

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, these 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 m^2 . 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 (m^2/g) determined by this method includes the external as well as internal (pore) 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 :

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

Powder Surface Area And Porosity

S. Lowell, Joan E. Shields



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materials **Characterization of Porous Solids and Powders: Surface Area, Pore Size and Density** Seymour Lowell, Joan E. Shields, Martin A. Thomas, Matthias Thommes, 2006-04-24 The growth of interest in newly developed porous materials has prompted the writing of this book for those who have the need to make meaningful measurements without the benefit of years of experience One might consider this new book as the 4th edition of Powder Surface Area and Porosity Lowell the sections on mercury porosimetry and particularly chemisorption have been updated and greatly expanded

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incorporate the current developments in food powder technology Examines powder properties including surface composition shelf life and techniques used to examine particle size Focuses on specialty powders such as dairy infant formulas powdered egg fruit and vegetable and culinary and specialty products The International Journal of Powder Metallurgy & Powder Technology ,1985 Growth, Dissolution and Pattern Formation in Geosystems B. Jamtveit,P. Meakin,2013-03-09 This book is the proceedings of the 11th Kongsberg seminar held at the Norwegian Mining Museum in the city of Kongsberg about 70 km Southwest of Oslo The Kongs berg district is known for numerous Permian vein deposits rich in native silver Mining activity in the area lasted for more than 300 years finally ceasing in 1957 The first eight Kongsberg seminars organized by professor Arne BjOrlykke now director of the Norwegian Geological Survey were focused on ore forming processes These seminars have always been a meeting point for people with a variety of geological backgrounds Since 1995 the Kongsberg seminars have focussed on geological processes rather than on specific geological systems and the selection of invited speakers has been strongly influenced by their interest in the dynamics of geological systems In 1995 and 1996 various aspects of fluid flow and transport in rocks were emphasized The first Kongsberg proceedings of the 1995 seminar published by Chapman and Hall Jamtveit and Yardley 1997 contained 17 chapters dealing with a wide range of topics from field based studies of the effects of fluid flow in sedimentary and metamorphic rocks to computer simulations of flow in complex porous and fractured media In 1997 the focus was changed to growth and dissolution processes in geological systems

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