E 2456-06
Terminology for Nanotechnology

Developed in Partnership with the Following Organizations*:

- American Institute of Chemical Engineers (AIChE)
- American Society of Mechanical Engineers (ASME)
- Institute of Electrical and Electronics Engineers (IEEE)
- Japanese National Institute of Advanced Industrial Science and Technology (AIST)
- NSF International
- Semiconductor Equipment and Materials International (SEMI)

* Additional information on each organization is available in the appendix to the E 2456 standard.

Designation: E 2456 – 06

Standard Terminology Relating to Nanotechnology[1]

This standard is issued under the fixed designation E 2456; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ϵ) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 Nanotechnology is an emerging field; this standard defines the novel terminology developed for its broad multi- and interdisciplinary activities. As the needs of this area develop, this standard will evolve accordingly. Its content may be referenced and/or adopted, in whole or in part, as demanded by the needs of the individual user.

2. Referenced Documents

2.1 *ASTM Standards:* [2]

E 1964 Practice for Compiling and Writing & Terminology

E 1992 Terminology Relating to Terminology Management

3. Significance and Use

3.1 This standard is intended to facilitate communication among members of the business, research, legal, government, and educational communities.

3.2 *Definitions*:

3.2.1 Terms and their related standard definitions in Section 4 are intended for use uniformly and consistently in all nanotechnology test methods, specifications, guides, and practices. The purpose of such use is to promote a clear understanding and interpretation of the standards in which they are used.

3.2.2 Definitions of terms are written in the broadest sense possible, consistent with the intended meaning using the following guidance considerations.

3.2.2.1 Terminology E 1992 and Practice E 1964 concepts are considered, especially Sections 6.5, 7, and 8 of Practice E 1964.

3.2.2.2 Terms and nomenclature are based on observed scientific phenomena and are descriptive, distinguishable, and have significant currency in the nanotechnology field as reflected in peer-reviewed articles and other objective sources. These terms and names should not disrupt accepted usage in other scientific and technological fields, and their preferred usage should follow accepted scientific syntax.

3.2.2.3 When incorporating a term or name from a related field, its underlying meaning is not redefined. Modifications are minimal and are done to elucidate scientific distinctions required by nanotechnology practitioners.

3.2.2.4 When conflicting or overlapping terms and names arise between scientific disciplines, precedence was given to the established term that has behind it a significant body of knowledge.

3.2.2.5 The definition of a term that can have different meanings in different technical fields, especially those fields beyond nanotechnology, is preceded by a limiting phrase, for example, "*in nanotechnology.*"

3.3 *Description of Terms*:

3.3.1 Descriptions of Terms are special purpose definitions intended to provide a precise understanding and interpretation of standards in which they are used.

3.3.2 A specific description of a term is applicable to the standard or standards in which the term is described and used.

3.3.3 Each standard in which a term is used in a specially defined manner beyond the definitions in Section 3 should list the term and its description under the subheading, descriptions of terms.

3.3.4 Practice E 1964, Section 13, are used to guide the contents of descriptions.

3.3.5 As nanotechnology is a rapidly developing field, it will be necessary to continually reassess the terms and definitions contained in this standard, for purposes of revision when necessary. The intent of the terms and definitions in this standard is to describe materials containing features between approximately 1 and 100 nm and to differentiate those properties different from properties found in either molecules or the bulk (interior) of larger, micron-sized systems.

3.4 *Discussion of Terms*:

3.4.1 Discussion sub-paragraphs are non-normative. They are used in this standard to provide explanatory information, to clarify distinctions between the use of terms in this standard as

[1] This terminology is under the jurisdiction of ASTM Committee E56 on Nanotechnology and is the direct responsibility of Subcommittee E56.01 on Terminology & Nomenclature.

Current edition approved Oct. 1, 2006. Published November 2006.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

compared with that in other contexts or other fields of technology and to suggest preferred usage of a term.

4. Terminology

agglomerate, *n—in nanotechnology*, a group of particles held together by relatively weak forces (for example, Van der Waals or capillary), that may break apart into smaller particles upon processing, for example.

aggregate, *n—in nanotechnology*, a discrete group of particles in which the various individual components are not easily broken apart, such as in the case of primary particles that are strongly bonded together (for example, fused, sintered, or metallically bonded particles).

fine particle, *n—in nanotechnology*, a particle smaller than about 2.5 micrometers and larger than about 0.1 micrometers in size.

DISCUSSION—Used in aerosols science to describe atmospheric aerosol involving particles that may be solids or liquids.

nano, *n—(1)* The SI definition, a prefix used to form decimal submultiples of the SI unit "meter", designating a factor of 10^{-9} denoted by the symbol "n". *(2)* Pertaining to things on a scale of approximately 1 to 100 nanometers (nm). *(3)* A prefix referring to an activity, material, process or device that pertains to a field of knowledge defined by nanotechnology and nanoscience.

nanoparticle, *n—in nanotechnology*, a sub-classification of ultrafine particle with lengths in two or three dimensions greater than 0.001 micrometer (1 nanometer) and smaller than about 0.1 micrometer (100 nanometers) and which may or may not exhibit a size-related intensive property.

DISCUSSION—This term is a subject of controversy regarding the size range and the presence of a size-related property. Current usage emphasizes size and not properties in the definition. The length scale may be a hydrodynamic diameter or a geometric length appropriate to the intended use of the nanoparticle.

nanoscale, *adj*—having one or more dimensions from approximately 1 to 100 nanometers (nm).

nanoscience, *n*—the study of nanoscale materials, processes, phenomena, or devices.

nanostructured, *adj*—containing physically or chemically distinguishable components, at least one of which is nanoscale in one or more dimensions.

DISCUSSION—While many conventional nanomaterials are distinguished by physical or chemical characteristics, biological recognition may also be the basis for defining a nanostructure. Though this concept is formally contained by the word 'chemically' such a feature would lead to a distinctive type of nanostructured system.

nanotechnology, *n*—A term referring to a wide range of technologies that measure, manipulate, or incorporate materials and/or features with at least one dimension between approximately 1 and 100 nanometers (nm). Such applications exploit the properties, distinct from bulk/macroscopic systems, of nanoscale components.

non-transitive nanoparticle, *n—in nanotechnology*, a nanoparticle that does not exhibit size-related intensive properties.

DISCUSSION—This term should be used when the subject material has stable properties that fall on a continuum that can be smoothly extrapolated from the behavior of the bulk (larger scale) material. Non-transitive nanoparticles are often applied in industries that exploit their features, such as minimal optical scattering or high surface areas, to improve the radiation absorption, abrasion resistance or mechanical strength of materials.

particle, *n—in nanotechnology*, a small object that behaves as a whole unit in terms of its transport and properties.

transitive nanoparticle, *n—in nanotechnology*, a nanoparticle exhibiting a size-related intensive property that differs significantly from that observed in fine particles or bulk materials.

DISCUSSION—This term should be used when the material has properties that emerge only on the nanoscale. It is reserved for the special case of nanoscale materials which have behavior that does not smoothly or simply extrapolate from the bulk, and also encompasses those systems which have features that respond to external forces in an interactive manner.

ultrafine particle, *n—in nanotechnology*, a particle ranging in size from approximately 0.1 micrometer (100 nanometers) to .001 micrometers (1 nanometer).

DISCUSSION—The term is most often used to describe aerosol particles such as those found in welding fumes and combustion by-products. The length scale may be measured by a particle's geometric, aerodynamic, mobility, projected-area, or hydrodynamic dimension.

APPENDIX

(Nonmandatory Information)

X1. Partnering Organizations

X1.1 About ASTM International

X1.1.1 ASTM International is one of the largest voluntary standards development organizations in the world-a trusted source for technical standards for materials, products, systems, and services. Known for their high technical quality and market relevancy, ASTM International standards have an important role in the information infrastructure that guides design, manufacturing and trade in the global economy.

X1.1.2 ASTM International, originally known as the American Society for Testing and Materials (ASTM), was formed over a century ago, when a forward-thinking group of engineers and scientists got together to address frequent rail breaks in the burgeoning railroad industry. Their work led to standardization on the steel used in rail construction, ultimately improving railroad safety for the public. As the century progressed and new industrial, governmental and environmental developments created new standardization requirements, ASTM answered the call with consensus standards that have made products and services safer, better and more cost-effective. The proud tradition and forward vision that started in 1898 is still the hallmark of ASTM International.

X1.1.3 Today, ASTM continues to play a leadership role in addressing the standardization needs of the global marketplace. Known for its best in class practices for standards development and delivery, ASTM is at the forefront in the use of innovative technology to help its members do standards development work, while also increasing the accessibility of ASTM International standards to the world.

X1.1.4 ASTM continues to be the standards forum of choice of a diverse range of industries that come together under the ASTM umbrella to solve standardization challenges. In recent years, stakeholders involved in issues ranging from safety in recreational aviation, to fiber optic cable installations in underground utilities, to homeland security, have come together under ASTM to set consensus standards for their industries.

X1.1.5 Standards developed at ASTM are the work of over 30,000 ASTM members. These technical experts represent producers, users, consumers, government and academia from over 120 countries. Participation in ASTM International is open to all with a material interest, anywhere in the world.

X1.2 About AIChE

X1.2.1 Founded in the United States in 1908, AIChE is a professional association of more than 40,000 chemical engineers representing 92 countries. Its members work with corporations, universities and government agencies, using their knowledge of chemical processes to develop safe and useful products for the benefit of society.

X1.2.2 The Institute serves its members by aiding their professional growth and fostering the dissemination of scientific knowledge through the development of award-winning publications and world-class conferences. Through its varied programs, AIChE is a focal point for information exchange on the frontiers of chemical engineering research in such areas as nanotechnology, sustainability, hydrogen fuels, biological and environmental engineering, and chemical plant safety and security.

X1.2.3 AIChE is also the incubator and ongoing supporter of high-tech knowledge centers and industry alliances, including: the Society for Biological Engineering (SBE), the Nanoscale Science and Engineering Forum (NSEF), the Institute for Sustainability (IfS), and the Center for Chemical Process Safety (CCPS). Through its varied programs, AIChE continues to be a focal point for information exchange on the frontier of chemical engineering research. Learn more at www.aiche.org.

X1.3 About NSF International

X1.3.1 NSF is an independent, not-for-profit organization that certifies products and writes standards for food, water and consumer goods. Founded in Ann Arbor, Michigan, in 1944, NSF is well known for the development of standards, product testing and certification services in the areas of environmental and public health safety. The NSF Mark is placed on millions of consumer, commercial and industrial products annually and is trusted by users, regulators, and manufacturers worldwide. NSF is also recognized by the World Health Organization as a Collaborating Centre for Food and Water Safety and Indoor Environment.

X1.3.2 NSF professionals include engineers, chemists, ttoxicologists, sanitarians, and computer scientists with extensive experience in public heath, food safety, water quality, and the environment. Technical resources at NSF include physical and performance testing facilities and analytical chemistry and microbiology laboratories. NSF certification programs are fully accredited by the American National Standards Institute (ANSI) and the Standards Council of Canada (SCC). NSF provides management system registration services to ISO 9000 and ISO 14000 standards through its subsidiary NSF-International Strategic Registrations, Ltd.

X1.3.3 By serving on the ANSI-Nanotechnology Standards Panel (ANSI-NSP), the ASTM E56.01 Terminology and Nomenclature Subcommittee and the U.S. Technical Advisory Group to ISO Technical Committee 229 Nanotechnologies, NSF is working to expedite the development of voluntary consensus standards that meet the emerging needs related to nanotechnology research, development and commercialization. NSF's key focus in serving the nanotechnology industry is in the field of human health, especially the early screening of nanomaterials for potential health effects. Learn more at www.nsf.org.

X1.4 About AIST

X1.4.1 On April 1, 2001, the National Institute of Advanced Industrial Science and Technology (AIST) began operations. The AIST is a newly formed research organization as the result of an amalgamation of the 15 research institutes and the Weights and Measures Training Institute. Through the fusion of the research activities of a wide variety of research groups and the fostering of creativity, AIST generates new technologies and new industries and contributes to the economic development of our country and, thus, to improvements in the lives of our people. With these goals in mind, AIST performs research and disseminates research results in the following areas:

X1.4.1.1 Industrial infrastructure technology, including measurement standards, geological surveys, and the development of base technologies necessary for the maintenance of the techno-infrastructure of Japan.

X1.4.1.2 Energy and environmental technology, which because of long lead times and high risk require the government to search for solutions.

X1.4.1.3 Interdisciplinary and broad-spectrum research activities to promote innovation and reinforce the international competitive strength of Japanese industry and encourage the creation of new industries.

X1.4.2 Learn more at http://www.aist.go.jp/index_en.html

X1.5 About the IEEE

X1.5.1 The IEEE is a leading developer of international standards that underpin many of today's products and services, particularly in telecommunications, information technology and power generation. With an active portfolio of nearly 900 active standards and over 400 projects under development, the IEEE is increasingly the central source for standardization in a broad range of emerging technologies, welcoming individual engineers and corporations to participate.

X1.5.2 IEEE standards foster interoperability, create uniform design, installation and testing methods, and protect users and the environment, among other benefits. The IEEE is committed to standards that provide key mechanisms for opening markets, stimulating innovation, enabling competition, encouraging customer confidence and optimizing business strategy. This requires a flexible and vigilant approach to managing a standards program that fits today's industry requirements. The availability of both consensus and consortia styles of standards development methods within the IEEE community gives industry the option to select the most effective standards approach to match the status of a technology and the needs of the market. More information about the IEEE standards program is found at: http://standards.ieee.org/.

X1.6 About ASME

X1.6.1 Established in 1880, ASME is a 120,000 member not-for-profit organization focused on technical, educational and research issues. ASME conducts one of the world's largest technical publishing operations, holds numerous technical conferences worldwide, and offers hundreds of professional development courses each year. ASME publishes and accredits users of internationally recognized industrial and manufacturing codes and standards that enhance public welfare and safety.

X1.6.2 ASME has established a Nanotechnology Institute to promote and facilitate the development of nanotechnology. Key areas addressed include education, nanomanufacturing, devices and systems, nanoscale phenomena, and the government and social impact. Annual events include the Integrated Nanosystems Meeting, the Nanotraining Bootcamp, and a focused technical track at the International Mechanical Engineering Congress and Exposition (IMECE). For more information please visit www.asme.org or www.nano.asme.org

X1.7 About SEMI

X1.7.1 SEMI is a global industry association serving companies that develop and provide manufacturing technology, materials and services to make semiconductors, flat panel displays (FPDs), micro-electromechanical systems (MEMS) and related microelectronics. SEMI maintains offices in Austin, Beijing, Brussels, Hsinchu, Moscow, San Jose (Calif.), Seoul, Singapore, Tokyo, Shanghai and Washington, D.C. For more information, visit SEMI at www.semi.org.

X1.7.2 The SEMI Standards Program, established in 1973, covers all aspects of semiconductor process equipment and materials, from wafer manufacturing to test, assembly and packaging, in addition to the manufacture of flat panel displays and micro-electromechanical systems (MEMS). About 1,500 volunteers worldwide participate in the program, which is made up of 17 global technical committees. Visit www.semi.org/standards for further details about SEMI Standards.