

Chapter 19

Al₂O₃ Nanobricks via an Organic Free Route Using Water as Solvent

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ABSTRACT

The chemical synthesis of nanomaterials has been studied by few researchers, but innumerable improvements and better methods have been reported in the past few years. This new approach of preparing aluminum oxide (Al₂O₃) nanobricks is based on a soft reaction of aluminum powder and de-ionized (DI) water at 200°C without use of any additives or surfactants. Powder X-ray diffraction studies reveal that the as prepared nanobricks are highly crystalline in nature and by morphological investigations using FESEM, it was revealed that the bricks are rectangular in shape having width of 90±15nm and breadth of ~200nm, which was confirmed by high resolution TEM. The technique could be extended and expanded to provide a general, simple, and convenient strategy for the synthesis of nanostructures of other functional materials with important scientific and technological applications. The prospects of the process are bright and promising.

INTRODUCTION

Innovations at the intersection of medicine, biotechnology, engineering, physical sciences and information technology are spurring new directions in R&D, commercialization and technology

transfer. The future of nanotechnology is likely to continue in this interdisciplinary manner. Nanotechnology is the next industrial revolution, and almost all industries will be radically transformed by it in a few years. Ceramics are regarded as versatile materials and aluminum oxide (Al₂O₃), one of the ceramic materials commonly known as sapphire is known to exist in a number of metastable

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polymorphs in addition to the thermodynamically stable α -Al₂O₃ or corundum form. Among which, α -Al₂O₃ is an important form of alumina because of its porous structure and high catalytic surface activity. This material has been widely used as catalysts, an adsorbent and as a support for industrial catalysis in hydrocarbon conversion (Lee & Crawford, 1987; Lee et al., 1997).

Various synthetic routes have been employed for the synthesis of Al₂O₃ nanostructures with various morphologies. Aside from nanorods, nanowires, nanobelts, nanotubes, limited studies have been made on nanobricks so far. The routes employed include the famous sol-gel chemistry, spray pyrolysis, precipitation, solvothermal, reverse micelles and physical approaches and have been well explained by Shah and Tokeer (2010). The chemical routes have attracted a great deal of attention and have been intensively studied in the recent years. These methods have the advantage of being used to produce α -form crystals at relatively low temperature but the starting materials are relatively expensive. The addition of catalysts or templates employed in other strategies involves a complicated process and may result in impurity in the products. Moreover, most of the pathways suggested for the synthesis of Al₂O₃ involve environmentally malignant chemicals which are toxic and not easily degraded in the environment. Organic solvents are practically problematic because many are toxic which makes the nanomaterials useless. Environmental friendly chemical synthesis requires alternative solvents such as ionic liquids, liquid and water. Water is particularly attractive because it is inexpensive, environmentally benign and bestowed with many virtues especially under supercritical conditions. In our preliminary studies reported earlier, we have obtained nanorods by varying the time and temperature of the reaction (Shah et al., 2009). It was proposed that the growth of nanostructures with different morphologies, sizes, compositions was mainly controlled by temperature and duration

of reaction process. Encouraged by the results, the present studies have been carried out keeping the time and temperature constant.

Interestingly, almost uniform sized nanobricks were obtained by a simple reaction of aluminum powder and de-ionized water at very low temperature of 200°C and the reaction time was 24 hours. By morphological investigations, it was revealed that the bricks are rectangular in shape having width of 90 ± 15 nm and breadth of ~ 200 nm. To the best of our knowledge, the synthesis of nanobricks without organics, catalyst and toxic solvents has not been reported so far. Detailed and systematic studies would be necessary to optimize the conditions for obtaining nanoparticles of desired dimensions.

EXPERIMENTAL

Aluminum foils as well as powder were used as a source of aluminum and were cleaned by ultrasonication in acetone and water for 20 minutes in each solvent. A closed cylindrical Teflon lined stainless steel chamber was used for the synthesis. De-ionized water was prepared in laboratory. Pure aluminum AR grade (Ranbaxy) with diameter of about 10 μ m was used as starting material. In the experiment, 2 mg of aluminum metal powder and 20 ml of de-ionized water have been well sonicated in a glass vial for around 10 minutes. Few drops of ethylenediamine were added to avoid the agglomeration. After sonication, the reaction mixture was transferred to teflon-lined stainless steel chamber of 100 ml capacity and has been kept at 200°C in an oven for 24 hours. After the desired time, the system was allowed to cool naturally. The reaction mixture was centrifuged to reclaim the precipitated sample and washed several times with DI water. The final product was air dried for few hours. A similar treatment was given to Al foils and the results were almost same.

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