

Surface Area, Density, and Porosity of Powders

A LARGE NUMBER of industries deal with powders at some point during their processing procedures. The characterization of surface area, porosity, density, and particle size is of particular importance. Especially in the case of metal powders, those characteristics are important factors for understanding and controlling material properties and processing behavior. Knowledge about the surface area of the powder is helpful in understanding the sintering behavior, because the reduction of surface area is the essential driving force for the sintering process. Porosity and density are closely related, and they may influence, for example, the hardness of the material.

Different techniques can be used to determine these powder characteristics. The methods used to determine surface area, density, and porosity are not specific to metal powders; many have been developed for testing other materials in powder form. The major characterization techniques are summarized below. Expanded discussions of several test methods can be found in subsequent sections of this article, including testing parameters, specifications, and instrumentation. When these techniques are used, however, the results of each test method can vary from the results obtained by a different technique. This is only partly due to sample variations. Yet, each test method determines those properties in a very specific way. Pore size and even surface area are ambiguous parameters. For example, the size of an ideal cylindrical pore would be defined as the radius or diameter of this cylinder. However, real pores are hardly ideal cylinders. The odd-shaped geometry of pores makes it difficult to define the size of such a pore, and each measuring technique has its own way of looking at those pores and determining an average pore size of the sample. The pore size also depends on whether the actual void size or the entrance size or neck of the pore is of interest. The latter could be the restricting factor for transport processes. It is also impossible to clearly define the surface area. Depending on the "yardstick" of the observer, a sample may have a larger or smaller surface area. An optical microscope may not show cracks and pores in a sample, whereas the same sample can show a substantial surface roughness under the electron

microscope or when analyzed by gas adsorption techniques. Correspondingly, the value of the calculated surface area will be different.

- **Gas adsorption method:** Determines the surface area of a powder sample by measuring the amount of gas adsorbed on the sample surface at low temperatures. The data are then used to calculate the monolayer capacity from which the surface area is calculated using the "known" size of the adsorbed molecules. Nitrogen at liquid nitrogen temperature is the most common gas used; krypton at liquid nitrogen temperature is used for samples with an area of less than 1 m². Gas adsorption can also be used to determine pore volume and pore size distribution ranging from one Angstrom to about 100 or 200 nm.
- **Permeametry:** Measures the resistance to fluid flow through a compacted powder bed. This information is used to determine related properties of a powder, such as pore size distribution, specific surface area, or the average particle size for a packed powder sample.
- **Pycnometry:** Determines density by measuring the difference between the specific and bulk volumes of a sample. This method is based on the displacement principle, using the powder as the solid body and helium, water, or mercury as the displaced medium. Pycnometry can be used to determine total pore volume or density. However, it does not provide quantification of the pore size or the pore size distribution.
- **Mercury porosimetry:** Measures the volume of mercury intruded into the pores of a powder sample as a function of the pressure applied to the mercury. This method gives pore size and distribution over a wide range; 0.3 nm to 3 nm depending on the capability (pressure range) of the apparatus used. The method is based on the nonwetting behavior of mercury toward most materials. However, certain metals, for example, gold or copper, can react with mercury, and before those samples are to be analyzed specific precautions have to be taken.

Although surface area, density, and porosity of powder are interrelated, a given powder sample

may require the use of several testing methods to provide a complete analysis of these characteristics, because each technique is more or less sensitive for a specific sample. A comprehensive treatment of each of the methods is given in this article.

Gas Adsorption

H. Giesche, School of Ceramic Engineering and Sciences, Alfred University

The Brunauer-Emmett-Teller (BET) (Ref 1) method of measuring specific surface area is based on the determination of the amount of gas that is adsorbed on the surface of the sample. The specific surface area (m²/g) determined by this method includes the external as well as internal (pores) surface area. The surface area of closed pores cannot be determined because the adsorbing gas molecules have no physical path to that surface.

Theory of BET Method

The BET model is based on a kinetic model of the adsorption process that was described first by Langmuir in 1916 (Ref 2, 3). Langmuir regarded the solid surface as an array of adsorption sites, and a state of dynamic equilibrium was postulated in which the rate molecules arrive from the gas phase and condense on the bare sites is equal to the rate at which molecules evaporate from occupied sites. In 1938 Brunauer, Emmett, and Teller extended Langmuir's kinetic monolayer adsorption theory to a multilayer adsorption theory. The following relationship was derived to calculate the monolayer capacity, V_m :

$$\frac{V}{V_m} = \frac{C(1 - (p/p_0)^{n+1})}{(p/p_0)(1 - (p/p_0)^{n+1}) + C(p/p_0)(1 - (p/p_0)^{n+1})}$$

Powder Surface Area And Porosity

Seymour Lowell



Powder Surface Area And Porosity:

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Surface Area and Porosity Lowell the sections on mercury porosimetry and particularly chemisorption have been updated and greatly expanded *Handbook of Non-Ferrous Metal Powders* Oleg D Neikov, N. A. Yefimov, Stanislav Naboychenko, 2009-02-24 The manufacture and use of the powders of non ferrous metals has been taking place for many years in what was previously Soviet Russia and a huge amount of knowledge and experience has built up in that country over the last forty years or so Although accounts of the topic have been published in the Russian language no English language account has existed until now Six prominent academics and industrialists from the Ukraine and Russia have produced this highly detailed account which covers the classification manufacturing methods treatment and properties of the non ferrous metals aluminium titanium magnesium copper nickel cobalt zinc cadmium lead tin bismuth noble metals and earth metals The result is a formidable reference source for those in all aspects of the metal powder industry Covers the manufacturing methods properties and importance of the following metals aluminium titanium magnesium copper nickel cobalt zinc cadmium noble metals rare earth metals lead tin and bismuth Expert Russian team of authors all very experienced English translation and update of book previously published in Russian **Characterization of Porous Solids and Powders**, 2006

Dispersions Erik Kissa, 1999-06-15 Explaining principles essential for the interpretation of data and understanding the real meaning of the result this work describes various methods and techniques used to characterize dispersions and measure their physical and chemical properties It describes a variety of dispersions containing particles ranging from submicron sizes to aggregates and from hard particles to polymer latices *Gmelins Handbuch der anorganischen chemie* Richard Joseph Meyer, 1984 **The International Journal of Powder Metallurgy & Powder Technology**, 1984 **Powder Metallurgy** Great Britain. Ministry of Supply, 1951 *Silicon Carbide and Related Materials 2003* Roland Madar, Jean Camassel, Elisabeth Blanquet, 2004-06-15 ICSCRM 2003 Proceedings of the 10th International Conference on Silicon Carbide and Related Materials 2003 Lyon France October 5 10 2003 *Journal of Powder & Bulk Solids Technology*, 1978

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