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## National Standard of the People's Republic of China

GB/T -XXXX

Grain boundary diffusion neodymium iron boron permanent magnet materials

晶界扩散钕铁硼永磁材料

*(English Translation)*

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Foreword

本文件按照GB/T 1.1—2020《标准化工作导则 第1部分：标准化文件的结构和起草规则》的规定起草。

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本文件由全国稀土标准化技术委员会（SAC/TC 229）提出并归口。

本文件起草单位：宁波韵升股份有限公司、北京中科三环高技术股份有限公司、安徽大地熊新材料股份有限公司、宁波招宝磁业有限公司、北京工业大学、包头天和磁材科技股份有限公司、宁波永久磁业有限公司、杭州美磁科技有限公司、有研稀土新材料股份有限公司、福建省长汀金龙稀土有限公司、中国科学院宁波材料技术与工程研究所、包头稀土研究院、赣州富尔特电子股份有限公司、中国北方稀土（集团）高科技股份有限公司

本文件主要起草人：吕向科、沈国迪、张民、竺晓东、梁凤基、曹朔豪、刘友好、贺琦军、岳明、董义、何挺、贾生礼、罗阳、张久磊、宋振纶、丁勇、付建龙、戚植奇、娄树普、刘峰、欧阳习科、黄秀莲、林建强、刘卫强、吴树杰、李建忠、闫文龙、杨丽景、姜建军、孙颖莉、庞再升。

SAC/TC 229 is in charge of this English translation. In case of any doubt about the contents of English translation, the Chinese original shall be considered authoritative.

This standard is drafted in accordance with the editorial rules given in the GB/T 1.1-2020 Directives for standardization -Part 1: Structure and drafting of standards.

Please note that some contents of this standard may involve patents. The publisher of this standard is not responsible for identifying patents.

This standard was prepared and proposed by SAC/TC 229 China Rare Earth Standardization Technical Committee.

Grain boundary diffusion neodymium iron boron permanent magnet materials

1. 范围

本文件规定了晶界扩散钕铁硼永磁材料的品种与牌号、要求、试验方法、检验规则和包装、标志、运输、贮存及随行文件。

本文件适用于经过晶界扩散工艺处理的烧结钕铁硼永磁材料。

1 Scope

This document specifies the categories, grades, requirements, test methods, inspection rules, packaging, signs, transportation, storage and accompanying files of grain boundary diffusion neodymium iron boron permanent magnet materials.

This document is applicable to sintered neodymium iron boron permanent magnet materials produced by grain boundary diffusion process.

2. 规范性引用文件

下列文件中的内容通过文中的规范性引用而构成本文件必不可少的条款。其中，注日期的引用文件，仅该日期对应的版本适用于本文件；不注日期的引用文件，其最新版本（包括所有的修改单）适用于本文件。

GB/T 2828.1—2012 计数抽样检验程序 第1部分：按接收质量限（AQL）检索的逐批检验抽样计划

GB/T 3217 永磁（硬磁）材料 磁性试验方法

GB/T 3850 致密烧结金属材料与硬质合金 密度测定方法

GB/T 4339 金属材料热膨胀特征参数的测定

GB/T 5167 烧结金属材料和硬质合金电阻率的测定

GB/T 7314 金属材料 室温压缩试验方法

GB/T 8170 数值修约规则与极限数值的表示和判定

GB/T 9097 烧结金属材料（不包括硬质合金） 表观硬度和显微硬度的测定

GB/T 9637 电工术语 磁性材料与元件

GB/T 13560 烧结钕铁硼永磁材料

GB/T 22315 金属材料 弹性模量和泊松比试验方法

GB/T 22588—2008 闪光法测量热扩散系数或导热系数

GB/T 24270 永磁材料磁性能温度系数测量方法

GB/T 29628 永磁（硬磁）脉冲测量方法指南

[GB/T 31967.2](http://www.sac.gov.cn/SACSearch/search?channelid=97779&templet=gjcxjg_detail.jsp&searchword=STANDARD_CODE=%27GB/T%2031967.2-2015%27&XZ=T) 稀土永磁材料物理性能测试方法 第2部分：抗弯强度和断裂韧度的测定

GB/T 34491 烧结钕铁硼表面镀层

GB/T 38437 用抽拉或旋转方式测量铁磁材料样品磁偶极矩的方法

GB 39176 稀土产品的包装、标志、运输和贮存

GB/T 40792 烧结钕铁硼永磁体失重试验方法

GB/T 40793 烧结钕铁硼表面涂层

GB/T 40793 稀土永磁材料高温磁通不可逆损失检测方法

NB/SH/T 0632 比热容的测定 差示扫描量热法

2 Normative references

The following referenced documents are indispensable for the application 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.

GB/T 2828.1-2012 *Sampling procedures for inspection by attributes - Part 1: Sampling schemes indexed by acceptance quality limit (AQL) for lot-by-lot inspection*

GB/T 3217 *Permanent magnet (magnetically hard) materials - Methods of measurement of magnetic properties*

GB/T 3850 *Impermeable sintered metal materials and hardmetals –Determination of density*

GB/T 4339 T*est methods for thermal expansion characteristic parameters of metallic materials*

GB/T 5167 *Sintered metal materials and hardmetals –Determination of electrical resistivity*

GB/T 7314 *Metallic materials –Compression test method at room temperature*

GB/T 8170 *Rules of rounding off for numerical values & expression and judgement of limiting values*

GB/T 9097 *Sintered metal materials, excluding hardmetals –Determination of apparent hardness and microhardness*

GB/T 9637 *Electrotechnical terminology - Magnetic materials and components*

GB/T 13560 *Sintered neodymium iron boron permanent magnet materials*

GB/T 22315 *Metallic materials –Determination of modulus of elasticity and Poisson’s ratio*

GB/T 22588—2008 *Determination of thermal diffusivity or thermal conductivity by the flash method*

GB/T 24270 *Method of measurement of temperature coefficient of magnetic properties of permanent magnetic materials*

GB/T 29628 *Guides for methods of measurement of the magnetic properties of permanent (magnetically hard) materials by pulsed field magnetometry*

GB/T 31967.2 *Test method for physical property of rare earth permanent magnetic materials–part 2: Determination of bending strength and fracture toughness*

GB/T 34491 *Coatings for sintered neodymium iron boron permanent magnets*

GB/T 38437 *Methods of measurement of the magnetic dipole moment of a ferromagnetic material specimen by the withdrawal or rotation method*

GB 39176 *Rare earth products packing, marking, transport and storage*

GB/T 40792 *Test method of weight loss of sintered neodymium iron boron permanent magnets*

GB/T 40793 *Nonmetallic coatings for sintered neodymium iron boron permanent magnets*

GB/T 40794 *Measurement method of irreversible magnetic flux loss due to high temperature for rare earth permanent magnet*

NB/SH/T 0632 *Standard test method for determining specific heat capacity by differential scanning calorimetry*

3 术语和定义

GB/T 9637和GB/T 13560界定的以及下列术语和定义适用于本文件。

3 Terms and definitions

For the purpose of this document, the terms and definitions given in GB/T 9637, GB/T 15676 and the following apply.

3.1晶界扩散钕铁硼永磁材料 grain boundary diffusion neodymium iron boron permanent magnet materials；GBD NdFeB PM materials

采用高温热处理工艺，促使烧结钕铁硼永磁材料表面包覆的重稀土元素沿着其晶界从表面扩散进入内部，提升了内禀矫顽力的永磁材料。

1. 采用机械加工和表面防护处理，或直接表面防护处理，形状和规格逐步接近用户设计的晶界扩散钕铁硼永磁材料，称为晶界扩散钕铁硼永磁体。
2. 晶界扩散钕铁硼永磁材料的化学成分、制造工艺、磨削后永磁材料*H*cJ的变化及应用参见附录A。

3.1 Grain boundary diffusion neodymium iron boron permanent magnet materials（GBD NdFeB PM materials）

By high temperature heat treatment process, the heavy rare earth elements coated on the surface of sintered NdFeB permanent magnet materials diffuse from the surface to the interior along its grain boundary, and the intrinsic coercivity is improved.

Note 1: By mechanical processing and surface protection treatment or direct surface protection treatment, the GBD NdFeB PM material whose shape and specification are gradually close to the user’s design is called GBD NdFeB PM.

Note 2: Chemical composition, manufacturing process, application of GBD NdFeB PM materials and change *H*cJ of permanent magnet materials after grinding are shown in Annex A.

4 分类与牌号

4.1 分类

晶界扩散钕铁硼永磁材料按内禀矫顽力大小分为高矫顽力H、特高矫顽力SH、超高矫顽力UH、极高矫顽力EH及至高矫顽力TH五个品种。

4 Classification and grade

4.1 Classification

Based on intrinsic coercivity value, GBD NdFeB PM materials can be classified into five categories, high coercivity (H), super high coercivity (SH), ultra-high coercivity (UH), extra high coercivity (EH) and top high coercivity (TH).

4.2牌号

依据晶界扩散钕铁硼永磁材料最大磁能积标称值大小可将每个品种划分为若干牌号。

4.2 Grade

Each category can be classified into several grades according to the maximum energy product of GBD NdFeB PM materials.

4.3牌号表示方法

晶界扩散钕铁硼永磁材料的牌号由材料制造特征、主称、磁特征的字符及连接符组成。第一部分G，表示晶界扩散工艺；第二部分NdFeB，由钕的元素符号Nd、铁的元素符号Fe和硼的元素符号B组成；第一部分与第二部分之间用“-”连接；第三部分数字，是钕铁硼永磁材料最大磁能积(*BH*)max的标称值（单位为kJ/m3）；第四部分数字，是钕铁硼永磁材料内禀矫顽力*H*cJ的最小值（单位为kA/m）的十分之一，数值采用四舍五入取整；第三部分与第四部分之间用“/”隔开。

G–NdFeB ΧΧΧ/ΧΧΧ

表示*H*cJ的最小值十分之一

表示 *(BH)*max的标称值

表示钕铁硼

表示晶界扩散工艺

示例：G-NdFeB 380/199表示晶界扩散钕铁硼永磁材料，最大磁能积(*BH*)max的标称值为380 kJ/m3，内禀矫顽力*H*cJ的最小值为1990 kA/m。

简化牌号参见附录B。

4.3 Grade representing method

The grade of GBD NdFeB PM materials is composed of characters, numbers and connectors, which represents manufacture method, material name, magnetic properties. The first part “G” represents GBD process. The second part “NdFeB” is composed of the element symbol of neodymium “Nd”, iron “Fe” and boron “B”. The first and second part are connected with “-”. The third part is a number, which represents the nominal value of the maximum energy product in kilojoules per cubic meter (kJ/m3). The fourth part is a number, which represents one tenth of the minimum value of the intrinsic coercivity in kiloamperes per meter (kA/m) after being rounded. The third and fourth part are separated by “/”.

G–NdFeB ΧΧΧ/ΧΧΧ

Represents one tenth of the minimum value of HcJ in kA/m

Represents the nominal value of (BH)Max in kJ/m3

Represents neodymium iron boron

Represents GBD process

Example: G-NdFeB 380/199 refers to GBD NdFeB PM material with the nominal value of the (BH)max of 380 kJ /m3, and the minimum HcJ of 1990 kA/m.

The brief grades are shown in Annex B.

5 要求

5.1磁性能

不同牌号永磁材料的主要磁性能（在20 ℃时）和方形度应符合表1的规定。

5 Requirements

5.1 Magnetic properties

The principal magnetic properties and squareness of permanent magnet materials in different grades (at 20℃) should meet the requirements in Table 1.

Table 1 The magnetic properties of GBD NdFeB PM materials at 20℃

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Category | Grade | Principal magnetic property | | | | squareness |
| *B*r  T  ≥ | *H*cJ  kA/m  ≥ | *H*cB  kA/m  ≥ | (*BH*)max  kJ/m3  Range value | *H*k/*H*cJ[[1]](#footnote-1))  %  ≥ |
| H | G-NdFeB 415/135 | 1.425 | 1353 | 1074 | 390～422 | 90 |
| G-NdFeB 440/135 | 1.470 | 1106 | 414～446 |
| G-NdFeB 455/135 | 1.495 | 1122 | 429～462 |
| SH | G-NdFeB 360/159 | 1.335 | 1592 | 1003 | 342～366 | 88 |
| G-NdFeB 380/159 | 1.365 | 1027 | 358～390 |
| G-NdFeB 400/159 | 1.395 | 1051 | 374～406 |
| G-NdFeB 415/159 | 1.425 | 1067 | 390～422 |
| G-NdFeB 440/159 | 1.470 | 1106 | 414～446 |
| UH | G-NdFeB 265/199 | 1.135 | 1990 | 852 | 247～271 | 86 |
| G-NdFeB 280/199 | 1.170 | 883 | 263～287 |
| G-NdFeB 300/199 | 1.220 | 916 | 287～310 |
| G-NdFeB 320/199 | 1.255 | 939 | 302～326 |
| G-NdFeB 335/199 | 1.285 | 963 | 318～342 |
| G-NdFeB 360/199 | 1.320 | 995 | 334～366 |
| G-NdFeB 380/199 | 1.365 | 1027 | 358～390 |
| G-NdFeB 400/199 | 1.395 | 1051 | 374～406 |
| G-NdFeB 415/199 | 1.425 | 1067 | 390～422 |
| G-NdFeB 430/199 | 1.455 | 1090 | 406～438 |
| EH | G-NdFeB 225/239 | 1.040 | 2388 | 780 | 207～231 | 86 |
| G-NdFeB 240/239 | 1.080 | 812 | 223～247 |
| G-NdFeB 265/239 | 1.135 | 852 | 247～271 |
| G-NdFeB 280/239 | 1.170 | 883 | 263～287 |
| G-NdFeB 300/239 | 1.220 | 916 | 287～310 |
| G-NdFeB 320/239 | 1.255 | 939 | 302～326 |
| G-NdFeB 335/239 | 1.270 | 955 | 310～342 |
| G-NdFeB 360/239 | 1.320 | 995 | 334～366 |
| G-NdFeB 380/239 | 1.365 | 1027 | 358～390 |
| G-NdFeB 400/239 | 1.395 | 1051 | 374～406 |
| TH | G-NdFeB 225/279 | 1.040 | 2786 | 780 | 207～231 | 86 |
| G-NdFeB 240/279 | 1.080 | 812 | 223～247 |
| G-NdFeB 265/279 | 1.135 | 852 | 247～271 |
| G-NdFeB 280/279 | 1.170 | 891 | 263～287 |
| G-NdFeB 300/279 | 1.220 | 931 | 287～310 |
| G-NdFeB 320/279 | 1.240 | 947 | 295～326 |
| G-NdFeB 335/279 | 1.270 | 963 | 310～342 |
| G-NdFeB 360/279 | 1.320 | 995 | 334～366 |

5.2 磁性能温度系数

永磁材料磁性能温度系数参见附录C。特殊要求由供需双方商定。

5.2 Temperature coefficient of magnetic properties

Temperature coefficient of magnetic properties of permanent magnet materials are shown in Annex C. In case of any special requirements, the supplier and the buyer can negotiate individually.

5.3其它物理性能

永磁材料其它物理性能参见附录D。特殊要求由供需双方商定。

5.3 Other physical properties

Other physical properties of permanent magnet materials are shown in Annex D. In case of any special requirements, the supplier and the buyer can negotiate individually.

5.4 失重

永磁材料试验持续时间96 h后失重应小于10 mg/cm2。

5.4 Weight loss

The weight loss of permanent magnet materials after 96 h test should be less than 10 mg / cm2.

5.5 表面防护

经过电镀镍、电镀镍铜镍、复合电镀镍与化学镍、电镀镀锌或PVD铝等方法处理的永磁体，其表面防护层厚度、耐蚀性和结合力应达到GB/T 34491规定的要求；经过磷化、锆化、电泳环氧、喷涂环氧、喷涂锌铝或CVD Parylene等方法处理的永磁体，其表面防护层厚度、耐蚀性和结合力应达到GB/T 40793规定的要求。

5.5 Surface protection

For the permanent magnets treated by nickel electroplating, nickel-copper-nickel electroplating, chemical nickel plating, zinc electroplating or PVD aluminum plating etc., the thickness, corrosion resistance and bonding strength of surface protection layer should meet the requirements in GB/T 34491. For the permanent magnets treated by phosphating, zirconization, electrophoretic epoxy, spray epoxy, spray aluminum or CVD Parylene etc., the thickness, corrosion resistance and bonding strength of surface protection layer should meet the requirements in GB/T 40793.

5.6 磁偶极矩一致性

永磁体磁偶极矩一致性（在20 ℃温度条件下）参见附录E的表E.1。特殊要求由供需双方商定。

5.6 Magnetic dipole moment consistency

The magnetic dipole moment consistency of permanent magnets at 20℃ is shown in table E.1 of Annex E. In case of any special requirements, the supplier and the buyer can negotiate individually.

5.7 高温磁通不可逆损失

永磁体高温磁通不可逆损失的要求由供需双方商定。

5.7 irreversible magnetic flux losses at high temperature

The requirements for irreversible magnetic flux losses at high temperature of permanent magnets can be negotiated by the supplier and the buyer.

5.8 外观质量

永磁体表面不应有影响使用的裂纹、砂眼、夹杂和边角脱落等缺陷，外观缺陷的尺寸限制及其它特殊要求由供需双方商定。

5.8 Appearance quality

Any surface defects such as cracks, sand holes, inclusions, damages of edge or corner and other defects will affect the use of permanent magnets are not allowed. As for the size limitation of appearance defects and other special requirements, the supplier and the buyer can negotiate individually.

5.9 尺寸

永磁体尺寸偏差、形状和位置偏差参见附录E的表E.2。特殊要求由供需双方商定。

5.9 Dimension

The size deviation, shape and position deviation of permanent magnets are shown in table E.2 of Annex E. In case of any special requirements, the supplier and the buyer can negotiate individually.

6 试验方法

6.1 磁性能

永磁材料主要磁性能的测量按照GB/T 3217或GB/T 29628的规定进行。

6 Test methods

6.1 Magnetic properties

The principal magnetic properties of permanent magnet materials are measured as specified in GB/T 3217 or GB/T 29628.

6.2磁性能温度系数

永磁材料磁性能温度系数的测量按照GB/T 24270的规定进行或采用脉冲法测量。

6.2 Temperature coefficients of magnetic properties

Temperature coefficients of magnetic properties of permanent magnet materials are measured as specified in GB/T 24270 or by pulse method.

6.3 其它物理性能

6.3.1永磁材料密度的测量按GB/T 3850的规定进行。

6.3.2永磁材料硬度的测量按GB/T 9097的规定进行。

6.3.3永磁材料抗压强度的测量按GB/T 7314的规定进行。

6.3.4永磁材料抗弯强度的测量按[GB/T 31967.2](http://www.sac.gov.cn/SACSearch/search?channelid=97779&templet=gjcxjg_detail.jsp&searchword=STANDARD_CODE=%27GB/T%2031967.2-2015%27&XZ=T" \t "_blank)的规定进行。

6.3.5永磁材料杨氏模量的测量按GB/T 22588—2008第6章的规定进行。

6.3.6永磁材料比热容的测量按NB/SH/T 0632的规定进行。

6.3.7永磁材料热传导率的测量按GB/T 22588的规定进行。

6.3.8永磁材料热膨胀系数的测量按GB/T 4339的规定进行。

6.3.9永磁材料电阻率的测量按GB/T 5167的规定进行。

6.3.10永磁材料最高使用温度的测量按GB/T\*\*\*\*\*（稀土永磁体高温磁通不可逆损失检测方法）的规定进行。

6.3 Other physical properties

6.3.1 The density of permanent magnet materials is measured as specified in GB/T 3850.

6.3.2 The hardness of permanent magnet materials is measured as specified in GB/T 9097.

6.3.3 The compressive strength of permanent magnet materials is measured as specified in GB/T 7314.

6.3.4 The bending strengthof permanent magnet materials is measured as specified in GB/T 31967.2.

6.3.5 The young's modulus of permanent magnet materials is measured as specified in chapter 6 of GB/T 22588—2008.

6.3.6 The specific heat capacity of permanent magnet materials is measured as specified in NB/SH/T 0632.

6.3.7 The thermal conductivity of permanent magnet materials is measured as specified in GB/T 22588.

6.3.8 The coefficient of thermal expansion of permanent magnet materials is measured as specified in GB/T 4339.

6.3.9 The resistivity of permanent magnet materials is measured as specified in GB/T 5167.

6.3.10 The maximum operating temperature of permanent magnet materials is measured as specified in GB/T 40794.

6.4 失重

永磁材料失重的测量按GB/T 40792的规定进行。

6.4 Weight loss

The weight loss of permanent magnet materials is measured as specified in GB/T 40792.

6.5 表面防护

永磁体表面防护层厚度、耐蚀性和结合力的测量按GB/T 34491或GB/T 40793规定进行。

6.5 Surface protection

The thickness, corrosion resistance and bonding strength of surface protection layer of permanent magnets are measured as specified in GB/T 34491 or GB/T 40792.

6.6　磁偶极矩一致性

永磁体磁偶极矩的测量按GB/T 38437的规定进行。永磁体磁偶极矩一致性为抽样产品磁偶极矩极差（最大值与最小值之差）与平均值的比值。

6.6 Magnetic dipole moment consistency

The magnetic dipole moment consistency of permanent magnets is measured as specified in GB/T 38437. The magnetic dipole moment consistency is the ratio of the extreme difference (difference between the maximum and minimum) to the average value of the magnetic dipole moments of the samples.

6.7　高温磁通不可逆损失

永磁体高温磁通不可逆损失测量按GB/T 40794的规定进行。

6.7 Irreversible magnetic flux losses at high temperature

The irreversible magnetic flux losses at high temperature of permanent magnets are measured as specified in GB/T 40794.

6.8　外观质量

采用目测的方式检测永磁体的外观质量。

6.8 Appearance quality

The appearance quality shall be inspected visually.

6.9　尺寸

应采用与5.9条要求相适应的量具测量尺寸。

6.9 Dimension

The dimension shall be measured by measuring tools suitable for the requirements of chapter 5.9.

6.10　数值修约

按GB/T 8170的规定进行。

6.10 Numerical rounding

The value rounding is carried out as specified in GB/T 8170.

7　检验规则

7.1　检验分类

检验分出厂检验和型式检验，本文件只规定出厂检验的检验规则，型式检验的检验规则由供需双方商定。

7 Inspection rules

7.1 Inspection classification

The inspection is divided into factory inspection and type inspection. This document only specifies the factory inspection rules. The type inspection rules can be negotiated by the supplier and the buyer.

7.2　检验项目

产品出厂检验项目应含5.1、5.5 、5.8和5.9规定的各项内容。

7.2 Inspection items

The factory inspection items of products should include the contents specified in 5.1, 5.5, 5.8 and 5.9.

7.3　产品出厂检验抽样和批次规则

产品出厂检验抽样按表2进行。检验磁性能项目，每批产品应由同一牌号、同一炉次制成的同一规格的产品组成。检验镀层（或涂层）防护和外观尺寸项目，每批产品应由同一表面处理工艺、同一规格的产品组成。

7.3 Sampling and batch rules for product factory inspection

The product sampling of factory inspection should be carried out according to table 2. For magnetic property inspection, each batch should consist of same grade and same specification products manufactured by same furnace. For coating inspection, appearance inspection, dimension inspection, each batch should consist of same specification products manufactured by same coating process.

Table 2 Sampling rules for product factory inspection

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No. | Inspection items | Sampling rules | Inspection requirements | Inspection methods |
| 1 | Magnetic properties | GB/T 2828.1—2012 Special inspection level S-2, Primary sampling plan for normal inspection | 5.1（Table 1） | 6.1 |
| 2 | Coating quality | ≥2 pieces/batch | 5.5 | 6.5 |
| 3 | Appearance quality | GB/T 2828.1—2012 General inspection levelⅠ, Primary sampling plan for normal inspection | 5.8 | 6.8 |
| 4 | Dimension | GB/T 2828.1—2012 General inspection levelⅠ, Primary sampling plan for normal inspection | 5.9 | 6.9 |

7.4　检验结果判定及重复检验规则

产品检验中的每项均合格时，则该批产品为合格；如有不合格项，则从该批产品中取双倍试样对不合格项目进行重复检验，重复检验时，所有重复检验项合格，则该批产品合格；若重复检验时仍存在不合格，则判定该批产品为不合格。

外观质量检验允许逐件检验。

7.4 Judgment of inspection results and recheck rule

If each inspection item of the samples is qualified, the batch of products is qualified. If any inspection item is unqualified, double samples should be taken from the unqualified batch for repeated inspection on unqualified item. During repeated inspection, if all repeated inspection items are qualified, the batch of products is qualified, if there are still unqualified items, the batch of products will be judged as unqualified.

For appearance quality inspection, it is allowed to be inspected one by one.

8　包装、标志、运输、贮存及随行文件

8.1　包装、标志、运输和贮存

8.1.1　产品一般以磁中性状态交货。如需方要求充磁并在合同中注明，可充磁交货。对取向方向不易辨别的产品，应标明充磁方向。

8.1.2　产品的包装、标志、运输和贮存应按GB 39176规定进行。

8 Packaging, signs, transportation, storage and accompanying files

8.1 Packaging, signs, transportation, storage

8.1.1 Products are generally delivered in a magnetically neutral state. If the buyer requires magnetization and indicates in the contract, products can be delivered after magnetization. For products whose orientation direction is difficult to distinguish, the direction of magnetization should be indicated.

8.1.2 The packaging, signs, transportation, storage of the products should comply with regulations in GB 39176.

8.2　随行文件

每批产品应附有随行文件，包括但不限于：

a) 产品合格证（包括供方信息、产品信息、本文件编号、出厂日期或包装信息）；

b) 质量证明书（包括制造商名称、产品名称、牌号、状态及规格、批号、净重和件数、本文件编号、出厂日期或包装日期）；

c) 各项分析检验结果或试验报告。

8.2 Accompanying files

Each batch of products should be attached with accompanying files, including but not limited to:

a) Product certificate (including supplier information, product information, code of this document, date of ex-factory or packaging information)

b) Quality certificate (including supplier name, product name, grade, state, specification, batch number, net weight, number of pieces, code of this document, date of ex-factory or date of packaging)

c) All inspection results or test reports

Annex A

(informative)

晶界扩散钕铁硼永磁材料的化学成分、制造工艺、磨削后永磁材料*H*cJ的变化及应用

Chemical composition, manufacturing process, application of GBD NdFeB PM materials and change *H*cJ of permanent magnet materials after grinding

A.1 化学成分

晶界扩散钕铁硼永磁材料是以金属间化合物Nd2Fe14B为基础的永磁材料，主要成分为钕（Nd）、铁（Fe）、硼（B）。为了获得不同性能，材料中的钕可用部分镨（Pr）、铽（Tb）、镝（Dy）等稀土元素替代，铁可被钴（Co）、铝（Al）等金属元素替代。永磁材料中重稀土的含量由表面到中心减小，在钕铁硼主相晶粒表层形成高重稀土含量的壳层。

A.1 Chemical composition

GBD NdFeB PM materials, which are mainly composed of neodymium (Nd), iron (Fe) and boron (B), is based on the intermetallic compound Nd2Fe14B. To obtain different magnetic properties, neodymium in the materials can be partially substituted by praseodymium (Pr), terbium (Tb), dysprosium (Dy) or other rare earth elements, iron (Fe) can be partially substituted by cobalt (Co), aluminium (Al) or other metallic element. The content of heavy rare earth decreases from surface to center in permanent magnet materials。A shell with high content of heavy rare earth is formed on the surface of NdFeB main phase grains.

晶界扩散钕铁硼永磁材料的化学成分范围见表A.1。

The composition ranges of GBD NdFeB PM materials are shown in Table A.1.

Table A.1 The composition of GBD NdFeB PM materials wt.%

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Composition | Total content of rare earth | B | Total content of the other elements (Cu, Al, Co, Ga, Zr, Nb etc.) | Fe |
| Content (mass fraction) | [28,35],  Wherein, the total content of Dy and Tb is (0,8] | [0.8,1.3] | (0,5] | balance |

A.2 制造工艺

晶界扩散钕铁硼永磁材料的通常工艺流程如图A.1所示，晶界扩散工艺的主要工序包括：

（1）前处理，采用酸洗、清水洗及喷砂等物理和/或化学方法，去除永磁材料表面的污物和氧化膜。

A.2 Manufacturing process

The general manufacturing process flow of GBD NdFeB PM materials is shown in Figure A.1. The main processes of GBD process include:

(1) Pretreatment

Physical and / or chemical methods such as acid pickling, water washing and sand blasting are used to remove impurities and oxide layer on the surface of permanent magnet materials.

（2）包覆工序，采用物理或化学的方法将扩散源附着在永磁材料表面。常见的扩散源为重稀土（Dy和Tb）的单质、合金、化合物或其混合物。常用的包覆工艺包括：①采用物理气相沉积（PVD）工艺在表面沉积重稀土单质或合金的薄膜；②采用喷涂、印刷、浸渍等工艺将重稀土化合物粉末与溶剂配置的浆料涂覆到表面，经烘干后形成粉末状涂覆层；③采用电泳、电镀、化学镀等工艺在表面制得重稀土金属或化合物的膜层。

(2) Coating process

The diffusion source is coated on the surface of permanent magnet materials by physical or chemical methods. Common diffusion sources are heavy rare earth (Dy and Tb) simple substances, alloys, compounds or mixtures of these substances. Common coating technology include: ①Thin films of heavy rare earth metals or alloys are deposited on the surface by physical vapor deposition (PVD). ②The slurry composed of heavy rare earth compound powder and solvent is coated on the surface by spraying, printing and dipping, and the powder coating layer is formed after drying. ③Films of heavy rare earth metals or compounds are coated on the surface by electrophoresis, electroplating and electroless plating.

(3）扩散工序，在真空环境下，采用高温热处理工艺，使重稀土元素沿晶界从磁体表面扩散进入内部，在主相晶粒表面形成高重稀土含量的壳层，提升永磁材料HcJ。在永磁材料厚度小于8mm的情况下，采用镝（Dy）扩散，可使得永磁材料的HcJ提升4 kOe～6 kOe，Br下降0～0.3 kGs；采用铽（Tb）扩散，可使得永磁材料的HcJ提升8 kOe～11 kOe，Br下降0～0.3 kGs。

(3) Diffusion process

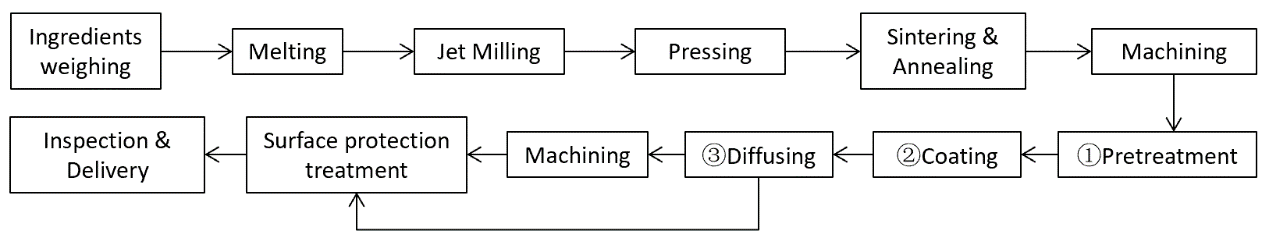
By high-temperature heat treatment process in the vacuum environment, the heavy rare earth elements diffuse into the interior of the magnet along the grain boundary from surface of magnet, and a shell with high heavy rare earth content on the surface of the main phase grain is formed, which improve *H*cJ of the permanent magnet material. When the thickness of permanent magnet material is less than 8mm, *H*cJ increases 4-6 kOe and Br decreases 0-0.3 kGs by dysprosium (Dy) diffusion, *H*cJ increases 8-10 kOe and Br decreases 0-0.3 kGs by terbium (Tb) diffusion.

Figure. A.1 The general manufacturing process flow of GBD NdFeB PM materials.

A.3 磨削后永磁材料HcJ的变化

采用磁化方向扩散并在磁化方向双面磨削的工艺，获得不同厚度的永磁材料；测量内禀矫顽力，获得磨削后永磁材料内禀矫顽力与厚度（双面磨削厚度）的关系，以此来表征磨削后永磁材料HcJ的变化，如图A.2所示。

A.3 *H*cJ change of permanent magnet material after grinding

Permanent magnetic materials with different thicknesses were obtained by diffusion and double-sided grinding in the magnetization direction. The intrinsic coercivity is measured to obtain the relationship between the intrinsic coercivity and thickness (thickness of double-sided grinding) of the permanent magnet material after grinding, so as to characterize the change of HcJ of the permanent magnet material after grinding, as shown in Figure A.2.

取磁化方向厚度为8 mm的烧结钕铁硼永磁材料，采用铽沿着8 mm两个磁化面向内部方向进行晶界扩散处理。将晶界扩散后的永磁材料垂直于8 mm方向的两个磁化面同步磨削去相同的尺寸，测试磨削后不同厚度永磁材料的磁性能。磨削后永磁材料的内禀矫顽力与厚度的关系如图A.2所示，该结果以厚度为8 mm的永磁材料为例表征了表面到中心位置内禀矫顽力的变化趋势。从结果可以得出，随着双面磨削量的增加，内禀矫顽力逐渐降低。当磨削后的永磁材料厚度为1 mm时，内禀矫顽力比磨削前8 mm厚的永磁材料内禀矫顽力下降了，但是仍然比扩散前烧结钕铁硼永磁材料的内禀矫顽力大幅提升。这表明在厚度为8 mm的晶界扩散永磁材料中心1 mm的区域内，已经有重稀土铽扩散进入，使得永磁材料内禀矫顽力提升。

For sintered NdFeB permanent magnet material with a thickness of 8 mm in the magnetization direction, terbium GBD treatment was carried out on two surfaces of the magnet perpendicular to the magnetization direction, which makes the heavy rare earth elements diffuse into the interior of the magnet along the magnetization direction. After grain boundary diffusion, the same thickness was ground on both sides of the magnet perpendicular to the magnetization direction. The magnetic properties of permanent magnet materials with different thickness after grinding were measured. The relationship between intrinsic coercivity and thickness of permanent magnet material after grinding is shown in Figure A.2. The results take the permanent magnet material with a thickness of 8 mm as an example to characterize the variation trend of intrinsic coercivity from surface to center. The results show that the intrinsic coercivity decreases with the increase of double-sided grinding. When the thickness of the ground permanent magnet material is 1 mm, the intrinsic coercivity is lower than that of the permanent magnet material before grinding, but it is still significantly higher than that of the sintered NdFeB permanent magnet material before diffusion. This shows that heavy rare earth terbium has diffused into the region 1 mm in the center of the GBD material with a thickness of 8 mm, which improves the intrinsic coercivity of the permanent magnet material.



晶界扩散钕铁硼磨削后永磁材料的内禀矫顽力与厚度关系

Figure. A.2 The relationship between the intrinsic coercivity and thickness of the permanent magnet material after grinding.

A.4 应用

晶界扩散钕铁硼永磁材料具有节省重稀土资源、高矫顽力的特点，可广泛地应用于新能源汽车、变频空调、3C电子、工业电机等领域。

A.4 Application

GBD NdFeB PM materials have the characteristics of saving heavy rare earth resources and high coercivity. They can be widely used in new energy vehicles, Inverter air conditioner, 3C electronics, industrial motors and other fields.

Annex B

(informative)

晶界扩散钕铁硼永磁材料的简化牌号

The brief grades of GBD NdFeB PM materials

B.1　简化牌号表示方法

晶界扩散钕铁硼永磁材料的简化牌号由材料制造特征和磁性能参数组成。第一部分G，表示材料制造特征晶界扩散工艺；第二部分为永磁材料最大磁能积(BH)max的标称值（单位为MGOe）；第三部分为品种，按4.1划分。

简化牌号示例：G50EH表示材料制造特征晶界扩散工艺，最大磁能积(BH)max的标称值为50MGOe，内禀矫顽力HcJ的最小值为30kOe。

B.1 The representation of brief grades

The brief grade of GBD NdFeB PM material is composed of material manufacturing characteristics and magnetic property parameters. The first part “G” represents GBD process. The second part is the nominal value of the maximum energy product (BH) max in MGOe. The third part represents categories which are classified according to 4.1.

Taking G50EH as an example, it indicates that the material manufacturing characteristic is GBD process, the nominal value of the maximum magnetic energy product (BH) max is 50MGOe and the minimum value of the intrinsic coercivity *H*cJ is 30kOe.

B.2　简化牌号与牌号的对照见表B.1。

B.2 The comparison between brief grades and grades is shown in table B.1.

Table B.2 The comparison between brief grades and grades

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No. | Brief grades | Grades | No. | Brief grades | Grades |
| 1 | G52H | G-NdFeB 415/135 | 19 | G28EH | G-NdFeB 225/239 |
| 2 | G55H | G-NdFeB 440/135 | 20 | G30EH | G-NdFeB 240/239 |
| 3 | G57H | G-NdFeB 455/135 | 21 | G33EH | G-NdFeB 265/239 |
| 4 | G45SH | G-NdFeB 360/159 | 22 | G35EH | G-NdFeB 280/239 |
| 5 | G48SH | G-NdFeB 380/159 | 23 | G38EH | G-NdFeB 300/239 |
| 6 | G50SH | G-NdFeB 400/159 | 24 | G40EH | G-NdFeB 320/239 |
| 7 | G52SH | G-NdFeB 415/159 | 25 | G42EH | G-NdFeB 335/239 |
| 8 | G55SH | G-NdFeB 440/159 | 26 | G45EH | G-NdFeB 360/239 |
| 9 | G33UH | G-NdFeB 265/199 | 27 | G48EH | G-NdFeB 380/239 |
| 10 | G35UH | G-NdFeB 280/199 | 28 | G50EH | G-NdFeB 400/239 |
| 11 | G38UH | G-NdFeB 300/199 | 29 | G28TH | G-NdFeB 225/279 |
| 12 | G40UH | G-NdFeB 320/199 | 30 | G30TH | G-NdFeB 240/279 |
| 13 | G42UH | G-NdFeB 335/199 | 31 | G33TH | G-NdFeB 265/279 |
| 14 | G45UH | G-NdFeB 360/199 | 32 | G35TH | G-NdFeB 280/279 |
| 15 | G48UH | G-NdFeB 380/199 | 33 | G38TH | G-NdFeB 300/279 |
| 16 | G50UH | G-NdFeB 400/199 | 34 | G40TH | G-NdFeB 320/279 |
| 17 | G52UH | G-NdFeB 415/199 | 35 | G42TH | G-NdFeB 335/279 |
| 18 | G54UH | G-NdFeB 430/199 | 36 | G45TH | G-NdFeB 360/279 |

Annex C

(informative)

晶界扩散钕铁硼永磁材料的磁性能温度系数

Temperature coefficient of magnetic properties of GBD NdFeB PM materials

表C.1为晶界扩散钕铁硼永磁材料磁性能温度系数。

Temperature coefficient of magnetic properties of GBD NdFeB PM materials are shown in table C.1.

Table C.1 Temperature coefficient of magnetic properties of GBD NdFeB PM materials

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Category | Base temperature (℃) | Upper limit temperature (℃) | *α* (*B*r), (%/K)  Reference value | *α* (*H*cJ), (%/K)  Reference value |
| H | 20 | 100 | -0.115 | -0.66 |
| 120 | -0.125 | -0.62 |
| SH | 20 | 100 | -0.115 | -0.61 |
| 150 | -0.125 | -0.55 |
| UH | 20 | 100 | -0.110 | -0.56 |
| 180 | -0.130 | -0.48 |
| EH | 20 | 100 | -0.105 | -0.55 |
| 200 | -0.130 | -0.46 |
| TH | 20 | 100 | -0.095 | -0.51 |
| 200 | -0.120 | -0.43 |

Annex D

(informative)

晶界扩散钕铁硼永磁材料的其它物理性能

Other physical properties of GBD NdFeB PM materials

表D.1为晶界扩散钕铁硼永磁材料的其它物理性能，供设计选材时参考，不作验收依据。

Other physical properties of GBD NdFeB PM materials are shown in table D.1, which is used as a reference for design and material selection, and is not used as a basis for acceptance.

Table D.1 Other physical properties of GBD NdFeB PM materials

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| No. | Parameter | | Unit | Reference value |
| 1 | Density | | g/cm3 | 7.60 |
| 2 | Vickers hardness | | HV | 500 |
| 3 | Compressive strength | | MPa | 1000 |
| 4 | Bending strength | | MPa | 200 |
| 5 | Young’s modulus | | GPa | 160 |
| 6 | Specific heat capacity | | J/(kg·K) | 440 |
| 7 | Thermal conductivity (20℃) | | W/(m·K) | 7.5 |
| 8 | Thermal expansion coefficient | C∥(20～100℃) | 10-6/K | 5 |
| C⊥(20～100℃) | 10-6/K | -1 |
| 9 | Resistivity | C∥(20℃) | μΩ·m | 1.5 |
| C⊥(20℃) | μΩ·m | 1.3 |
| 10 | Maximum operating temperature | H | ℃ | 120 |
| SH | ℃ | 150 |
| UH | ℃ | 180 |
| EH | ℃ | 200 |
| TH | ℃ | 230 |

Annex E

(informative)

晶界扩散钕铁硼永磁体的磁偶极矩一致性、尺寸及形位偏差

Magnetic dipole moment consistency, dimension and geometric tolerances of GBD NdFeB PM

E.1 表E.1为晶界扩散钕铁硼永磁体磁偶极矩一致性。

E.1 Magnetic dipole moment consistency of GBD NdFeB PM is shown in table E.1.

Table E.1 Magnetic dipole moment consistency of GBD NdFeB PM

|  |  |
| --- | --- |
| The mass of permanent magnet / m | Magnetic dipole moment consistency |
| m≥10g | ≤4% |
| 10g>m≥5g | ≤6% |
| 5g>m≥0.5g | ≤8% |
| m<0.5g | ≤12% |

E.2　表E.2为晶界扩散钕铁硼永磁体尺寸及形位偏差。

E.2 Dimension and geometric tolerances of magnetic properties of GBD NdFeB PM are shown in table E.2.

Table E.2 Dimension and geometric tolerances of magnetic properties of GBD NdFeB PM

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Dimension range  (mm) | Deviation value | | | | | | |
| Square | | | | Segment | | |
| Parallelism  (mm) | Flatness for key surface  (mm) | Verticality  (mm) | size deviation  (mm) | Internal diameter / External diameter  (mm) | Angle | Chord length  (mm) |
| ≤10 | ∥0.03 | *□* 0.02 | ⊥0.05 | ±0.03 | ±0.05 | ±1° | ±0.05 |
| ＞10～20 | ∥0.03 | *□* 0.02 | ⊥0.10 | ±0.05 | ±0.10 | ±30′ | ±0.10 |
| ＞20～50 | ∥0.05 | *□* 0.03 | ⊥0.15 | ±0.10 | ±0.15 | ±30′ | ±0.15 |
| ＞50～80 | ∥0.10 | *□* 0.05 | ⊥0.20 | ±0.15 | ±0.20 | ±20′ | ±0.20 |

1. *H*k*为退磁曲线磁极化强度为0.9B*r*时对应的磁场强度。*

   *H*k *is the magnetizing field strength corresponding to the magnetic polarization with a value of 0.9 B*r *in the demagnetizing curve.* [↑](#footnote-ref-1)