OTC Ozark Technical Ceramics, Inc.

Custom Fabrication

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402 Ware Street, Webb City, MO 64870

(417)-673-2463 / Fax (417) 673-2464

www.ozarktech.com

OZARK has R&D roots which have tentacles in many disciplines of Ceramic fabrication. Our extruded and slip cast products are discussed elsewhere, and constitute our production base, but we have retained many of the processes and products that have been developed over the years. Our facility is well positioned for specialized production of Al2O3 and MgO materials, including multiple dry pressing options and a fair amount of machining capability.
Of course, the act of defining "custom" ceramics almost nullifies the term, but we associate it mostly with specialized pressed parts (from Al2O3 or MgO), machining operations, or the occasional exotic process (tape casting, material doping, etc..).

Dry Pressing Processes

In Dry pressing a dry ceramic powder is mixed with organic binders and compacted into the desired shape under pressure in a die cavity. Uni-Axial dry pressing may involve compaction in one direction or two (opposite of course). Isostatic Pressing is a variants of dry pressing for limited applications. Other variants include Semi-Dry pressing, and Hot Pressing, which are suited for either very simple materials or very complex materials (neither is available from OZARK).

Uni-axial Dry Pressing- This is the method of choice for most simple shapes of constant cross section, such as pellets, beads, bushings, plates, and disks. The Length to Diameter (or diagonal measure) ratio (L/D) should be greater than 0.02 and less than 3.0. Longer lengths may exhibit an "hourglass" effect.

Isostatic Pressing – This is the last resort for cost reasons. It offers some unique advantages in shape forming, and under ideal conditions offers the best forming conditions.

Equipment

1) 150 ton and 50 ton dual action platen presses
2) 12 ton full auto Hydramet press
3) Loomis Wet Bag Isostatic Press with 60,000 psi rated 6"diam. x 18" L. vessel

Machining Processes

Machining is performed on an as-needed basis only. The more mature a ceramic technology is, the less Machining is required (Imagine machining a toilet bowl out of a solid block- you couldn't afford to buy it!) The prime directive in the forming step is for "near-net shape" fabrication.

Powders

OZARK uses raw materials that are difficult to get, and often require bulk purchases, long delays, and some particle size processing. As a courtesy to our customers, we make these materials available in small quantities. We are glad to provide referrals to our sources for your long term needs.

So what kind of pressing do we do?

OZARK divides the dry pressing kingdom up into 3 families, based on the scale of the part and the likely equipment used for production

Small Pressings – Shapes that can be produced on our 12 Ton Hydramet dry press.

1) Quantities of 500 pieces or more are usually tooled for full automatic production, with automatic die fill, press, and eject cycles.
2) Quantities of 100-500 pieces may be tooled for semi-automatic production, with some manual intervention in filling, pressing, or ejecting.
3) Quantities under 100 are usually tooled for manual cycling.
4) Dimensional limits are 0.10" minimum lateral dimension, and 1.5" maximum lateral dimension or length.
5) Some compound press motions are available on a limited basis to produce complex shapes, see design guide for information.

Large Pressings – Sizes over 1.5" lateral dimension and some limited quantity runs made in full manual operation and hand tooling. May be performed on 50 ton single action or 150 ton double action press

Isostatic Pressings – Used only when required to provide maximum density or improved microstructure. May be used to provide complex shapes not feasible to dry press. Also can produce precision ID features or billets for intensive machining.

1) Quantities of 500 pieces or more are usually tooled for full automatic production, with automatic die fill, press, and eject cycles.
2) Dimensional range from 1" to 3" OD x 10" long. Maximum ID/Length ratio about 5:1.

DO try this at Home (anyplace but OZARK!)

OZARK specializes in dry pressing in limited areas of advanced technical nature. We are not in the high volume, low cost material market. This market is adequately serviced by established vendors and requires narrowly defined equipment made specifically for that mission. Our maximum press rate is about 6 spm (strokes per minute), compared to several hundred spm for most standard industry equipment. At a modest rate of $60.00/hour for machine time, it is easy to infer a twenty cent floor, which is outrageous by industry standards.

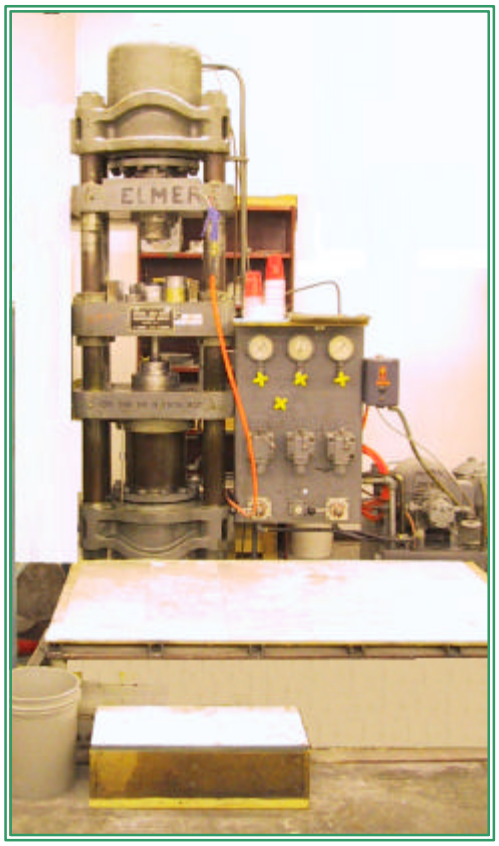
These limitations make OZARK a non-contender for many smaller shapes in established production quantities. This may be a area of expansion for future OZARK development, but is not an immediate priority as long as our customers can acquire their ceramic needs from established sources. If OZARK does integrate our product line into this area, we will limit the materials to our high tech, high purity materials, and not likely produce steatite, glass, or clay based materials.

OZARK has a rather limited inventory of large size tooling. If the demand justifies it, this is a candidate for product integration, and we may offer bulk pressings of high purity alumina and MgO materials in the future.

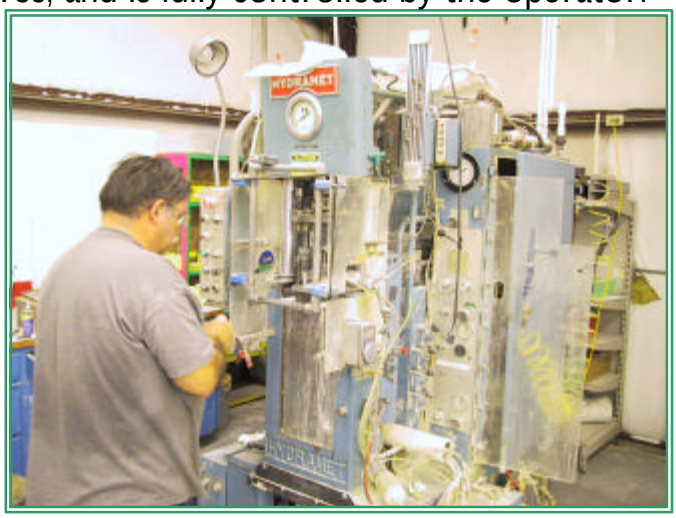
We will be glad to refer you to possible sources for any materials that are not a logical candidate for our capabilities.

Disclaimer…

Our alumina and MgO pressings are not a fully engineered product for all applications. They are routinely used in electrical stand-off applications, high temperature and chemical resistance, and for some mechanical requirements. They are not proven for wear resistance, high dielectric, or metallizing applications.



150 Ton dual platen press: Our largest press (code name ELMER) is flexible in design and offers 150 ton pressing force with a large opening for tooling and a compound lower ram for complex shape forming or part ejection. The ram travel is 6", which allows forming of parts up to 3" finished fired length. It does not have any feed shuttle features, and is fully controlled by the operator.



50 Ton dual platen press: This unit is a basic H-frame press which can be used readily for quick setups, or as a more operator friendly unit for some hand pressing jobs.

12 Ton Hydramet dry press: This is a high precision machine for exotic and demanding applications, and was designed for pressing of boron nitride. It has full automatic features, including programmable die fill features, die lube and dry, press cycles, core rod, and ejection controls. It is used for smaller parts in quantities of 500 or more, and of course where ultra-precision cycles are required.

Loomis Wet Bag Isostatic press: This press has a 6" diameter x 18" long pressure vessel rated for 60,000 psi.

PLEASE contact us if any questions!!!

D - CUSTOM FAB

In sufficient quantity, Dry Pressing is the production method of choice for well-proportioned parts of constant cross-sectional area such as pellets, beads, bushings, plates, or disks. Some surface features such as grooves, bosses, chamfers and blind holes can be obtained within design limits. The options available are expanded by the tricks of the trade, involving complex tooling design, fill techniques, and press motions. The rules that govern acceptable shapes are driven by the need to form the compact uniformly and the forces of die wall friction.

The following suggestions may help you avoid unnecessary expense. Most of this discussion is in the context of a simple cylindrical pellet for simplicity. For rectangular or complex shapes, the maximum lateral dimension (diagonal of a rectangle) may be considered as the diameter. Tubular shapes are explained as appropriate.

Length to Diameter Ratio (L/D) – This is the NUMBER ONE consideration. In long parts, it is difficult to achieve compaction of the middle of the part. The ends become more densely compacted, and therefore shrink LESS in firing, resulting in an "hourglass" shaped part. The standard rule of thumb is about 3:1 for a comfortable L/D ratio for a simple cylindrical rod. If minor hourglassing is acceptable, then up to about 5:1 is plausible. We have heard claims of up to 10:1, but any longer pieces are candidates for extrusion or other methods.

Too small of an L/D ratio (very thin parts) is also bad. This restriction is a result of die fill considerations and green part strength. The rule of thumb is that the diameter should not be greater than about 50 times the thicknes. It is difficult to get uniform filling out of shallow depths. The difficult technical materials OZARK produces are too weak to handle at high ratios. The sweet spot for L/D ratio is about 1:1.

I.D. – Through holes are easily accommodated on the pressing axis (blind holes discussed later). The hole size cannot cause the part to violate L/D guidelines (about 6 times the wall thickness). It also cannot be more than about 6 diameters deep, or the Length/ID ratio.

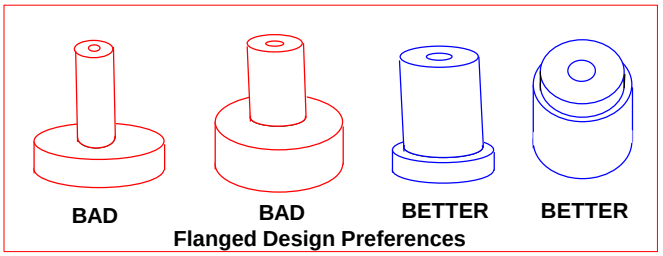
Irregular shaped holes (oval, square, etc.) are allowed at a substantial increase in tooling cost, lead time, and tolerance control.

Threaded holes or other re-entrant angles are not possible to make by dry pressing.

Surface features – Blind holes, counterbores, grooves, chamfers, bosses, and embossed details are permitted within limits. Features that appear on one face only and are less than about 20% of the part thickness can usually be achieved by modification of the tooling. They must conform with other rules, and of course very complex features (such as raised letters) add considerable cost in tooling. Surface features should not occur on both sides. The resulting surface finish will not be as smooth as other areas and may have slight cratering or cosmetic imperfections.

(continued on next page)

Flanged parts – A flange (or conversely a chimney) is a very complicated element for a dry pressed part. It requires a proportionately shaped die fill, complicated tooling, and precisely controlled compound press motions. For successful design, maximize the allowable thickness of the flange (If it is about ½ the length, it is often called a shoulder bushing). Minimize the OD of the flange. Don't let the tubular part become elongated to the point of violating L/D ratios.



Flanged Design Preferences

Conical OD's and Tapers – Modest tapers may be obtained at extra tooling expense. Tooling is very specific to the shape, and any design changes or dimensional tweaking requires a complete re-tooling effort.

Length – The maximum press length is a function of press geometry and maximum press stroke. OZARK has a maximum pressing capacity of about 4" long. Length limitations may also be imposed by cross-section restrictions in the case of larger shapes.

Size - OZARK can press shapes in size ranges from 0.125" diameter to 60 square inches (approx. 8" diameter). Within the L/D requirements, OZARK can press lengths from about .060" to 4.0".

Tolerances – OZARK recommends a minimum tolerance window of +/- 1% for round dimensions and +/- 2% (or 0.005" minimum) for vertical dimensions (height, thickness). A well controlled dry pressing process is consistent within about +/- 0.5%, and the other 0.5% is needed for production variables. Very precise results can be specified if needed, but looser tolerances should be permitted for short runs to save cost and improve delivery.

Interior – There is a limit to the distance that outgassed binders can travel through the part during burnout. The organic binders cannot easily escape from deep within a thick part, and firing flaws are the result. The furthest the vapors can be expected to travel to the nearest surface is about 0.6", suggesting a recommended maximum overall thickness dimension of about 1.25".

Surface – In most cases, except as required by dimensional tolerances, surfaces are as pressed and fired. This may vary from a very smooth, vitrified appearance to a rougher texture of about 32 RMS. There could be some slight chips, spalls, or surface binder burnout artifacts.

Microstructure – Our fully fired alumina bodies are approximately 96% dense with fully closed porosity. The grain size is believed to be about 10-20 micron average. The fired bodies do not always prove to be crack-free by dye penetration, but the parts do not demonstrate appreciable reduction of strength. The results vary by part design, production methods, and firing requirements. If microcracking or ultimate strength is a critical defect for your application, please consult with us for specifications.

OTC Ozark Technical Ceramics, Inc.

Custom Fabrication
DA5/CC8 - Dry Pressed BN Preforms

(This flyer is included here as well as our "Specialty Extrusions section" as reference information to describe the evolution of OZARK's Dry Pressing .abilities in context)

What is Boron Nitride?

Boron Nitride (BN) is a very simple molecule with strongly covalent chemical bonds. This has very adverse effects on the sintering properties, and BN cannot be formed and fired by conventional ceramic processing methods. Boron Nitride does not sinter at atmospheric pressure, and will not even sinter by hot pressing without the aid of some chemical additives (which are impurities, even if they are deliberately added). The ceramic fabricating resume is further weakened by the sensitivity of BN to oxidizing atmospheres, it is readily oxidized to B2O3 at low temperatures. This makes it impossible to remove binders used in forming.

There are some coating and deposition techniques available to deploy BN in selected applications. Hot pressed BN shapes are commercially available, at about 95-98% purity. These shapes are machinable within limits, but at great expense. Otherwise, there are no commercial techniques for bulk production of high purity, high integrity BN shapes.

What is a Dry Pressed BN preform?

Dry pressing is a conventional ceramic fabrication technique, but because of the sensitivity of BN to oxidizing environments, a binderless pressing technique had to be developed. A specially developed, high purity powder was developed by Union Carbide, and is still available from a successor company. This powder can be pressed to 90% of theoretical density without binder, and will retain some modest strength because the particles interlock into a "jig-saw" puzzle effect.

Although BN is a natural lubricant, dry pressing is very difficult and requires precision tooling design and press motions to prevent galling of tooling or other related failures. The tooling must be coated with a small amount of a proprietary lubricant with each cycle. The lube remains on the outer surfaces of the part, and is removed with a special furnacing cycle under exotic atmospheres to reduce carbon and oxygen content in the finished preform.

After the purification cycle, the parts are a little weaker than before, and in the case of delicate tubular shapes, they have to be packed in high purity BN powder for shipping. The customer must be properly equipped to handle and load the delicate insulators.

Why was the Dry Pressed BN preform developed?

In the late '70's, BN was very attractive to the Nuclear Industry as an insulator to use in fuel rod simulators. The thermal conductivity and temperature capability was a good match for the thermal properties of a nuclear fuel rod, and an efficient way to introduce it into the annulus of a tubular heater design was needed. Government and industry specialists combined to develop the dry pressed high purity BN preform. (Reg McCulloch, founder of Delta M Corporation, was instrumental in this project). The glory days of the BN preform and fuel rod simulators ended due to the Three Mile Island accident, which caused funding priorities to shift away from simulated experiments to real time data acquisition. OZARK has managed to keep the dry press fabrication technology viable, in spite of lapses of many years between production orders.

Are extruded shapes available?

Basically, no. Although OZARK is a kick-ass expert at extrusions of exotic materials, and has successfully extruded BN shapes, the binder removal problem prevents any practical application of extruded shapes.

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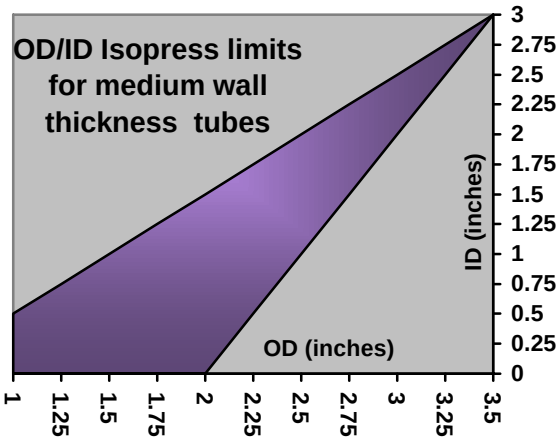
OZARK considers Isostatic pressing to be the bizarro-world method of choice for dry pressing. There are a few size and shape categories that defy dry pressing or slip casting techniques, mainly long, thick-walled tubes. Otherwise, it is used at OZARK only when microstructure considerations require it, or rarely, when tooling considerations suggest it.

OZARK's pressure vessel is 6" diameter x 18" deep. When tooling and firing shrinkage is factored in, the part size capacity is about 3 ½" x 10", in the best case, under perfect equipment conditions. The vessel is rated for 60,000 psi, which exceeds the industry standard of 30,000 psi. In spite of this high pressure rating, we have seldom found it useful to press compacts in excess of 20,000 psi, and our normal operating range is 8-12,000 psi.

Medium Walled Tubes - Isostatic pressing is a viable technique for producing tubes that are not candidates for slip casting because the wall is too thick to be cast, or where a precision ID surface is desired and a suitable mandrel can be made and de-molded. It can also be justified to produce an irregular ID, such as a square or hexagonal shape.

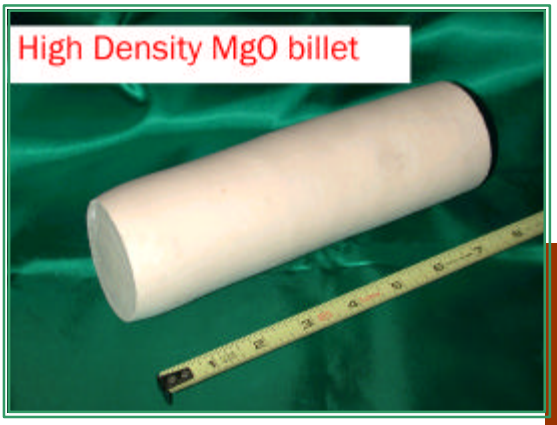
The chamber dimensions and shape guidelines limit this technique to a range of tube sizes as indicated in the chart.



Complex shapes: With ingenious tooling, or custom rubber bags made off a complex pattern, some complex shapes with re-entrant angles can be made that cannot be made by other techniques. Spark plug insulators are the classic example of a fully mature part that benefits from Isostatic pressing by the use of highly automated process lines that churn out over one million parts per day.

Billets for machining:

In regular dry pressing, binders are added to encourage compaction and adhesion, and to give the pressed part green strength for handling and firing operations. In some limited cases, the unique nature of isostatic pressing and the thickness and strength of the part will permit pressing without binder, especially for production of billets. The absence of binder allows the potential to make thicker cross-sections than would normally be possible.



If you want OZARK to consider making a shape by isostatic pressing, then empty your bank accounts and hold a gun to our head, and we will consider it.

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Machining is the third step of the classic definition of a ceramic manufacturing process. This traditional description is Forming, Firing, and **MACHINING**. It is the objective of ceramic engineers to eliminate the need for machining by net shape forming, or at least minimize it with near-net shape forming.

The more mature a fabrication technology is, and the more established the part, the less likelihood of any significant amount of machining, especially of the fully fired body. Our familiar example is the humble toilet bowl. If it had to be machined from a block of marble, only Bill Gates could afford one. Instead, it is very efficiently made to the final shape with a very small amount of trimming and finishing.

On the other hand, it is often more efficient to perform extensive machining on easily formed shapes for prototype items or very small production quantity runs. Lastly, there is an upper boundary to the precision that can be achieved by net shape forming, and any finer tolerances must be achieved by machining.

There are 4 basic opportunities to machine the formed ceramic.

1) Newly formed - The first opportunity occurs immediately when the green body is formed, but before any drying operations. Wet or semi-dry parts can be lightly trimmed to remove flashing and smooth out joint lines, etc..

2) Green machining – This is a very important opportunity. If the binder strength is sufficient to hold the part and permit machining operations, many traditional machining methods can be employed. There is a risk of introducing stresses which will develop in firing, so discretion must be used. Some drilling and single point machining operations can be performed which are impossible later. Abrasive machining operations are possible if wheel loading is prevented. All operations must be done dry, so the proper selection of abrasives and techniques is important.

Another advantage of green machining is the possibility of recycling broken parts and cutting scraps. The key disadvantage to green machining is a lack of final precision due to firing variables.

3) Bisque machining – Some delicate parts may be “pre-fired” to permit water-cooled machining techniques or to obtain enough strength for holding the part for machining. This is not as convenient as Green machining, but offers less risk in stressing delicate parts, and is the only way to obtain some detailed features.

4) Hard-fired machining – This can be the portal to hell, but is a necessary evil whenever high precision tolerances are needed. Since the part is fully fired, there is no further shrinkage to deal with, and what you see is what you get. You only have to machine the quantity needed, and don’t have to worry about latent defects that appear in firing. It can only be performed with diamond tools run wet. Some of the simplest tasks are very difficult, such as producing precision lengths of small rods with high quality end cuts.

OZARK does not represent itself to be a third party machining facility. We use our limited capabilities to fine tune or finish off customers' parts as needed, and occasionally agree to help out our good customers when they have emergency needs that can't be addressed by other sources. For all of our phobia about the subject, it has been more effective to do our own work than to source out jobs, so we must be pretty effective. Truth is, these are hard jobs with high downside potential. The following may give you some guide to our limitations (capabilities).

Cylindrical grinding – Although it seems like this should be the hardest machining task, it actually is the one with the most inherent precision. This is because there is readily available equipment for precision grinding that is convertible to the diamond tools and coolant needs of ceramic machining. Furthermore, the measuring instruments are operator friendly and give high accuracy and repeatability.

We are limited by the innate ability to mount and secure the object. Our maximum diameter is on the order of 8", with 4-12" maximum length, depending on diameter and other factors. On short lengths of mounting friendly shapes, we have achieved tolerances of +/- 0.0002" on 6.000" diameters for both roundness and dimension. Now that we've done it, we don't want to go there again!

Sawing – This is done with our precision cylindrical grinder as a platform with a diamond saw blade substituted for the normal diamond abrasive wheel. It can be a difficult job due to the delicacy of thin walled tubes, which makes effective mounting difficult.

Centerless grinding – This is a clumsy operation that nonetheless can achieve very precise results. We can only do this with an attachment to our surface grinder, and only resort to it when necessary. Our dimensional range is on the order of 0.25" to 2.0", and the Length should exceed the diameter.

Surface grinding – Again, a potentially high precision machine with many user unfriendly problems. The feed rates are extremely slow, mounting techniques are very clumsy (no magnetic chucks here), and you can see 14 hours of effort explode in the last 5 minutes. In theory, flat surfaces of 0.0002 in/in are achievable, and thickness precision of about 0.001", but these results are rarely achieved in practice.

Core Drilling – Through holes can often be made by core drilling with readily available diamond core drills. Blind holes cannot be made at all. Under optimum conditions, holes can be drilled a few diameters deep, and with 0.001" precision. There is an almost guaranteed amount of chipping on the bottom of the hole where the breakout occurs. It is difficult to position holes absolutely, depending on the fixturing techniques to hold the part in position.

Reaming – Under the right conditions of stock removal, a special expandable diamond router bit can be used to form very precise ID's. A reasonably thick wall is required, and a near net shape blank should only need 0.003-.005" of stock removed. We currently use this technique to make tubes with 0.7474" ID's within 0.0005" accuracy over a 2.75" length.

Chamfering, Deburring, etc.. Some modest stock removal can be done with free-hand grinding equipment. This should not be counted on for any purpose except to break sharp edges.

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Custom Fabrication
DD1 - HIGH PURITY POWDERS

OZARK does not mine, synthesize or manufacture any of the raw materials that are used in our finished ceramics. We do a modest amount of calcination and doping to some of our as-received materials, and some of our product areas demand extensive particle size manipulation, but otherwise we depend on quality sources for our feedstocks. As a convenience to our customers, we will re-package our high purity powders for your use in limited quantities which are impractical to obtain from the bulk suppliers. We are not in the business of re-selling other vendors' products, and will gladly supply you with the names and contacts for you to purchase directly if you wish. Until then, we have established the following price schedules and grade descriptions for your reference:

Grade	CUMX	CKMV	CTM	CCA	CUH
Material	MgO	MgO	MgO	Al2O3	HfO2
Purity	99.8%	99.4%	96.4%	99.99%	99.9%
Country of Origin	Japan	Japan	U.S.A	France	U.S.A
Mesh Size*	-400	-50+200	-80	-400	-400
Particle size*	~10 µ	~200 µ	~150 µ	~1 µ	~2 µ
Bulk Density	poor	good	good	poor	fair
Typical use	backfill	setter sand	setter sand	backfill	backfill
		PRICING			
20 gm	---	---	---	---	$15.00
50 gm	---	---	---	---	$30.00
100 gm	$10.00	---	---	$10.00	$50.00
500 gm	$25.00	$15.00	---	$25.00	$200.00
2-4 lb ($/lb)	$25.00	$15.00	$5.00	$20.00	$175.00
5-9 lb ($/lb)	$20.00	$12.50	$3.00	$20.00	$175.00
10-24 lb ($/lb)	$20.00	$12.50	$2.50	$20.00	$175.00
25+ lb ($/lb)	$20.00	$12.50	$2.00	$20.00	$175.00

Applications:

Junction Backfill – Thermocouple cable manufacturers often need to expose the element wires in the ceramic to perform welding and junctioning operations, or they may not be able to slide the ceramic over the junction at the beginning. An ideal powder will have good bulk density for packing densely, and not contain coarse particles which can cause wire damage on further processing. This suggests about a 200 to 270 mesh fine powder with limited submicron content. Unfortunately, OZARK has limited grades available, and the designated grades are the best available from our choices

Heater fill – Cartridge heater manufacturers use MgO grain to complete the heater assembly by filling the grain around the wound core. A free flowing, good bulk density powder is needed, with less emphasis on maximum particle size.

Setter sand – MgO is an excellent inert material for use as a firing sand to prevent contamination from firing setters and permit free movement of parts. It can also be used to mechanically stabilize MgO crucibles used at very high temperatures. A coarser material is preferred, with few fines for convenience of use.

Doping – MgO is a popular additive in many ceramic compounds, and high purity fused MgO powders are not readily available.

PARTICLE SIZE PROCESSING: The suggested pricing is for "as-is" material. There is a fee to perform sieving operations on the coarser materials to refine the particle size if needed. On the fine end of the scale, if we have some milled powders on hand that meet your requirements, there is no fee to substitute them.

RECYCLING? – OZARK has often been asked about the possibility of recycling unused MgO or HfO2 products. Unfortunately for the environment perhaps, there is no practical re-processing scheme that will supply the quality of raw materials needed for our process. Even our 96.4% grade material is actually an engineered 99+% purity raw material, and no small scale processes can achieve that result at any price, much less in a cost effective manner.

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Thank you for reviewing our company information. In many places, we make reference to the fact that we are glad to give referrals for you to obtain the ceramics you need. We frequently are asked for items resembling our products in shape or description, but are actually a case of mistaken identity. We have prepared this information to help facilitate your search. This excerpt is from our standard response::

Thank you for contacting OZARK TECHNICAL CERAMICS with your request. Please note the following points:

1) We don't attempt to quote every possible item we might be able to make if we think you are better served by established vendors.
2) We are not able to manufacture everything in the ceramic universe because of material, equipment, or production limitations.
3) We choose not to put our name on someone else's product or profit by re-selling their product when you would be better served by contacting them directly. We prefer not to profit from our insider information and to earn our reputation as a quality vendor.

Lastly, we are naming our direct competitors in our base market areas. We think we should earn your business with fair, cost-based pricing and excellent service. Please exercise discretion with our pricing information. We do not participate in predatory pricing to capture business or price gouging to take advantage of an exclusive market situation.

We are not thoroughly networked in the ceramics community, but in case you are not either, you might find it useful to contact the following vendors for further development of your request. If you learn of new sources we can add to the list, and would like to share your discovery, let us know and we will add them. If a phone number is obsolete, please let us know.

OZARK cannot vouch for the products, service, or experience you will have with these suppliers. We hope it is a positive one, and you will remember OZARK for your next MgO (or Al2O3) needs.

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(see text on previous page)

Foundry Crucibles – Thick walled, <99% MgO, coarse grain, large shapes

American Refractories & Crucibles, North Haven , CT; PH (203) 239-1624; FAX (203)-239-5829
Bartley Crucible, Trenton, NJ; PH (609) 393-0066; FAX (609-393-1866
Bay State Crucible, Taunton, MA 02780, PH (508) 824-5121, FAX (508) 880-5665

Refractory Ware – kiln furniture, saggers

Applied Ceramics, Atlanta, GA; PH (404) 448-6888 ; FAX (404) 368-8261 ;www.appliedceramics.com
Magneco Metrel, Addison, IL; PH (630) 543-6660; FAX (630) 543-1479
Ferro Industries, (HQ); Cleveland, OH; PH (216) 641-8580; FAX (216) 641-8831; www.ferro.com

Slip Cast MgO - (our competitors), high density MgO shapes

Custom Technical Ceramics, Arvada, CO PH (303) 431-7798, FAX (303) 431-6168
Aceram Tech, Chalk River, ON; (613) 589-2196; FAX (613) – 584-1984

Slip Cast Al2O3 -

CoorsTek; Golden, CO; PH (303) 278-4000; FAX (303) 271-4901; www.coorstek.com
Ipsen Ceramics, Pecatonica, IL, (815) 239-2385, FAX (815) 239-2387, www.ipsenceramics.com
Wesgo/Duramic, Fairfield, NJ; PH (973)227-8877, FAX (973) 227-7135

Dry Pressing – Alumina, Steatite, high production shapes

Alumina Ceramic Components , Latrobe, PA; PH (724)532-1900; FAX (724) 532-5804
Superior Technical Ceramics; St. Albans, VT; (802)527-7726, FAX (802) 527-1181

Extrusions (Mullite, low Alumina) or closed end tubes or long tubes (over 10")

Bolt Technical Ceramics; Conroe, TX; PH (935) 539-2552; FAX (936) 539-2548
CoorsTek; Golden, CO; PH (303) 278-4000; FAX (303) 271-4901; www.coorstek.com
Vesuvius McDanel; Beaver Falls, PA; (724) 843-8300; FAX (724)-843-5644; www.techceramics.com

Extrusions - (our competitors), low density MgO, Al2O3

Du-Co Ceramics; Saxonburg, PA ; PH(412)352-1511, FAX(412)352-1266.
Saxonburg Ceramics, Saxonburg, PA, PH (412) 352-1561, FAX (412)352-4180
Norton Industries, Worcester, MA (508) 795-5046; FAX (?)

Hafnia – Cast shapes and Powder

Shapes - Custom Technical Ceramics, Arvada, CO PH (303) 431-7798, FAX (303) 431-6168
Powder – Oremet Wah Chang, Albany, OR; PH (541) 926-4211, FAX (541) 926-6994

MgO Powders – Bulk quantities

High Purity – Nissho Iwai American (Tateho broker), N.Y., N.Y.; PH (212) 704-6826; FAX ()
Heater grade – Universal America, Greenville, TN; PH (423) 787-0333, FAX (423) 787-0775

Ozark Technical Ceramics, Inc. 402 Ware St. Webb City, MO 64870-2789
Tel. (417) 673-2463 / FAX (417) 673-2464 / website: www.ozarktech.com