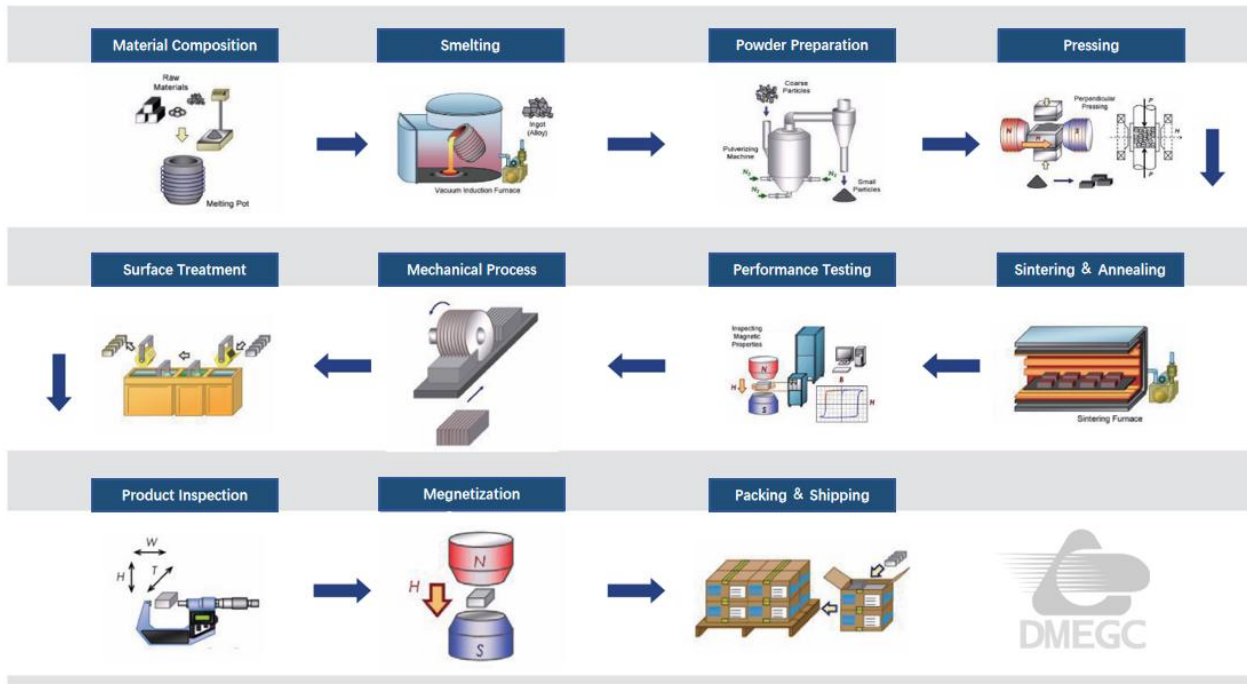
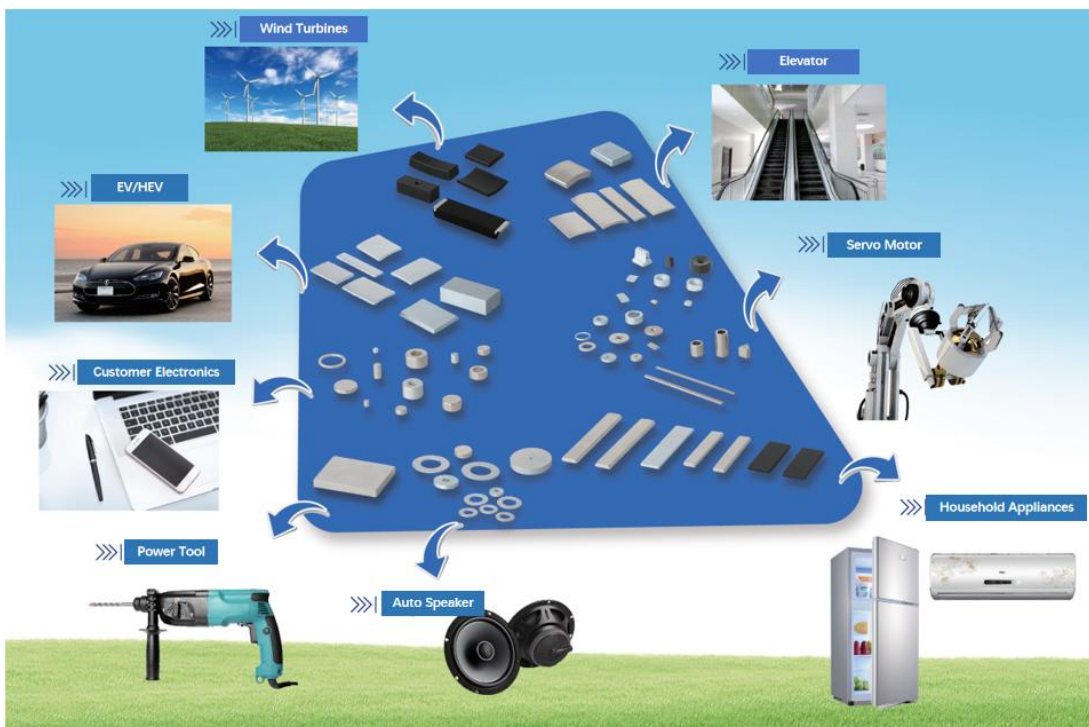


Production Process



Main applications of sintered NdFeB magnets

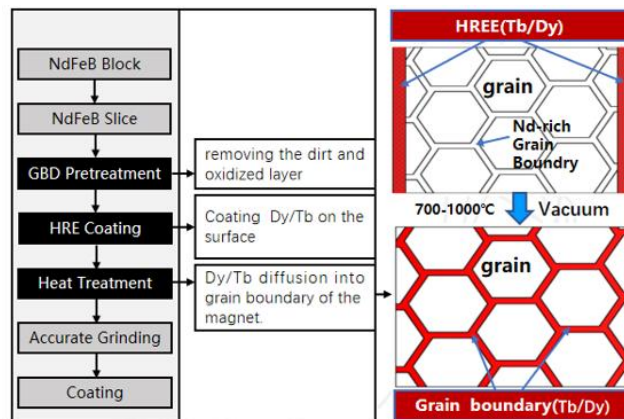


Different NdFeB Production Technologies

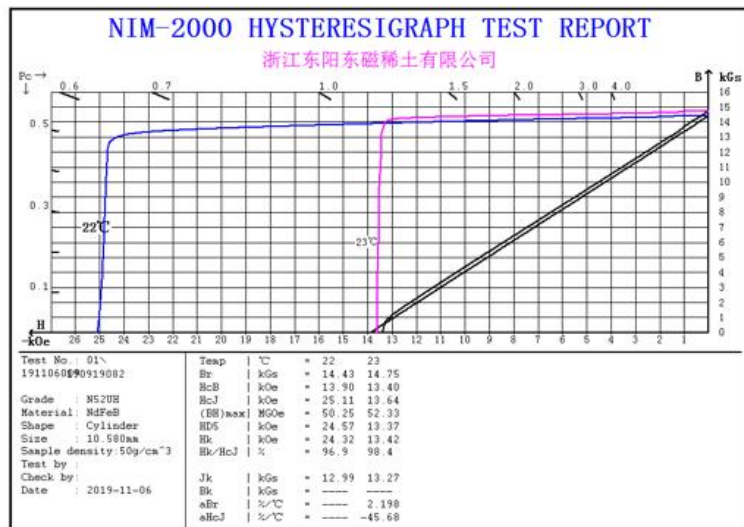
1. GBD - Grain Boundary Diffusion

GBD technology is the most effective method to enhance magnetic performance with small amount of heavy rare earth elements. The process is carried out between the machining process and surface treatment process. The process and mechanism diagram are shown in Graph 1.

Putting the material containing HRE (Dy or Tb) onto the surface of NdFeB magnet, the HRE will diffuse from surface to the inner space of the magnet during the high temperature treatment. The grain boundary will be reached with Dy or Tb and the coercivity of the magnet enhanced. The BH curves are shown in Graph 2, significant increase of the coercivity of the magnet after GBD treatment is visible.



Graph 1. Process and mechanism diagram of GBD process



Graph 2. Comparison of magnetic properties before and after GBD process

GBD process can be realized in different ways depending on the geometry-shape of magnet. DMEGC possess the most mature GBD technologies:

1. Spray technology
2. Adhesion technology and
3. Physical Vapor Deposition - PVD technology

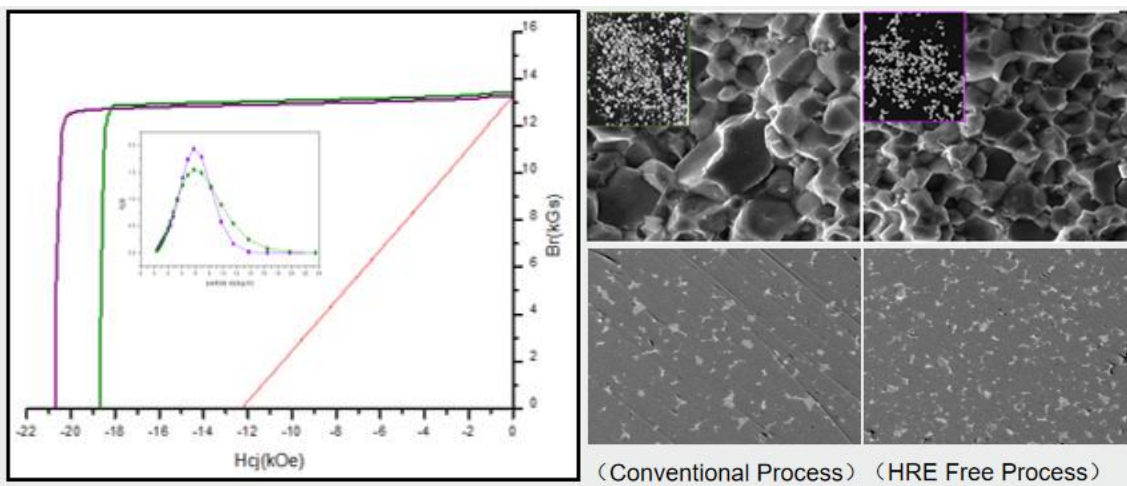
DMEGC can produce magnets using both Dy and Tb - GBD, depending on material grade.

Advantages of GBD Technology

- 1) Significant increase of the coercivity which cannot be achieved by conventional process able preparation of the materials resistant to the very high temperature - ultrahigh grades.
- 2) Significant reduction of heavy rare earth elements and therefore cost. Magnets are more environmentally friendly.

2. Heavy Rear Earth – HRE Technology

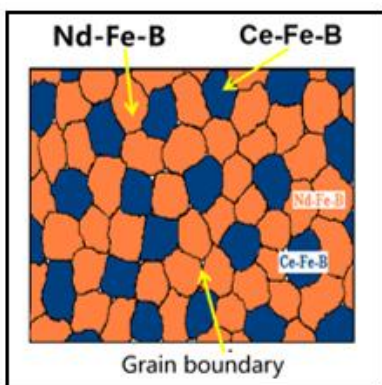
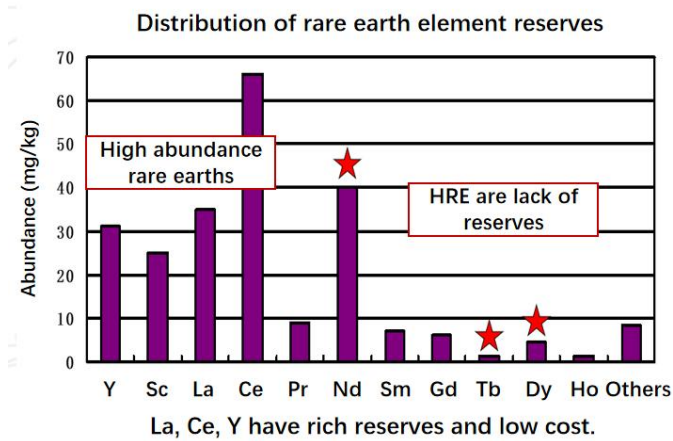
There are two types of the HRE Technology, Less HRE & HRE Free Technology. Aim of these technologies is to reduce the amount of HRE in magnets, on this may cost will be reduced and magnets will be more environmentally friendly. Less HRE & HRE Free Technology is carried out by properly composition designing of material, refining particle size, and improving distribution of magnetic powder, controlling the grain size of material and distribution of grain boundary, to achieve high performance without or using less heavy rare earth elements (Dy, Tb). The equivalent performance will be obtained compare with conventional heavy rare earth process by using less amount of Dy or Tb. This technology is suitable to produce mid and low material grades.



Graph 3.

3. Ce Replacement Technology

The relatively cheap and high-abundance rare earth element Cerium-Ce, see the Graph 4, is used to partially replace Nd in the material, see the Graph 5. On this way reduction of Nd amount in the material will lead to the cost saving as well as to the realization of the balanced utilization of rare earth elements.



Microstructure diagram

Coating Technology

Sintered NdFeB magnets are very sensitive to corrosion and need additional protection of the surface. Almost all magnets will be surface treated before they are sent to customers. There are several types of the coatings which are used depending on the different corrosion resistance requirements, such as surface passivation, Ni, Ni-Cu-Ni, Zn, epoxy, etc. The characteristics of standard DMEGC coatings are shown in Table 1.

Table 1. Coating characteristics

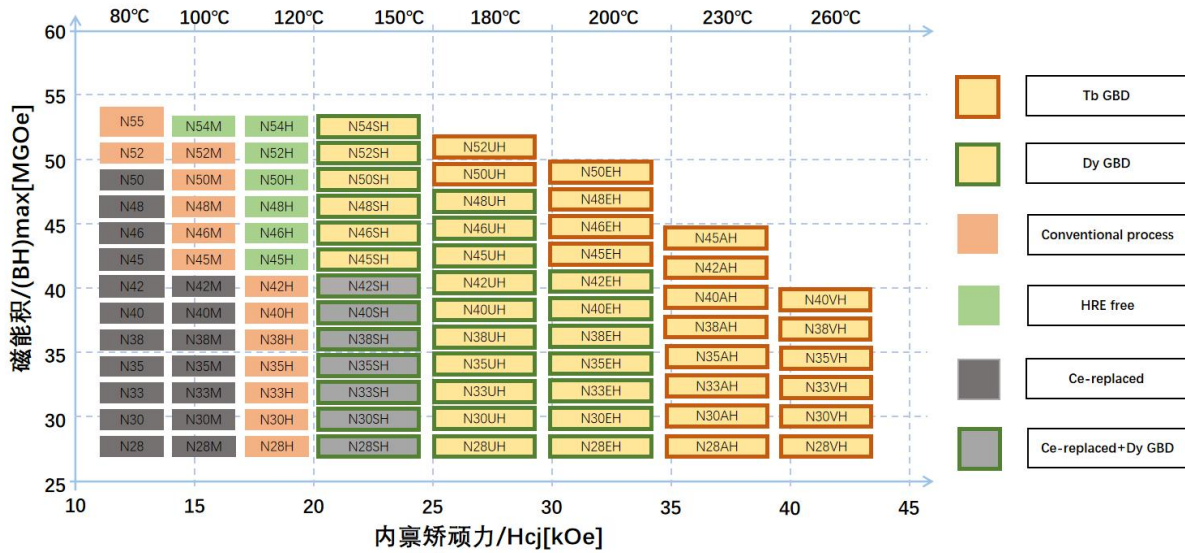
Surface treatment types	Thickness(μ m)	Consistency in thickness	Impact on magnetic properties	Neutral salt spray testing(Hr)	PCT testing(Hr)	Abrasion performance	Soak performance	Circumstance applied	Production cost
Passivation	—	super	less	—	—	inferior	super	instant protection	medium
Bluing	—	super	little	—	—	inferior	super	instant protection	low
White Zn	≥ 4	medium	little	≥ 24	—	inferior	super	dry	low
Color Zn	≥ 4	medium	little	≥ 48	—	inferior	super	dry	low
Ni	≥ 10	inferior	large	≥ 24	≥ 300	medium	medium	humid	medium
Ni-Cu-Ni	≥ 12	inferior	large	≥ 48	≥ 500	medium	medium	humid	medium
Ni-electrolytic Ni	≥ 15	super	large	≥ 72	≥ 500	super	medium	humid	high
Ni-Au	≥ 10	inferior	large	≥ 72	≥ 300	inferior	medium	ornament/electric conductivity	high
Ni-Ag	≥ 12	super	large	≥ 72	≥ 300	inferior	medium	weld/electric conductivity	high
Electrophoretic epoxy	≥ 15	super	less	≥ 96	≥ 500	worse	medium	insulation/humid	high
Spray epoxy	≥ 10	super	less	≥ 72	≥ 500	worse	medium	insulation/humid	high
Ni-Cu-epoxy	≥ 25	medium	large	≥ 120	≥ 500	worse	medium	high salt content/humid	high

Downloads

1. BH Curves

Please refer to the PDF document attachment.

2. NdFeB Grades diagram



3. NdFeB Grades magnetic performance table.

Characteristics of sintered NdFeB magnets at $23^\circ\text{C} \pm 2^\circ\text{C}$

Material Grade	Br		Hcb,min		Hcj,min		(BH)max		α_{Br}	β_{Hcj}	Tw	ρ
	T	kGs	kA/m	kOe	kA/m	kOe	kJ/m^3	MG0e	%/°C	%/°C	°C	g/cm^3
N55	1.45-1.49	14.5-14.9	836.0	≥ 10.5	955.4	≥ 12	398-414	50-52	-0.13	-0.65	80	7.5

N52	1.42-1.47	14.2-14.7	836.0	≥10.5	955.4	≥12	398-414	50-52	-0.13	-0.65	80	7.5
N50	1.39-1.44	13.9-14.4	836.0	≥10.5	955.4	≥12	382-398	48-50	-0.13	-0.65	80	7.5
N48	1.37-1.41	13.7-14.1	836.0	≥10.5	955.4	≥12	358-382	45-48	-0.13	-0.65	80	7.5
N45	1.33-1.37	13.3-13.7	836.0	≥10.5	955.4	≥12	334-358	42-45	-0.13	-0.65	80	7.5
N42	1.29-1.33	12.9-13.3	836.0	≥10.5	955.4	≥12	318-334	40-42	-0.13	-0.65	80	7.5
N40	1.26-1.29	12.6-12.9	859.9	≥10.8	955.4	≥12	302-326	38-40	-0.13	-0.65	80	7.5
N38	1.22-1.26	12.2-12.6	859.9	≥10.8	955.4	≥12	279-310	35-38	-0.13	-0.65	80	7.5
N35	1.17-1.22	11.7-12.2	859.9	≥10.8	955.4	≥12	263-286	33-35	-0.13	-0.65	80	7.5
N33	1.14-1.17	11.4-11.7	859.9	≥10.8	955.4	≥12	239-270	30-33	-0.13	-0.65	80	7.5
N30	1.08-1.14	10.8-11.4	859.9	≥10.8	955.4	≥12	223-246	28-30	-0.13	-0.65	80	7.5
N55M	1.45-1.49	14.5-14.9	1019.1	≥12.8	1114.6	≥14	398-415	50-52	-0.13	-0.65	100	7.5
N52M	1.42-1.47	14.2-14.7	1019.1	≥12.8	1114.6	≥14	398-415	50-52	-0.13	-0.65	100	7.5
N50M	1.39-1.44	13.9-14.4	1011.1	≥12.7	1114.6	≥14	382-399	48-50	-0.13	-0.65	100	7.5
N48M	1.41-1.45	13.7-14.1	995.2	≥12.5	1114.6	≥14	358-384	45-48	-0.13	-0.65	100	7.5
N45M	1.37-1.41	13.3-13.7	971.3	≥12.2	1114.6	≥14	334-361	42-45	-0.13	-0.65	100	7.5
N42M	1.33-1.37	12.9-13.3	955.4	≥12.0	1114.6	≥14	318-338	40-42	-0.13	-0.65	100	7.5
N40M	1.29-1.33	12.6-12.9	939.5	≥11.8	1114.6	≥14	302-322	38-40	-0.13	-0.65	100	7.5
N38M	1.26-1.29	12.2-12.6	915.6	≥11.5	1114.6	≥14	279-307	35-38	-0.13	-0.65	100	7.5
N35M	1.22-1.26	11.7-12.2	875.8	≥11.0	1114.6	≥14	263-285	33-35	-0.13	-0.65	100	7.5
N33M	1.17-1.22	11.4-11.7	836.0	≥10.5	1114.6	≥14	239-263	30-33	-0.13	-0.65	100	7.5
N30M	1.14-1.17	10.8-11.4	796.2	≥10.0	1114.6	≥14	223-240	28-30	-0.13	-0.65	100	7.5
N55H	1.45-1.49	14.5-14.9	1099.5	≥13.8	1353.5	≥17	398-420	50-52	-0.125	-0.62	120	7.5
N52H	1.42-1.47	14.2-14.7	1074.8	≥13.5	1353.5	≥17	398-420	50-52	-0.125	-0.62	120	7.5
N50H	1.39-1.44	13.9-14.4	1035.0	≥13.0	1353.5	≥17	382-398	48-50	-0.125	-0.62	120	7.5
N48H	1.37-1.41	13.7-14.1	1011.1	≥12.7	1353.5	≥17	358-383	45-48	-0.125	-0.62	120	7.5
N45H	1.33-1.37	13.3-13.7	971.3	≥12.2	1353.5	≥17	334-361	42-45	-0.125	-0.62	120	7.5
N42H	1.29-1.33	12.9-13.3	955.4	≥12.0	1353.5	≥17	318-338	40-42	-0.125	-0.62	120	7.5
N40H	1.26-1.29	12.6-12.9	939.5	≥11.8	1353.5	≥17	302-322	38-40	-0.125	-0.62	120	7.5
N38H	1.22-1.26	12.2-12.6	915.6	≥11.5	1353.5	≥17	279-307	35-38	-0.125	-0.62	120	7.5
N35H	1.17-1.22	11.7-12.2	875.8	≥11.0	1353.5	≥17	263-285	33-35	-0.125	-0.62	120	7.5
N33H	1.14-1.17	11.4-11.7	836.0	≥10.5	1353.5	≥17	239-263	30-33	-0.125	-0.62	120	7.5
N30H	1.08-1.14	10.8-11.4	796.2	≥10.0	1353.5	≥17	223-240	28-30	-0.125	-0.62	120	7.5
N55SH	1.45-1.49	14.5-14.9	1099.5	≥13.8	1592.4	≥20	398-420	50-52	-0.12	-0.60	150	7.5
N52SH	1.42-1.47	14.2-14.7	1074.8	≥13.5	1592.4	≥20	398-420	50-52	-0.12	-0.60	150	7.5
N50SH	1.39-1.44	13.9-14.4	1035.0	≥13.0	1592.4	≥20	382-398	48-50	-0.12	-0.60	150	7.5
N48SH	1.37-1.41	13.7-14.1	1011.1	≥12.7	1592.4	≥20	366-383	46-48	-0.12	-0.60	150	7.5
N45SH	1.33-1.37	13.3-13.7	995.2	≥12.5	1592.4	≥20	334-368	42-46	-0.12	-0.60	150	7.5
N42SH	1.29-1.33	12.9-13.3	955.4	≥12.0	1592.4	≥20	318-338	40-42	-0.12	-0.60	150	7.5
N40SH	1.26-1.29	12.6-12.9	939.5	≥11.8	1592.4	≥20	302-322	38-40	-0.12	-0.60	150	7.5
N38SH	1.22-1.26	12.2-12.6	915.6	≥11.5	1592.4	≥20	279-307	35-38	-0.12	-0.60	150	7.5
N35SH	1.17-1.22	11.7-12.2	875.8	≥11.0	1592.4	≥20	263-285	33-35	-0.12	-0.60	150	7.5
N33SH	1.14-1.17	11.4-11.7	836.0	≥10.5	1592.4	≥20	239-263	30-33	-0.12	-0.60	150	7.5
N30SH	1.08-1.14	10.8-11.4	796.2	≥10.0	1592.4	≥20	223-240	28-30	-0.12	-0.60	150	7.5

N52UH	1.42-1.47	14.2-14.7	1074.8	≥13.5	1990.4	≥25	398-420	50-52	-0.12	-0.5	180	7.55
N50UH	1.39-1.44	13.9-14.4	1035.0	≥13.0	1990.4	≥25	382-398	48-50	-0.12	-0.5	180	7.55
N48UH	1.37-1.41	13.7-14.1	1011.1	≥12.7	1990.4	≥25	366-383	46-48	-0.12	-0.5	180	7.55
N45UH	1.33-1.37	13.3-13.7	995.2	≥12.5	1990.4	≥25	334-368	42-46	-0.12	-0.5	180	7.55
N42UH	1.29-1.33	12.9-13.3	971.3	≥12.2	1990.4	≥25	318-337	40-42	-0.12	-0.5	180	7.55
N40UH	1.26-1.29	12.6-12.9	955.4	≥12.0	1990.4	≥25	302-322	38-40	-0.12	-0.5	180	7.55
N38UH	1.22-1.26	12.2-12.6	923.6	≥11.6	1990.4	≥25	279-307	35-38	-0.12	-0.5	180	7.55
N35UH	1.17-1.22	11.7-12.2	891.7	≥11.2	1990.4	≥25	263-284	33-35	-0.12	-0.5	180	7.55
N33UH	1.14-1.17	11.4-11.7	859.9	≥10.8	1990.4	≥25	239-270	30-33	-0.12	-0.5	180	7.55
N30UH	1.08-1.14	10.8-11.4	812.1	≥10.2	1990.4	≥25	223-240	28-30	-0.12	-0.5	180	7.55
N50EH	1.39-1.44	13.9-14.4	1035.0	≥13.0	1990.4	≥25	382-398	48-50	-0.115	-0.45	200	7.6
N48EH	1.37-1.41	13.7-14.1	1011.1	≥12.7	2388.5	≥30	366-383	46-48	-0.115	-0.45	200	7.6
N45EH	1.33-1.37	13.3-13.7	995.2	≥12.5	2388.5	≥30	334-368	42-46	-0.115	-0.45	200	7.6
N42EH	1.29-1.33	12.9-13.3	971.3	≥12.2	2388.5	≥30	318-337	40-42	-0.115	-0.45	200	7.6
N40EH	1.26-1.29	12.6-12.9	939.5	≥11.8	2388.5	≥30	302-322	38-40	-0.115	-0.45	200	7.6
N38EH	1.22-1.26	12.2-12.6	923.6	≥11.6	2388.5	≥30	279-307	35-38	-0.115	-0.45	200	7.6
N35EH	1.17-1.22	11.7-12.2	883.8	≥11.1	2388.5	≥30	263-285	33-35	-0.115	-0.45	200	7.6
N33EH	1.14-1.17	11.4-11.7	859.9	≥10.8	2388.5	≥30	239-270	30-33	-0.115	-0.45	200	7.6
N30EH	1.08-1.14	10.8-11.4	820.1	≥10.3	2388.5	≥30	223-240	28-30	-0.115	-0.45	200	7.6
N45AH	1.33-1.37	13.3-13.7	979.3	≥12.3	2786.6	≥35	334-369	42-46	-0.11	-0.4	230	7.6
N42AH	1.29-1.33	12.9-13.3	971.3	≥12.2	2786.6	≥35	318-337	40-42	-0.11	-0.4	230	7.6
N40AH	1.26-1.29	12.6-12.9	955.4	≥12.0	2786.6	≥35	302-322	38-40	-0.11	-0.4	230	7.6
N38AH	1.22-1.26	12.2-12.6	923.6	≥11.6	2786.6	≥35	279-307	35-38	-0.11	-0.4	230	7.6
N35AH	1.17-1.22	11.7-12.2	883.8	≥11.1	2786.6	≥35	255-285	32-35	-0.11	-0.4	230	7.6
N33AH	1.14-1.17	11.3-11.7	851.9	≥10.7	2786.6	≥35	239-262	30-32	-0.11	-0.4	230	7.6
N30AH	1.08-1.14	10.8-11.4	820.1	≥10.3	2786.6	≥35	223-240	28-30	-0.11	-0.4	230	7.6

* α (Br), β (H ϵ j), ρ is for reference.

Explain what is α and β .

4. Testing Equipment and Method

Microchemistry



French, HORIBA JY ICP plasma spectrometer



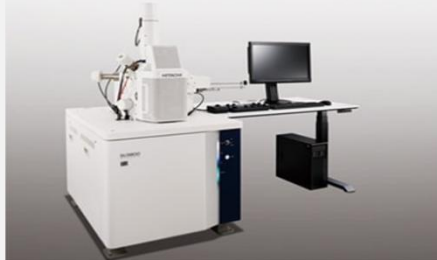
China Steel Research nano CS-2800 high frequency infrared carbon sulfur analyzer



China Steel Research nano ONH-3000 pulse infrared thermal conductivity oxygen and nitrogen hydrogen analyzer



Keyence VHX-7000 metallographic microscope



Hitachi HITACHI S-3000N Electron Microscope (SEM)



German New Patek (SYMPATEC GMBH) HELOS-RODOS

Magnetic performance test



China Metrology Institute-double electromagnet high temperature permanent magnet measuring instrument NIM62000TA



German Magnet-PHYSIK. Magnetic moment detection instrument (ELECTRONIC FLUXMETER EF5)



China Ningbo Canmag KCS-908PC (Magnetic declination tester)



Link Join MATS-2100RMT multi-polar magnetic ring

Reliability trial



Temperature Test Box,
Japan, ESPEC SEG-021H



HAST. Highly Accelerated
Stress Test System
Japan, ESPEC EHS-212MD



High and low temperature
impact test box
Japan, ESPEC TSE-11-A

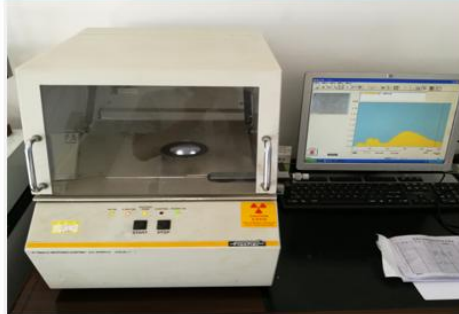


High and low temperature (hot
and humidity) test box
Japan, ESPEC GPR-2

Surface treatment test



Salt spray test chamber YT-60T



The Fisher XUL-XYM Coating thickness tester

Mechanical test



MTS (Meters) CMT5105 Series
Microcomputer control electronic
universal test machine
(Electronic universal testing machine)

- Maximum test force: 100KN
- Relative error of the test force display value: $\pm 0.5\%$
- Displacement resolution: 0.025um



Hardness tester (HVT-1000Z)



- Weighing range: 120g
- Weighing accuracy: 0.01mg
- Partic density: 0.01 m g/cm³

Electronic Density tester (DX-100E)

Dimensional test



Keyence IM 7200 image size meter



Hexagon Coordinate Measuring Machine(CMM)

- Basic software: PC-DMIS
- Data interface: STEP CAD 3D / IGES CAD 3D
- Sitting test: TESA, Switzerland
- Head test / sucker: Leitz, Germany
- **Maximum allowable value error $MPE_{\epsilon}(m)$** Maximum rate of change $<10Vs / s$: $1.5 + 3.0L / 1000$
- **Maximum allowable detection error, $MPE_{\epsilon}(m)$** : 1.5
- Location repeatability: 0.5 m