HORIBA Scientific

Application Note

Surface Area of Aluminum Oxide

AN244

Aluminum oxide, or alumina, is a compound composed of aluminum and oxygen. Its chemical formula is Al_2O_3. It is one of the most abundant minerals in the Earth's crust and has many practical applications due to its unique properties.

Introduction

Aluminum oxide is naturally occurring and most commonly found as bauxite. The extraction of aluminum from bauxite involves refining processes that ultimately lead to the production of aluminum oxide. Some of its uses include:

- Abrasive Material: As a result of its hardness, aluminum oxide is a widely used abrasive in such materials as sandpaper and various abrasive compounds as well as other grinding and cutting applications.
- Ceramics: Aluminum oxide is used in the production of ceramics and refractories. As a result of its high melting point, hardness, and resistance to chemical wear, it is suitable in applications such as kiln furniture, ceramic insulators, and crucibles used in high-temperature processes.
- Catalyst Support: Aluminum oxide can be used as a catalyst support material in various chemical reactions. Its large surface area and stability make it an ideal substrate for supporting catalysts in processes like catalytic cracking in the petroleum industry.

Additional Applications:

- Filler in Plastics and Polymers
- Dental and Medical Applications
- Coatings
- Flame Retardants
- Jewelry
- Electrical Insulation

Aluminum oxide's reactivity, catalytic activity, adsorption capacity, and overall performance in many applications are dictated by the surface area. A larger surface area means more exposed sites for chemical reactions to occur. This is crucial in applications such as:

Figure 1. Example of aluminum oxide.

- Industrial catalytic processes which involve supported metal catalysts on high-surface-area aluminum oxide substrates. The high surface area of alumina allows for more active sites to interact with reactants, increasing reaction rates and efficiency.
- The surface area and porosity of aluminum oxide influences its ability to adsorb or absorb gases, liquids, and dissolved substances in various applications such as gas purification, water treatment, filtration, and separation processes.
- High-surface-area alumina can be used as an electrode support material in applications like fuel cells, batteries, and capacitors.
- The surface area of aluminum oxide particles can affect the sintering process of ceramics. High surface area (often because of small particle size) can promote densification and improve the mechanical properties of the final ceramic material.

Gas Adsorption Technique

Surface area in this case is measured by a technique known as gas adsorption or physical adsorption (physisorption). Surface area is typically reported as meters squared per gram.

Adsorption takes place on the surface of a material. Gas molecules of known cross sectional area are carefully inventoried as they adhere to the surface. By knowing the number of moles of gas adsorbed and their cross section, the total surface area under test can easily be calculated.

The adsorption process occurs due to surface energy typically described as Van der Waals forces. Left alone, most materials will adsorb water or other vapors to satisfy this surface energy. Thus, to take advantage of these surface forces for measurement, the adsorbed impurities must be removed. This is accomplished through a process known as degassing, whereby a sample is placed in a holder and an inert flow of gas passes through the sample powdered bed as it is gently heated. The applied heat causes the adsorbed impurities to break free of the surface of the material and the flow of gas sweeps them away.

Cleaned in such a way, the sample holder may now be placed on an analysis station where it is cooled (typically to liquid nitrogen temperatures) in a cryogen Dewar as a gas mixture (typically nitrogen in a carrier gas of helium) flows across the surface. As the sample and gas cool, nitrogen molecules in the flowing gas mixture lose energy and are adsorbed onto the sample surface.

Again, monitoring the number of moles of gas adsorbed as a function of gas concentration allows us to calculate several adsorption data points. For more rapid analysis, a single point may be collected. The most common calculation method applied to derive specific surface area is the Brunauer, Emmett and Teller (BET) method.

Experimental

A commercially available aluminum oxide powder sample was sent to the HORIBA Instruments Incorporated applications lab in Irvine, California for analysis. The sample was analyzed using the new SA-9650 surface area analyzer. Three separate aliquots each weighing approximately 0.12 g were placed in sample tubes. Degassing was performed on the 3 integrated degas stations of the SA-9650 at 300°C for 4 hours. Samples were then transferred to the 3 analysis stations and separate analyses were performed for single point and multi point surface area. Each type of test was repeated 3 times. The results are shown in the following tables.

Single Point*

	Channel 1	Channel 2	Channel 3	Average of 3 Channels	CoV (%)
Test 1	176.08	175.26	176.49	175.94	0.29
Test 2	170.80	172.83	174.22	172.62	0.81
Test 3	173.28	170.75	173.96	172.66	0.80
Average of 3 Tests	173.4	172.9	174.9	**All results in m^2/g**	
CoV (%)	1.24	1.07	0.65		

Multi-Point*

	Channel 1	Channel 2	Channel 3	Average of 3 Channels	CoV (%)
Test 1	179.20	178.44	180.12	179.25	0.38
Test 2	178.29	177.17	178.12	177.86	0.28
Test 3	176.86	174.11	177.55	176.17	0.84
Average of 3 Tests	178.1	176.6	178.6	**All results in m^2/g**	
CoV (%)	0.54	1.03	0.62		

*The difference between single point and multi point analyses are linked to assumptions made in the single point calculation. Multi-point results are typically more accurate. However, in terms of repeatability and reproducibility, either measurement is quite robust and single point measurements are extremely fast – supporting high throughput, production, or quality control environments.

Conclusion

The HORIBA SA-9650 surface area analyzer proved to be an ideal instrument for measuring the surface area of aluminum oxide both by single and multi-point analysis. The analyses were fast, repeatable and the instrument is robust. The methodology described in this document should be useful as a guide to using the SA-9650 for aluminum oxide or other powdered samples.