One of the unique features of this chemical treatment and hardening method is that virtually no change will occur in the original dimensions of the machined part during the hardening process. Therefore, expensive diamond machining of the finished hardened part is eliminated.

These new ceramic materials will withstand repeated water quenching from 1000° F. as well as prolonged exposure to temperature extremes of 2000° F. to —300° F. Mohs scale hardness is in excess of 9, normally being about equal to that of silicon carbide. Rockwell hardness can be as high as A–85 to A–90, with associated compressive strengths in excess of 125,000 p.s.i.

In addition to their use for the manufacture of precision parts, many of these ceramics exhibit excellent characteristics for low friction and low wear rate bearing and seal applications: in particular, journal bearings, thrust bearings and sliding type bearings and seals. When used in this manner, lubrication may be by means of a wide variety of conventional and non-conventional lubricants. Among those successfully tested to date include: tap water, sea water, alcohol, kerosene, polyethylene glycol trichlorethylene, lubricating oils, silicone fluids and liquid metals. Solid lubricants have been used with good results at temperatures up to about 2000° F. In addition, lightly loaded bearings have been operated for limited periods at high speed without lubrication.

Life tests of sleeve-type bearings have been and still are currently in progress. However, to date wear has been too low to obtain quantitative data, even after many months' time. Rub-shoe type wear rate tests have consequently been conducted and have shown exceptionally low wear rate characteristics. For example, a ceramic shoe of this invention riding on a ceramic wheel of the same material exhibited many times less wear than a bearing bronze shoe riding against a steel wheel using oil as the lubricating media. Also, unlike a conventional bronze-steel bearing combination, very heavy loads can be applied to many of the ceramic-to-ceramic material bearings without their showing any tendency toward galling, even when running with such poor lubricants as alcohol or water.

A special variation in treatment of this invention has also been found that will produce a honing or finishing material that appears to be superior in several respects to both natural and artifically produced grinding stones. For example, one such ceramic will remove metal far more rapidly than will an Arkansas stone, while at the same time producing a finer and more highly polished finish.

Another ceramic material of this invention displays a wide variation in electrical and heat conduction with relatively small changes in temperature.

The basic method employed for producing the new ceramic materials consists of chemically impregnating a porous, refractory oxide structure followed by a low temperature cure. The porous refractory acts as the skeletal framework around which the final ceramic structure is formed.

The simplest chemical hardening method consists of impregnating the porous refractory structure with a solution of phosphoric acid. The thoroughly impregnated material is then cured in an oven with the final temperature reaching at least 600–1000° F. or higher. With a suitable refractory base material, this simple acid treatment will produce a hard ceramic body having numerous uses.

A more dense, harder and structurally stronger ceramic can be formed by impregnating the porous base material with one or more refractory oxides prior to the final acid treatment. This may be accomplished by impregnation of the porous structure with a water soluble metal salt solution and subsequently converting to the oxide by simply elevating the temperature to the required conversion point. Normally, this salt to oxide conversion will take place at a temperature less than about 1000° F.

X-ray diffraction tests indicate that these chemical treatment methods form a new microcrystalline structure or at least a very close bond between the added oxides, and/or phosphoric acid and the porous refractory skeletal structure.

As mentioned previously, the ceramic material is built around a porous refractory base material that functions as the skeletal structure. The types of such materials that are suitable for use in the present invention include various grades of alumina, titania, beryllia magnesia, magnesium silicate and stabilized zirconia. Silica has been tested but does not provide satisfactory results. These materials were obtained from the manufacturer in an "underfired" or "machinable" form. In this condition, these materials were normally found to be soft enough to allow machining by conventional means, and exhibited a relatively high effective porosity (10% to 50%) to allow for subsequent chemical treatment by the process of this invention. Table I lists the major type designation, manufacturer, hardness, porosity and fabrication method for each of the skeletal refractory materials tested.

TABLE I.—UNDERFIRED, POROUS REFRACTORY BASE MATERIALS

| Base material | Manufacturer's type designation | Manufacturer | Major oxide | Other oxides | Sintering temp., ° F. | Effective porosity, percent | Mohs hardness | Remarks |
|---|---|---|---|---|---|---|---|---|
| Alumina | AHP-99 | Coors | 99% $Al_2O_3$ | 0.5% $SiO_2$<br>0.2% CaO<br>0.2% MgO | 2,670 | 45.7 | 2–3 | Isostatic pressed. |
| Do | AP-99-L3 | do | 99% $Al_2O_3$ | | 2,570 | 42.4 | 2–3 | Extruded. |
| Do | AP-99-I1 | do | 99% $Al_2O_3$ | | 1,700 | | 0–1 | Do. |
| Do | AP-99-I2 | do | 99% $Al_2O_3$ | | 2,130 | | 1 | Do. |
| Do | AP-99-L1 | do | 99% $Al_2O_3$ | | 2,642 | | | Do. |
| Do | AP-99-L2 | do | 99% $Al_2O_3$ | | 2,670 | | 5–6 | Do. |
| Do | AP-99C-L1 | do | 99% $Al_2O_3$ | | 2,642 | | 4–5 | Cast. |
| Do | AP-99C-I2 | do | 99% $Al_2O_3$ | | 2,130 | | | Do. |
| Do | AP-99C-L3 | do | 99% $Al_2O_3$ | | 2,570 | | | Do. |
| Do | AP-995-L3 | do | 99.5% $Al_2O_3$ | | 2,570 | | | Extruded. |
| Do | AP-997-L3 | do | 99.7% $Al_2O_3$ | | 2,570 | | | Cast. |
| Do | AP-94-I1 | do | 94% $Al_2O_3$ | 3.75% $SiO_2$<br>0.9% CaO<br>0.75% MgO<br>0.5% $ZrO_2$<br>0.1% $Fe_2O_3$ | 1,700 | 33.1 | 2–3 | Extruded. |
| Do | AP-94-I2 | do | 94% $Al_2O_3$ | 3.75% $SiO_2$<br>0.9% CaO<br>0.75 MgO<br>0.5% $ZrO_2$<br>0.1% $Fe_2O_3$ | 2,130 | 33.0 | 2–3 | Do. |
| Do | AP-94-I2 | do | 94% $Al_2O_3$ | 3.75% $SiO_2$<br>0.9% CaO<br>0.75% MgO<br>0.5% $ZrO_2$<br>0.1% $Fe_2O_3$ | 2,130 | 44.1 | 2–3 | Isostatic pressed. |
| Do | AP-85-I1 | do | 85% $Al_2O_3$ | 10% $SiO_2$<br>2.75% MgO<br>1.25% CaO<br>0.75% BaO<br>0.25% $Fe_2O_3$ | 1,700 | 33.4 | 2–3 | Extruded, |