irish Republic	24	64	118	96	115

Table 5 (Contd.) **Exports of mica by countries 1971-1974 (a)**

	1971	1972	1973	1974*(p)*	*Average value per tonne in 1974*
	Tonnes				*£ fob*
Ground mica (cont.)					
Denmark	72	75	75	116	125
Jamaica	33	116	153	86	59
Oman	-	101	39	75	72
Nigeria	41	126	36	47	105
Austria	56	57	83	18	90
Norway	1	44	43	57	83
Kuwait	5	108	43	3	155
Czechoslovakia	89	78	44	4	96
Trinidad and Tobago	23	42	54	15	51
Malaysia	10	8	50	16	109
Other countries	175	443	548	215	111
Total	1,791	4,851	4,652	1,528	92
Value £ fob	123,256	337,486	365,707	140,681	
Waste mica					
to: Fed. Rep. of Germany	740	164	59	54	79
Netherlands	364	28	30	20	105
Belgium-Luxembourg	338	27	0	9	58
Nigeria	189	86	33	30	90
Irish Republic	48	44	3	84	86
Norway	1	9	85	44	85
Portugal	74	23	51	52	67
Denmark	69	16	-	30	134
Italy	106	2	-	16	102
Malaysia	38	15	6	5	102
Austria	44	-	6	3	121
Sweden	181	43	-	1	125
France	103	13	10	0	-
Switzerland	121	22	4	-	-
Kuwait	81	104	182	-	-
Czechoslovakia	26	67	100	-	-
Oman	-	89	125	-	-
Iran	20	61	33	-	-
Other countries	985	72	68	88	82
Total	3,528	885	795	436	88
Value £ fob	297,202	58,099	64,509	38,243	
Worked mica					
to: Rep. of South Africa	21	16	19	20	3,380
Fed. Rep. of Germany	10	19	69	80	585
France	11	45	17	41	3,291
Canada	2	3	2	10	4,305
United States	14	3	8	5	6,059
New Zealand	5	6	10	21	3,657
Belgium-Luxembourg	3	4	29	15	2,676
Norway	2	4	5	5	3,262
Austria	5	5	11	3	2,537

Table 5 (Contd.) **Exports of mica by countries 1971-1974 (a)**

	1971	1972	1973	1974*(p)*	*Average value per tonne in 1974*
	Tonnes				*£ fob*
Worked mica (cont.)					
Italy	2	2	7	3	6,858
Poland	3	4	1	5	12,257
India	2	1	6	5	3,401
Thailand	1	6	-	6	641
Portugal	1	14	24	1	3,109
Switzerland	4	7	12	5	2,402
Spain	3	7	11	3	2,693
Australia	30	4	6	2	3,834
Sweden	3	3	1	5	3,332
Netherlands	7	4	4	3	3,919
Irish Republic	2	1	24	2	1,558
Denmark	2	0	1	3	1,657
Hong Kong	1	0	1	4	1,871
Finland	2	1	3	1	8,729
China	-	-	-	7	10,414
German Dem. Rep.	-	-	-	5	2,108
Oman	-	-	0	10	313
Other countries	17	7	19	12	2,001
Total	153	166	290	282	2,680
Value £ fob	435,611	367,319	465,573	756,749	

Source: HM Customs and Excise

(a) Includes re-exports
(p) Provisional

Production and consumption

Production of mica in Scotland between 1942 and 1944 is known to have amounted to 3.25 tonnes of sheet and 85 tonnes of scrap mica. There is a small current production of mica in Scotland but production figures, collected by the Business Statistics Office are not separately available because of confidentiality. The recent level of flake mica production in Devon is not known but is estimated to be in the region of 2,000 tonnes a year. This production was as waste recovered from china clay working, 0.9 tonnes of micaceous residue resulting from every 1 tonne of china clay produced. The current levels of china clay output would give rise to some 3 million tonnes of mica-rich residue. Mica recovered from this residue was not recorded in official production statistics. Imported waste and ground mica could be extensively replaced by domestic production, which is believed to have increased substantially during the past 20 years to meet demand from a growing number of user industries. However, by June 1975 the Lee Moor operation was evidently no longer economic and production ceased.

Consumption can be estimated as the excess of imports over exports, which in 1974 was 6 thousand tonnes, but this ignores the unknown quantity of domestic production. Inadequate statistics make future demand forecasts difficult.

Substitutes

The demand for alternatives to natural mica was stimulated by supply difficulties during the Second World War and substitutes were successfully developed for some end uses. Dependence upon rather unreliable sources of supply, and the variable quality of natural mica are continuing factors which favour the development of alternative materials. Rising prices have contributed to the inroads that reconstituted mica has made into the market for built-up mica.

The possibilities for new substitutes for mica being discovered are limited. Research on synthetic mica, originally aimed at producing large single crystals, has been more successful in developing a range of micas with special properties which are in effect new materials whose applications do not generally overlap with those of natural mica.

No other material has the full range of properties shown by mica. Therefore, in applications in which a high degree of flexibility and cleavability is necessary, there are no technically acceptable substitutes. Already mica has been largely replaced by other materials in some applications that were formerly important, such as stove windows, sparking plugs and radio condensers, and further substitution by glass and ceramic materials is conceivable. Lower qualities of sheet mica can be substituted for higher grades of sheet and reconstituted mica in some instances. The use of reconstituted mica (mica paper) for electrical insulation in place of built-up mica made from splittings is perhaps the most significant substitution being made at present and could become more important in the future. The trend towards miniaturization of electronic equipment has had the effect of limiting requirements for mica in spite of the expansion of the industry.

Synthetic mica is a potential substitute for natural sheet mica but in spite of much research it does not at present seem likely that large crystals can be grown economically and in substantial amounts. Fluorphlogopite is the variety of mica that can be most successfully synthesised; it is a colourless

mica with better thermal stability than muscovite. Fluorphlogopite is produced commercially in the United States and Japan by fusing a mixture of pure compounds and cooling slowly for several days. A few large crystals can be obtained from each batch and the remainder is ground for use in reconstituted mica or in glass-bonded mica where it has some advantages over natural muscovite.

There are various alternative materials to ground mica as a filler and surface coating powder. Examples are talc and crushed slate.

Industry

English Clays Lovering Pochin and Co Ltd until recently was the only major producer of mica from United Kingdom sources. Microfine Minerals and Chemicals Ltd and Deering Products Ltd are the main producers of ground mica. A large number of companies have interests in the fabrication and use of mica.

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