



Standard Guide for Size Measurement of Nanoparticles Using Atomic Force Microscopy¹

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1. Scope

1.1 The purpose of this document is to provide guidance on the quantitative application of atomic force microscopy (AFM) to determine the size of nanoparticles² deposited in dry form on flat substrates using height (z-displacement) measurement. Unlike electron microscopy, which provides a two-dimensional projection or a two-dimensional image of a sample, AFM provides a three-dimensional surface profile. While the lateral dimensions are influenced by the shape of the probe, displacement measurements can provide the height of nanoparticles with a high degree of accuracy and precision. If the particles are assumed to be spherical, the height measurement corresponds to the diameter of the particle. In this guide, procedures are described for dispersing gold nanoparticles on various surfaces such that they are suitable for imaging and height measurement via intermittent contact mode AFM. Generic procedures for AFM calibration and operation to make such measurements are then discussed. Finally, procedures for data analysis and reporting are addressed. The nanoparticles used to exemplify these procedures are National Institute of Standards and Technology (NIST) reference materials containing citrate-stabilized negatively charged gold nanoparticles in an aqueous solution.

1.2 The values stated in SI units are to be regarded as standard. No other units of measurement are included in this standard.

1.3 *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 This guide is under the jurisdiction of ASTM Committee E56 on Nanotechnology and is the direct responsibility of Subcommittee E56.02 on Characterization: Physical, Chemical, and Toxicological Properties.

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² Having two or three dimensions in the size scale from approximately 1 nm to 100 nm as in accordance with Terminology E2456; this definition does not consider functionality, which may impact regulatory aspects of nanotechnology, but which are beyond the scope of this guide.

2. Referenced Documents

2.1 ASTM Standards:³

E1617 Practice for Reporting Particle Size Characterization Data

E2382 Guide to Scanner and Tip Related Artifacts in Scanning Tunneling Microscopy and Atomic Force Microscopy

E2456 Terminology Relating to Nanotechnology

E2530 Practice for Calibrating the Z-Magnification of an Atomic Force Microscope at Subnanometer Displacement Levels Using Si(111) Monatomic Steps (Withdrawn 2015)⁴

E2587 Practice for Use of Control Charts in Statistical Process Control

2.2 ISO Standards:⁵

ISO 18115-2 Surface Chemical Analysis - Vocabulary - Part 2: Terms Used in Scanning-Probe Microscopy

ISO/IEC Guide 98-3:2008 Uncertainty of measurement—Part 3: Guide to the Expression of Uncertainty in Measurement (GUM:1995)

3. Terminology

3.1 For definitions pertaining to nanotechnology terms, refer to Terminology E2456.

3.2 For definitions pertaining to terms associated with scanning-probe microscopy, including AFM, refer to ISO 18115-2.

3.3 Definitions of Terms Specific to This Standard:

3.3.1 *agglomerate, n*—in nanotechnology, an assembly 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. **E2456**

3.3.1.1 *Discussion*—Using imaging based techniques, such as AFM, it is generally difficult to differentiate between

³ 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.

⁴ The last approved version of this historical standard is referenced on www.astm.org.

⁵ Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, CP 56, CH-1211 Geneva 20, Switzerland, <http://www.iso.org>.