Flame Spray Pyrolysis for the Production of Nanoparticles

Peter Bishop, Virginie Buche, Graham Henderson, Hanna Rajantie, Bénédicte Thiébaut

Johnson Matthey Technology Centre, Reading, UK.

ABSTRACT

A one-step process for nanoparticle synthesis via flame spray pyrolysis at Johnson Matthey Technology Centre, UK, is presented. The effect of precursor concentration, feed rate and dispersion gas flow rate is studied on the synthesis of ZnO. The higher the precursor feed rate or concentration, the larger the formed particles. On the other hand, the higher the dispersion gas flow rate the smaller the particle size of the product.

Keywords: flame spray pyrolysis, nanoparticles

1 INTRODUCTION

Flame spray pyrolysis is a one-step combustion process of a solution precursor(s) to produce nanomaterials.[1] These range from single metal oxides such as Al_2O_3 to more complex mixed oxides or catalysts. Particle sizes can be produced in the range of 10 to 100 nm depending on process parameters. This production tool allows rapid preparation of nanomaterials and versatility in material compositions.

The objective of this study is to introduce a flame spray pyrolysis facility located at Johnson Matthey Technology Centre, UK. The design of the equipment is based on work by Pratsinis et al. [2] The facility is designed to deliver nanomaterials up to a speed of 100 g/h, a scale suitable for application development. The potential markets for such materials are wide and include both conventional and new applications such as catalysts, household, healthcare and cosmetic including stain removal, self cleaning and antibacterial, electronics such as displays, plastics and paints, packaging composites, textiles, aerospace and construction, energy and environment. In this paper we study a range of process parameters and their effect on particle size of ZnO nanoparticles.

1.2 Working with Johnson Matthey

Johnson Matthey is a speciality chemicals company focussed on its core skills in catalysts, precious metals and fine chemicals. Johnson Matthey has developed its technologies for almost 200 years, demonstrating the company's ability to maintain world leadership by adapting to changing customer needs.

The flame spray pyrolysis facility, based at Johnson Matthey Technology Centre in Sonning Common, UK, has been built as a part of a UK TSB (Technology Strategy Board) funded project. The equipment operates on an open access basis and is available for users outside Johnson Matthey to synthesise novel nanomaterials. Our scientific expertise in catalysts and materials preparation is available in order to develop the right products.

2 EXPERIMENTAL

2.1 The process

The precursor solution to be combusted is introduced into the nozzle through a needle using a syringe pump. The solution is sprayed with a dispersing O_2 stream. The formed mist is ignited with a pre-ignited flame (CH_4/O_2 mix) and the resulting flame is further protected with a sheath gas (air or O_2). The resulting flame is in the region of 5-15 cm high and produces temperatures between 1500–2000 °C depending on the solvent used. The formed powder from the decomposition of reagents in the liquid feed is rapidly cooled downstream. The powder is collected onto bag filters in a collection chamber as shown in the scheme in

Figure 1. The more accurate description of the process is presented in Reference 2.

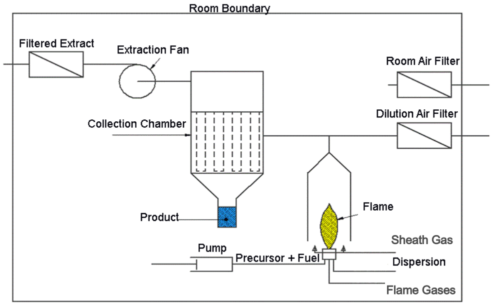

Figure 1. Schematic of the flame spray process.

2.2 Synthesis of ZnO

Zinc oxide (ZnO) nanoparticle synthesis is presented here. ZnO is used, for instance, as a UV barrier in various applications. [3] Zn acetate (Alfa Aesar) precursor was dissolved in ethanol (Hayman) containing 0.5 mol/l of 1-hexylamine (Alfa Aesar). The reaction mixture was sprayed into a supporting CH_4/O_2 flame. Dispersion gas was O_2.Unless otherwise stated the pressure drop across the nozzle was 1 bar, Zn acetate concentration was 1 mol/l with 25 ml/min feed rate and dispersion gas flow rate 20 l/min. Various process parameters were investigated, eg. precursor concentration, precursor feed rate and dispersion gas flow rate. The effect on particle size of the product was studied. The precursor concentrations of 0.25, 0.5, 0.75 and 1 mol/l were used. The precursor feed rates of 10, 25, 40 ml/min were studied as well as the O_2 dispersion gas feed rates of 10, 20, 30 and 40 l/min.

The Zn acetate precursor underwent a pyrolysis process in an O_2 rich environment to give a clean white powder of nano-size ZnO.
The synthesised particles were analysed by TEM, XRD, BET surface area and UV-visible measurements.

3 RESULTS

Typical TEM micrographs of the material are shown in Figure 2. The mean particle size was approximately 20 nm.

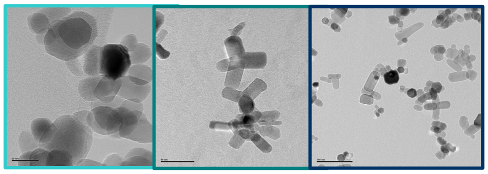

Figure 2. TEM micrographs of nano-size ZnO.

The effect of precursor concentration on product particle size is shown in Figure 3. The particle size was determined using XRD. The particle size of the product increases with increasing precursor concentration. The same effect was seen when the feed rate of a given precursor solution concentration (1 mol/l) is increased. The specific surface area increases with decreasing particle size as expected. The effect of dispersion gas O_2 flow rate on particle size and surface area was also studied. Increasing the dispersion flow rate results in smaller particle sizes.

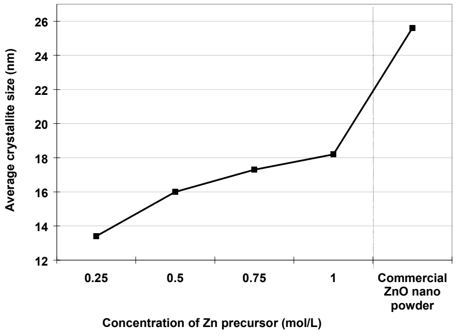

Figure 3. Effect of Zn precursor concentration on particle size.

The UV-visible spectra of the flame spray processed ZnO is in Figure 4. The spectra show very good barrier properties and sharp increase in transmittance at approximately 380 nm.

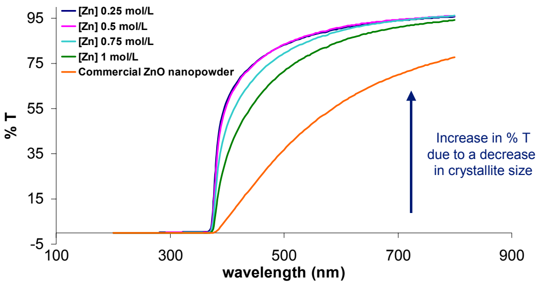

Figure 4. UV-visible spectra of ZnO prepared with various Zn acetate precursor concentrations. ZnO c= 0.001 mol/l, dispersed in water.

4 CONCLUSIONS

We have introduced a flame spray pyrolysis facility at Johnson Matthey Technology Centre in Sonning Common, UK. We have shown that the process is rapid and by changing the process parameters the product properties can be engineered. We have synthesised ZnO and have shown using this material that increasing the precursor feed rate or concentration increases the particle size. On the other hand, increasing the dispersion gas flow rate decreases the particle size. We have also shown the UV barrier properties of the produced ZnO.

5 REFERENCES

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