

INTELLIGENCE  
IN  
GRAPHITE







# INTO THE BLACK. GRAPHITE.

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# BLACK IS BEAUTIFUL.

GRAPHITE – A MATERIAL MADE FOR BIG TASKS.

Just like diamond, graphite is a crystalline form of carbon with valuable properties – excellent electrical and thermal conductivity, outstanding lubrication properties, enormous resistance to temperature and oxidation as well as the ability to form intercalation compounds. Graphite is ideally suited to tackling major tasks – no wonder it is sometimes referred to as “black gold”.

Commercially viable deposits of graphite are limited, which is why graphite is listed among the world’s so-called “critical raw materials”. In an effort to guarantee a steady supply of raw material at all times, Advanced Metallurgical Group N.V. (AMG), the Amsterdam-based parent company of Graphit Kropfmühl, operates internationally. The group’s production sites are located in Germany, Great Britain, France, the Czech Republic, the USA, China, Mexico, Brazil and Sri Lanka.

AMG WORLDWIDE – CRITICAL RAW MATERIALS



- Cr** Cr Chromium
- Si** Silicon
- V** FeV & FeNiMo
- Sb** Antimony
- Ti** Titanium alloys & coatings
- Ta** **Nb** Tantalum & niobium
- C** Natural graphite
- Al** Aluminium master alloys & aluminium powder

## GRAPHIT KROPFMÜHL – EXPERTS IN RAW MATERIALS FOR MORE THAN 140 YEARS.

Since its foundation in 1916, Graphit Kropfmühl and its global production sites have been synonymous with outstanding raw materials expertise. Innovation, market proximity and an absolutely customer-centric approach have helped us become a trend-setting graphite refiner. Our leading position as an international graphite specialist is both a motivation and obligation in equal measure.

A strong focus on research and development work ensures that our product range is continuously optimised.

We are committed to developing high-quality specialist products and solutions using cutting-edge and quality-driven processes on the back of intensive dialogues with our customers and partners. In addition to our own mine at Kropfmühl in Lower Bavaria, we also hold stakes in mines in Africa and Asia in an effort to ensure the supply of raw materials.

We have spent decades combining the value and character of graphite with the creativity to craft truly extraordinary products.



Ore from Kropfmühl:  
Graphite content of  
up to 30%



Ore from Sri Lanka: characterised by a  
special structure and a high graphite  
content of up to 99%

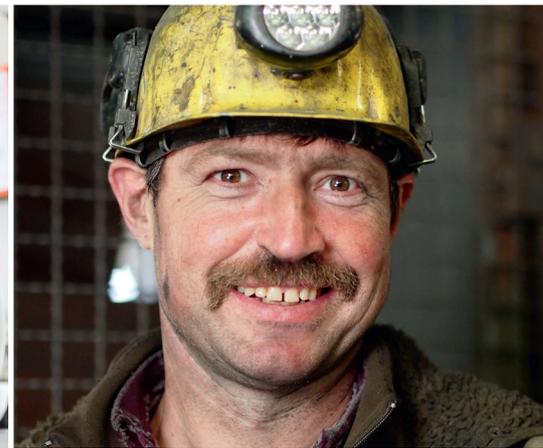


Ore from Mozambique:  
excellent crystallinity and high  
density – graphite from Africa





INTO THE  
**BLACK**  
FOR YOU.



# WORKING IN THE MATERIAL WORLD.

## GRAPHIT KROPFMÜHL GMBH

- Central administration
- Underground mine
- Research and development centre
- Refining of natural graphite
- Production of powder lubrication premixes
- Production of graphite dispersions
- Production of formed graphite parts

## WEDEL PLANT (NEAR HAMBURG)

- Storing, homogenisation and screening of natural graphite
- Storage of expandable graphite

## GRAPHITE TÝN SPOL. S.R.O., CZECH REPUBLIC

- Purification and micronizing of natural graphite
- Processing of synthetic graphite
- Production of graphite dispersions
- Sale of formed graphite parts
- Production of expandable graphite
- Expandable and expanded graphite

## QINGDAO KROPFMÜHL GRAPHITE CO. LTD., CHINA

- Refining of expandable graphite
- Micronizing and screening of natural graphite and synthetic graphite

## BOGALA GRAPHITE LANKA PLC, SRI LANKA

- Underground mine
- Purification and screening of natural graphite
- Micronizing
- Production of graphite dispersions
- Lubricants

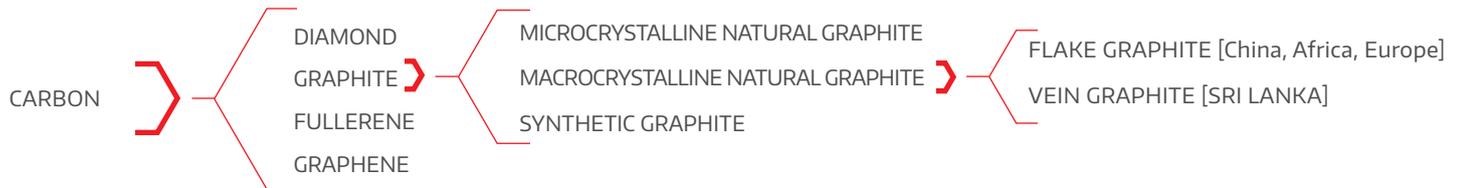
## GK ANCUABE GRAPHITE MINE S.A., MOZAMBIQUE

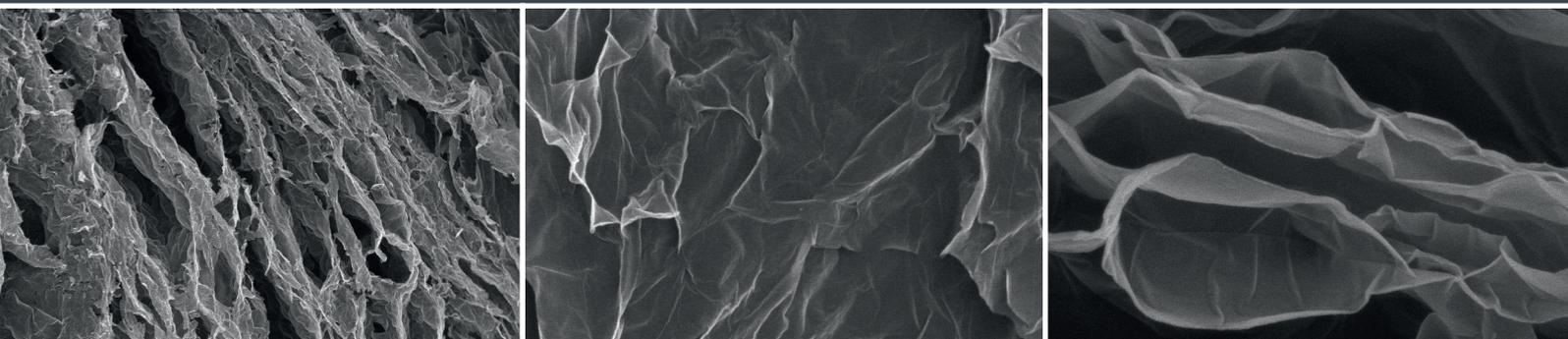
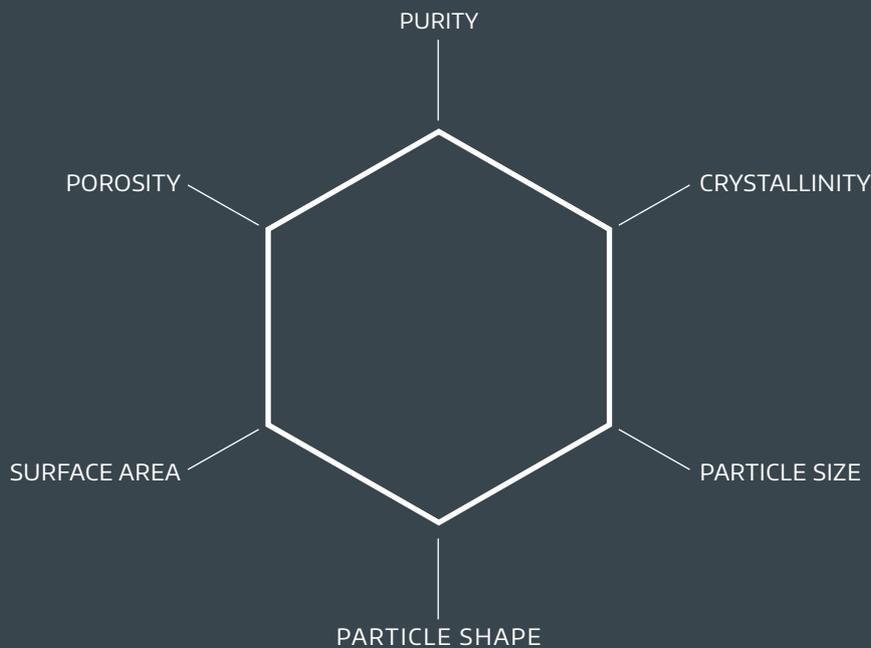
- Opencast mine
- Purification and screening of natural graphite

# THE SIXTH ELEMENT.

## GRAPHITE - INCREDIBLY VERSATILE.

In the conventional periodic table, the element carbon is located in sixth position. Graphite grades can be characterised by six interrelated and mutually influencing parameters: **purity, crystallinity, particle size, particle shape, surface and porosity.** These parameters can be precisely influenced when processing graphite, allowing the optimal combination of properties to be achieved for each respective application.





## CARBON

Carbon can be found in large amounts in the sun as well as in the atmosphere of most planets. Although the carbon content on earth is less than 0.1 percent, it still forms the basis for organic chemistry and therefore for life itself.

Carbon has the special ability to form compounds with itself and other elements such as oxygen, hydrogen and nitrogen. Crystalline carbon is known in four allotropic forms: graphite, graphene, diamond and fullerene.

## RESISTANCE TO OXIDATION AND TEMPERATURE STRESS

Its excellent degree of crystallisation makes graphite highly resistant to oxidation, cyclic temperature stress and to most chemical agents. This makes graphite ideal for applications in refractory and chemical materials.

## OUTSTANDING CONDUCTIVITY

The thermal and electric conductivity of graphite stems from its free electrons. The size and orderliness of the crystallites is key in determining this property.

## EXCELLENT LUBRICATION PROPERTIES

Graphite has excellent lubrication abilities due to the large distances between layers in the crystal lattice which are connected by weak forces. Graphite demonstrates its strengths particularly impressively in the face of high temperatures and pressure.

## FORMATION OF INTERCALATION COMPOUNDS

The bonding strength between the layer planes allows the intercalation of certain molecules within the graphite lattice. This intercalation ability allows the application of graphite in flame protection and batteries.

# BLACK IS COLOURFUL.

Starting with the crude ore, multiple steps first have to be taken to produce graphite of the highest quality and products tailored to specific customers and applications. As it holds its own secure and controlled raw materials sources in Asia, Africa and Europe, the Graphit Kropfmühl Group is able to guarantee its customers security of supply and consistent product quality.

## FLOTATION

The flotation process was used for the first time commercially in Kropfmühl and has been continuously improved ever since. Flotation is the name given to the hydro-mechanical separation of graphite and its accompanying minerals with the aim of increasing the carbon content to up to 98%.



## MICRONISING AND SIEVING

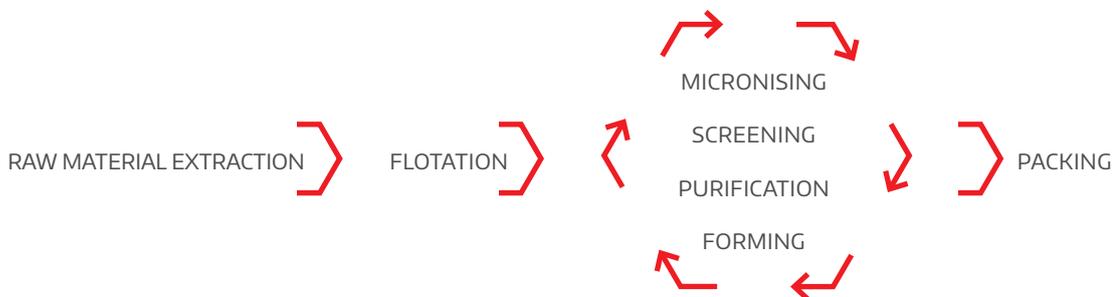
In addition to the carbon content, the grain size is another important parameter. Grain fractions can be separated using vibrating screens or large air separators. Following purification, part of the graphite is ground down to a fineness of under 2µm. The various micronizing methods used also help determine the particle characteristics.

## PROGRESS

Graphit Kropfmühl stands out as a pioneering technology company thanks to its in-depth and constant commitment to exploring new processing techniques and developing special graphite products for state-of-the-art applications. We also contribute our comprehensive know-how and help pioneer forward-looking projects as part of our cooperation with universities and research institutes.

## PURIFICATION

Grades with a graphite content of over 98% require additional processing steps following flotation. The chemical purification of graphite allows purities of **> 99%**, while the combined chemical/thermal purification process even enables a purity of **99.99%**.





# BLACK ON WHITE.

## PENCILS – BACK TO THE ROOTS.

The humble pencil was invented following the discovery of a graphite deposit in England. However, at the time, in around 1550, people thought that they had discovered lead ore. As the extracted material left a mark and slid pleasingly across surfaces, it was clamped between two wooden rods and the first pencil was created. Indeed, people believed that pencils contained lead right up to the 18th century, until the chemist Karl Wilhelm Scheele proved that the supposed lead ore was in fact a quite different material: graphite. So contrary to popular belief, pencils are filled with graphite and not lead!



The pencil core is in fact a mixture of graphite and clay binder.

Graphite is a key raw material both in traditional wood pencils and modern fine-lead pencils. The hardness of the pencil is determined by the mix of graphite and clay used.

# TRIAL BY FIRE.

## CRUCIBLES – GRAPHITE STANDS THE HEAT..

More than 2,000 years ago, the Celts were already aware that graphite could be used to produce flame-proof ceramics. Due to its high resistance to oxidation, its excellent thermal conductivity as well as its chemically inert behaviour, "black gold" still plays an important role in the refractory industry to this day, both in magnesite bricks for furnace linings and in continuous casting gutters. In addition, graphite is used as a coating for high-quality molten metal in order to prevent oxidation.

We use large flake graphite with a well-pronounced crystal structure for producing refractory materials. These guarantee a long useful life as well as outstanding quality.

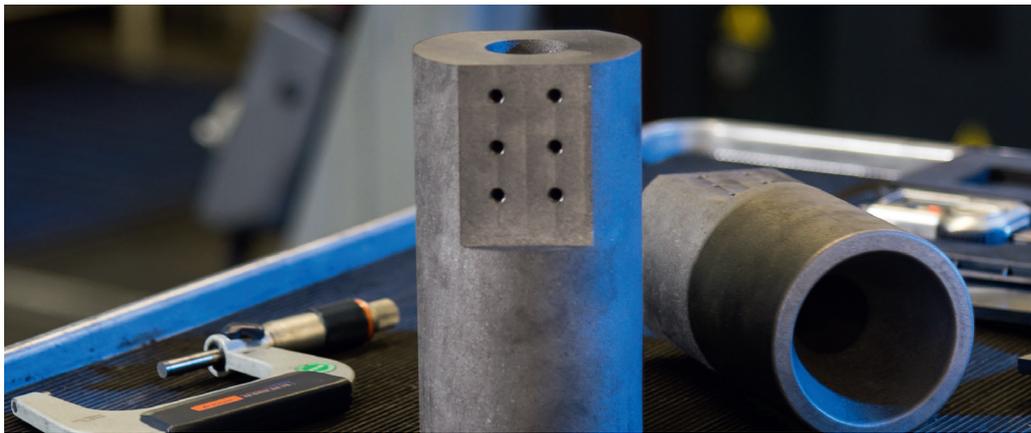


Proven over millennia: the heat conductivity of large graphite flakes in the crucible.

# BLACK MAGIC.

## FORMED GRAPHITE PARTS – GRAPHITE TAILORED TO FIT.

Due to the unusual physical and chemical properties, graphite guarantees that various construction-related and formed parts work efficiently. It is also incredibly flexible in this respect, as almost all geometric shapes and variations can be produced.



### FORMED PARTS MADE TO MEASURE.

We produce tailored formed graphite parts based on individual drawings and measurements. Isostatic or moulded synthetic graphite of various specifications can be used depending on the application. Modern software allows us to transform drawn sketches in CAD to 2D or 3D designs and implement these right down to the smallest detail. Our specialisation on individual production and small series production allows us to deliver on your wishes quickly and flexibly.

### PRECISE.

Following the production process, our formed graphite parts go through a stringent screening procedure, as tailored products also required tailored quality control. Extensive experience, limitless care and attention, state-of-the-art production sites and processes ensure top-notch product quality and reliability.



Our employees produce your custom formed parts using an absolutely precise approach. Cutting-edge production facilities and processes are combined with a wealth of technical experience to guarantee first-class quality every time.



B75B

# VITAL CONNECTIONS.

## POWDER METALLURGY – FROM POWDER TO CAR PARTS.

Parts produced using powder metallurgy are becoming increasingly important, particularly in the automobile industry. For the production of sintered parts, metal powders are mixed with small quantities of additives such as waxes and graphite. These powder mixtures are then pressed under high pressure into so-called green compacts. As part of this process, graphite ensures reduced wear of the press die and provides internal lubrication within the powder mixture. As a result, graphite makes maximum compression possible. In the sintering process, in which the green compacts are heated to slightly below melting point, the material is then compressed further. Moreover, fine graphite goes into solution in the metal and in doing so increases the mechanical strength of the workpiece.

## SELF-LUBRICATION – SMOOTHLY DOES IT.

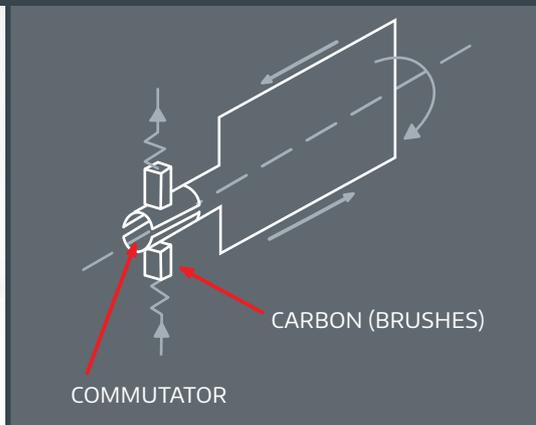
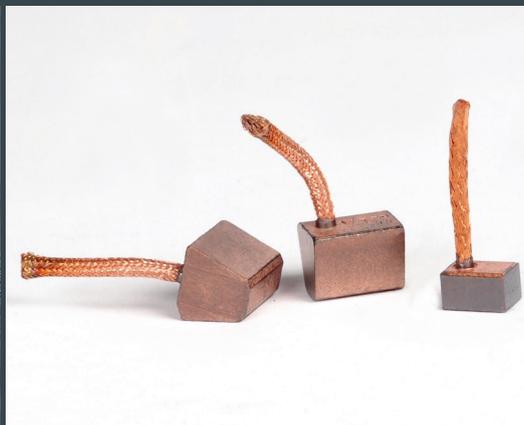
Special powder mixtures exist for self-lubricating sintered parts. These special mixtures contain coarser graphite that only goes into solution to a small extent during the sintering process. The graphite particles are largely incorporated into the matrix of the workpiece in intact condition and are gradually exposed during the useful life of the part, which enables the graphite to develop its lubricating effect.

## CARBON BRUSHES – SMALL BUT VITAL.

These small parts are contained in almost all electrical motors in cars, such as windscreen wipers, fuel pumps and fan motors. They establish electrical contact to the rotating component of a machine via sliding rings or collectors. And although this technique for transmitting current is over a century old, it is by no means obsolete. Indeed, it is still known as a reliable solution that meets the high standards of innovative industries such as the automobile sector (start-stop technology). Carbon brushes for starters, for instance, not only have to endure around 40,000 start cycles, but also have to come through a comprehensive testing process. As a result, a wealth of expertise is packed into the materials used for such components. In addition to pure carbon and graphite materials, impregnated versions and composites of graphite and other metals are often used.

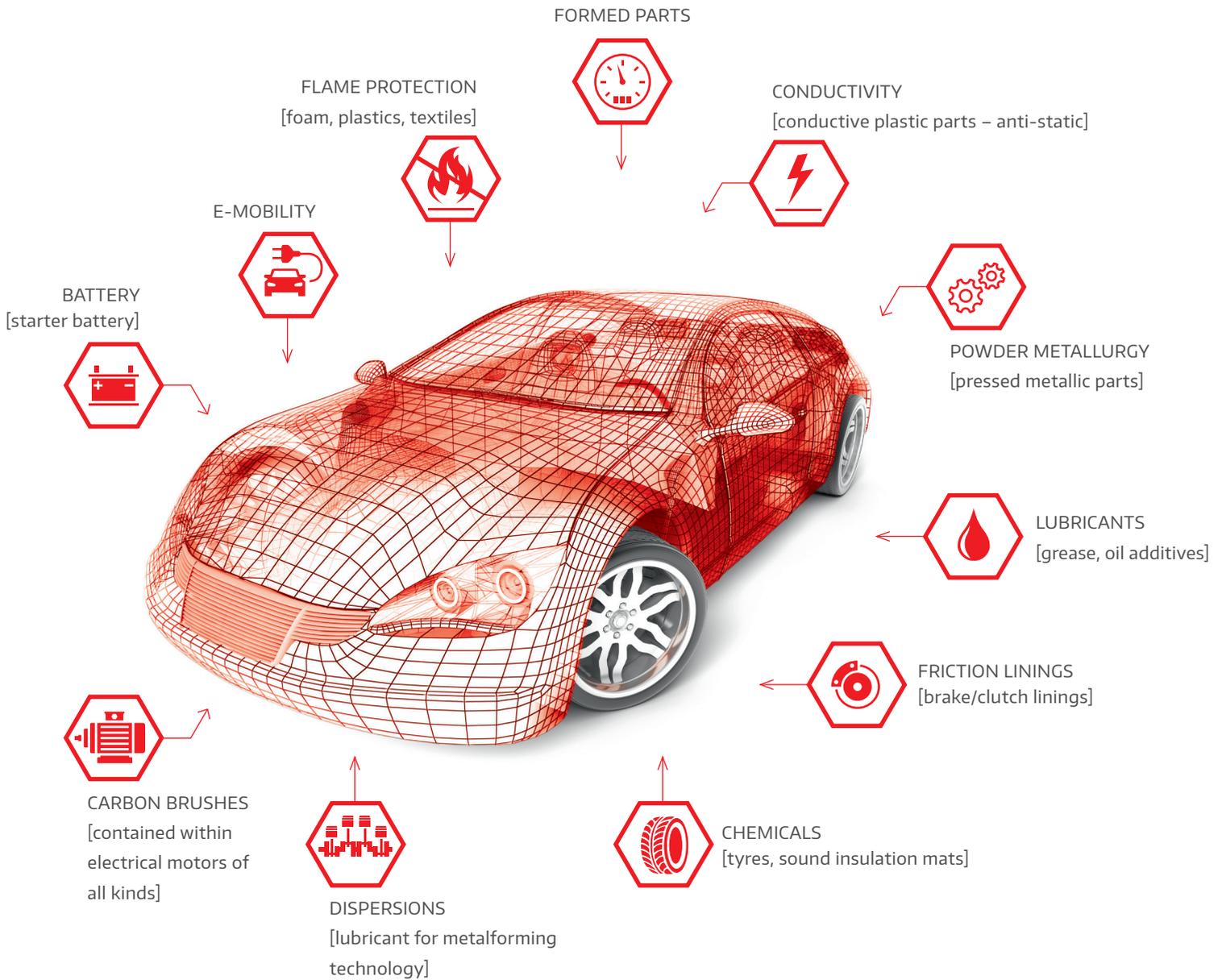
## RELIABLE QUALITY.

Only a constant raw material quality, reproducible process parameters and specialist knowledge ensure the dimensional accuracy and perfect quality of complex graphite products.



# BLACK FROM BUMPER TO BUMPER.

The first generation of electric vehicles are finally in series production at several automobile manufacturers. Graphite has a key role to play within e-mobility. And when it comes to cars and graphite, e-mobility is just the tip of the iceberg. "Black gold" is nowadays closely connected to the entire automobile industry due to its versatile range of uses. Every conventional car includes between 80 and 100 sintered parts containing graphite.

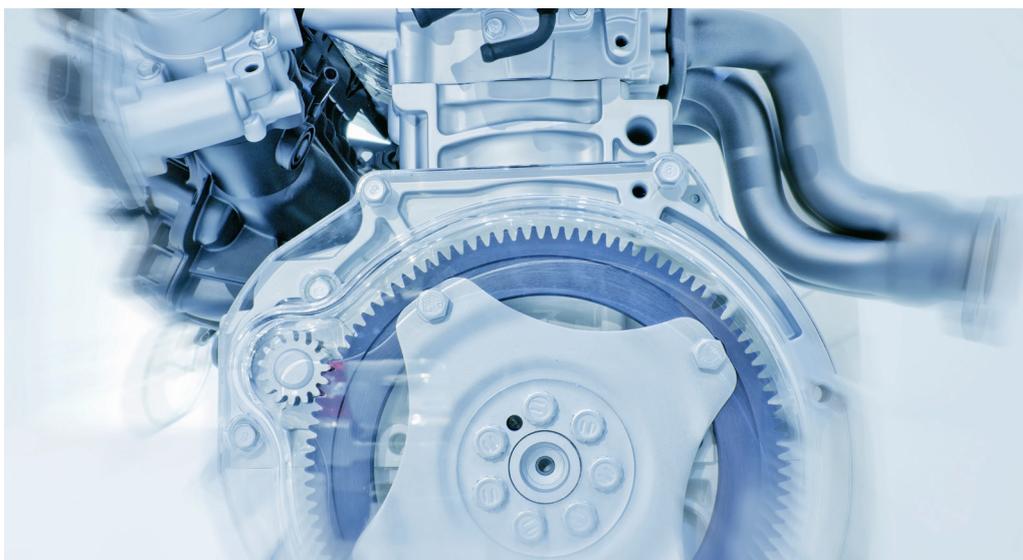


## GRAPHITE GETS E-CARS ON THE ROAD.

Graphite is an efficient high-tech material with a bright future. The trend towards electro-mobility has the potential to become a growth driver for graphite. Forecasts estimate that demand will quadruple in the period up to 2030.

In this field, graphite is used in the production of innovative energy storage and conversion systems. Graphite has proven itself as the best value anode material in modern lithium-ion batteries in terms of energy storage abilities, cyclical stability and

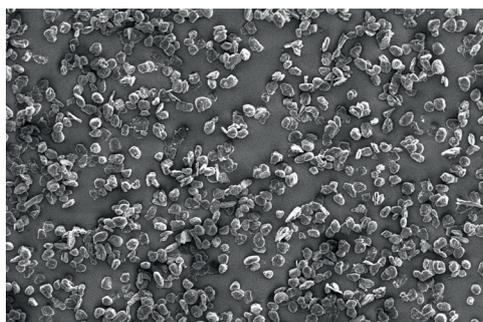
cost efficiency. The latest developments combine graphite with hetero-materials like silicon which have an even higher capacity. For their meaningful application, the cyclical stability of such anode materials has to be increased as well as the – currently low – capacity of the cathodes improved. The refinement of natural graphite for e-mobility is therefore a highly attractive research field.



Graphite: an important basis for promising hybrid technology.



Lithium-ion batteries are often the first choice as energy storage units, e.g. for mobile devices, due to their high energy density combined with relatively low weight.



Natural graphite is ideally suited to operate as a high quality storage material within a Li-ion battery.

# SMOOTHLY DOES IT.

## VEIN GRAPHITE.

This type of graphite can be particularly easily moulded and combined with other materials, e.g. copper. It can be found in battery cells, carbon brushes, in powder metallurgy, plastic applications, flame retardant materials and lubricants. "Vein graphite" extends through rock like veins.

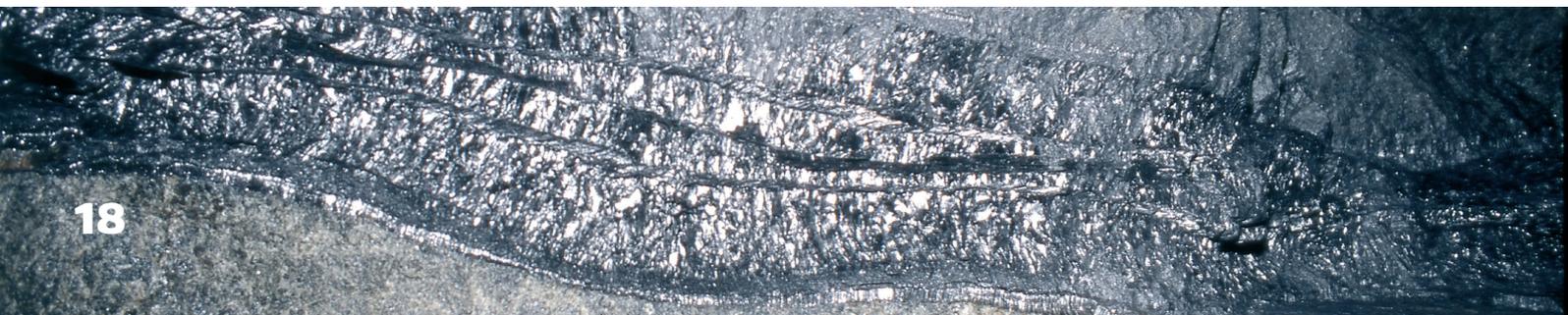
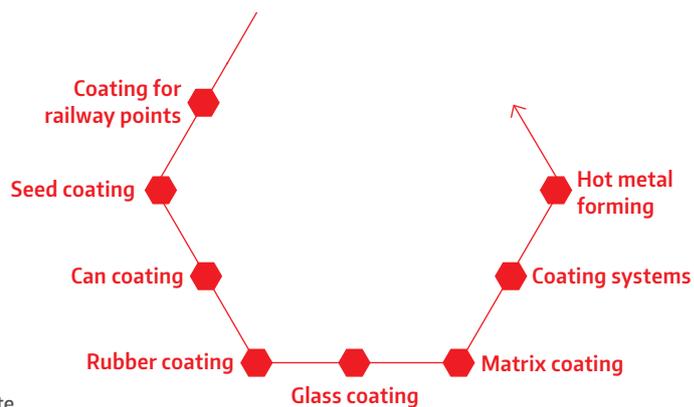
It is graphite in its most natural form, and something rather special. Formed by hydrothermal liquids, vein graphite exists with a purity of up to 99.5% in its natural state underground. It consists of needle-shaped particles, which are the secret behind this graphite's special properties. Due to the varied particle sizes up to centimetre-sized lumps, the range of vein graphite products is highly diverse.

Part of the value of this special type of graphite stems from its limited occurrence. At the start of the 20th century, the world economy was only supplied with vein graphite from Sri Lanka, so-called "Ceylon Graphite". This is still the only country where the material is commercially extracted today. The Bogala Mine, where Graphit Kropfmühl is the main shareholder, supplies the world market with the lion's share of this type of graphite. We offer the best vein graphite in various forms – from course lumps to fine powders.



An homage to its origins: a Sri Lankan elephant carved from a fine piece of Sri Lankan vein graphite.

### FIELDS OF APPLICATION



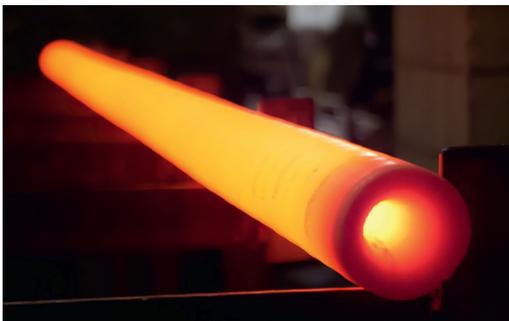
## LUBRICANTS.

Due to Van der Waals forces, pure graphite is a wondrous material when it comes to lubrication. The particles slide easily against one another and in doing so lower friction. As every type of graphite, in contrast to oil, neither combines with dirt nor is resinous, it is an outstanding addition to lubricants and ideal for use in thermally intense lubrication points – even in areas where oil lubrication is impossible.



## MANDREL LUBRICATION.

In modern tube rolling mills, a pre-produced hot hollow is rolled over a mandrel to shape seamless tubes. After the rolling process, the mandrel and/or mandrel bar is removed from the rolled tube blank and cooled down in preparation for the next rolling process. Adding a coating of graphite is also part of this preparation. This is vital in order to ensure that the hollow “glides” perfectly on the mandrel bar during rolling and it is therefore decisive for the subsequent quality of the tube. High-quality graphite from Kropfmühl has been a reliable guarantee for high-quality tube production processes for years.



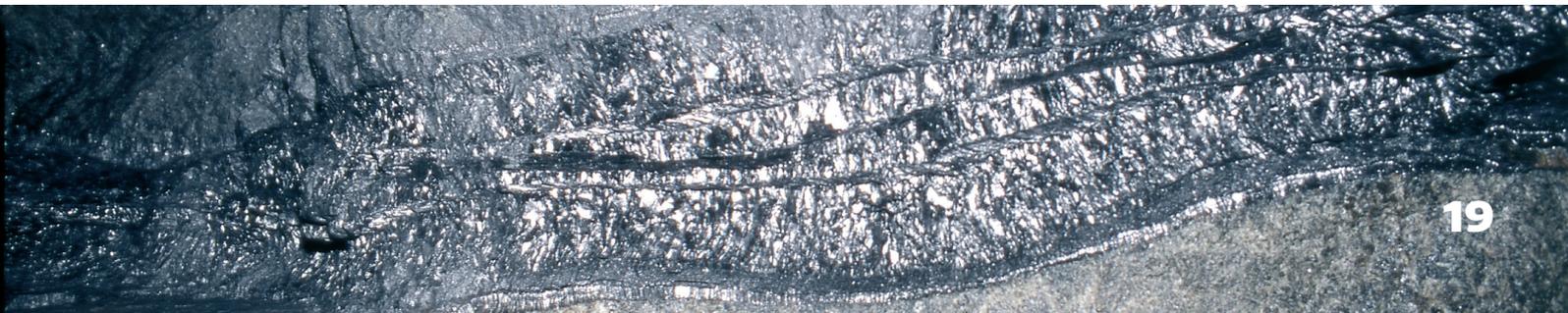
As a lubricant, graphite plays a decisive role in the production of seamless tubes.

## DISPERSION.

Dispersion is the mixing of at least two different materials. Graphite dispersions are used in applications that require a uniform and fine distribution of graphite on the surface of the material which is to be coated.

Depending on each individual application, the following dispersion properties are of decisive importance: sedimentation stability, surface tension, wetting behaviour on different surfaces, adhesive power on different surfaces, drying time, viscosity and pH level.

In order to improve the dispersing effect, tailor-made formulations also contain protective colloids, preserving agents and other additives in addition to graphite and the dispersion agent (usually water). Graphite dispersions can be specifically produced for each individual application. In addition to custom dispersions, Graphit Kropfmühl also sells powder premixes which the customer/consumer can then mix with water.

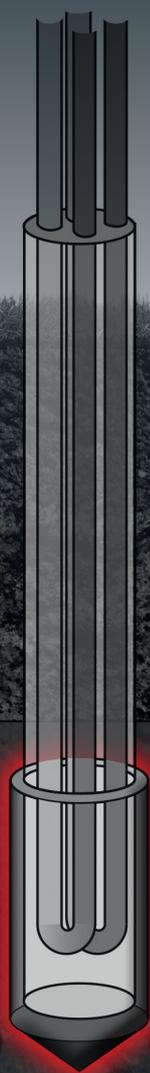


# LIVE BETTER WITH GRAPHITE.

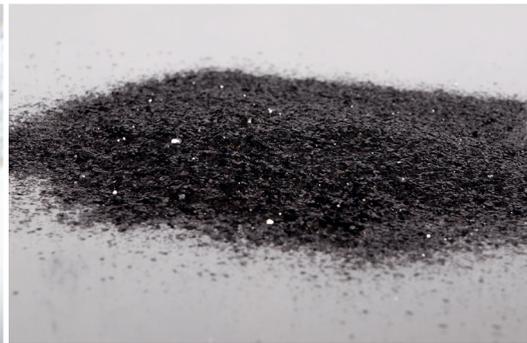
## GEOTHERMAL – HARVESTING ALTERNATIVE ENERGY WITH GRAPHITE.

For more than 10 years, a specially-developed, macrocrystalline natural graphite has been used for harvesting geothermal energy. For the long-term storage of heating energy, the geothermal tube storage system has proven to be a successful type of earth-bound heat pump. Vertical holes are drilled into suitable areas of ground and specific water pipes are then installed in these drill holes.

The heat exchangers installed in the holes are embedded in fill material containing graphite. This ensures that thermal contact exists between the heat exchanger and the surrounding ground, and also that the pipes are mechanically fixed. The natural graphite helps achieve constant first-class thermal conductivity of  $> 2.0 \text{ W/mK}$ . In addition, thanks to graphite's good lubrication, it sustainably supports the safety of the geothermal system.



The thermal contact is well embedded in filling material made of natural graphite, ensuring that thermal contact exists between the head of the geothermal heat exchanger and the surrounding ground. Outstanding heat conductivity levels are achieved thanks to the use of natural graphite.



Drywall panels cool and heat with low energy input [left]. Making the decisive difference: crystalline graphite powder [centre]. Grey EPS board provides outstanding insulation levels [right].

**DRYWALL PANELS –  
BEAT THE HEAT WITH GRAPHITE.**

Modern buildings often lack traditional storage mass and therefore cooling becomes a necessity. Cooling ceilings are a particularly effective solution in this case. They offer the option of heating and cooling “gently” with low energy requirements.

High-performance drywall panels make surface temperature regulation systems even more energy efficient. Gypsum plaster regulates the room atmosphere and offers excellent fire resistance. Meanwhile, a graphite core provides outstanding thermal conductivity abilities. The panels combine both properties and therefore achieve a heating conductivity rating of 0.45 W/mK that far exceeds the performance of thermal panels used to date.

**GREY EPS –  
NICE AND COSY WITH GRAPHITE.**

With the help of graphite technology, the most efficient insulation material on the market has now got even better. As part of a special process, graphite particles are worked into the foam structure of conventional white EPS (expanded polystyrene). This “grey” EPS offers outstanding graphite properties like infrared radiation and therefore heat reflection. This boosts insulation performance by up to 20%.

Grey EPS is particularly well suited to buildings with high energy standards, such as low-energy or passive houses, or buildings aiming to achieve the best insulation levels with limited space, such as renovated old structures.

THE INTELLIGENCE OF SMALL  
**BLACK CELLS.**

Wafer-thin, incredibly flexible, extremely conductive and stronger than steel – graphene is seen by many as the wonder material of the future. Among other techniques, graphene is produced by splitting graphite – a process known as exfoliation.

### GRAPHENE – A GRAPHITE-BASED WONDER

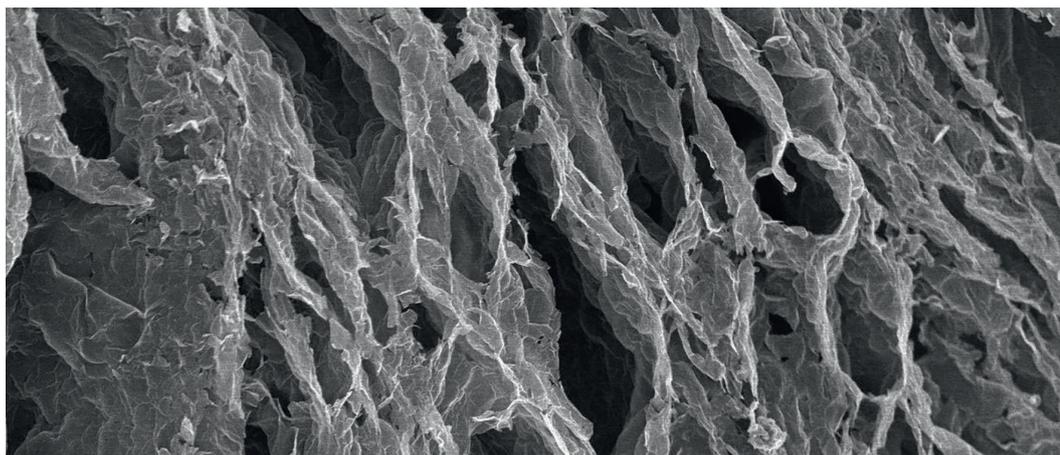
In its crystalline form, graphite consists of parallel layers called graphenes. Graphenes are incredibly flat 2D crystals which are made up of just one layer of carbon atoms.

For a long time, researchers did not believe that such mono-atomic layers existed until the physicians Geim and Novoselov made a sensational discovery in 2004 while analysing graphite: graphene. They received the Nobel Prize for this global research breakthrough in 2010.

### GRAPHENE – THE WORLD'S THINEST MATERIAL

Graphene atoms are grouped in hexagonal rings reminiscent of honeycomb to form a stable mechanical network. When viewed from a distance, the carbon hexagons form a slightly wavy surface.

Due to its stability and high elasticity, graphene combines the hardness of a diamond with the bendiness of an ultra-thin film in one material. Due to its electrical hyper-conductivity, graphene has the potential to revolutionise microelectronics and computer technology. Graphit Kropfmühl has been producing graphene by the kilo for years.



# BLACK PASSION.

## WHAT DRIVES US.

The versatility offered by this crystal structure is the key to graphite's success.

We aim to mirror the material's best characteristics in striving for success as a company.

We pay particular attention to occupational safety, quality assurance and sustainability.

We also take social responsibility seriously and aim to deliver on our responsibilities as a company.

**Intelligence in Graphite.**





## OCCUPATIONAL SAFETY

Occupational safety and promoting good health are important components of the company strategy when it comes to achieving our targets. This is not just about maintaining the motivation and ability of our employees to perform but also improving our performance in these areas with a view to achieving sustainable company success. Preventive measures and safe conditions for fulfilling the tasks required are guaranteed and realised for every employee to the greatest extent possible.



## SOCIAL RESPONSIBILITY

For us, taking social responsibility means always being aware of relevant social causes and integrating them into our corporate decision-making. We see it as our task to protect the environment and the climate by doing business in an energy-efficient way.

The graphite we produce is checked and analysed with regard to any possible influences on the environment. In general, graphite is not a hazardous material. Its use, processing or disposal are not generally expected to have environmental impacts.

For us, ethical principles form the foundation for fair interaction with customers, business partners, employees and colleagues. We are also committed to adhering to moral and legal standards.



## QUALITY ASSURANCE

For us, quality is the result of a systematic continuous process. Our aim is to not only fulfil our promises but to exceed them for the satisfaction of our customers and partners alike. The quality of our products and services is the key factor when it comes to our competitiveness. We invest a great deal of effort in training our personnel in quality assurance and optimisation, and actively involve all employees in the improvement process.



## CORPORATE COMMITMENT

The promotion of cultural events, educational initiatives and sports offerings is a key concern for our company.

For instance, we have been actively supporting the employees and families of our new research centre in Mozambique.

Regionally, we support the foundation "Stiftung Kropfmühl" and are committed to maintaining Germany's only graphite visitor mine through the charity "Förderverein Graphit Kropfmühl Besucherbergwerk e.V." which was founded in 2010.

History and tradition are strongly rooted in our company and the surrounding region. As a result, the tradition of the miner's association and its choir and band are still maintained to this day.



## SUSTAINABILITY

Environmental protection enjoys a high priority within our company policy. As a result, every employee is regularly trained in working in a resource-conserving way in general and specifically in relation to their job. No product waste is produced during the processing of graphite.

All secondary products which are produced are used as raw materials in other combinations.

Certificate DE17/18/18842560.01

The management system of  
**Graphit Kropfmühl GmbH**  
Langheinrichstraße 1  
D-54051 Hauszenberg

has been assessed and certified as meeting the requirements of  
**OHSAS 18001:2007**

For the following activities  
Mining, Development, Processing,  
Stocking and Selling of Graphite





INTELLIGENCE IN GRAPHITE



