Designation: E3059 – 16

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 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 safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health 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.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E2456 Terminology Relating to Nanotechnology

E2996 Guide for Workforce Education in Nanotechnology Health and Safety

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, 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.

[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. Published April 2016. DOI: 10.1520/E3059-16.

[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.

[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.

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 topics cover vacuum systems and pressurized gases.

5. Significance and Use

5.1 The purpose of this guide is to provide 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, 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.

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 the technology and have a base education that enables synthesis of emerging safety procedures and practices.

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.

NOTE 1—See Guide E2996 for details.

6.3 Students should also have a basic knowledge of the physical and chemical properties of nanoscale materials.

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.

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.

NOTE 2—See the ABSA/OSHA BSL Factsheet[4] for details.

8.10 *Safety Equipment:*

8.10.1 Personal protective equipment.

NOTE 3—For 8.10 and 8.11, see "Biosafety in Microbiological and Biomedical Laboratories, 5th Ed," published by the Centers for Disease control and Prevention[5] for details.

8.10.2 Biological safety cabinet (BSC):

[4] Available from American Biological Safety Association (ABSA), 1200 Allanson Road, Mundelein, IL 60060-3808, http://www.absa.org/pdf/OSHABSLFactSheet.pdf.

[5] Available from Centers for Disease Control and Prevention (CDC), 1600 Clifton Rd., Atlanta, GA 30329-4027, http://www.cdc.gov/biosafety/publications/bmbl5/index.htm.

8.10.2.1 Classes I–III.
8.10.3 Decontamination facilities:
8.10.3.1 Autoclave.
8.10.3.2 Fumigation chamber.

8.11 *Training:*
8.11.1 Safety.
8.11.2 Microbiological practices.

VACUUM SYSTEMS

8.12 *Vacuum Definitions:*
8.12.1 Pressure units.
8.12.2 Pressure ranges.
8.12.3 Vapor pressure.
8.12.4 Absolute versus relative pressure.
8.12.5 Gas flow:
8.12.5.1 Viscous and molecular flow.
8.12.5.2 Laminar and turbulent flow.
8.12.6 Pump down curves.

8.13 *Vacuum System Components:*
8.13.1 Vacuum tubing:
8.13.1.1 Flexible vacuum tubing.
8.13.1.2 Rigid vacuum tubing.
8.13.2 Vacuum fittings and flanges:
8.13.2.1 O-ring fittings and Klein Flange (KF) flanges.
8.13.2.2 Swagelok connections.
8.13.2.3 Metal sealed connections – Vacuum Coupling Radiation (VCR) fittings and Conflat (CF) flanges.
8.13.3 Vacuum feedthroughs:
8.13.3.1 Bellows and flexible line feedthroughs.
8.13.3.2 Mechanical feedthroughs.
8.13.3.3 Ferrofluidic feedthroughs.
8.13.3.4 Electrical feedthroughs.
8.13.3.5 Optical feedthroughs.
8.13.4 Vacuum valves:
8.13.4.1 Ball valves.
8.13.4.2 Butterfly valves.
8.13.4.3 Needle valves.
8.13.4.4 Gate valves.

8.14 *Vacuum Gauges:*
8.14.1 Vacuum gauge ranges and measurement mechanisms.
8.14.2 Direct force measurement gauges:
8.14.2.1 Bourdon tube gauge.
8.14.2.2 Capacitance manometer.
8.14.3 Thermal conductivity gauges:
8.14.3.1 Thermocouple gauge.
8.14.3.2 Pirani gauge.
8.14.4 Ionization gauges:
8.14.4.1 Thermal ionization gauge (ion gauge).
8.14.4.2 Residual gas analyzer (RGA).

8.15 *Vacuum Pumps:*
8.15.1 Roughing pumps:
8.15.1.1 Rotary vane pump.
8.15.1.2 Dry scroll pump.
8.15.2 High vacuum pumps:
8.15.2.1 Turbo molecular pump (turbo pump).
8.15.2.2 Diffusion pump.
8.15.2.3 Cryogenic pump (cryo pump).
8.15.3 Ultra-high vacuum pumps:
8.15.3.1 Sputter ion pump (ion pump).
8.15.3.2 Titanium sublimation pump (TSP).

PRESSURIZED GASES

8.16 *Gas Cylinders:*
8.16.1 Compressed Gas Association (CGA) gas cylinder connections.

8.17 *Pressure Regulators.*

8.18 *Gas Tubing.*

9. Keywords

9.1 cleanroom; education; fume hood; glove box; health; nanomaterial; nanoparticle; nanotechnology; pressurized gas; safety; vacuum

RELATED MATERIAL

ASTM E3001 Standard Practice for Workforce Education in Nanotechnology Characterization
ASTM E3034 Standard Guide for Workforce Education in Nanotechnology Pattern Generation
ISO 14644 Series Cleanrooms and Associated Controlled Environments
ISO 14698 Series Cleanrooms and Associated Controlled Environments – Biocontamination Control