Session 12-2

Production of Alumina Particles Using a Plasma Torch

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Abstract

A method to modify ceramics using a low power microwave plasma torch is described. The size, shape, surface area, and phase of alumina particles were dramatically modified by passage through an atmospheric pressure argon plasma, operated at 1 kW or less power. Specifically, irregularly shaped particles of gamma-alumina with an average diameter of 11 mu m were converted to smaller (ca. 4 mu m) spherical particles primarily consisting of delta- and alpha- (corundum) phases. Also notable was the finding that modifications of the particles, such as changes in surface area, correlate to applied plasma energy. The plasma torch was operated with an argon flow rate of 5 slpm, power of between 400 and 1000 W, and average particle residence time in the plasma of 0.1 s.

Introduction

There are many methods for producing nanoparticles including, lame reactors, pyrolysis reactors, evaporation and condensation aerosol generators, collision and coalescence mechanisms, and nanoparticle agglomerates and aerogels[1]. The existing methods all have their advantages and disadvantages (Table 1).

Methods for preparing spherical Al_2O_3 particles are known. These methods generally require plasmas generated from high power (about 10 kW) sources. Although spherical alumina particles can be generated by high power methods such as ablation from aluminum electrodes, control of the spherical particle size is not possible using high power methods. The major advantage of the Atmospheric Pressure Plasma Torch is that it is very versatile at a low cost.

The Atmospheric Pressure Plasma Torch can be used to create nanoparticles of many shapes and sizes depending on the precursor, the power and the flow rates of the plasma gas and the aerosol gases[2]. In the current investigation spherical alumina nanoparticles were produced using the atmospheric pressure plasma torch, however, in the past many shapes and sizes of particles with different compositions have been made using this same method. The goal of this research is to synthesize dense particles of alumina having a controlled particle size and narrow particle size distribution.

Table 1. Synthesis Method Comparison

Nanoparticle Synthesis Method	Flame	Evap/Cond Reaction	Laser	Plasma	Hot Wall	Spray Pyrolysis	Atm. Pres. Plasma Torch
Spread	Broad	Narrow	Narrow	Broad	Narrow	Narrow	Narrow or Broad
Morphology	Solid, Agglomerates	Solid	Solid	Agglomerates Solid	Spherical Solid	Spherical Solid, Porous Hollow	Solid, Solid Spherical, Agglomerates, Core-Shell
Material	Oxides	Oxides, Metals	Oxides Non-oxides	Oxides, Non-oxides	Oxides, Non-oxides, Semi-conductors	Oxides Non-oxides	Oxides, Non-oxides, Metals

Synthesis Method

Alumina nanoparticles were synthesized using an atmospheric plasma torch (Fig.1). In the synthesis 900W of microwave power was used with an argon plasma gas flow rate of 3.509 mL/s. The precursor used in the synthesis of the alumina consists of 20µm spherical aluminum particles. The precursor was placed in a beaker in an ultrasonic bath, which excited the aluminum and passed through the torch using an aerosol carrier gas that was a mixture of Argon and Oxygen. The O_2 and Ar had flow rates of 0.2022 mL/s and 0.5287 mL/s, respectively. At these flow rates alumina was produced at 124.4 mg/hr. By changing the parameters of the apparatus such as the microwave power, plasma gas flow rate and the aerosol gas flow rates we believe we can change the particle size and get a more uniform size distribution.

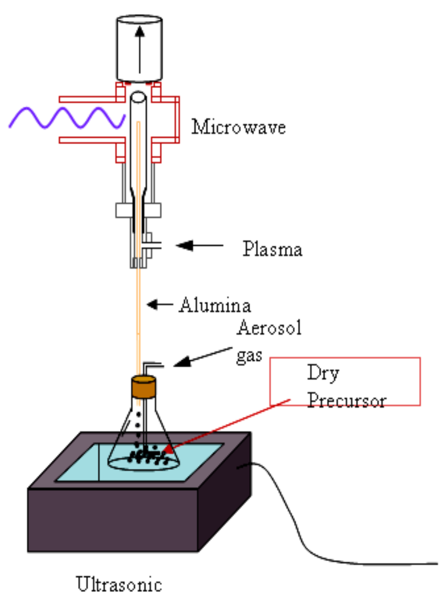

Figure.1. Schematic of Torch Apparatus

Results

Alumina powder was collected from a filter with nano-sized pores (Fig.2). Scanning electron microscope (SEM, 5200 Hitachi) images were produced to determine the particles size and shape. From the image below (Fig.3.) it can be seen that the particles are spherical in shape and that they range from ~10nm to ~70nm, however, this is only a rough estimate.

Figure 2. Alumina Nano Powder.

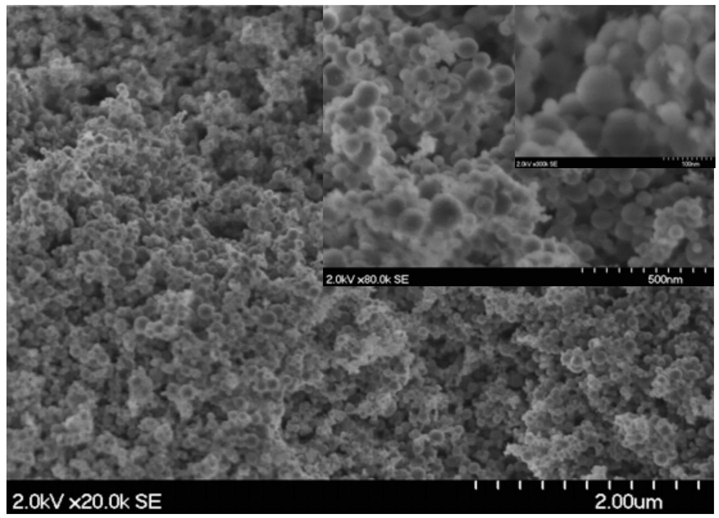

Figure 3. SEM Images of the Alumina Nanoparticles.

Transmission electron microscopy (TEM, JOEL 2010) was carried out to further investigate the produced alumina nanoparticles (Fig.4). An imaging package (Image J®), was utilized to measure the size of 400 particles. The analysis of several TEM images, showed a particle size distribution with a particles size beyond 100nm. The distribution chart (Fig. 5) shows that the majority of the particles have sizes ranging from 5-70 nm, which is consistent with the results obtained from SEM imaging.

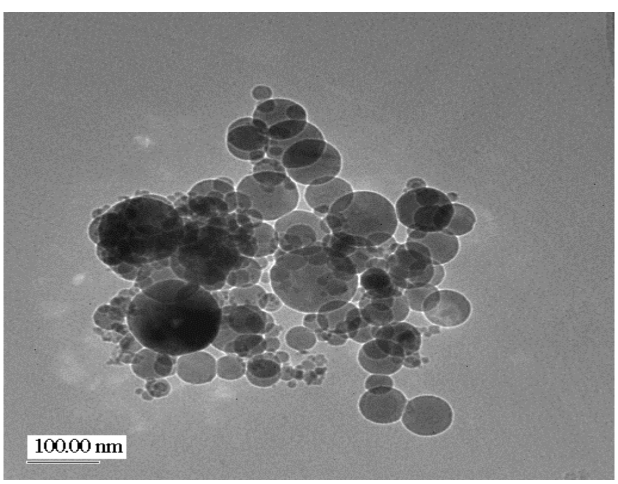

Figure 4. TEM Image of the Alumina Nanoparticles.

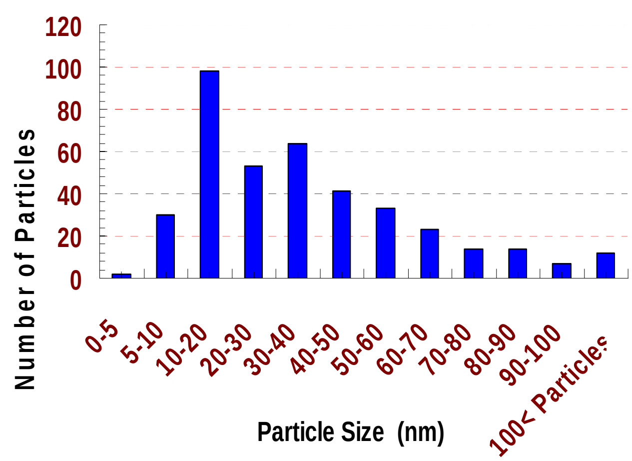

Figure 5. Particle Size Distribution

X-ray diffraction was performed using a Phillips model, MPD diffractometer. This technique not only provides phase information, but also shows qualitative insight into the degree of crystallization. The x-ray diffraction results (Fig.6) show that we have a fairly pure grade of the tetrahedral d phase of alumina[3].

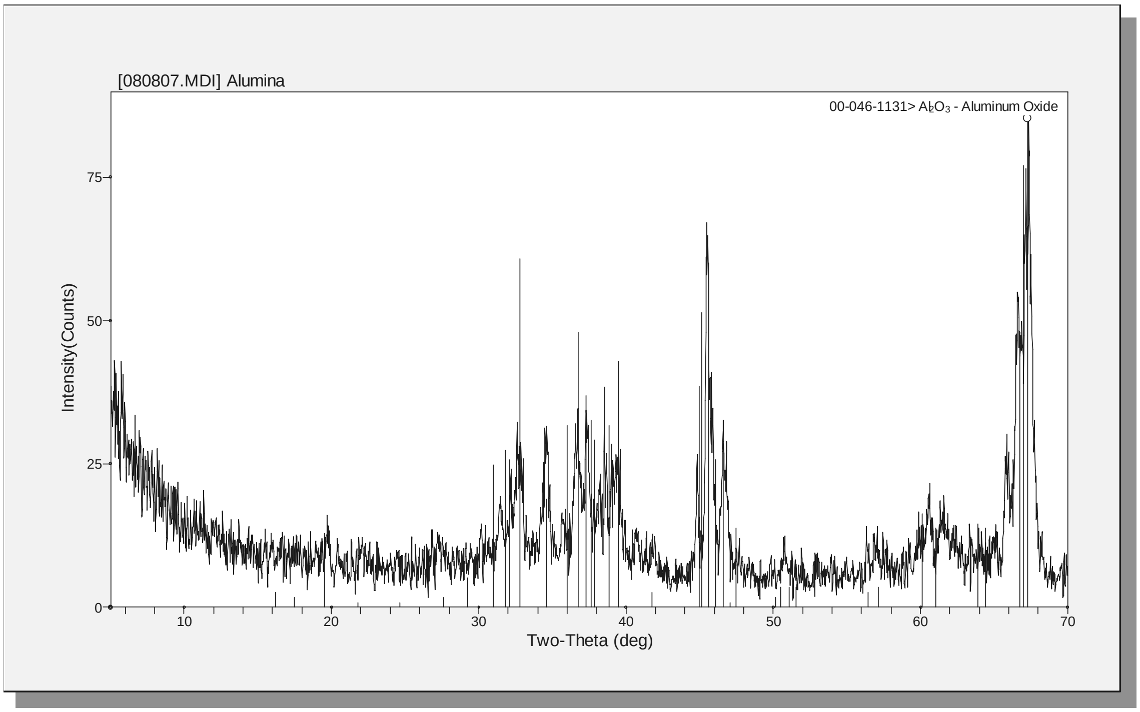

Figure 6. X-ray Diffraction of the Alumina Nanoparticles

Conclusions

The proposed method of producing alumina nanoparticles via plasma torch is very versatile. Through further investigation, the size of the alumina nanoparticles could potentially be controlled. The particles produced are spherical in shape. However, the size distribution of the particles is fairly broad and more research needs to be done to tune this method to obtain the desired uniform sized particles. The particle size and particle size distribution can be controlled through adjusting various parameters, which include: the density of the precursor particles in the aerosol that enter the plasma hot zone, the flow rates of the aerosol gas and the plasma gas, the amount of time that precursor particles remain in the plasma hot zone, the composition of the plasma gas and aerosol gas, and the level of power used to generate the plasma.

References

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