

Barium Titanate Properties And Uses

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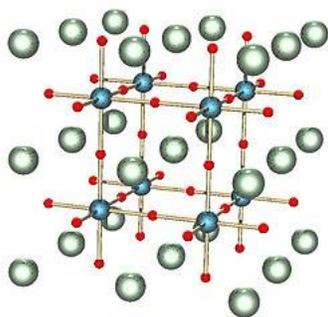
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Abstract- Barium titanate (BTO) is an inorganic compound. The solid exists in one of four polymorphs depending on temperature. Production and handling properties. Uses of Barium titanate. Oxides, sulfides, and alkoxides

Keywords- Barium titanate-Oxides, sulfides, and alkoxides

I. INTRODUCTION

Barium titanate (BTO) is an inorganic compound with chemical formula BaTiO_3 . It is the barium salt of metatitanic acid. Barium titanate appears white as a powder and is transparent when prepared as large crystals. It is a ferroelectric, pyroelectric, and piezoelectric ceramic material that exhibits the photorefractive effect. It is used in capacitors, electromechanical transducers and nonlinear optics.

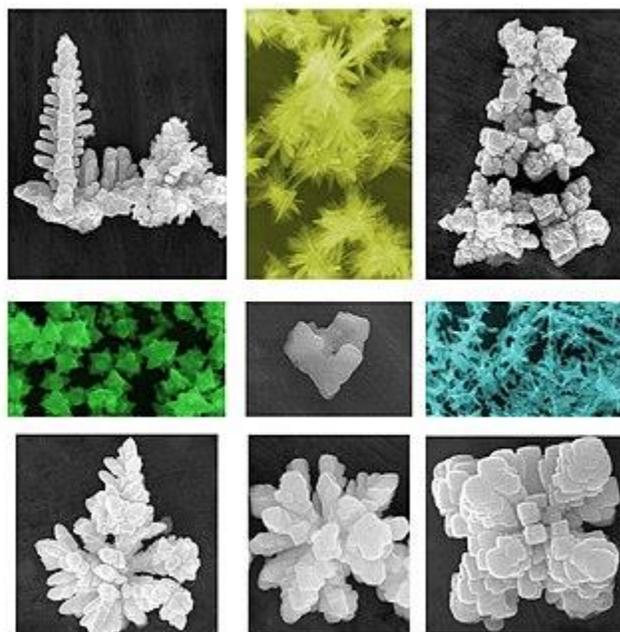


The solid exists in one of four polymorphs depending on temperature. From high to low temperature, these crystal symmetries of the four polymorphs are cubic, tetragonal, orthorhombic and rhombohedral crystal structure. All of these phases exhibit the ferroelectric effect apart from the cubic phase. The high temperature cubic phase is easiest to describe, as it consists of regular corner-sharing octahedral TiO_6 units that define a cube with O vertices and Ti-O-Ti edges. In the cubic phase, Ba^{2+} is located at the center of the cube, with a nominal coordination number of 12. Lower symmetry phases are stabilized at lower temperatures and involve movement of the Ti^{4+} to off-center positions. The remarkable properties of this material arise from the cooperative behavior of the Ti^{4+} distortions.[3]

Above the melting point, the liquid has a remarkably different local structure to the solid forms, with the majority of

Ti^{4+} coordinated to four oxygen, in tetrahedral TiO_4 units, which coexist with more highly coordinated units.[4]

II. PRODUCTION AND HANDLING PROPERTIES



Scanning Electron Microscopy (SEM) images showing particles of BaTiO_3 . The different morphologies depend on the synthesis conditions (precipitation, hydrothermal and solvothermal synthesis): size and shape can be varied by changing the concentration of precursors, the reaction temperature and the time. Color (if added) helps to emphasize the grayscale levels. In general, the synthesis of Barium titanate by precipitation from aqueous solution allows to produce particles with spherical shape with size that can be tailored from a few nanometers to several hundred nanometers by decreasing the concentration of reactants. At very low concentration the particles have the tendency to develop a dendritic-like morphology, as reported in the images.

Barium titanate can be synthesized by the relatively simple sol-hydrothermal method.[5] Barium titanate can also be manufactured by heating barium carbonate and titanium dioxide. The reaction proceeds via liquid phase sintering. Single crystals can be grown at around $1100\text{ }^\circ\text{C}$ from molten potassium fluoride.[6] Other materials are often added

as dopants, e.g., Sr to form solid solutions with strontium titanate. Barium titanate reacts with nitrogen trichloride and produces a greenish or gray mixture; the ferroelectric properties of the mixture are still present in this form.

Much effort has been spent studying the relationship between particle morphology and its properties. Barium titanate is one of the few ceramic compounds known to exhibit abnormal grain growth, in which large faceted grains grow in a matrix of finer grains, with profound implications on densification and physical properties.[7] Fully dense nanocrystalline barium titanate has 40% higher permittivity than the same material prepared in classic ways.[8] The addition of inclusions of barium titanate to tin has been shown to produce a bulk material with a higher viscoelastic stiffness than that of diamonds. Barium titanate goes through two phase transitions that change the crystal shape and volume. This phase change leads to composites where the barium titanates have a negative bulk modulus (Young's modulus), meaning that when a force acts on the inclusions, there is displacement in the opposite direction, further stiffening the composite.[9]

Like many oxides, barium titanate is insoluble in water but attacked by sulfuric acid. It is also soluble in concentrated hydrochloric acid, and hydrofluoric acid.[10] Its bulk room-temperature bandgap is 3.2 eV, but this increases to ~3.5 eV when the particle size is reduced from about 15 to 7 nm.[11]

III. USES

Barium titanate is a dielectric ceramic used in capacitors, with dielectric constant values as high as 7,000. Over a narrow temperature range, values as high as 15,000 are possible; most common ceramic and polymer materials are less than 10, while others, such as titanium dioxide (TiO₂), have values between 20 and 70.[12] High-purity barium titanate powder is reported to be a key component of new barium titanate capacitor energy storage systems for use in electric vehicles.[13]

It is a piezoelectric material used in microphones and other transducers, albeit largely replaced by lead zirconate titanate. The spontaneous polarization of barium titanate single crystals at room temperature range between 0.15 C/m² in earlier studies,[14] and 0.26 C/m² in more recent publications,[15] and its Curie temperature is between 120 and 130 °C. The differences are related to the growth technique, with earlier flux grown crystals being less pure than current crystals grown with the Czochralski process,[16] which therefore have a larger spontaneous polarization and a higher Curie temperature.

Barium titanate crystals find use in nonlinear optics. The material has high beam-coupling gain, and can be operated at visible and near-infrared wavelengths. It has the highest reflectivity of the materials used for self-pumped phase conjugation (SPPC) applications. It can be used for continuous-wave four-wave mixing with milliwatt-range optical power. For photorefractive applications, barium titanate can be doped by various other elements, e.g. iron.[17] Thin films of barium titanate display electrooptic modulation to frequencies over 40 GHz.[18]

The pyroelectric and ferroelectric properties of barium titanate are used in some types of uncooled sensors for thermal cameras.

Polycrystalline barium titanate has a positive temperature coefficient of resistance, making it a useful material for thermistors and self-regulating electric heating systems. For these applications, barium titanate is manufactured with dopants to give the material semiconductor properties. Specific applications include overcurrent protection for motors, ballasts for fluorescent lights, automobile cabin air heaters, and consumer space heaters.[19][20]

Due to their elevated biocompatibility, barium titanate nanoparticles (BTNPs) have been recently employed as nanocarriers for drug delivery.[21]

Magnetoelectric effect of giant strengths have been reported in thin films grown on barium titanate substrates.[22][23]

Natural occurrence Barioperovskite is a very rare natural analogue of BaTiO₃, found as microinclusions in benitoite.[24]

IV. TITANIUM COMPOUNDS

The +4 oxidation state dominates titanium chemistry,[1] but compounds in the +3 oxidation state are also numerous.[2] Commonly, titanium adopts an octahedral coordination geometry in its complexes,[3][4] but tetrahedral TiCl₄ is a notable exception. Because of its high oxidation state, titanium(IV) compounds exhibit a high degree of covalent bonding.[1]

V. OXIDES, SULFIDES, AND ALKOXIDES

The most important oxide is TiO₂, which exists in three important polymorphs; anatase, brookite, and rutile. All three are white diamagnetic solids, although mineral samples can appear dark (see rutile). They adopt polymeric structures in

which Ti is surrounded by six oxide ligands that link to other Ti centers.[5]

The term titanates usually refers to titanium(IV) compounds, as represented by barium titanate (BaTiO_3). With a perovskite structure, this material exhibits piezoelectric properties and is used as a transducer in the interconversion of sound and electricity.[6] Many minerals are titanates, such as ilmenite (FeTiO_3). Star sapphires and rubies get their asterism (star-forming shine) from the presence of titanium dioxide impurities.[7]

A variety of reduced oxides (suboxides) of titanium are known, mainly reduced stoichiometries of titanium dioxide obtained by atmospheric plasma spraying. Ti_3O_5 , described as a Ti(IV)-Ti(III) species, is a purple semiconductor produced by reduction of TiO_2 with hydrogen at high temperatures,[8] and is used industrially when surfaces need to be vapor-coated with titanium dioxide: it evaporates as pure TiO, whereas TiO_2 evaporates as a mixture of oxides and deposits coatings with variable refractive index.[9] Also known is Ti_2O_3 , with the corundum structure, and TiO, with the rock salt structure, although often nonstoichiometric.[10] The alkoxides of titanium(IV), prepared by treating TiCl_4 with alcohols, are colorless compounds that convert to the dioxide on reaction with water. They are industrially useful for depositing solid TiO_2 via the sol-gel process. Titanium isopropoxide is used in the synthesis of chiral organic compounds via the Sharpless epoxidation.[11] Titanium forms a variety of sulfides, but only TiS_2 has attracted significant interest. It adopts a layered structure and was used as a cathode in the development of lithium batteries. Because Ti(IV) is a "hard cation", the sulfides of titanium are unstable and tend to hydrolyze to the oxide with release of hydrogen sulfide.[12]

VI. HALIDES

Titanium(III) compounds are characteristically violet, illustrated by this aqueous solution of titanium trichloride. Titanium tetrachloride (titanium(IV) chloride, TiCl_4 [18]) is a colorless volatile liquid (commercial samples are yellowish) that, in air, hydrolyzes with spectacular emission of white clouds. Via the Kroll process, TiCl_4 is used in the conversion of titanium ores to titanium metal. Titanium tetrachloride is also used to make titanium dioxide, e.g., for use in white paint.[19] It is widely used in organic chemistry as a Lewis acid, for example in the Mukaiyama aldol condensation.[20] In the van Arkel–de Boer process, titanium tetraiodide (TiI_4) is generated in the production of high purity titanium metal.[21]

Titanium(III) and titanium(II) also form stable chlorides. A notable example is titanium(III) chloride (TiCl_3), which is used as a catalyst for production of polyolefins (see Ziegler–Natta catalyst) and a reducing agent in organic chemistry.[22]

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