Hydrothermal Methods Of Nanoparticles: An Overview

Deepak Kumar*

School of Chemical Engineering and Physical Sciences, Lovely Professional University, Phagwara, Punjab-144411(INDIA)

Abstract

Advancement of the nanotechnology variation in the synthesis method plays an important role for technological revolution. The different branches of science is depends on the crystal structure of the molecules. The variation in chemical and physical structure of the nanoparticles using hydrothermal technology was discussed. Different types of nanomaterials were also discussed using this methodology.

Keywords; Hydrothermal method, supercritical temperature, zirchonium oxide, titanium oxide

Introduction

The nucleation and the growth of the nanoparticles plays an important for various applications. The size, shape and the crystal structure effects the nucleation of the nanoparticles.Due to the wide range applications and the large surface to volume ratio the role of nanoparticles are also important for the industrial purpose as well as household. Most of the nanoparticles are better than bulk materials due to their confine size, surface area, porosity and the better mechanical properties. The nano sized particles also shows tremendously catalytic application in organic synthesis. These particles are better than bulk particles because nanoparticles are easily dispersed without any agglomeration[1].

Nanoparticles are widely used in different areas such as electro-chemical sensors, gas sensors, solar cells, photovoltaic cells, and photocatalysis. Now a days the medical field are also dependent on nanoparticles for drug delivery, hypothermia, bio sensing, nano medicine and many more. The various methods are adopted for the synthesis of nanoparticles suchas laser ablation, sono-chemical, chemical vapour deposition, sol-gel and hydrothermal.Out of them hydrothermal method is the best method to synthesize the nanoparticles.In this method only water used as a solvent and only heat is required,no calcination are required. Other benefits of this method is the proper orientation of crystals and their growth at a high temperature and pressure is required. Generally for the hydrothermal reaction the temperature is below 300°C and the pressure is less than 25 MPa is required. Because the critical temperature of the water is 374°C and the pressure is 22 MPa. The hydrothermal reaction depends on the various factors such as solubility, solvent-antisolvent interaction and the dielectric constant. When the inorganic salt dissolved in the water the dielectric constant of the water reduced eight times under supercritical situtations and the rate of the reaction enhanced two to three folds. The phenomena behind this theory is electrostatic theory. On the basis of this phenomena the growth and the nucleation of the nanoparticles are effected and also alters the crystal structure of the nanoparticles[2].

The requirement of the industry is the fine crystal structure, easily transformation, and the phase equilibrium of the reaction. In hydrothermal reaction if we altered the temperature and pressure conditions the morphology

and the structure of the nanoparticles was changed[3]. In the present article we reported the various nanoparticles are synthesized by hydrothermal method and their role in different applications. The morphology of these nanoparticles are also reported.

Various nanoparticles formed by hydrothermal method

Magenese oxide nanoparticles

The different state of MnO_2 nanoparticles are used in supercapacitor, lithium ion, and solar cell applications. The different morphology of the MnO_2 nanoparticles are depends on the precursor used during the reaction[4]. The surfactant free different shape of MnO_2 nanoparticles was synthesized by Chen et al. in the presence of water and isopropanol. When the reaction was carried out in the presence of isopropanol at its refux point the needle shaped MnO2 nanoparticles was obtained while when this reaction was carried out in the presence of ammonium persuphate which act as an oxidizing agent in the reaction the single crystal nanowires of MnO_2 was achieved[5]. Simiarly When this reaction was carried out in the presence of NaOH solution at 170°C for 12 hr in the Teflon coated seal tube the bundles of MnO_2 nanoparticles was obtained. This process is reported by Ma et al. [6].

Zirchonium oxide

ZrO_2 nanoparticles are widely used in optical, mechanical and electrical applications. The bans gap of the ZrO_2 nanoparticles is wide band gap that's by it used in photocatalytic applications. This nanoparticles are synthesized by different methods such as sol-gel, laser ablation, sonochemical and green method. But the hydrothermal method is the most advanced method to synthesize the various morphological nanoparticles of zirchonium oxide. Because in this method the ultrafine nanoparticles was obtained due to low agglomeration, homogenous distribution, control morphology and size distribution. L.Kumari et al. have synthesized ZrO_2 nanoparticles using the zirchonim nitrate precursor less than 200 °C for 24 hr in Teflon coated seal tube. During the variation of the reaction time the morphology of the nanoparticles are also varied from hexagon to rod like nanoparticles [7].

Titanium oxide nanoparticles

TiO_2 nanoparticles used in various areas such as photocatalysis, sensors, medicine and many more. The specific crystal structure is required for each type of application. Because titanium oxide nanoparticles possess two types of crystal structure such as anatase and rutile. For the catalysis applications high temperature is required and for that anatase crystal structure is required for the titanium oxide nanoparticles while for high permetivity and resistence the rutile form of the titanium oxide nanoparticles are required.

The varsity of the titanium oxide nanoparticles in different applications, many methods are required for the synthesis, but for the specific crystal structure and the morphology hydrothermal and microwave method is the best method to synthesizethis nanoparticles. Focher et al. have been synthesized titanium oxide nanoparticles

using $TiOCl_2$ precursor for 30 min to 1 hr under hydrothermal conditions. The obatained nanoparticles are hexagonal shape[8].

Conclusions

The hydrothermal method is the best method for the synthesis of different nanoparticles. No other solvent and surfactant are required in this method. Various application in which the size, particle distribution and the alignment of the nanoparticles are required for that this method is a suitable method. Different types of nanoparticles are obtained by variation of the precursors and the reaction time.

References

1. Rajamathi, M. and Seshadri, R., 2002. Oxide and chalcogenide nanoparticles from hydrothermal/solvothermal reactions. *Current Opinion in Solid State and Materials Science*, *6*(4), pp.337-345.
2. Hayashi, H. and Hakuta, Y., 2010. Hydrothermal synthesis of metal oxide nanoparticles in supercritical water. *Materials*, *3*(7), pp.3794-3817.
3. Byrappa, K. and Adschiri, T., 2007. Hydrothermal technology for nanotechnology. *Progress in crystal growth and characterization of materials*, *53*(2), pp.117-166.
4. Liu, X., Chen, C., Zhao, Y. and Jia, B., 2013. A review on the synthesis of manganese oxide nanomaterials and their applications on lithium-ion batteries. *Journal of Nanomaterials*, *pp*. 1-8.
5. Chen, S., Zhu, J., Han, Q., Zheng, Z., Yang, Y. and Wang, X., 2009. Shape-controlled synthesis of one-dimensional MnO2 via a facile quick-precipitation procedure and its electrochemical properties. *Crystal Growth & Design*, *9*(10), pp.4356-4361.
6. Ma, R.E.N.Z.H.I., Bando, Y., Zhang, L.I.A.N.Q.I. and Sasaki, T., 2004. Layered MnO2 nanobelts: hydrothermal synthesis and electrochemical measurements. *Advanced Materials*, *16*(11), pp.918-922.
7. Kumari, L., Li, W. and Wang, D., 2008. Monoclinic zirconium oxide nanostructures synthesized by a hydrothermal route. *Nanotechnology*, *19*(19), p.195602.
8. Corradi, A.B., Bondioli, F., Focher, B., Ferrari, A.M., Grippo, C., Mariani, E. and Villa, C., 2005. Conventional and microwave-hydrothermal synthesis of TiO2 nanopowders. *Journal of the American Ceramic Society*, *88*(9), pp.2639-2641.

.