



Designation: C1326 – 13 (Reapproved 2023)

Standard Test Method for Knoop Indentation Hardness of Advanced Ceramics¹

This standard is issued under the fixed designation C1326; 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 test method covers the determination of the Knoop indentation hardness of advanced ceramics. In this test, a pointed, rhombic-based, pyramidal diamond indenter of prescribed shape is pressed into the surface of a ceramic with a predetermined force to produce a relatively small, permanent indentation. The surface projection of the long diagonal of the permanent indentation is measured using a light microscope. The length of the long diagonal and the applied force are used to calculate the Knoop hardness which represents the material's resistance to penetration by the Knoop indenter.

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 *Units*—When Knoop and Vickers hardness tests were developed, the force levels were specified in units of grams-force (gf) and kilograms-force (kgf). This standard specifies the units of force and length in the International System of Units (SI); that is, force in newtons (N) and length in mm or μm . However, because of the historical precedent and continued common usage, force values in gf and kgf units are occasionally provided for information. This test method specifies that Knoop hardness be reported either in units of GPa or as a dimensionless Knoop hardness number.

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

1.5 *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.*

¹ This test method is under the jurisdiction of ASTM Committee C28 on Advanced Ceramics and is the direct responsibility of Subcommittee C28.01 on Mechanical Properties and Performance.

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2. Referenced Documents

2.1 ASTM Standards:²

C730 Test Method for Knoop Indentation Hardness of Glass

C849 Test Method for Knoop Indentation Hardness of Ceramic Whitewares

E4 Practices for Force Calibration and Verification of Testing Machines

E177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods

E384 Test Method for Microindentation Hardness of Materials

E691 Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

IEEE/ASTM SI 10 Standard for Use of the International System of Units (SI) (The Modern Metric System)

2.2 European Standard:³

CEN ENV 843-4 Advanced Technical Ceramics, Monolithic Ceramics, Mechanical Properties at Room Temperature, Part 4: Vickers, Knoop, and Rockwell Superficial Hardness Tests

2.3 ISO Standard:⁴

ISO 9385 Glass and Glass Ceramics—Knoop Hardness Test

3. Terminology

3.1 Definitions:

3.1.1 *Knoop hardness number (HK), n* —an expression of hardness obtained by dividing the force applied to the Knoop indenter by the projected area of the permanent impression made by the indenter.

3.1.2 *Knoop indenter, n* —a rhombic-based pyramidal-shaped diamond indenter with edge angles of 172° 30' and 130° 00'.

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 European Committee for Standardization (CEN), 36 rue de Stassart, B-1050, Brussels, Belgium, <http://www.cenorm.be>.

⁴ Available from International Organization for Standardization (ISO), 1, ch. de la Voie-Creuse, Case postale 56, CH-1211, Geneva 20, Switzerland, <http://www.iso.ch>.

4. Summary of Test Method

4.1 This test method describes an indentation hardness test using a calibrated machine to force a pointed, rhombic-based, pyramidal diamond indenter having specified face angles, under a predetermined force, into the surface of the material under test and measures the surface projection of the long diagonal of the resulting impression after removal of the load.

NOTE 1—A general description of the Knoop indentation hardness test is given in Test Method E384. The present test method differs from this description only in areas required by the special nature of advanced ceramics.

NOTE 2—This test method is similar to Test Methods C730 and C849, but differs primarily in the choice of force and the rate of force application. In addition, the length correction factor for the resolution limits of optical microscopes is not utilized.

5. Significance and Use

5.1 For advanced ceramics, Knoop indenters are used to create indentations. The surface projection of the long diagonal is measured with optical microscopes.

5.2 The Knoop indentation hardness is one of many properties that is used to characterize advanced ceramics. Attempts have been made to relate Knoop indentation hardness to other hardness scales, but no generally accepted methods are available. Such conversions are limited in scope and should be used with caution, except for special cases where a reliable basis for the conversion has been obtained by comparison tests.

5.3 For advanced ceramics, the Knoop indentation is often preferred to the Vickers indentation since the Knoop long diagonal length is 2.8 times longer than the Vickers diagonal for the same force, and cracking is much less of a problem (1).⁵ On the other hand, the long slender tip of the Knoop indentation is more difficult to precisely discern, especially in materials with low contrast. The indentation forces chosen in this test method are designed to produce indentations as large as may be possible with conventional microhardness equipment, yet not so large as to cause cracking.

5.4 The Knoop indentation is shallower than Vickers indentations made at the same force. Knoop indents may be useful in evaluating coating hardnesses.

5.5 Knoop hardness is calculated from the ratio of the applied force divided by the projected indentation area on the specimen surface. It is assumed that the elastic springback of the narrow diagonal is negligible. (Vickers indenters are also used to measure hardness, but Vickers hardness is calculated from the ratio of applied force to the area of contact of the four faces of the undeformed indenter.)

5.6 A full hardness characterization includes measurements over a broad range of indentation forces. Knoop hardness of ceramics usually decreases with increasing indentation size or indentation force such as that shown in Fig. 1.⁶ The trend is known as the indentation size effect (ISE). Hardness ap-

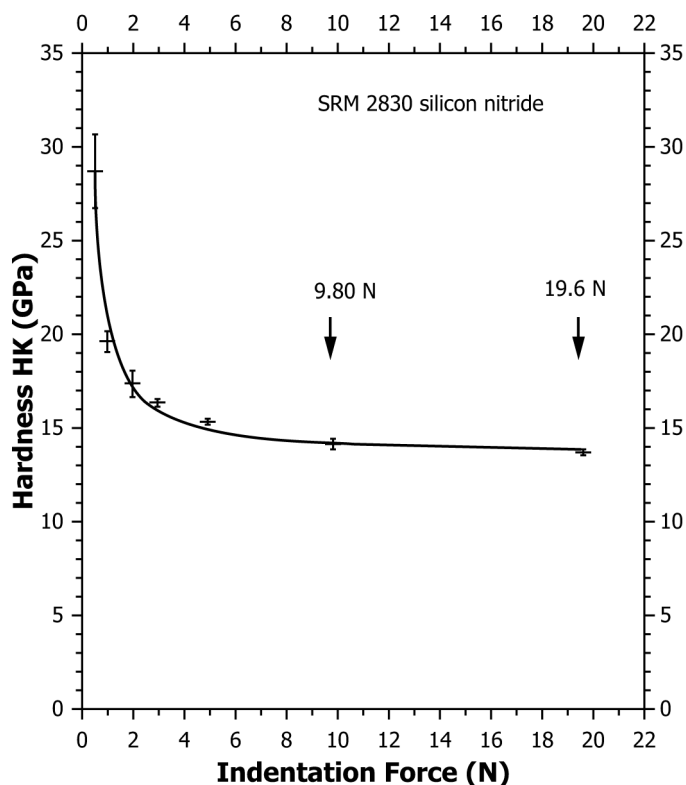


FIG. 1 A Typical Indentation Size Effect (ISE) Curve for a Ceramic (The data shown are for NIST SRM 2830 silicon nitride)

proaches a plateau constant hardness at sufficiently large indentation size or forces (loads). The test forces that are needed to achieve a constant hardness vary with the ceramic. The test force specified in this standard is intended to be sufficiently large that hardness is either close to or on the plateau, but not so large as to introduce excessive cracking. A comprehensive characterization of the ISE is recommended but is beyond the scope of this test method which measures hardness at a single, designated force.

6. Interferences

6.1 Cracking from the indentation tips can interfere with interpretation of the exact tip location. The forces chosen for this test method are sufficiently low that tip cracking, if it occurs, will cause tiny, rather tight cracks at the indentation tips in advanced ceramics. Such cracks will have a negligible interference on measurements of the long diagonal length (2) (unlike Vickers indentations in ceramics).

6.2 Cracking or spalling from the sides of the Knoop impression may also occur, possibly in a time-dependent manner (minutes or hours) after the impression is made. Small amounts of such lateral cracking have little or no influence upon measured hardness, provided that the tip impressions are still readable and the tips are not dislodged (2).

6.3 Porosity (either on or just below the surface) may interfere with measuring Knoop hardness, especially if the indentation falls directly onto a large pore or if the indentation tip falls in a pore.

⁵ The boldface numbers in parentheses refer to the list of references at the end of this test method.

⁶ Standard Reference Materials Program (NIST) 100 Bureau Drive, Stop 2300 Gaithersburg, MD 20899-2300.