Designation: ~~E3034 – 15~~ E3034 – 20

Standard Guide for Workforce Education in Nanotechnology Pattern Generation[1]

This standard is issued under the fixed designation E3034; 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 guide provides a framework for a basic workforce education in pattern generation topics related to nanotechnology, to be taught at an undergraduate college level. The education should be broadbased, preparing an individual to work in one of many areas in ~~naotechnology~~nanotechnology research, development, or manufacturing. The individual so educated may be involved in nanoscale pattern definition.

1.2 This guide may be used to develop or evaluate an education program for pattern generation topics 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 While no units of measurements are used in this standard guide, values stated in SI units are to be regarded as standard.

1.4 *This standard does not purport to address all of the methods and concepts needed for pattern generation in 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.*

1.6 *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
E3001 Practice for Workforce Education in Nanotechnology Characterization
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 ~~Oct. 15, 2015~~Sept. 1, 2020. Published ~~November 2015~~October 2020. Originally approved in 2015. Last previous edition approved in 2015 as E3034 – 15. DOI: ~~10.1520/E3034-15.~~10.1520/E3034-20.

[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 80004-2 Nanotechnologies – Vocabulary—Part 2: ~~Nano-Objects~~Nano-objects
ISO/TS 80004-8 Nanotechnologies – Vocabulary—Part 8: Nanomanufacturing ~~Processes~~processes

3. Terminology

3.1 *Definitions:*

3.1.1 For definitions of terms related to nanotechnology in general, refer to Terminology E2456 and ISO/TS 80004-2.

3.1.2 For definitions of terms related to nanotechnology pattern generation in general, refer to ISO/TS 80004-8.

3.2 *Definitions of Terms Specific to This Standard:*

~~3.2.1 *education, n*—the teaching of specific topics as part of a degree or certificate program, or as training to provide additional skills and knowledge.~~

3.2.1 *pattern, n*—a design or a layout for fabricated structures.

3.2.2 *pattern generation, n*—the technique(s) to create and transfer a pattern onto a medium as applied in fabrication at the micro- or nanoscale; for example, photolithography is an optical technique used in chip manufacturing for generating a pattern on a substrate.

4. Summary of Guide

4.1 This guide designates a list of six topics on pattern generation 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 topic (8.1) pertains to the design of the patterns. The following five topics cover various lithography techniques. Three of the topics (8.2, 8.3, and 8.5) cover techniques requiring physical masks to generate the patterns on a substrate. The other two topics (8.4 and 8.6) do not utilize any physical masks, but use either electronic design files (8.4) or engineering of the materials (8.6).

4.3 Within each of the six 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 a basic educational structure for pattern generation in 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 standard 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 Workers may transition in their roles in the workplace. Participants in such education will have a broad understanding of a complement of pattern generation methods, 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 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.

NOTE 1—See Guide E2996 for details.

6.3 A basic knowledge of the physical and chemical properties of nanoscale materials.

NOTE 2—See Guide E3089 for details.

6.4 During the pattern generation procedure, measurements have to be made to track the progress and product quality after various process steps. Students should have a basic understanding of characterization methods at the nanoscale.

NOTE 3—See Practice E3001 for details.

7. Concepts and Skills to be Covered

7.1 Relevant methods for workforce education in nanotechnology pattern generation are listed in Section 8, with specific important topics to be covered for each method. Additional methods or topics, or both, may be added on an as-needed basis.

8. Concepts and Techniques Relevant to Nanotechnology Pattern Generation

8.1 *Layout Design:*

8.1.1 Define function.

8.1.2 Design partition.

8.1.3 Design simulation.

8.2 *Optical Lithography:*

8.2.1 *Optics for ~~lithography:~~Lithography:*

8.2.1.1 Diffraction.

8.2.1.2 Interference.

8.2.1.3 Reflection.

8.2.1.4 Refraction.

8.2.1.5 Scattering.

8.2.2 *Resists:*

8.2.2.1 Sensitivity.

8.2.2.2 Contrast.

8.2.2.3 Dose.

8.2.2.4 Positive/negative photoresists.

8.2.2.5 Adhesion promoters.

8.2.2.6 Chemically amplified photoresist.

8.2.2.7 Lift-off resist.

8.2.2.8 Anti-reflective ~~coating (TARC/BARC).~~coating.
(1) Top anti-reflective coating (TARC).
(2) Bottom anti-reflective coating (BARC).

8.2.2.9 Edge bead remover.

8.2.3 *Systems:*

8.2.3.1 Light sources and their wavelengths.

8.2.3.2 Immersion lithography.

8.2.3.3 Contact lithography.

8.2.3.4 Proximity lithography.

8.2.3.5 Projection lithography.

8.2.4 *Process Steps:*

8.2.4.1 Substrate cleaning.

8.2.4.2 Dehydration bake.

8.2.4.3 Spin coat primer.

8.2.4.4 Spin coat photoresist.

8.2.4.5 Soft bake.

8.2.4.6 Alignment

8.2.4.7 Exposure.

8.2.4.8 Post exposure bake.

8.2.4.9 Development and rinse.

8.2.4.10 Hard bake (if needed).

8.3 *X-Ray Lithography:*

8.3.1 X-ray lithography.

8.3.2 Extreme ultra violet (EUV) lithography.

8.4 *Direct Writing:*

8.4.1 *Electron/Ion Beam/Laser Lithography:*

8.4.1.1 *Resists:*
(1) Positive/negative resists.
(2) Chemically amplified resists.
(3) Adhesion promoter.