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## **1- ADVANCED CERAMIC POWDERS:**

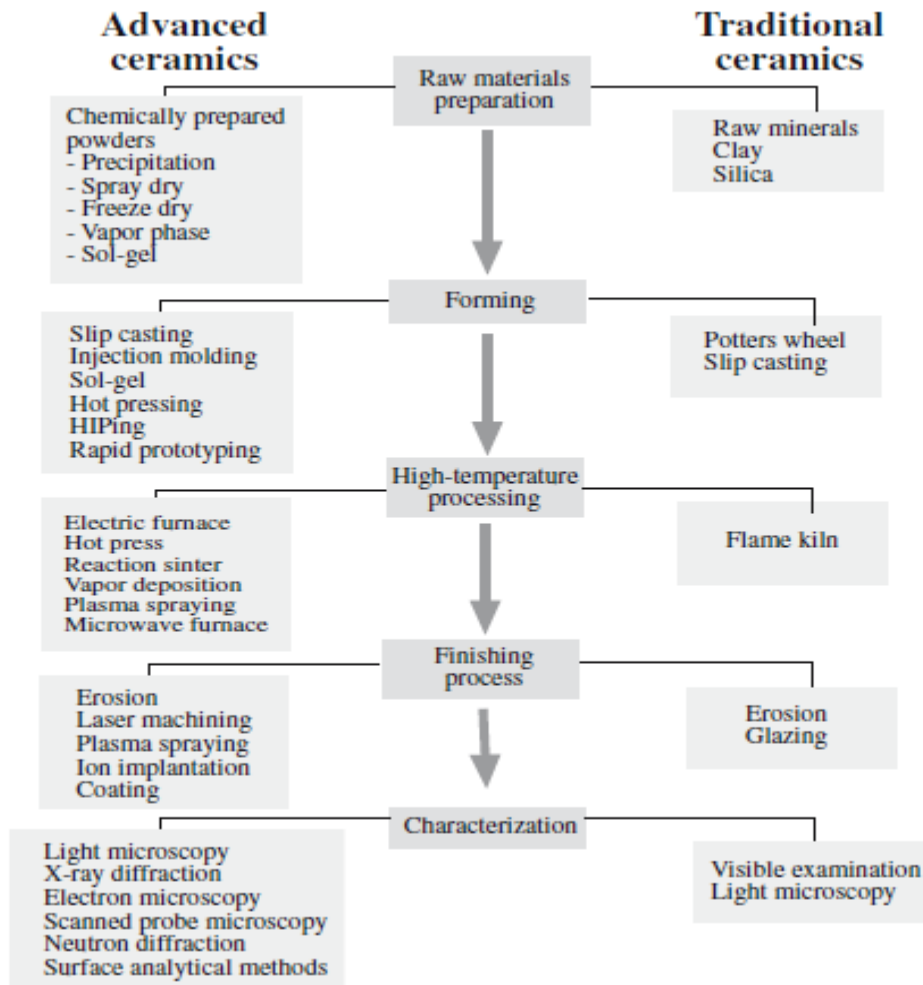
The applications for ceramic materials are diverse, from bricks and tiles to electronic and magnetic components. These applications use the wide range of properties exhibited by ceramics. The functions of ceramic products are dependent on their chemical composition and microstructure, which determines their properties. It is the interrelationship between structure and properties. Ceramics can divide according to their properties and applications into *traditional* or *advanced*.

Traditional ceramics include high-volume items such bricks and tiles, toilet bowls (white wares), and pottery.

Advanced ceramics include newer materials such as laser host materials, piezoelectric ceramics, and ceramics for dynamic random access memories (DRAMs), often produced in small quantities with higher prices. There are other characteristics that separate these categories.

*Traditional ceramics* are usually based on clay and silica. There is sometimes a tendency to equate traditional ceramics with low technology; however, advanced manufacturing techniques are often used. Competition among producers has caused processing to become more efficient and cost effective. Complex tooling and machinery is often used and may be coupled with computer-assisted process control.

*Advanced ceramics* are also referred to as “special,” “technical,” or “engineering” ceramics. They exhibit superior mechanical properties, corrosion/oxidation resistance, or electrical, optical, and/or magnetic properties. While traditional clay-based ceramics have been used for over 25,000 years, advanced ceramics have generally been developed within the last 100 years. The following Figure compares traditional and advanced ceramics in terms of the type of raw materials used, the forming and shaping processes, and the methods used for characterization.



*Comparison of different aspects of traditional and advanced ceramics.*

## **1-1 OXIDES:**

The raw materials used for oxide ceramics are almost entirely produced by chemical processes to achieve a high chemical purity and to obtain the most suitable powders for component fabrication.

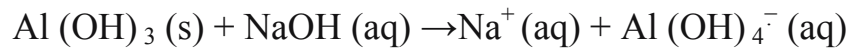
### ***1-1.1 Alumina***

Aluminum oxide ( $\text{Al}_2\text{O}_3$ , alumina, corundum) is the most widely used inorganic chemical for ceramics and is produced from the mineral bauxite using the Bayer process. Bauxite is a mixture of hydrated aluminum oxide with iron oxide ( $\text{Fe}_2\text{O}_3$ ), silica ( $\text{SiO}_2$ ), and titania ( $\text{TiO}_2$ ) impurities. It results from the decay and weathering of aluminous rocks, often igneous, under tropical conditions. Like kaolin, bauxite occurs as both primary deposits and secondary deposits. The Bayer process produces a nominal 99.5%  $\text{Al}_2\text{O}_3$  product. The alumina can be prepared in a range of grades to suit specific applications. The

grades differ by the size and shape of the crystals and the impurity content. The dominant impurity, accounting for up to 0.5%, is Na<sub>2</sub>O. The crystal size can be adjusted to measure between 0.1 and 25 μm. The steps in the Bayer process are as follows:

● **Physical beneficiation:** The bauxite from the mine is first ground, fairly coarsely, to a particle size of <1 mm. Grinding increases the total surface area of the particles, leading to a reduction in the processing time for the chemical reaction in the following step.

● **Digestion:** The coarsely ground bauxite is treated with a sodium hydroxide (NaOH) solution at 150–160°C and 0.5 MPa total pressure. Most of the hydrated alumina goes into solution as sodium aluminate:

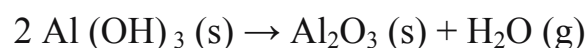


● **Filtration:** The solid impurities, mainly SiO<sub>2</sub>, TiO<sub>2</sub>, and Fe<sub>2</sub>O<sub>3</sub>, remain undissolved and are separated by filtration.

● **Precipitation:** After cooling, the filtered sodium aluminate solution is seeded with very fine gibbsite [a naturally occurring hydrated alumina, α-Al (OH)<sub>3</sub>] and at the lower temperature the aluminum hydroxide reforms as the stable phase. Reducing the pH by bubbling CO<sub>2</sub> through the solution encourages precipitation.

● **Washing:** The precipitate is filtered and washed to reduce the sodium content.

● **Calcination:** The powder is calcined at temperatures in the range 1100–1200°C to convert the hydroxide to the oxide:



At this stage the alumina is in the form of agglomerates of small grains about 5-10 μm in diameter.

● **Milling:** The powder is then milled to give the desired particle size and particle size distribution. The alumina produced in this way contains ≥99.5% Al<sub>2</sub>O<sub>3</sub> and, as mentioned earlier, the major impurity is Na<sub>2</sub>O. The powder may also contain small amounts, on the order of 0.001%, SiO<sub>2</sub>. This level of purity is sufficient

for many applications. Table 1.1 gives typical compositions of the main forms of calcined aluminas.

**TABLE 19.7 Composition of Calcined Aluminas**

	Normal Na <sub>2</sub> O (wt%)	Low Na <sub>2</sub> O (wt%)	Reactive (wt%)
Al <sub>2</sub> O <sub>3</sub>	98.9–99.7	99.5–99.8	>99.5
SiO <sub>2</sub>	0.02–0.05	0.07–0.12	0.04–0.08
Fe <sub>2</sub> O <sub>3</sub>	0.04–0.05	0.04–0.06	0.01–0.02
Na <sub>2</sub> O	0.3–0.6	<0.13	0.08

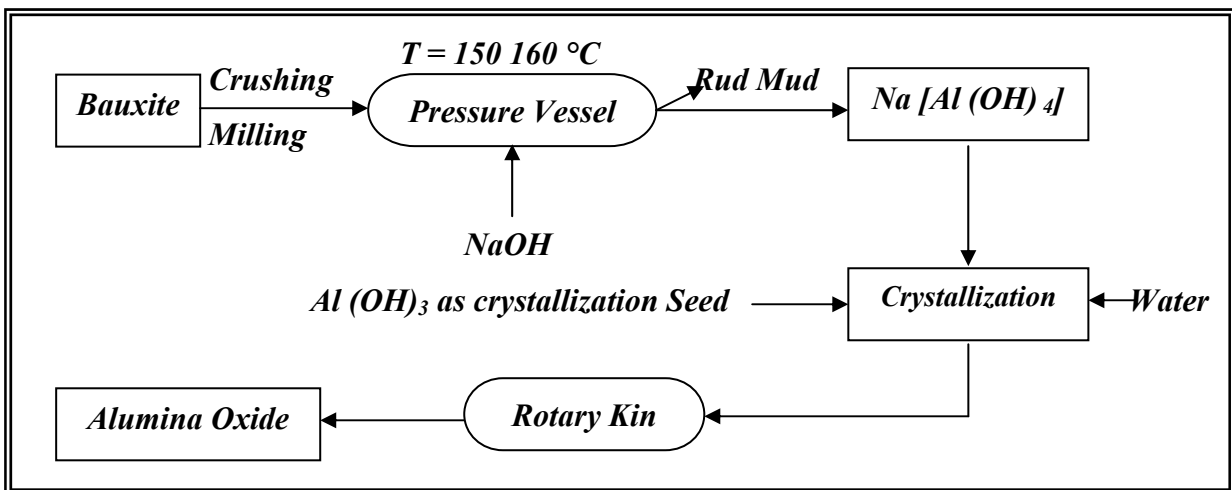


Figure 1.1 Bayer Process