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Standard Guide for Workforce Education in Nanotechnology Health and Safety[1]

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1. Scope

1.1 This guide provides a framework for basic workforce education in health and safety topics related to nanotechnology, to be taught at an undergraduate college level. This education should be broad to prepare an individual to work safely within one of the many areas in nanotechnology research, development, or manufacturing.

1.2 This guide may be used to develop or evaluate an education program for health and safety issues 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 The immediate and long term hazards, if any, of many nanomaterials are unknown. This guide does not address concerns with consumer usage and eventual disposal of products that contain nanomaterials.

1.5 *This standard does not purport to address all of the techniques, materials, and concepts associated with health and safety topics related to nanotechnology. It is the responsibility of the user of this standard to utilize other knowledge and skill objectives as applicable to local conditions or required by local regulations.*

1.6 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.7 *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

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

2.2 *ISO Standards:*[3]

ISO/TS 80004-1 Nanotechnologies – Vocabulary – Part 1: Core terms

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

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

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

4. Summary of Guide

4.1 This guide designates a list of health and safety subject areas that are relevant to nanotechnology workforce education. Selection of the areas is based on inputs from industry, nanotechnology educators, and subject matter experts.

[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.

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[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.

4.2 Within each subject area, important topics recommended to be covered are listed specifically.

4.3 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 This guide is to provide, at the undergraduate college level, a basic educational structure in the health and safety 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 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.

5.5 Workers may transition in their roles in the workplace. Participants in such education will have a broad understanding of the health and safety aspects associated with working in a manufacturing or research setting, thus increasing their marketability for jobs within as well as beyond the nanotechnology field.

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

NOTE 1—See Guide E3089 for details.

7. Concepts and Skills to be Covered

7.1 The minimum recommended course content for workforce education in nanotechnology health and safety is listed below. Subject areas include known and potential health risks, safe work practice in the nanotechnology workplace, nanotechnology and general laboratory safety, and understanding of Safety Data Sheets (SDSs). Important topics to be covered for each area are listed specifically.

HEALTH ISSUES

7.2 The unique properties of nanomaterials generally are not reflected on current SDS documentation. The list of health issues noted in this guide is not meant to be an exhaustive list of all possible health issues, but rather a list of the minimum issues that must be considered.

7.3 *Define health issues:*
7.3.1 Acute exposure.
7.3.2 Chronic exposure.
7.3.3 Irritant.
7.3.4 Mutagen.
7.3.5 Teratogen.
7.3.6 Carcinogen.
7.3.7 Sensitizers.
7.3.8 Asphyxiation.

7.4 *Define novel properties and behaviors of nanomaterials:*
7.4.1 Awareness of size and shape of materials.
7.4.2 Reactivity based on size:
7.4.2.1 Impact of shape on reactivity.
7.4.2.2 Agglomeration state.
7.4.2.3 Solubility.
7.4.2.4 Bioactivity.
7.4.2.5 Fire and explosion risks.

7.5 *Frequently used nanomaterials:*
7.5.1 *Carbon based materials:*
7.5.1.1 Carbon black.
7.5.1.2 Fullerenes.
7.5.1.3 Carbon nanotubes.
7.5.2 *Metal oxides:*
7.5.2.1 Forms of titanium dioxide.
7.5.2.2 Forms of zinc oxide.
7.5.2.3 Forms of silicon dioxide.
7.5.3 *Metallic nanoparticles:*
7.5.3.1 Gold nanoparticles.
7.5.3.2 Silver nanoparticles.
7.5.4 Quantum dots.
7.5.5 Other nanostructured particles.

7.6 *Identify exposure paths for nanoparticle interaction:*
7.6.1 Inhalation.
7.6.2 Ingestion.
7.6.3 Dermal.

HEALTH CONCERNS RELATED TO PROCESSING TOOLS COMMONLY USED IN NANOMANUFACTURING

7.7 High-voltage/high-current fields.

7.8 Ionizing and non-ionizing radiation.

7.9 Thermal (infrared).

7.10 Ultraviolet.

7.11 X-ray.

7.12 High vacuum.

7.13 Inert gases under pressure.

7.14 Chemical exposure.

SAFE WORK PRACTICE IN LABORATORIES UTILIZING NANOTECHNOLOGY OR IN THE NANOMANUFACTURING ENVIRONMENT, OR BOTH

7.15 Current best practices or case studies on work practices, or both.

7.16 Current knowledge of nanomaterial exposure levels established by the National Institute for Occupational Safety and Health (NIOSH), American Conference of Industrial Hygienists (ACGIH), etc.

7.17 Prevention through design.

7.18 Process Safety Management (PSM).

7.19 Hazard evaluation.

7.20 Risk assessment.

7.21 Hazard mitigation.

7.22 *Hierarchy of hazard control:*
7.22.1 Elimination.
7.22.2 Substitution.
7.22.3 Engineering controls.
7.22.4 Administrative controls.
7.22.5 Personal protective equipment (PPE).

7.23 *PPE specific to nanomanufacturing:*
7.23.1 Respirators:
7.23.1.1 Various types.
7.23.1.2 Ability to screen material.
7.23.1.3 Proper use.
7.23.2 Dust collection efficiency of filters.
7.23.3 Cleanup and disposal of unbound nanoparticles.
7.23.4 Spill management.
7.23.5 Industrial hygiene.

7.24 Fire extinguishers.

7.25 Safety showers.

7.26 Eye wash stations.

7.27 PPE specific to handling and research.

7.28 Wet bench safety guidelines.

7.29 Glove box safety guidelines.

7.30 Bottled gas safety procedures.

7.31 Vacuum systems safety procedures.

7.32 Toxic gas alarm technology.

7.33 Gas abatement systems and regulations.

ENVIRONMENTAL STEWARDSHIP

7.34 *Current best practices or case studies on environmental stewardship, or both:*
7.34.1 *Pollution abatement devices:*
7.34.1.1 In air.
7.34.1.2 In water.
7.34.2 *Nanomaterial abatement techniques:*
7.34.2.1 Converting nanomaterials to safer forms.
7.34.3 Proper disposal of nanomaterials

UNDERSTANDING SAFETY DATA SHEETS

7.35 Identification.

7.36 Hazard(s) identification.

7.37 Composition/information on ingredients.

7.38 First aid measures.

7.39 Fire-fighting measures.

7.40 Accidental release measures.

7.41 Handling and storage.

7.42 Exposure controls/personal protection.

7.43 Physical and chemical properties.

7.44 Stability and reactivity.

7.45 Toxicological information.

7.46 Ecological information.

7.47 Disposal considerations.

7.48 Transport information.

7.49 Regulatory information.

7.50 Other information, including date of preparation or last revision.

8. Keywords

8.1 education; health; nano; nanomaterial; nanoparticle; nanotechnology; safety