Opinion

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A Quick Discussion on Titanium Dioxide

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Opinion

Titanium dioxide (TiO_2) is the most important oxide of titanium, and it crystallises in three structural forms. Brookite, anatase, and rutile are among them. At all temperatures, rutile is the thermodynamically favoured form. Titanium dioxide (TiO_2) is a chemically inert, semiconducting substance having photocatalytic activity in the presence of light with energy equal to or greater than its band-gap energy. These qualities lend themselves to a wide range of applications. Titania has received extensive attention in recent decades for these reasons, as well as the relatively low cost of the raw material and its processing. TiO_2 has been classed as biologically inert in humans and animals and is commonly regarded as a "natural" material, which adds to its relatively favourable public acceptance. In fact, for nearly 100 years, most TiO_2 has been produced from the mineral illmenite, $FeTiO_3$, using the "sulphate" or "chloride" technique.

The annual global production of titania powder in 2005 was expected to be over 5 million tons, raising concerns about its abundance in the environment. The fraction of nano-sized titania is projected to be around 2.5 percent in 2009, rising to 10 percent by 20154, with an exponential increase over the last decade. Nanoparticles (NPs) are particles that have at least one dimension smaller than 100 nm. As a result, particles with various morphologies, such as equi-axial forms, whiskers, nano-tubes, and nanorods, must be examined. Although micron-sized and nano-sized TiO_2 powders are chemically equivalent in general, nano-powders may exhibit physical and chemical properties that differ from coarser grades and should not be treated in the same way. A recent paper evaluated the size-dependent features of a range of inorganic NPs and stated that they are likely to be of concern due to the advent of unique properties when they have diameters of 30 nm.

One of two major processes is used to transform the ores to pigmentary TiO_2. High TiO_2-content ores are chlorinated in the presence of coke, a reducing agent, to produce titanium tetrachloride in the chloride process. Prior to gas-phase oxidation, this is purified by distillation. During oxidation, aluminium chloride is typically added to ensure that the product has a rutile structure. The sulphate process attacks ilmenite or slag with sulfuric acid to produce soluble sulphates. The titanyl sulphate is controlled hydrolyzed, resulting in the precipitation of a hydrous oxide, which is subsequently calcined. Crystalline TiO_2 occurs in three polymorphs in nature: anatase, rutile, and brookite, with rutile being the most stable. A powder with an average particle size of 230 nm scatters visible light, but one with an average particle size of 60 nm scatters UV rays while reflecting visible light. Under UV light, TiO_2 exhibits photocatalytic activity, which is caused by the titania's electronic structure and is, to a considerable extent, more resembling anatase than rutile and brookite. An electron is promoted from the valence band to the conduction band in the presence of light with energy equivalent to or greater than the TiO_2 band-gap energy, leaving a positive hole behind. TiO_2 mediates oxidative damage both with and without UV exposure. Uchino shown that, when exposed to UV light, TiO_2 NPs of various crystalline structures and sizes release varying amounts of hydroxyl radicals, and that cytotoxicity against Chinese hamster ovary cells corresponds with radical generation. Dodd and Jha confirmed that the major harmful species created by UV-irradiated nano-sized TiO_2 are hydroxyl radicals, which react to form carboxyl radicals.

Several investigations have found that photo-activated anatase TiO_2 has higher cytotoxicity and genotoxicity than similarly activated rutile TiO_2. These discrepancies could be attributed to the fact that anatase particles have a larger absorbance gap and a lower electron effective mass, resulting in enhanced charge carrier mobility. Because ROS are significant signalling modulators, cells exposed to NPs may impact cellular signalling cascades that control activities such as cell proliferation, inflammation, and cell death via increased ROS generation. Kang have verified the significance of oxidative stress in TiO_2-induced inflammation. 35 ROS production was related with the activation of a pro-inflammatory cascade in the mouse peritoneal macrophage cell line RAW 246.7 exposed to nano-TiO_2, as evidenced by ERK1/2 phosphorylation, tumour necrosis factor TNF production, and macrophage inflammatory protein MIP-2 secretion.