Effects of Particle Shape on Measured Particle Size

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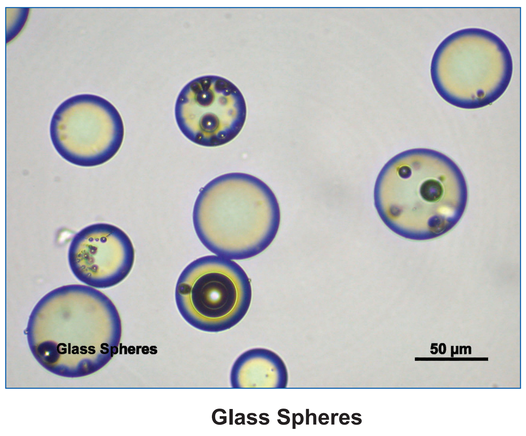
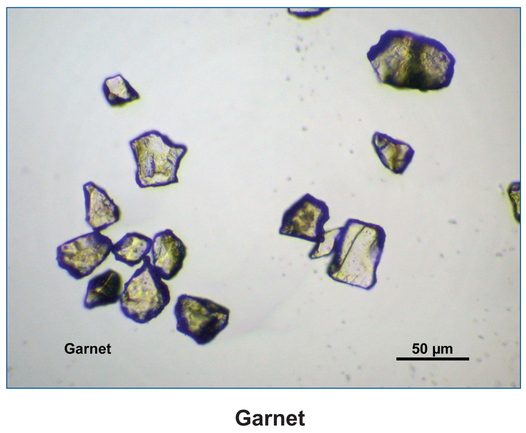
Background

Particle size analysis is a commonly performed test with a broad range of applications encompassing virtually all industries. Numerous techniques exist for measuring particle size distribution, most of which express the results in terms of equivalent spherical diameter. However, when the particles are not spherical, different measurement techniques produce different particle size distributions for a given sample. Understanding what the particle size technique actually measures, how it performs the measurement, and the key assumptions around which the technique is based are crucial when selecting a particle size technique for your sample or application.

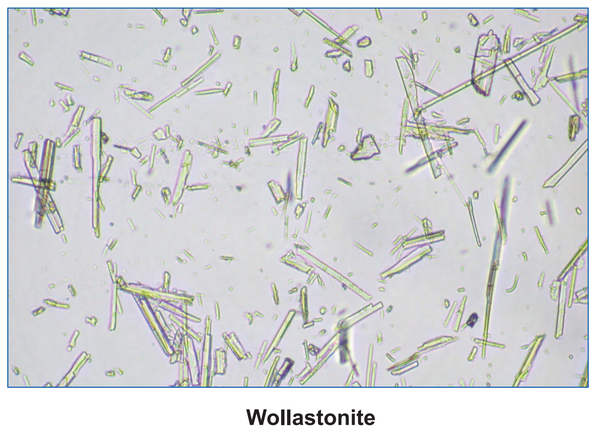
Samples of glass beads, garnet, and wollastonite were selected for their shape features; spherical, cubic, and rod-shaped particles, respectively. The particle size distribution of each material was analyzed using laser light scattering, sedimentation, electrical sensing zone, dynamic image analysis, and scanning electron microscopy. The effect particle shape has on the reported particle size is discussed for each of these materials and techniques. Images are bright-field transmitted light using a polarized light microscope (MVA Scientific Consultants).



Glass Spheres



Garnet



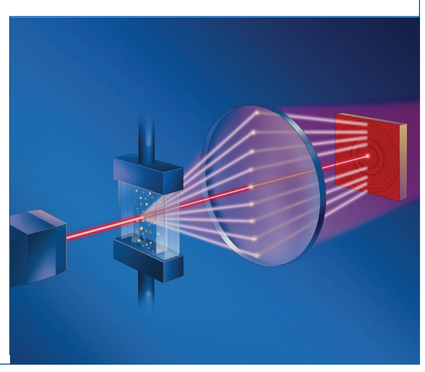
Wollastonite

Techniques

Laser Light Scattering Analysis Technique

The basic assumption of laser light scattering is described by Mie or Fraunhofer Theory which suggests particles will scatter light at various angles and intensities relative to their particle size. Simply stated, large particles tend to scatter light at small angles and small particles will scatter light at wider angles. Once the scattering pattern is measured, a particle size distribution is deconvoluted using theoretical models as defined by Mie or Fraunhofer Theory. The particle size is the diameter of a sphere that would scatter light at the same angle and intensities given the optical properties of the material. This depends on the orientation of the particle when analyzed.

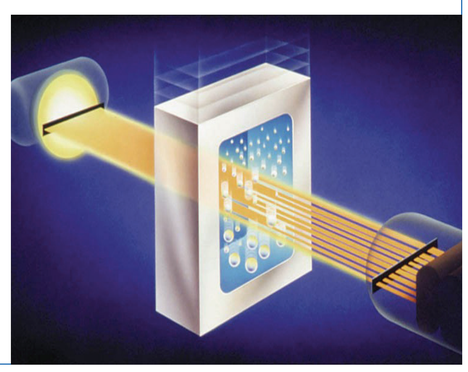
However, non-spherical or irregular-shaped particles will scatter light depending on the orientation of the particle in the cell. The orientation is affected by the particle shape and fluid flow characteristics of the system. It is important to note that with light scattering instruments, the concentration of particles typically is extremely low to minimize multiple-scattered light.



Sedimentation

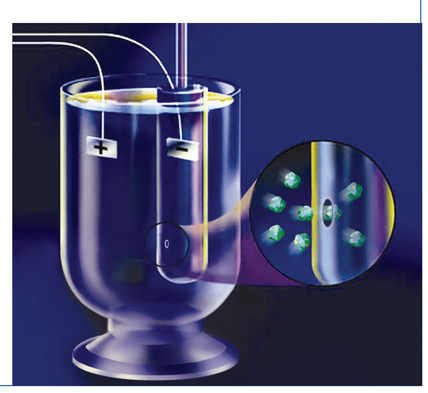
Particle size by sedimentation is described by Stokes' law. Sedimentation type instruments measure the terminal velocity with which particles in a fluid settle as gravitational force acting on the particle are opposed by the buoyancy of the fluid and viscous drag forces acting against the settling of particles, proportional to the cross-sectional surface area of the particle. The concentration of particles is determined by the absorption of a collimated x-ray beam. The intermediate intensity of the beam is compared to the intensity of the beam through liquid only (baseline) and when all particles are present (100 percent). Particle size distribution is then determined by using Stokes' law to calculate the residual size of the particle passing through the x-ray detection zone after all coarser particles have fallen below the beam

Sedimentation technique requires accurate values for particle density, fluid density, and fluid viscosity in order to obtain accurate particle size values. The particle size is the diameter of a sphere that would settle at the same terminal velocity as the particle in question, under the same conditions.



Electrical Sensing Zone Technique

Electrical Sensing Zone detects the volume of electrolyte liquid displaced by a particle as individual particles pass through a sensing zone. The sensing zone is a small hole located near the bottom of a test tube. The volume of a particle is equal to the volume of displaced liquid which is determined by measuring the amplitude of the electrical pulse generated by the decrease in electrolyte. Particle size distribution is determined by the sum of the number of particles (pulses) occurring in each volume (amplitude) class. The particle size reported by this technique reports is the diameter of a sphere that has the same volume as the particle that was measured.

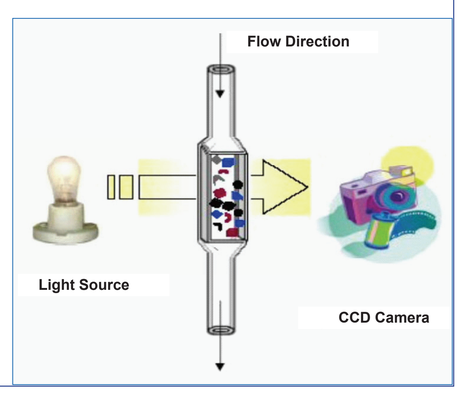


Scanning Electron Microscopy

This technique directly measures the particle size by using the microscope's contrast mechanisms to differentiate the particle from the background. The magnification is selected and the number of pixels that fill the particle are counted and reported as the particle area. All particle dimensions and shape factors are calculated in two dimensions for each particle recognized. Samples need to be physically dispersed onto a substrate for analysis.

Dynamic Image Analysis

Historically, microscopes, which apply Static Image Analysis, have been used as a common tool for particle analysis. However, due to the excessive labor time required, the advent of Dynamic Image Analysis is becoming more and more popular. Dynamic Image Analysis in the particle analysis field is defined as image analysis methods while particles are in motion. This entails using techniques for dispersing particles in liquid or gas, taking in-focus, still images of these particles while in motion, and analyzing the images using a multitude of shape parameters. Generally, the use of Dynamic Image Analysis is important when the shape, not just the size, of particles is important to the raw material being analyzed. Nevertheless, there are range limitations in Dynamic Image Analysis mostly brought about by limitation of available optics. The smallest particle size which can be viewed with the product used at Micromeritics Analytical Services is 3 micrometers.



Experimental Conditions

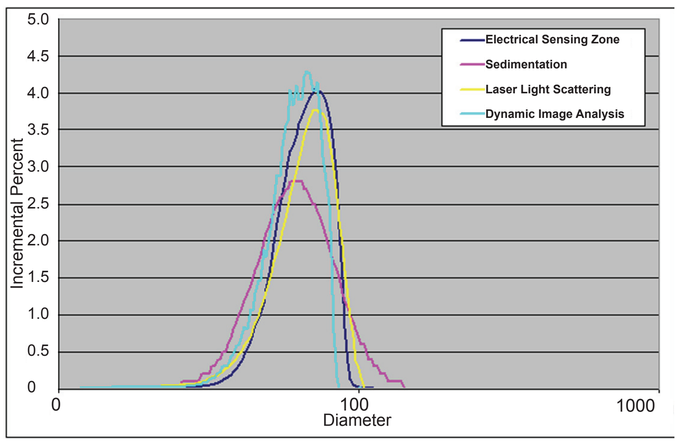
An important consideration with any particle size analysis is sampling and dispersion. All samples were dispersed using the same liquid with similar dispersion energy profiles. Separate samples were used for each technique, so there is potential for sample-to-sample variation to be included in the results. Another potential sampling consideration is that the SediGraph measures samples at nearly 3% solids volume, while the other techniques are much more dilute, usually well under 0.5% solids by volume.

Discussion of Results

Glass Spheres

One would expect similar results for each technique, since the glass particles are nearly spherical and the various techniques relate particle size to an equivalent sphere. The SediGraph result produces a slightly broader frequency distribution. This is due to a density gradient or distribution which exists in the glass spheres. The median (D50) results are very similar from each particle size technique.

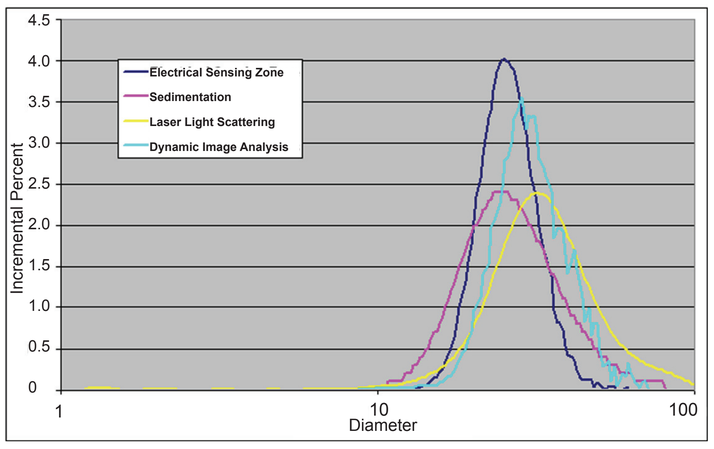
Technique	D10	D50	D90	Mode
Electrical Sensing Zone	49.46	66.52	82.42	72.37
Sedimentation	41.02	61.55	89.10	63.10
Laser Light Scattering	45.01	66.94	84.98	71.12
Dynamic Image Analysis	45.14	61.71	75.87	67.13



Garnet

Garnet is not spherical, but rather more cubic-shaped. With cubic-shaped samples, the diagonal distance from opposite corners of a particle is longer than the diameter of an equivalent volume sphere by about 30%. This is why the results are larger with the flowing techniques (light scattering and image analysis) than with the instruments which are sensitive to the equivalent spherical diameter.

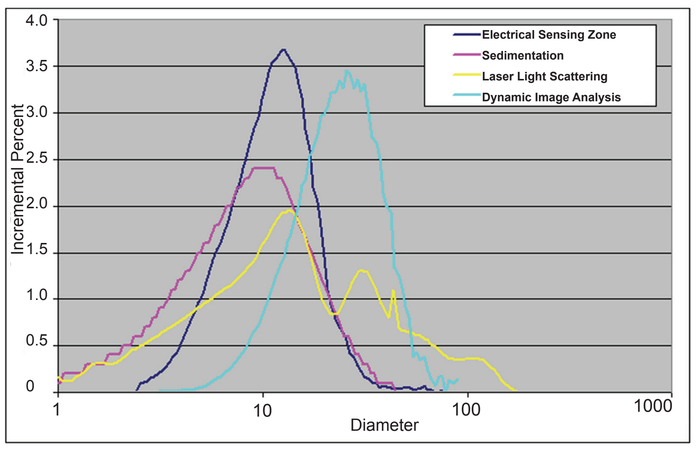
Technique	D10	D50	D90	Mode
Electrical Sensing Zone	19.71	25.56	33.82	24.68
Sedimentation	16.39	25.37	40.77	25.12
Laser Light Scattering	20.14	32.40	53.36	31.77
Dynamic Image Analysis	21.90	29.84	42.83	28.51



Wollastonite

The same flow and shape effects that resulted in slightly different garnet particle sizes are more pronounced with the rod-shaped wollastonite. The light scattering and image analysis technique see the largest particle dimension because of the orientation of the particles. The electrical sensing zone and sedimentation techniques report a particle diameter equivalent to a spherical measurement. Light scattering has a thicker flow path than the image analyzer and therefore some particles can be oriented with the smaller size exposed to the detection system.

Technique	D10	D50	D90	Mode
Electrical Sensing Zone	5.53	11.13	18.91	12.46
Sedimentation	2.72	8.33	18.40	10.00
Laser Light Scattering	2.92	12.69	53.51	13.40
Dynamic Image Analysis	11.73	23.55	41.29	25.71



Summary

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As you can see, particle shape can certainly have major effects on the reported particle size. Each technique showed good repeatability using the same sample with the same technique. However, it is important to understand that different techniques will produce potentially dramatically different particle size results and that the differenences in the results are to be expected. The sizing technique is only one of the variables that we must take into account; the others are sample preparation, dispersion energy, and sampling which we only briefly mentioned here.

MICROMERITICS ANALYTICAL SERVICES The Particle Testing Authority