



Standard Practice for Calibrating the Z-Magnification of an Atomic Force Microscope at Subnanometer Displacement Levels Using Si (111) Monatomic Steps¹

This standard is issued under the fixed designation E 2530; 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 practice covers a measurement procedure to calibrate the z-scale of an atomic force microscope using Si (111) monatomic step height specimens.

1.2 *Applications*—This procedure is applicable either in ambient or vacuum condition when the atomic force microscope (AFM) is operated at its highest levels of z-magnification, that is, in the nanometer and sub-nanometer ranges of z-displacement. These ranges of measurement are required when the AFM is used to measure the surfaces of semiconductors, optical surfaces, and other high technology components.

1.3 The values stated in SI units are to be regarded as the standard. The values given in parentheses are for information only.

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.*

2. Referenced Documents

2.1 ISO Standards:²

ISO Draft International Standard 25178-2 Geometrical Products Specification (GPS)---Surface Texture: Areal---Part 2: Terms, Definitions and Surface Texture Parameters.

ISO Committee Draft 25178-6 Geometrical Products Specification (GPS)---Surface Texture: areal---Part 6: Classification of methods for measuring surface texture.

ISO/TS 21748: 2004 Guidance for the Use of Repeatability, Reproducibility and Trueness Estimates in Measurement Uncertainty Estimation

GUM: 1993 Guide to the Expression of Uncertainty in Measurement

3. Terminology

3.1

3.1.1 *Atomic force microscope (AFM), n*—surface topography measurement method whereby the surface height is sensed from the mechanical force of attraction or repulsion between a probe tip and a surface.

3.1.2 *Coordinate axes, n*—coordinate system in which surface topographic measurements are performed.

3.1.2.1 *Discussion*—It is usual to use a rectangular coordinate system in which the axes form a right Cartesian set, the x-axis being the direction of tracing colinear with the mean line, the y-axis also nominally lying on the real surface, and the z-axis being in an outward direction (from the material to the surrounding medium).

3.1.3 *Si(111), n*—single crystal surface of silicon, oriented near the (111) crystal plane and perhaps with either a grown oxide overlayer or native oxide layer, which, when prepared appropriately, contains a large number of separated monatomic steps and atomically smooth terraces between them.

3.1.4 *x-y displacement stage, n*—mechanical means used to move a probe with respect to a surface (or vice versa) along the two coordinate axes in the plane of the surface.

3.1.5 *z-magnification (alternatively, z-sensitivity or z-scale), n*—term that describes the sensitivity of the output of a surface profiling instrument to displacements in the z-direction.

4. Significance and Use

4.1 Careful use of this practice can yield calibrated z-magnifications traceable to the SI unit of length with uncertainties ($k = 2$) of approximately 7 % over height ranges of approximately 1 nm.

5. Calibration Specimen

5.1 The physical step height specimen is the vicinal Si (111) surface (see Fig. 1), defined in 3.1.3, containing numerous monatomic steps, having on average a calibrated step height value. The calibrated value has been traditionally assigned to be 314 pm based on X-ray value of lattice parameter of bulk silicon (1). However, recent analysis (2-7), also taking into account independent measurements by other sources, has

¹ This test method is under the jurisdiction of ASTM Committee E42 on Surface Analysis and is the direct responsibility of Subcommittee E42.14 on STM/AFM. Current edition approved Nov. 1, 2006. Published November 2006.

² Available from International Organization for Standardization (ISO), 1 rue de Varembe, Case postale 56, CH-1211, Geneva 20, Switzerland, <http://www.iso.ch>.