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Direct synthesis of TiO_2 nanoparticles by using the solid-state precursor TiH_2 powder in a thermal plasma reactor

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ABSTRACT

We attempt the direct synthesis of TiO_2 by using the solid state precursor TiH_2 powder with oxygen in a thermal plasma reactor. Nanocrystalline titanium dioxide powder has been synthesized by using thermal plasma synthesis in a non-transferred arc thermal plasma reactor. The thermal plasma-synthesized powder product consists of nano-sized particles of anatase and rutile phases of titanium dioxide. Particle compositions were observed on collecting powder from different positions of the reactor and varying the amount of flow rate of reactive gases (O_2). The characteristics of the powder such as particle size, size distribution and phases were analyzed using various techniques such as XRD, SEM, TEM, XPS, EDS and particle size analyzer. UV–visible reflection spectroscopy of the plasma-synthesized TiO_2 powders showed the absorbance in the visible region leading to effective photocatalytic activity, which is clearly confirmed from the XPS analysis. XPS analysis reveals the presence of –OH bonds on the surface of nanoparticles, which is the significant evidence of better quality of powders in comparison to other methods. Also, we have investigated the phase transformation phenomenon of anatase to rutile. At 1000 °C, complete transformation of the anatase to rutile occurs. Powders prepared in this procedure are white in colour and their diameter varies from 10 nm to 150 nm. Average particle size distributes in the range of 20–50 nm. The unique property about the plasma-synthesized powders is high resistance to heat treatment, with enhanced photocatalytic activity.

Keywords: Titanium hydride; Thermal plasma; Phase transformation; Titanium dioxide

1. Introduction

Apart from use in paint industries, titanium oxide is being extensively used to address a variety of environmental pollution problems. Titania based photocatalysts are used for a variety of applications such as decomposition of unwanted and toxic organic compounds and destruction of pollutants from contaminated water, air and harmful bacteria (Oh and Park, 2001). Research is going on the synthesis and processing of nano-crystalline materials because of their wide range of applications for improving material structures and functional properties. The high efficiency of the photocatalysis of TiO_2 nano-crystalline, in combination with their structural and thermal stability makes this material well suited for cleaning air, water, soil and for degrading hazardous chemicals (Sandim et al., 2005). Titanium dioxide based catalysts offer certain specific advantages. The band gap of TiO_2 is about 3.2 eV and can be shifted to the visible region by suitable doping (Li and Ishigaki, 2004). Titanium oxide is non-toxic in nature, photo-chemically stable and relatively inexpensive. In near future, depending on the particle morphology, crystal structure, size distribution and phase compositions, titanium oxide will find more versatile applications. TiO_2 is a polymorphic material that exits in three crystalline polymorphs, namely, stable rutile (tetragonal), metastable anatase (tetragonal) and metastable brookite (orthorhombic). Anatase and rutile are

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