Celanese

The chemistry inside innovation™

GUR® UHMW-PE

ULTRA-HIGH PERFORMANCE POLYETHYLENE POWDER

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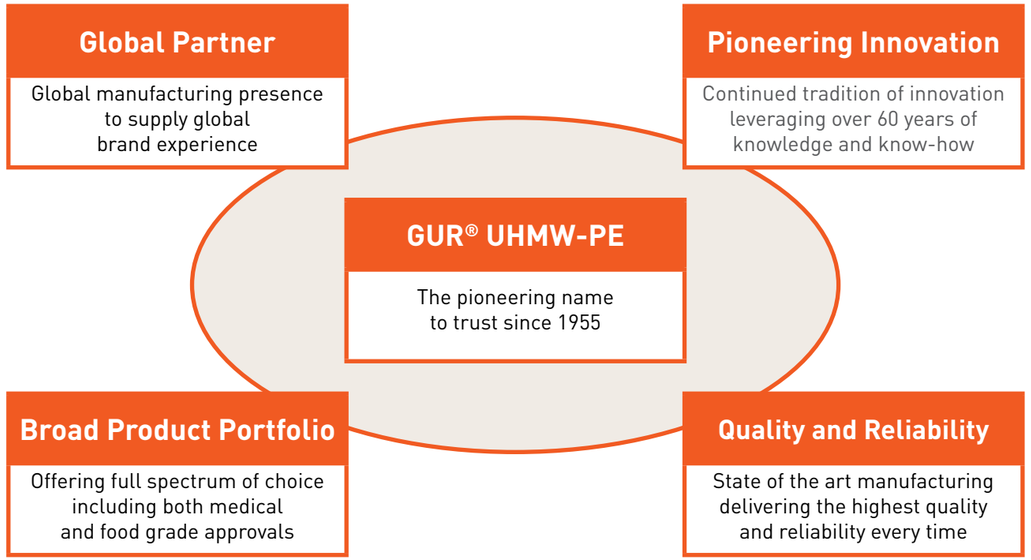
Front cover: GUR® UHMW-PE is frequently being used for waterlocks and storm-surge barriers

Introduction to GUR® UHMW-PE Ultra High Performance Polyethylene Powder

GUR® UHMW-PE Ultra High Performance Polyethylene Powder

- Welcome to the world of GUR® UHMW-PE – an ultra high performance polyethylene powder encompassing both ultra high and very high molecular weight polyethylene
- First launched in 1955 in Oberhausen (Germany), GUR® UHMW-PE has become synonymous with high quality, performance and innovation representing a unique thermoplastic and engineering material in our portfolio
- From the early 1950s to the present day, Celanese has been and continues to be a leading pioneer in UHMW-PE, having developed a broad range of high performance powders in a wide array of applications
- We are the only truly global supplier of UHMW-PE serving our customers around the world from manufacturing facilities in Europe, North America and Asia



GUR® UHMW-PE
Pioneering Technology
Since 1955

GUR® UHMW-PE was first officially introduced to the world at the 1955 K-fair (International Plastics Show) in Düsseldorf, Germany.

The catalyst technology enabling GUR® UHMW-PE was discovered by Dr. Karl Ziegler in 1953 at his lab in Mülheim, Germany, which is very close to the first production facility in Oberhausen.

Since its inception, GUR® UHMW-PE has grown into the leading UHMW-PE product used in a broad range of applications.

Our first production plant in Oberhausen proudly continues to supply high quality products and delivering pioneering innovations to industry.

Factory of Ruhrchemie; Photography Emil Schütte, 1954; © LVR-Industriemuseum

A short history of GUR® UHMW-PE	
1953	Catalyst discovered by Karl Ziegler (Nobel prize for Chemistry in 1963)
1955	First pilot plant at Oberhausen
1955	GUR® UHMW-PE introduced at K-Fair
1960s	First manufacturing unit and development of processing technologies and applications
1981	Process modernization with new catalyst systems
1982	3rd line built in Oberhausen
1983	Opening of Bayport, Texas plant
1988	4th line built in Oberhausen
1992	European ISO 9001 certification
1996	Expansion of 4th line in Oberhausen
1998	Global ISO 9001 certification
2002	Opening of Bishop, Texas plant
2004	Oberhausen capacity expansion
2008	Opening of Nanjing, China plant

Karl Waldemar Ziegler
1898-1973

First applications in the textile industry: e.g. GUR® UHMW-PE replacing wood in textile shuttle

GUR® UHMW-PE
Global Presence

Since the invention of GUR® UHMW-PE, Celanese has continued to invest in capacity and technology to meet the growing needs of our customers. Our broad manufacturing footprint is unique in the industry, enabling us to meet the global needs of our customers. Our dedicated facilities ensure consistent product quality and security of supply.

Oberhausen, Germany
The Oberhausen site is the original home of GUR® UHMW-PE, where production first started in 1960. About 80 employees at this site are involved in production, research, application development and quality assurance.

Bishop, Texas
The facility was built in 2002, replacing the first GUR® UHMW-PE plant in the US located in Bayport, Texas

Nanjing, China
The latest GUR® UHMW-PE facility was built in the Celanese chemical complex in Nanjing, China to better serve our customers in Asia.

GUR® UHMW-PE
Unique Properties

Processing technologies

Standard processing technologies: compression molding, ram extrusion, porous sintering (without pressure). Other processing options (depending on grade): screw extrusion, membrane extrusion, gel spinning, injection molding.

Properties

- Exceptional notched impact strength
- Very good sliding properties
- Very low wear
- High chemical resistance
- Very good resistance to stress cracking
- Broad range of application fields due to temperature resistance ranging from -269 °C to +80 °C

Grades

- Standard grades, partially modified grades and specialty grades for compression molding, ram extrusion, and porous products
- Premium grades for orthopedic implants
- Special grades for melt processing
- Functional grades for heat conductance, antistatic properties, and as additives (e.g., micropowders)

Due to very long molecular chains, GUR® UHMW-PE shows extremely high melt viscosity; most grades show no melt flow at all and retain their shape in molten state

GUR® UHMW-PE is a linear polyethylene and differentiated from other PE standard grades by a very high degree of polymerization. The molecular weight (= MW) determined by viscometry of our standard grades ranges from 3.9 to 10.5 million g/mol, Grades with lower MW are also available.

The extreme molar mass is responsible for the fact that the melted product does not flow (MFR = 0). Therefore, special processing methods like compression molding and ram extrusion are required.

Given its unique low melt flow properties, GUR® UHMW-PE is usually not compounded into a pellet like most other thermoplastics but is sold as a powder.

During the manufacturing process, GUR® UHMW-PE powder can be produced with different molecular weights, bulk densities and particle sizes.

The different grades of GUR® UHMW-PE include different combinations of these variables which impart different performance characteristics of the material. With a broad range of grades, GUR® UHMW-PE powders are well-suited to meet a wide range of needs.

GUR® UHMW-PE in comparison with lower MW polyethylenes.

GUR® UHMW-PE
Unique Properties

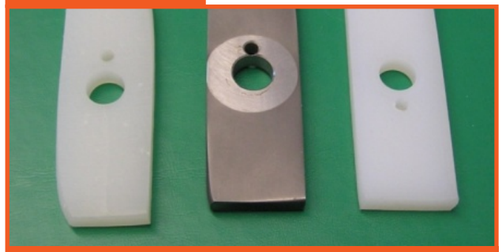
Impact strength

Dock fenders made from GUR® UHMW-PE.

Wear resistance at low temperatures

Polar sledge, sliding surface made of GUR® UHMW-PE

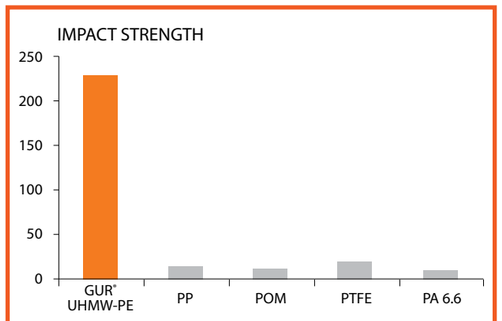
Abrasion resistance



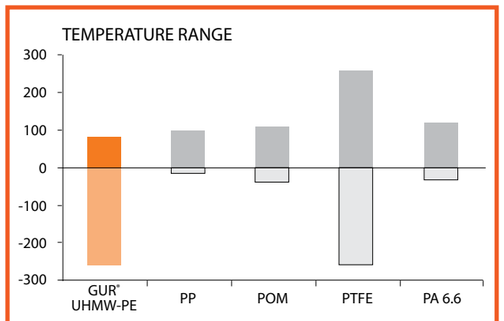
Test specimens of Sand-Slurry Test: GUR® UHMW-PE (on the right) shows the lowest abrasion values, compared to HDPE (left) and steel (middle).

Coefficient of friction

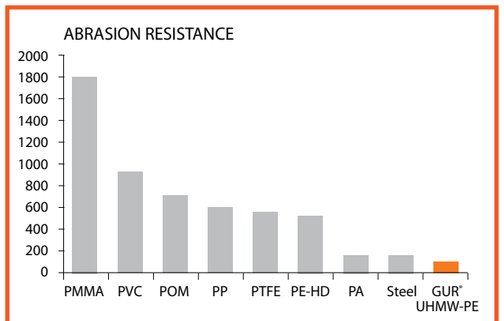
Chain guide, typical application for GUR® UHMW-PE.



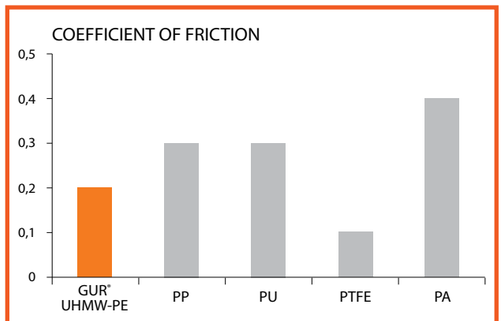
Results of modified „double notched" Charpy impact test showing amount of energy absorbed by a material at the break point.



Typical operating temperature ranges for a selection of different materials.



Material loss performance relative to GUR® UHMW-PE (=100) for different materials after a defined number of rotations in a sand-water mixture.



GUR® UHMW-PE is an excellent material for sliding applications, possessing self-lubricating properties, particularly in dry sliding movement against metal surfaces.

One of the most unique attributes of GUR® UHMW-PE is its extremely high impact strength, which is retained even at very low temperatures. The impact strength is so high, in fact, that under the standard notched impact test (ISO 179) GUR® UHMW-PE does not break. Therefore, a special "double-notched" impact test is used.

The results above clearly demonstrate the extreme outperformance of GUR® UHMW-PE relative to other polymers.

GUR® UHMW-PE has a relatively broad operating temperature range especially in cold temperatures. For example, GUR® UHMW-PE retains its wear resistance performance even at the temperature of liquid helium at -269 °C. While GUR® UHMW-PE does not does not flow above the melting point, we recommend not to exceed a constant operating temperature of 80 °C.

Another truly unique property of GUR® UHMW-PE is its extreme abrasion resistance which can be, as shown in chart above, almost twice as good as steel. This makes GUR® UHMW-PE the material of choice in applications where wear is extremely high and customers are looking for a material to extend the lifetime of critical parts.

GUR® UHMW-PE is also an excellent material for sliding applications. GUR® UHMW-PE possesses self-lubricating properties which allow it to perform very well in "dry sliding" situations such as against metal surfaces like steel, brass or copper.

Abrasion resistance and natural lubricity make GUR® UHMW-PE the perfect material for bushings which are liners in cyclinders with rotating shafts. In addition to minimizing friction, GUR® UHMW-PE also tolerates foreign particles (e.g., dust, sand, etc.) which can cause misalignment.

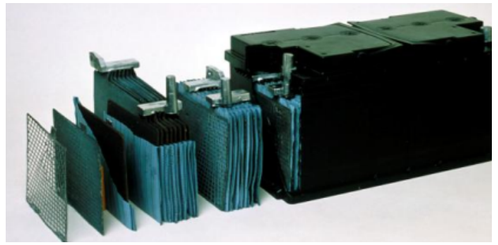
GUR® UHMW-PE
Application Overview

As can be seen from the limited selection here, the unique properties and form flexibility of GUR® UHMW-PE makes it the material of choice for a very broad range of applications.

From medical, to high-tech or food industries, GUR® UHMW-PE offers its unique set of properties to address different application needs. From chemical resistance to surface slip properties or a pressed plate, membrane or fiber, GUR® UHMW-PE has proven itself as a truly unique and adaptable material.

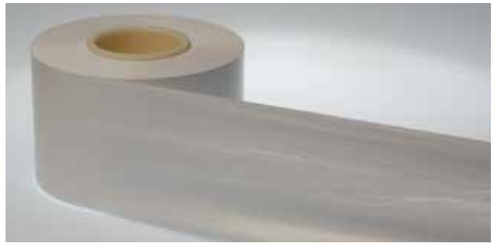
Semifinished products, plates and profiles

- Components that are exposed to wear, e.g. castors, cog wheels, chain guides, bearing bushings, chain tensioners.
- Linings for handling of bulk goods, e.g. conveying troughs, slides, wagons, bunkers.
- Pumps and valves for chemically demanding media.
- GUR® UHMW-PE components are also applied in the fields of sound and shock absorption.



Lead-acid battery separators

- GUR® UHMW-PE is used as a binder for separators in lead-acid batteries, for automotive starter batteries.
- The separator prevents short circuits between the anode and cathode.

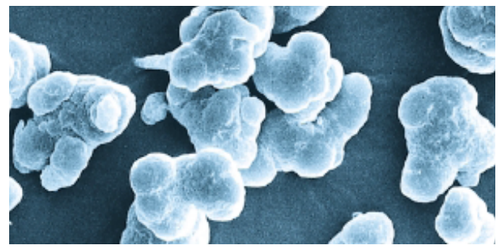


Microporous membranes

- GUR® UHMW-PE microporous membranes have multiple applications as separators in lithium ion batteries and ultracapacitors.
- Also used as breathable membrane in outdoor garments and liquid filters for ultra-filtration.

Filtration

- Porous parts which are manufactured from GUR® UHMW-PE powders are used for filtering liquids, particulates and gases.
- Sintering without pressure also enables high-strength dust filters for very diverse separation tasks.
- GUR® UHMW-PE constitutes the matrix in activated carbon filters used in water treatment.



Functional additives

- Additive for paints and coatings: GUR can improve surface properties like sliding behavior, texture and gloss.
- Additive for thermoplastics and rubbers (e.g. films, tires, belts): GUR can improve sliding properties and abrasion resistance.

Fibers

- Gel spinning technology enables manufacturing of extremely high-strength and stretch-resistant filament yarn, e.g. for cut-resistant gloves.
- GUR® UHMW-PE filaments are also used to manufacture fabrics to absorb the impact of projectiles, for example, bullet-proof vests.
- GUR® UHMW-PE-based fibers have numerous application-specific advantages in maritime and other civil fields, e.g. plaited fishing lines and fishing nets, as well as mooring ropes.

Medical engineering

- Celanese's special GUR® UHMW-PE medical grades are used as bearing partners in endoprostheses (artificial joints).
- Ortheses, either for a temporary immobilization of selected parts of the body (e.g. ankles) or to be worn as a corset (trunk orthesis).
- Special medical filters.

GUR® UHMW-PE Semifinished Goods

Benefits of GUR® UHMW-PE semifinished goods

- Wear, impact and chemical resistant

Applications/properties

- Truck linings
- Dock fenders
- Chain guides
- Ski soles
- Pump valves

Applications/properties

GUR® UHMW-PE is used in packaging and filling plants, food industry, transport, conveying and storage technology, assembly systems and the printing and textile industries. GUR® UHMW-PE can provide a trouble-free operation with low maintenance in profiles for chain/belt drives, curved guides, chain and belt deflecting and tensioning devices, bearing bushings, rail track disks and impact absorbing elements.

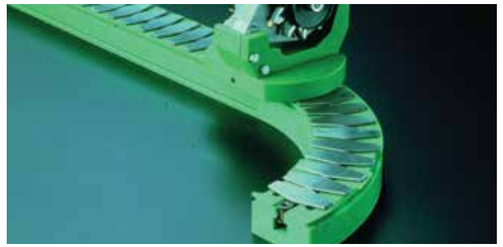
Sliding surfaces made from sintered GUR® UHMW-PE are used worldwide for downhill and cross-country skis and snowboards, ice-skating rinks and bowling alleys.

Pumps and shut-off valves are used in chemical plants, waste incineration and wastewater treatment that operate in harsh environments, where the components come under attack from aggressive acids, alkalis and gases as well as abrasive solids. The tough qualities of GUR® UHMW-PE ensure that reliability and service endurance are not compromised.

In addition, the good slip properties of GUR® UHMW-PE make for smooth-running pump impellers.

The good slip properties of GUR® UHMW-PE are also the reason why this material is widely used in linings for conveyor troughs, silos and truck bodies. The rare combination of low friction coefficient with exceptional wear resistance is the key material selection factor. GUR® UHMW-PE lining sheets ensure rapid loading and discharging of bulk products.

Since GUR® UHMW-PE can also be antistatic-modified, the risk of explosions due to dusty environments (e. g., mining and coal preparation) can be minimized.



GUR® UHMW-PE Lead-Acid Battery Separators

Benefits of GUR® UHMW-PE in lead-acid battery separators

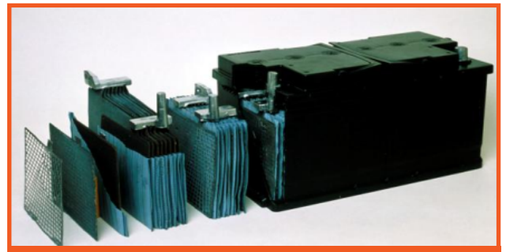
- GUR® UHMW-PE separators offer a cost-effective performance
- GUR® UHMW-PE separators allow rapid fabrication of a pocket
- Constant Quality

Requirements

- Microporous
- No obstruction of ion flow at low temperature
- Avoidance of short circuit by metal particles or $PbSO_4$ growth
- High puncture resistance
- Resistant to H_2SO_4

Applications

- Automotive
- Industrial and recreational



Structure of a lead acid car battery: multiple separator envelopes are stacked together

Lead-acid Batteries are used in today's cars for starting, lighting and ignition (SLI battery). Starting (or cranking) of a combustion engine requires large bursts of energy.

Lead-acid batteries are able to deliver these high currents and peaks and can be recharged for >1000 cycles. The separator must ensure no short circuits between anode and cathode inside the "flooded cell" type battery (35% sulfuric acid and 65% water).

GUR® UHMW-PE is used as binder in the separator. The separator is made of GUR® UHMW-PE, silica, antioxidant and oil in a gelation process. The blend is extruded and the oil extracted afterwards.

An effective separator must possess a number of properties; such as permeability, porosity, pore size distribution, specific surface area, mechanical design and strength, electrical resistance, ionic conductivity, and chemical compatibility with the electrolyte. In service, the separator must have good resistance to acid and oxidation. The area of the separator must be a little larger than the area of the plates to prevent material shorting between the plates. The separators must remain stable over the battery's operating temperature range.

GUR® UHMW-PE Microporous Membranes for Energy Storage

Benefits of GUR® UHMW-PE

- Wide range of products
- Application & technical support
- Constant quality

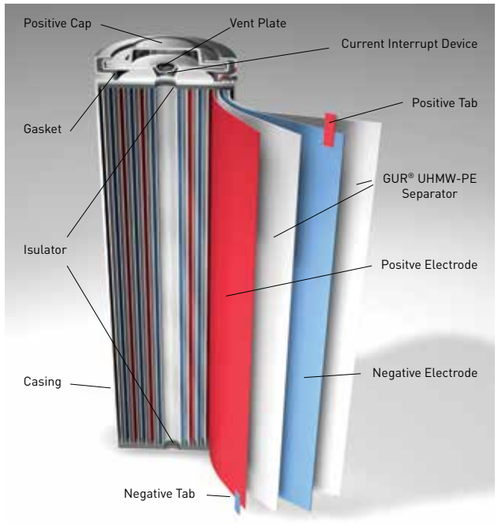
Applications

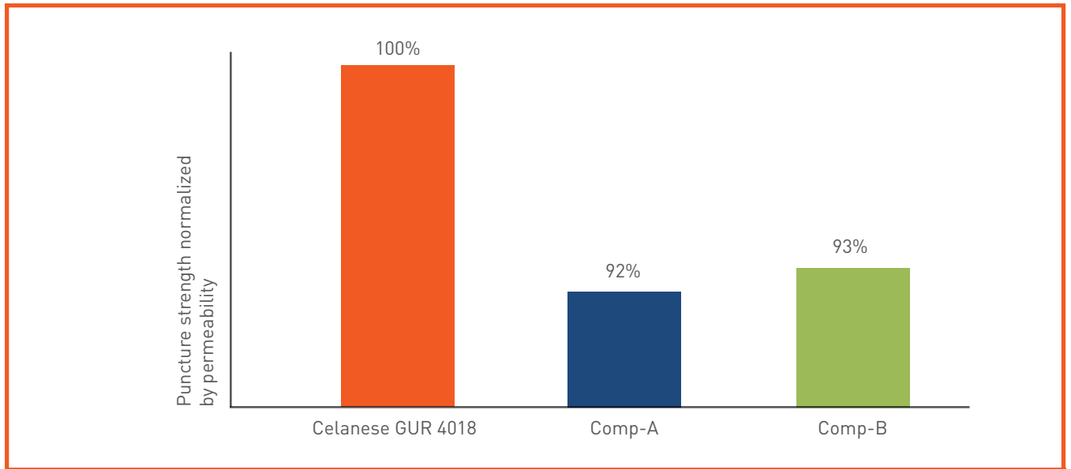
- Rechargeable hand-held devices
- Electronics
- Automotive

Microporous membranes cover the nominal pore size range from 10 – 100 nm. Membranes in this range using GUR® UHMW-PE are further characterized by 40 to 60% void fraction or porosity and are typically between 5 and 30 µm thick. Base weights of such membranes are low due to the inherent specific gravity of the polymer and can range from 2 to 17 grams / square meter depending on the thickness and porosity.

Microporous membranes are vital elements to both function and safety in the energy storage market in particular lithium ion batteries. Lithium ion batteries are the primary technology used for batteries in cell phones, smart phones, tablets and computers. In addition to consumer electronics, lithium ion battery technology is being used for stationary storage. For example, solar and wind energy generators use lithium ion batteries as a means to store energy during peak times for use during off-peak hours. Finally, the recent rapid growth in electric mobility (e.g. cars, buses, bikes, etc.) would not be possible without lithium ion batteries for efficient and safe energy storage and delivery.

Microporous membranes made from GUR® UHMW-PE separate the positive and negative electrodes in these batteries allowing the flow of lithium ions due to its porosity. Without this flow of ions, there would be no energy delivery to the growing consumer electronics market.
The membranes also act as a fire and explosion hazard safety mechanism by separating the reactive materials and closing the pores when the battery reaches elevated temperatures.





Balance between mechanical strength and permeability

Celanese has been a trusted material supplier into these end markets since the beginning and continues to support the industry as performance demands increase with expanding use in different applications. Our GUR® UHMW-PE portfolio covers the entire spectrum of molecular weights, particle size and morphology which offers a rich set of options for manufacturers to choose from when searching for the right material for their particular process and performance targets.

In addition to unrivalled choice of materials, Celanese UHMW-PE offers the best balance between mechanical strength and porosity. As seen in the graph at the bottom of this page, membranes made with GUR® UHMW-PE offer the best puncture strength versus membranes of comparable permeability made from competitive materials.

Celanese is well positioned to globally supply with high performing materials as well as technical know-how. Our Technology and Innovation team is there to support you with material selection and testing to help accelerate your efforts to keep pace in this fast-paced and dynamic industry.

GUR® UHMW-PE Pioneers in Porous Technology

Processing

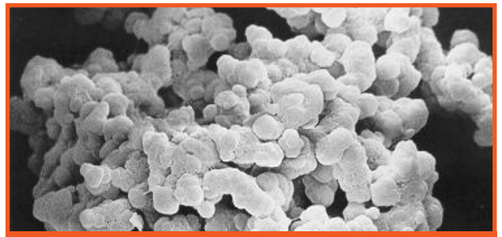
Pressureless sintering of the powder can be achieved in one process step. Alternatively, the starting material is sintered into semifinished products such as sheets, films, pipes, and rods, and then fabricated into final products in a second step.

Benefits of GUR® UHMW-PE

- Well controlled porosity and flow resistance
- Improved damping behavior
- Excellent uniformity of raw material
- High consistency of powder properties and quality
- Good compatibility with other filter media such as activated carbon
- Good mechanical strength
- Outstanding chemical resistance
- Ph. Eur., FDA, USDA and NSF (51 & 61) compliant grades

Applications/Functionalities

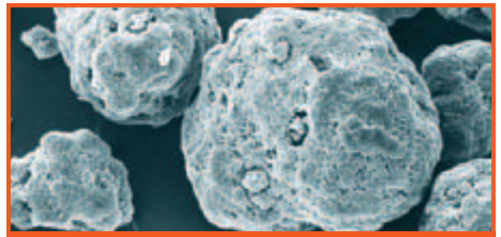
- Filtration, separation
- Fluidizing, venting, degassing, silencing
- Storage, wicking, support



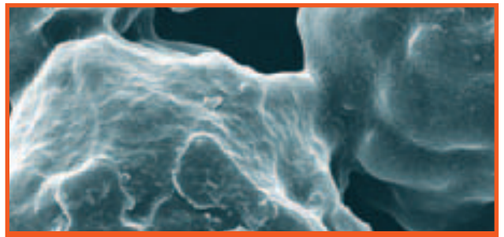
GUR® 2122 powder with a bulk density of <300g/l prior to molding

GUR® UHMW-PE high performance powder is a versatile sintering material with universal application. Under carefully controlled thermal treatment and suitable processing technology, porous parts with exceptional properties can be produced from this material.

GUR® UHMW-PE has an extremely high melt viscosity due to its average molecular weight of up to 10.2 million g/mol. When heated above its crystalline melting point of about 134°C, the polymer changes into a viscoelastic melt. In this process, the external form of the polymer particles is substantially retained, and only the surface of the individual polymer particles fuse at their contact points forming a porous network.



GUR® UHMW-PE powder with a bulk density of >400 g/l prior to molding



The same GUR® UHMW-PE powder after sintering. Particles retain their shape and morphology.

Processors can choose between powders with different particle size, particle size distribution, bulk density, particle surface, molecular weight and powder morphology (spheroidal or flocculent). In this way the porosity and geometry of the porous part can be tailored to suit specific application requirements. Despite their interconnected cell structure, porous products made from GUR® UHMW-PE high performance powder possess surprisingly good mechanical properties such as high strength and flexural resistance. In combination with their excellent resistance to most chemicals, all of these outstanding properties make porous parts made from GUR® UHMW-PE suitable for many demanding applications.

Some examples of GUR® UHMW-PE used in porous applications include liquid and dust filtration, silencers for sound damping and ink management for writing instruments.

GUR® UHMW-PE porous parts act as silencers e.g. for pneumatic systems (Festo AG & Co. KG)

Writing nibs for highlighter made of porous GUR® UHMW-PE.

GUR® UHMW-PE Carbon Blocks for Water Filtration

Processing

GUR® UHMW-PE is blended with activated carbon (or other active materials) and sintered into blocks either by mold sintering or by extrusion.

Unique properties

Due to its high molecular weight, GUR® UHMW-PE provides some unique properties for the manufacturing of water filters.

- In molten state, material does not flow due to its high viscosity but just softens
- Particles retain their shape and morphology and act as a binder matrix
- The active carbon is immobilized, forming a solid structure

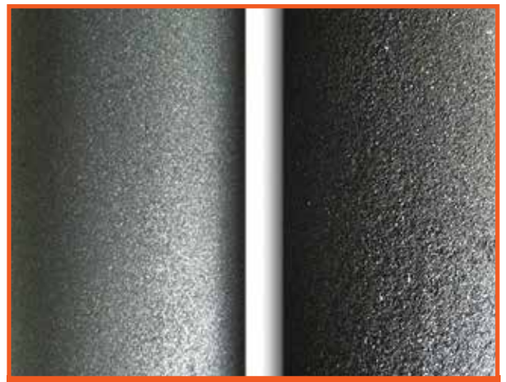
Benefits of GUR® UHMW-PE

Filtration efficiency is determined by the active surface area of the carbon. A high surface area allows more harmful contaminants to be removed from the water and bonded to the carbon. There are no channeling effects in the active media as seen in loose packing. GUR® UHMW-PE outperforms other thermoplastic materials such as HDPE and LDPE.

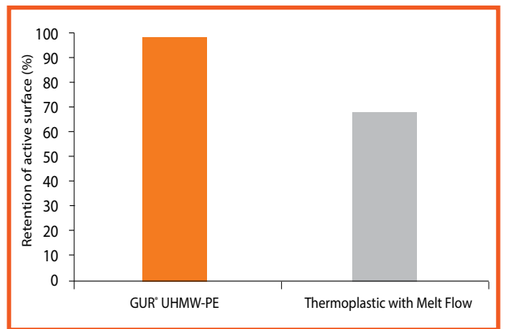
- Maintains high carbon surface area
- Ensures high utilization of carbon
- Increases filtration efficiency and longer component life

Applications

- Counter-top and under-the-counter carbon block filters
- Sports and drinking water bottles
- Faucet-mount filter for point-of-use filtration



GUR® (left) vs. LDPE extruded activated carbon block



Retention of active carbon surface area

Cleaner Water with GUR® UHMW-PE for Filters

According to the World Health Organization and the United Nations, an average person needs 20 to 50 liters of clean water per day. One in 6 people worldwide lack access to clean water, often resulting in serious–even life-threatening–health issues. A common solution to cleaning contaminated water is to filter it at the point of use with active media like carbon.

Harmful substances – such as chlorine, lead, mercury, cadmium, asbestos and volatile organic chemicals – are then absorbed by the carbon. The carbon can be granulated or bound with GUR® UHMW-PE for significantly increased filter performance.

GUR® UHMW-PE is the world leader in porous applications, with the broadest portfolio, including specialty products designed specifically for filtration components for cleaner, safer water.

GUR® UHMW-PE Functional Additives

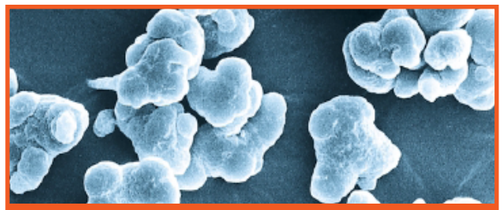
Benefits of GUR® UHMW-PE as an additive

Major property improvements which may be achieved in a matrix material by adding GUR® UHMW-PE

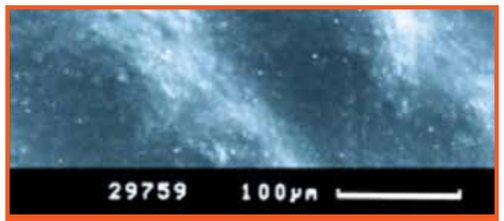
- Increases scratch/abrasion/cut resistance of matrix
- Decrease in crack propagation of matrix
- Improves coefficient of friction (sliding properties) of matrix
- Improves mechanical properties, e.g. impact strength and flexural modulus of matrix
- Gives unique surface texturing, e. g. anti-slip properties, anti-stick properties, matting effect
- Good chemical compatibility with many matrix polymers
- Good matrix adhesion due to unique grain morphology
- No melt flow. Keeps particle shape during processing
- Biocompatible & no fluorine content
- Very good chemical resistance

GUR® UHMW-PE micropowders have exceptional properties as additives in a wide range of applications. In the molten state, because of their very high melt viscosity, they exhibit a rubber-elastic behavior and therefore maintain their particle shape and morphology.

This thermal-rheological property is of paramount importance for numerous applications. GUR® UHMW-PE micropowders are available in various particle sizes, tight particle size distribution and unique morphologies.



GUR® UHMW-PE micropowders unique particle shape and morphology



The SEM picture shows good binding of the structurebody of 60µm-product with the paint layer (Layerthickness 80 microns).

Example applications	Functions and key benefits
Protective coatings	Texturing additive, scratch resistance, dry lubricating additive
Decorative paint	Matting agent
Technical rubbers	Processing aid, wear resistance enhancer
Sealants	Dispersant, co-binder, anti-scratch additive
Plastic compounds & packaging	Slip/anti-slip additive, surface effects
Cosmetics & industrial soaps	Soft peeling/scrubbing additive

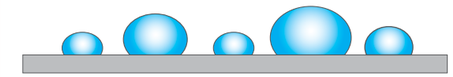
Hydrophilic GUR® UHMW-PE

Due to its chemistry, Polyethylene in general is hydrophobic (i. e. it does not like water or other polar media). A droplet of water, placed on a PE surface shows a contact angle of more than 90°. However, some applications require a GUR® UHMW-PE that is compatible with polar media. For these applications we offer special GUR® UHMW-PE grades with a hydrophilic surface functionality. The effect is visualized on the photo on the right hand side: The hydrophilic GUR® UHMW-PE is compatible with the water and mixes well with it. The regular (hydrophobic) GUR® UHMW-PE is not compatible with the water and floats on the surface.

The hydrophilic GUR® UHMW-PE grades offer advantages when used as additives in polar media. For example, they can be better dispersed in paint or coating formulations without separating from the liquid.

Another example is their usage as additive in polar resins like Polyurethanes. Their good compatibility with the matrix material leads to strong bonding between matrix and additive. This is required for good mechanical strength of the blend.

Wettability: Hydrophilic surfaces form thin water films with contact angles between 0 and 90°



On hydrophobic surfaces a full wettability is not achievable and water droplets show a contact angle of over 90°

GUR® UHMW-PE is inherently hydrophobic: the GUR® UHMW-PE powder does not mix with water and floats on the surface. (right side). However, Celanese offers as well hydrophilic grades, which mix well with water (left side)

GUR® UHMW-PE Fibers

Processing

Gel spinning technology makes it possible to produce extremely high-tenacity, low-stretch filament yarns from GUR® UHMW-PE.

Benefits of GUR® UHMW-PE converted to fibers

- High strength/low weight
- Low specific gravity – floats on water
- Abrasion resistance
- Excellent chemical resistance
- Moisture resistant
- High durability

Applications:

- Protective gear such as cut-resistant gloves, fall protection harnesses.
- Braided fishing lines, nets
- Ropes (e.g. for the mooring of mobile oil platforms)
- Ballistic fabrics, composites and articles

Fishing line

The strength-to-weight ratio of GUR® UHMW-PE-based fibers is unmatched when compared to other polymeric fibers. Fiber tenacities exceeding 35 grams/denier and moduli greater than 1,300 grams/denier are possible. These properties combined with the low specific gravity offer many technical and commercial advantages. Marine ropes and nets made with GUR® UHMW-PE are lightweight, making them easier to transport, and they also improve fuel economy. Cut resistant gloves offer better dexterity and overall comfort, leading to better compliance and reduced injuries. GUR® UHMW-PE-based fabrics and composites offer ballistics protection by absorbing and dissipating the energy that are associated with particular threats. In the ballistics market, there is a constant trade-off between performance, weight and cost in regard to ballistics solutions. The need to improve ballistics performance continues as threat levels increase around the globe. GUR® UHMW-PE is leading the way to develop new materials that enable improved performance and lower-weight solutions.

UHMW-PE mooring rope

Miitary ballistic vest

GUR® UHMW-PE Tapes

Processing

Solid-state technology, which makes it possible to produce high-tenacity tapes and articles from GUR® UHMW-PE without the use of plasticizers or solvents.

Benefits of GUR® UHMW-PE converted to tapes

- High strength and modulus
- Low specific gravity
- Abrasion resistance
- Creep resistance
- Excellent chemical resistance

Applications:

- Ballistic composites and articles
- Marine and industrial ropes
- Construction and reinforced panels
- Industrial textiles

Examples GUR® UHMW-PE tapes in various slit widths.

The technology exists that makes it possible to orient GUR® UHMW-PE to obtain high-tenacity tapes and articles. This approach offers multiple advantages compared with conventional gelation processing. Solid-state conversion eliminates the use of plasticizers and solvents and, as a result simplifies manufacturing costs and complexities. Furthermore, the conversion to ballistics panels is also simplified because GUR® UHMW-PE-based tapes can be arranged and layered in the typical 0°/90° configuration without the need of binders.

In ballistics, GUR® UHMW-PE-based tapes ideally offer cost advantages when trying to balance weight and ballistics performance. This is most evident for vehicle-armor applications, where relatively large surface areas need protection.

Beyond ballistics, significant opportunities exist for solid-state tapes. Marine and industrial ropes could take advantage of the inherent creep resistance compared with more conventional polyolefins. Industrial ropes could fill a performance “gap” in the mid-tenacity range. Large reinforced panels could be combined with other polyethylene sheets to improve modulus and make single polymer composites.

GUR® UHMW-PE
Orthopedic Implants

Our premium implant grades are now available with vitamin E

Today, most implants are treated by modern irradiation techniques for sterilization and/or performance improvement. As a result of these processes, free radicals are formed in the UHMW-PE which can accelerate in vivo oxidation and shelf aging of the implants. Degradation of the material results in reduced mechanical properties, including reduced wear resistance.

Vitamin E is a collective term for the group of tocopherols, of which alpha-tocopherol shows the best properties as an antioxidant. It is a natural substance that already exists in the human body and can be used as a stabilizer for the orthopedic implants made from UHMW-PE. Alpha-tocopherol acts as a radical scavenger and eliminates the free radicals preventing oxidation of the material.

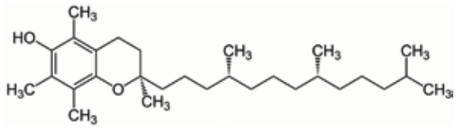
Celanese now provides the first vitamin E powder blend available on a commercial basis. The material is produced in accordance with ASTM F2965 and can be processed like virgin GUR® UHMW-PE premium powder. All mechanical properties remain unchanged compared to the original GUR® UHMW-PE premium grades. The blend follows the typical high standards of product cleanliness and shows a very uniform vitamin E distribution.

Benefits of GUR® UHMW-PE

Celanese, as the leader in UHMW-PE with over 50 years of application experience, helps meet the needs of orthopedic surgeons with proven long-term material performance in joint replacements.

GUR® UHMW-PE outstanding properties

- Low wear
- High purity
- Biocompatibility
- Excellent lubricity
- Abrasion resistance
- High energy absorption



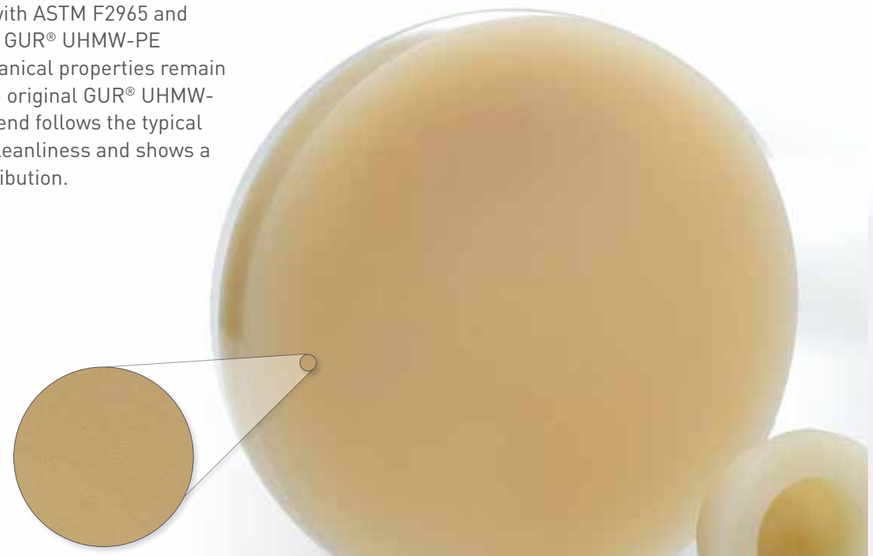


Illustration of homogeneous distribution of vitamin E

Compression molded parts made of GUR® UHMW-PE vitamin E filled grades

Ball socket of hip implant made of GUR®

This combination of properties opens up a wide range of applications for GUR® UHMW-PE in the orthopedics device sector.

The biocompatibility and flexibility of part design have led to GUR® UHMW-PE's successful use in orthopedic implants for over 50 years. As a result of continual product optimization, GUR® 1020 and GUR® 1050 are now the most frequently used materials for articulating bearing surfaces in orthopaedic surgical implant technology.

Celanese has taken into account the special requirements of medical technology for orthopedic implants by ensuring exceptionally high quality and compliance with the approval and conformity criteria of regulatory agencies: USP Class VI, FDA Master Files.

GUR® UHMW-PE
Medical and Pharmaceutical Filtration

Benefits of EP compliant Grades

- Produced to meet strict requirements of Ph. Eur. 3.1.3 (Polyolefins) Version 8.0
- Material tests to confirm compliance

Applications

- Filtration of bodily fluids (e.g. blood)
- Drug reservoirs or venting
- Medical packaging
- Chromatography, separation, affinity and extraction filters
- Clinical sciences diagnostic filters

Available GUR® UHMW-PE Ph. Eur. compliant grades

- GUR 2122 EP
- GUR 4022-6 EP
- GUR 4012 EP
- GUR 4018 EP

GUR® UHMW-PE – EU Pharmacopoeia Compliant Grades

The European Pharmacopoeia (Ph. Eur.) defines requirements for the qualitative and quantitative composition of medicines, the tests to be carried out on medicines and on substances and materials used in their production. The European Directorate for the Quality of Medicines and Healthcare is responsible for maintaining the Ph. Eur. which is currently on version 8.0.

Building on our extensive experience in implant grade materials, Celanese offers a line of GUR® UHMW-PE grades which are compliant with Monograph 3.1.3 of the Ph. Eur. 8.0. Confirmation of conformity to Ph. Eur. 8.0 is a common requirement for many applications in the more sensitive areas of medical, clinical sciences and life sciences fields.

EP grades are produced to ensure compliance to all specifications laid out in monograph 3.1.3 which includes strict limits on elements such as ash content, heavy metal extractables, acidity and alkalinity. Material comes with Celanese confirmation of conformity.

Listed EP grades are commercially available. Additional grades could be developed if sufficient market demand exists. Please speak with your Celanese sales representative if the grade you are interested in is not listed.

GUR® UHMW-PE
Melt Processable Grades

Melt processable GUR® UHMW-PE

As described in the GUR® UHMW-PE unique properties section, GUR® UHMW-PE is characterized by its lack of melt flow, which usually requires special processing technologies such as compression molding or ram extrusion.

Therefore, we have developed special melt processable grades which maintain the unique properties of GUR® UHMW-PE while being compatible with the following process technologies:

- Screw extrusion
- Injection molding
- Injection compression molding

With these melt processable grades, GUR® UHMW-PE can be applied to broader applications that would benefit from its very unique properties.

For example, these grades can be used to make extruded pipes, pipe liners or composite pipes, which offer a highly abrasion resistant solution extending the lifetime of the pipe and therefore reducing ongoing maintenance costs. GUR® UHMW-PE's low coefficient of friction also means less energy required for pumping, less frequent clogging of pipes and, depending on the pipeline design, smaller diameters compared to conventional pipe systems.

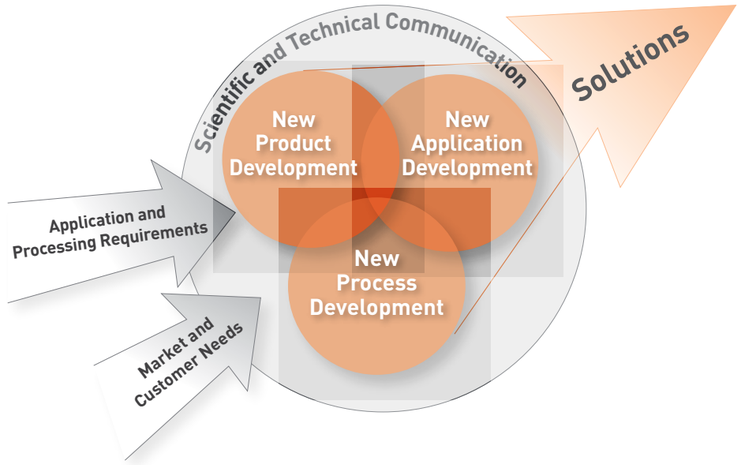
With deep knowledge and expertise on materials and processing, Celanese is the ideal partner to identify the optimal solution to address your needs.

GUR® UHMW-PE
Pioneers in Technology and Innovation

Since the days when Dr. Karl Ziegler originally brought back his exiting new catalyst technology to our Oberhausen manufacturing site in 1995, our dedicated Research and Development team has continued to translate this into new products and applications.

Our R&D group remains at the forefront of UHMW-PE development in the world and remains committed to driving value-added technologies in the future.

Today the group can be subdivided into two parts: 1) New product development and 2) New application development. These two groups both work in close coordination with our internal teams, customers and development partners to deliver novel solutions.



Benchtop (Grams) → **Pilot Plant** (Kilograms) → **Manufacturing** (Tons)

New product development

This group is focused on developing new polymerization and process technologies to enable new product properties meeting the needs of our customers.

Our research facility has a complete pilot plant facility, which provides an efficient development pathway from lab to manufacturing scale.

New application development

The application developement group is working closely with our commercial team and customers to find new innovative application areas for GUR® UHMW-PE. A close relationship with existing customers as well as other interested development partners allows us to tailor products to the need of the market for known or new applications. Examples may be membranes, fibers, or the use of GUR® UHMW-PE particles as additives to improve the properties of other materials. Our research center is equipped with all of the latest processing and test equipment which is able to translate the basic material properties to very special market needs.

GUR® UHMW-PE
Typical Physical Properties & Test Methods

Properties	Unit	Test Method	GHR 8110	GUR 2122	GUR 2126	GUR 4018	GUR 4012	GUR 4113	GUR 4120	GUR 4022	GUR 4152	GUR 4150	GUR 4170	Properties
Average molecular weight	g/mol	Calculated from VN using Margolies´equation	$0,8*10^6$	$4,2*10^6$	$4,2*10^6$	$0,6*10^6$	$1,7*10^6$	$3,7*10^6$	$4,7*10^6$	$5,3*10^6$	$7,6*10^6$	$8,7*10^6$	$10,2*10^6$	Average molecular weight
Viscosity number (VN)	ml/g	ISO 1628, part 3	600	2100	2100	500	1100	1900	2300	2500	3300	3700	4200	Viscosity number (VN)
Average particle size (d50)	µm	Laser scattering	120	130	30	110	135	120	120	145	180	120	120	Average particle size (d50)
Density	g/cm³	A	0,95	0,93	0,93	0,95	0,94	0,93	0,93	0,93	0,93	0,93	0,92	Density
Bulk density	g/cm³	ISO 60	0,44	0,25	0,28	0,45	0,45	0,46	0,45	0,45	0,48	0,45	0,45	Bulk density
Mechanical Properties														**Mechanical Properties**
Impact strength (Charpy) (with 14˝ V-notch on both sides)	kj/m²	ISO 11542, part 2	25	170	140	45	190	190	240	160	120	180	170	Impact strength (Charpy) (with 14˝ V-notch on both sides)
Wear by the sand-slurry method (based on GUR 4120 = 100)	none	internal test method	310	100	100	250	140	130	100	100	95	85	80	Wear by the sand-slurry method (based on GUR 4120 = 100)
Tensile modulus E_t	MPa	ISO 527, part 1/2; test speed 1 mm/min	1100	770	770	1050	900	800	660	630	780	570	800	Tensile modulus E_t
Tensile stress at yield σ_y	MPa	ISO 527, part 1/2; test speed 50 mm/min	26	21	21	25	22	21	20	19	21	19	22	Tensile stress at yield σ_y
Tensile strain at yield ε_y	%	ISO 527, part 1/2; test speed 50 mm/min	9	13	13	8	9	13	14	14	13	15	12	Tensile strain at yield ε_y
Tensile stress @ 50% strain σ_{50}	MPa	ISO 527, part 1/2; test speed 50 mm/min	18	20	20	18	19	21	19	19	21	19	19	Tensile stress @ 50% strain σ_{50}
Tensile stress at break σ_B	MPa	ISO 527, part 1/2; test speed 50 mm/min	35	39	39	37	42	44	43	40	36	40	37	Tensile stress at break σ_B
Nominal elongation at break ε_{tB}	%	ISO 527, part 1/2; test speed 50 mm/min	650	400	400	870	550	410	465	400	300	360	430	Nominal elongation at break ε_{tB}
Ball indentation hardness, 30 sec value	N/mm²	ISO 2039, part 1	47	38			42	39	36		40	36	35	Ball indentation hardness, 30 sec value
Shore hardness D, 15 sec value		ISO 868	63	60	60	63	60	62	60	60	60	60	60	Shore hardness D, 15 sec value
Thermal Properties														**Thermal Properties**
Heat deflection temperature HDT/A (1.8 MPa)	°C	ISO 75, part 1/2	41	41	41	43	41		38	41	41	38	38	Heat deflection temperature HDT/A (1.8 MPa)
Vicat softening temperature VST/B/50	°C	ISO 306	80	80	80	80	80	80	80	80	80	80	80	Vicat softening temperature VST/B/50
Melting point	°C	DSC, 10 K/min	130 - 138	130 - 138	130 - 138	130 - 138	130 - 138	130 - 138	130 - 138	130 - 138	130 - 138	130 - 138	130 - 138	Melting point

GUR® UHMW-PE Grades: Properties Overview

Property [1]	d50			MW			BD	
	small	medium	coarse	low	medium	high	low	high
GHR 8020			+	+				+
GHR 8110		+		+				+
GUR 1020*		+			+			+
GUR 1050*		+				+		+
GUR 2024			+		+		+	
GUR 2105		+		+			+	
GUR 2105-1	+			+			+	
GUR 2122		+			+		+	
GUR 2122-5			+		+		+	
GUR 2126	+				+		+	
GUR 4016		+		+				+
GUR 4018		+		+				+
GUR 4012		+			+			+
GUR 4022		+			+			+
GUR 4022-6			+		+			+
GUR 4122		+			+			+
GUR 4122-5			+		+			+
GUR 4020-3	+				+			+
GUR 4120		+			+			+
GUR 4130		+			+			+
GUR 4032		+			+			+
GUR 4050-3	+					+		+
GUR 4056-3**	+					+		+
GUR 4150		+				+		+
GUR 4150-3	+					+		+
GUR 4170		+				+		+
GUR 4523		+			+			+
GUR 4550		+				+		+
GUR 4113		+			+			+
GUR 5113		Pellet			+			+
GUR 5129		Pellet			+			+
GUR 5523		Pellet			+			+
Hostalloy 731		Pellet		+				+
GUR X160	+			+			+	
GUR X161**	+				+		+	

Impact Strength			Abrasion resistances			Property [1]
medium	high	very high	medium	high	very high	
+			+			GHR 8020
+			+			GHR 8110
		+			+	GUR 1020*
		+			+	GUR 1050*
+					+	GUR 2024
+			+			GUR 2105
+			+			GUR 2105-1
	+				+	GUR 2122
	+				+	GUR 2122-5
	+				+	GUR 2126
+			+			GUR 4016
+			+			GUR 4018
		+		+		GUR 4012
	+				+	GUR 4022
	+				+	GUR 4022-6
	+				+	GUR 4122
	+				+	GUR 4122-5
		+			+	GUR 4020-3
		+			+	GUR 4120
		+			+	GUR 4130
		+			+	GUR 4032
		+			+	GUR 4050-3
		+			+	GUR 4056-3**
		+			+	GUR 4150
		+			+	GUR 4150-3
	+				+	GUR 4170
	+				+	GUR 4523
		+			+	GUR 4550
		+		+		GUR 4113
		+		+		GUR 5113
	+			+		GUR 5129
	+				+	GUR 5523
+			+			Hostalloy 731
+			+			GUR X160
	+				+	GUR X161**

*medical
**hydrophilic

[1] Property and its ranges: d50 average particle size (small <100µm, coarse >170µm);
MW molecular weight (low <1Mio g/mol, high >7Mio g/mol); BD bulk density (low <0,35 g/cm3, high >0,35g/cm3);
impact strength (medium <100kJ/m2, very high >180kJ/m2); abrasion resistance (medium >200, very high <120)
2) Second digit of grade name (=1) indicate stearate additive

GUR® UHMW-PE Product Stewardship and Quality

Regulatory Approvals

Assessment under food legislation the GUR® UHMW-PE and GHR® standard grades, in natural color, when used in accordance with recommendations given in our product literature and in accordance with 21 CFR 177.1520, meets the applicable FDA polyolefin regulation, including specifications 2.1 and 2.2.

GUR® 4120, GUR® 4130 and GUR® 4150 are approved by the USDA for direct contact with meat or poultry prepared under Federal inspection. In recommendation (Empfehlung) III "Polyethylenes", the German Federal Institute for Consumer Health Protection and Veterinary Medicine (BgVV) regulates the use of polyethylene for the manufacture of consumer articles as defined in Article 5, Para. 1, No. 1 of the German "Food and Consumer Articles Law"(LMBG).

The BgVV recommendations lay down in accordance with the present state of science and technology under what conditions a consumer article made from plastics satisfies the requirements of Article 31, Para. 1of the LMBG. The recommendations state that articles must be suitable for their intended application and should not impart odor or taste to food. All basic grades comply with Recommendation III. There are therefore no objections on health grounds to the use of these materials for the production of consumer articles for food contact applications.

Quality management

The fulfillment of the quality requirements of our customers is a fundamental principle for Celanese. In this process we are constantly updating our certification and processes. Our processes have been registered since the early 1990's under ISO 9000.

From this base in 2003 Celanese built "The Integrated Management System" (DCS).

The most important certifications for Celanese include:

ISO 9001

IATF 16949

ISO 14001

Certification to the standard ISO 9001 and IATF 16949 has been achieved by all Celanese production sites. Also we have the environmental standard ISO 14001.

For the up to date certification information please refer to our home page www.celanese.com where copies of our certificates are available for download.

Celanese

The chemistry inside innovation™

ENGINEERED MATERIALS

celanese.com/engineered-materials

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