Designation: ~~E3059 – 16~~ E3059 – 22

Standard Guide for Workforce Education in Nanotechnology Infrastructure[1]

This standard is issued under the fixed designation E3059; 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 This document provides guidelines for basic workforce education in the infrastructure topics related to nanotechnology to be taught at an undergraduate college level. This education should be broad to prepare an individual to work within one of the many areas in nanotechnology research, development, or manufacturing. The individual so educated may be involved in material handling, manufacture, distribution, storage, use, or disposal of nanoscale materials.

1.2 This guide may be used to develop or evaluate an education program for the infrastructure used in the nanotechnology field. This guide provides listings of key topics that should be covered in a nanotechnology education program on this subject, but it does not provide specific course material to be used in such a program. This approach is taken in order to allow workforce education entities to ensure their programs cover the required material while also enabling these institutions to tailor their programs to meet the needs of their local employers.

1.3 ~~The~~ While no units of measurements are used in this guide, values stated in SI units are to be regarded as standard. ~~No other units of measurement are included in this standard.~~

1.4 *This standard does not purport to address all of the methods and concepts pertaining to the infrastructure for nanotechnology. It may not cover knowledge and skill objectives applicable to local conditions or required by local regulations.*

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate ~~safety~~ safety, health, and ~~health~~environmental practices and determine the applicability of regulatory limitations prior to use.*

~~1.5 This standard does not purport to address all of the methods and concepts pertaining to the infrastructure for nanotechnology. It may not cover knowledge and skill objectives applicable to local conditions or required by local regulations.~~

1.6 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E2456 Terminology Relating to Nanotechnology

E2996 Guide for Workforce Education in Nanotechnology Health and Safety

E3089 Guide for Nanotechnology Workforce Education in Material Properties and Effects of Size

[1] This guide is under the jurisdiction of ASTM Committee E56 on Nanotechnology and is the direct responsibility of Subcommittee E56.07 on Education and Workforce Development.

Current edition approved ~~April 1, 2016~~Feb. 1, 2022. Published ~~April 2016~~April 2022. Originally approved in 2016. Last previous edition approved in 2016 as E3059 – 16. DOI: ~~10.1520/E3059-16.~~10.1520/E3059-22.

[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.

2.2 *ISO Standards:*[3]
ISO/TS 80004-1 Nanotechnologies – Vocabulary – Part 1: Core Terms
ISO 14644-1 Cleanrooms and Associated Controlled Environments – Part 1: Classification of Air Cleanliness

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms related to nanotechnology in general, refer to Terminology E2456 and ISO/TS 80004-1.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *nanomanufacturing, n*—intentional synthesis, generation or control of ~~nano-materials;~~nanomaterials, or fabrication steps in the nanoscale, for commercial purposes. **ISO/TS 80004-1**

3.2.2 *nanomaterial, n*—material with any external dimension in the nanoscale or having internal structure or surface structure in the nanoscale. **ISO/TS 80004-1**

3.2.3 *nanoscale, adj*—having one or more dimensions from approximately 1 to 100 nanometres (nm). **E2456**

3.2.4 *nanotechnology infrastructure, n*—the basic equipment and facilities (such as controlled environments) that are needed to properly conduct nanoscale research and development or nanomanufacturing.

4. Summary of Guide

4.1 This guide designates a list of topics on nanotechnology infrastructure relevant to nanotechnology workforce education. Selection of the techniques, concepts, and materials are based on inputs from industry, nanotechnology educators, and subject matter experts.

4.2 In this list, the first two topics pertain to controlled environments. The subsequent two topics cover vacuum systems and pressurized ~~gases.~~gases, respectively.

4.3 Within each of the four topics in the list, important sub-topics recommended to be covered are listed specifically.

4.4 This approach provides both a broad education as well as in-depth emphasis for key subjects within the time constraints of an instructional course or program.

5. Significance and Use

5.1 The purpose of this guide is to ~~provide~~ provide, at the undergraduate college level, a basic educational structure in the infrastructure aspects of nanotechnology to organizations developing or carrying out education programs for the nanotechnology workforce. This guide helps to describe the minimum knowledge base for anyone involved in ~~nanomanufacturing, nanomaterials characterization,~~ nanomanufacturing or nanomaterials research.

5.2 The basic education should prepare an individual for varied roles in the nanotechnology workplace. The material in this guide may require a post-secondary two-year science or technology background to be understood sufficiently. ~~Depth on the topics should be sufficient to transfer between various applications of nanotechnology such as nanomaterial fabrication, nanomaterial characterization, nanolithography, and patterning.~~

5.3 ~~Nanoscale materials might present unique health and environmental hazards due to their unique properties. The hazards, if any, presented by nanomaterials can be very different from those presented by bulk/macroscopic materials.~~Workers may transition in their roles in the workplace. Participants in such education will have a broad understanding of a complement of topics related to the infrastructure required for advanced research and manufacturing, thus increasing their marketability for jobs within as well as beyond the nanotechnology field.

[3] Available from International Organization for Standardization (ISO), ISO Central Secretariat, BIBC II, Chemin de Blandonnet 8, CP 401, 1214 Vernier, Geneva, Switzerland, http://www.iso.org.

5.4 Because nanotechnology is a rapidly developing field, the individual educated in nanotechnology needs to be cognizant of changing and evolving safety procedures and practices. Individuals should be aware of how to ~~keep current on~~ maintain an up-to-date understanding of the technology and have ~~a~~sufficient base education ~~that enables~~ to enable the synthesis of emerging or evolving safety procedures and practices.

5.5 This guide is intended to be one in a series of standards developed for workforce education in various aspects of nanotechnology. It will assist in providing an organization a basic structure for developing a program applicable to many areas in nanotechnology, thus providing dynamic and evolving workforce education.

6. General Background Knowledge and Skills

6.1 Introductory algebra, chemistry, physics, and statistics at the college level.

6.2 The environmental, health, and safety (EHS) hazards presented by nanoscale materials can be very different from those presented by bulk materials. Students should have a basic understanding of the unique EHS factors when handling nanoscale ~~materials.~~ materials (see Note 1).

NOTE 1—See Guide E2996 and the National Nanotechnology Initiative's webpage on recent EHS research[4] for ~~details.~~more information.

6.3 Students should also have a basic knowledge of the physical and chemical properties of nanoscale ~~materials.~~materials (see Note 2).

NOTE 2—See Guide E3089 for details.

7. Concepts and Skills to be Covered

7.1 The methods or topics, or both, relevant for workforce education in nanotechnology infrastructure are given in Section 8, with important topics to be covered for each method listed specifically. Additional methods or topics, or both, may be added on an as-needed basis.

8. Concepts and Techniques Relevant to Nanotechnology Infrastructure

8.1 The minimum recommended course content for workforce education in nanotechnology should include education on the infrastructure used in nanomanufacturing, nanomaterials characterization or nanomaterials research.

CONTROLLED ENVIRONMENTS

8.2 *Cleanroom Classification:*

8.2.1 Cleanliness level standards – ISO 14644-1 versus the discontinued Federal Standard 209E.

8.3 *Cleanroom Components:*

8.3.1 Heating, ventilation, and air conditioning (HVAC) system.

8.3.2 Air filtration system:

8.3.2.1 High Efficiency Particulate Air (HEPA) filters.

8.3.2.2 Ultra Low Particulate Air (ULPA) filters.

[4] Available from U.S. National Nanotechnology Coordination Office (NNCO), 2415 Eisenhower Ave., Alexandria, VA 22314, https://www.nano.gov/Highlights-Federal-NanoEHS-Report.

8.3.3 Lighting system.

8.3.4 Deionized water system.

8.3.5 Scrubbers.

8.3.6 Chemical and chemical waste storage systems.

8.4 *Safety Equipment:*

8.4.1 Personal protective equipment (PPE).

8.4.2 Toxic gas and fire detectors and alarms.

8.4.3 Eye wash/shower stations.

8.5 *Site Surveys – Applicability of a Room or Environment for a Particular Tool or Equipment:*

8.5.1 Vibration.

8.5.2 Electromagnetic field.

8.5.3 Controlled temperature/humidity range.

8.6 *Fume Hoods:*

8.6.1 Uses and limitations.

8.6.2 Constant flow.

8.6.3 Constant volume.

8.7 *Glove Boxes:*

8.7.1 Uses and limitations.

8.7.2 Pump down and transfer procedures.

8.8 *Training:*

8.8.1 Safety.

8.8.2 Gowning and de-gowning procedures appropriate for cleanliness level.

8.8.3 Cleanroom practices.

BIO-CONTROLLED ENVIRONMENTS

8.9 *Laboratory Safety Level Classification:*

8.9.1 Biosafety Levels ~~1—4.~~1–4 (see Note 3).