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# Fine ceramics (advanced ceramics, advanced technical ceramics) — Silicon nitride materials for rolling bearing balls and rollers

*Céramiques techniques — Matériaux en nitrure de silicium pour billes utilisées dans les roulements à billes*

Reference number
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# Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 206, *Fine ceramics*.

This second edition cancels and replaces the first edition (ISO 26602:2009), which has been technically revised.

The main changes compared to the previous edition are as follows:

— the title has been revised;

— Clauses 1, 2, 3, 5, 6 have been revised;

— Annex A has been revised;

— Table B.1 has been revised;

— bibliography has been revised.

# Fine ceramics (advanced ceramics, advanced technical ceramics) — Silicon nitride materials for rolling bearing balls and rollers

## 1 Scope

This document specifies the requirements for preprocessed silicon nitride materials for rolling bearing balls and rollers.

This document provides a classification defining physical and mechanical properties of silicon nitride preprocessed bearing rolling element materials. The materials are classified in three categories by the specification of characteristics and microstructures. Methods for sample preparation and observation of microstructures are provided in Annex A.

NOTE 1 The silicon nitride product means the sintered body of which the main component is silicon nitride material.

NOTE 2 This document can be used for processed rolling bearing balls and rollers upon consultation between the parties concerned.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14627, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for fracture resistance of silicon nitride materials for rolling bearing balls at room temperature by indentation fracture (IF) method*

ISO 14704, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for flexural strength of monolithic ceramics at room temperature*

ISO 14705, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for hardness of monolithic ceramics at room temperature*

ISO 17561, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for elastic moduli of monolithic ceramics at room temperature by sonic resonance*

ISO 17562, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for linear thermal expansion of monolithic ceramics by push-rod technique*

ISO 18754, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Determination of density and apparent porosity*

ISO 20501, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Weibull statistics for strength data*

ISO 20507, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Vocabulary*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 20507 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

**3.1**
**fracture resistance**
$K_{I, IFR}$
resistance measured in accordance with the indentation fracture (IF) method

Note 1 to entry: This method is specified in ISO 14627.

**3.2**
**inclusion**
region that differs from the normal silicon nitride microstructure

Note 1 to entry: Typical inclusions in the $Si_3N_4$ ceramics for rolling bearing balls and rollers are coarser agglomerates of sintering additives and impurities of foreign composition than the normal $Si_3N_4$ constituents.

**3.3**
**material lot**
defined quantity of raw material ready for the shaping and densification of roller shapes and/or test items

**3.4**
**material class**
specific combination of physical and mechanical properties of the silicon nitride material

**3.5**
**preprocessed rolling bearing balls and rollers**
densified unit of material from a material lot before final shaping and finishing

**3.6**
**processed rolling bearing balls and rollers**
rolling bearing balls and rollers after final shaping and finishing

## 4 Physical and mechanical properties

Typical ranges of physical and mechanical properties of a preprocessed rolling element are given in Table 1. Physical and mechanical properties shall be measured in accordance with 6.1 to 6.4. Values for thermal conductivity, specific heat and electrical resistivity are subject to agreement between the parties concerned.

**Table 1 — Physical and mechanical properties**

| Properties | Minimum | Maximum |
|---|---|---|
| Density ($g/cm^3$) | 3,0 | 3,6 |
| Elastic modulus (GPa) | 270 | 330 |
| Poisson's ratio | 0,23 | 0,29 |
| Coefficient of thermal expansion, $\times 10^{-6}/°C$ (applicable range: room temperature to 500 °C) | 2,0 | 3,7 |

## 5 Material classification

Silicon nitride materials for rolling bearing balls and rollers shall be divided into three classes according to the physical and mechanical properties of the material, as specified in Annex B.

# 6 Test

## 6.1 Density

Preprocessed rolling bearing balls or rollers shall be used as the test specimens.

The test shall be conducted in accordance with ISO 18754.

## 6.2 Elastic modulus

Test pieces shall be fabricated from the same material lot as the preprocessed rolling bearing balls and rollers.

The test shall be conducted in accordance with ISO 17561.

## 6.3 Poisson's ratio

Test pieces shall be fabricated from the same material lot as the preprocessed rolling bearing balls and rollers.

The test shall be conducted in accordance with ISO 17561.

## 6.4 Coefficient of thermal expansion

Test pieces shall be fabricated from the same material lot as the preprocessed rolling bearing balls and rollers.

The test shall be conducted in accordance with ISO 17562.

## 6.5 Flexural strength and Weibull modulus

Test pieces shall be fabricated from the same material lot as the preprocessed rolling bearing balls and rollers.

Average values for flexural strength at room temperature and Weibull modulus shall be evaluated in accordance with ISO 14704 and ISO 20501. Either 4-point or 3-point test methods may be used for flexural strength.

## 6.6 Hardness

Polished sections of the preprocessed rolling bearing balls and rollers shall be used for the test.

Average values for Vickers hardness shall be evaluated in accordance with ISO 14705. The recommended test force shall be HV20, and HV5 and HV10 are also allowed if the sample is too small to be indented.

## 6.7 Indentation fracture resistance

**6.7.1** Polished sections of the preprocessed rolling bearing balls and rollers shall be used for the indentation fracture (IF) method. The surface finishing shall be carried out to avoid residual stress.

**6.7.2** Average values for fracture resistance in the indentation fracture (IF) method shall be evaluated in accordance with ISO 14627.

## 6.8 Microstructure

Polished sections of the preprocessed rolling bearing balls and rollers shall be used for microstructure inspection. Sample preparation and observation shall be conducted as described in Annex A.

## 7 Test report

The test report shall include the following information:

a) a reference to this document, i.e. ISO 26602;

b) the date of the test;

c) the raw powder lot;

d) the test results:

   1) density;

   2) elastic modulus;

   3) Poisson's ratio;

   4) coefficient of thermal expansion;

   5) average flexural strength and average Weibull modulus;

   6) Vickers hardness (test conditions, average hardness);

   7) average fracture toughness and fracture resistance (test method, average fracture toughness or fracture resistance);

   8) microstructure (sizes and numbers of pores and inclusions);

e) the material class;

f) any additional information relevant to the evaluation.

# Annex A
(normative)

# Microstructure observation procedure

**WARNING — This annex describes general methods for sample preparation and the observation methods for silicon nitride rolling bearing element materials. However, because there is no formally standardized ISO procedure and definitive methods for microstructure observation are not available, some aspects of evaluation may need to be agreed between parties.**

## A.1 Sample preparation

Sections of silicon nitride rolling bearing balls and rollers shall be prepared by cutting, grinding and lapping. The sections shall be polished using either of the following two methods.

a) After rough polishing with diamond powders of less than 50 μm in diameter, the sections shall be polished using abrasive powders such as alumina or diamond with sizes of less than or equal to 1 μm.

b) After rough polishing with diamond powders of less than 50 μm in diameter, the sections shall be chemically polished with abrasive powders such as cerium oxide, chromium oxide or iron oxide.

In either case, the sections shall be polished until grinding scratches disappear, and shall then be ultrasonically cleaned.

## A.2 Observation

The section shall be placed on the stage of an optical microscope. The number or total area of sections to be examined shall be agreed between parties depending on the bearing size and the application conditions. Pores and inclusions shall be searched for with a 100x to 200x magnification. The number and size of any pores and inclusions found shall be determined, and the pore size and inclusion size shall be identified by their maximum size in the section. Alternatively, the size and number of pores and inclusions may be determined by a scanning electron microscope (SEM), secondary electron image or backscatter electron image, as necessary.

## A.3 Additional remarks

The observed portion depends on the size and shape of the ball and roller and the application condition of the bearing; it may be recommended that these be determined between parties to the characterization.

Colour variation is a very difficult problem to be clarified, which may also require discussion between suppliers and their customers. If the volume rating of porosity is required, it is recommended that the methodology in ISO 4499-4 for hard metals be adopted. Observation of the macrostructure at lower magnification may be useful for reviewing visible cracks and defects.

# Annex B
(normative)

# Material classification for silicon nitride materials

Table B.1 provides the specification of physical and mechanical properties and of the microstructure of the classified silicon nitride rolling bearing element materials in three categories: Classes 1, 2 and 3.

**Table B.1 — Material classification**

| | Class 1 | Class 2 | Class 3 |
|---|---|---|---|
| 1. Average flexural strength (MPa)[a] | | | |
| a) 4-point test method | | | |
| i) Average strength: 40 mm (span of supports) | min. 760 | min. 660 | min. 480 |
| 30 mm (span of supports) | min. 800 | min. 700 | min. 530 |
| ii) Weibull modulus | min. 12 | min. 9 | min. 7 |
| b) 3-point test method | | | |
| i) Average strength: 40 mm (span of supports) | min. 894 | min. 798 | min. 595 |
| 30 mm (span of supports) | min. 915 | min. 817 | min. 629 |
| ii) Weibull modulus | min. 12 | min. 9 | min. 7 |
| 2. Average Vickers hardness (GPa)[b] | min. 14,2 | min. 13,3 | min. 12,7 |
| 3. Average indentation fracture resistance (MPa $\sqrt{m}$ ) | | | |
| $K_{I, IFR}$ (indentation fracture resistance) | min. 6,0 | min. 5,0 | min. 5,0 |
| 4. Microstructure | | | |
| a) Pore size (µm) | max. 10 | max. 10 | max. 25 |
| b) Inclusion (number/cm$^2$) | | | |
| Size (µm) ≥ 25 to < 50 | ≤ 4 | ≤ 8 | ≤ 16 |
| ≥ 50 to < 100 | ≤ 1 | ≤ 2 | ≤ 4 |
| ≥ 100 to < 200 | 0 | ≤ 1 | ≤ 2 |
| ≥ 200 | 0 | 0 | ≤ 1 |

NOTE If it is required to determine the true fast fracture toughness of the test material, the indentation fracture resistance calculated above is not an equivalent number.

[a] Either test method may be used.

[b] The recommendable test force shall be HV20; HV5 and HV10 are also allowed.

# Bibliography

[1] ISO 4499-4:2016, *Hardmetals — Metallographic determination of microstructure — Part 4: Characterisation of porosity, carbon defects and eta-phase content*

[2] ASTM F2730, *Standard Specification for Silicon Nitride Cylindrical Bearing Rollers*

[3] Niihara K., Morena R., Hasselman D.P.H. Evaluation of $K_{IC}$ of brittle solids by the indentation method with low crack-to-indent ratios. *J. Mater. Sci.* 1982, **1** pp. 13–16

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