Properties and application prospects of different grades mullite

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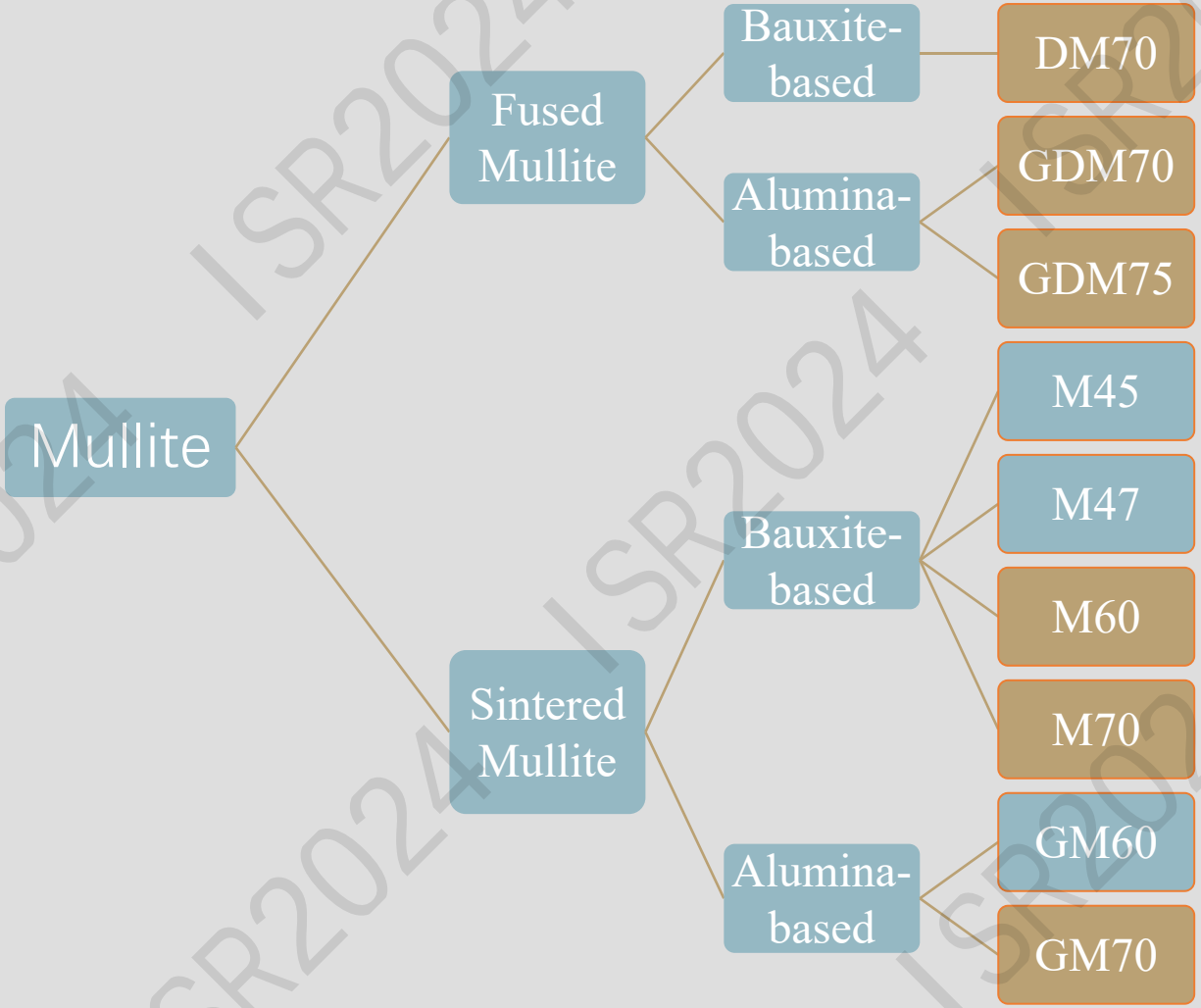
TITLE

Part 01 Development of mullite

Mullite originated from the island of Mull in United Kingdom，has excellent high temperature strength and good thermal shock resistance, is now widely used in various fields of refractory materials. With the depletion of bauxite resources, bauxite quality is becoming more and more unstable. Bauxite is listed as a national strategic resource with strict control since 2024. The application of mullite has been further developed. Therefore, more and more enterprises are inclined to use mullite due to its high quality stability, and its high temperature performance compared with some bauxite.

In the world, more and more enterprises have shifted part of focus to the research of mullite and prepare to produce high-performance and high-stability products with lower grade raw materials in the future.

Classification of mullite



Part 02 Properties of mullite

Low thermal expansion

High refractoriness

Resistance to chemical corrosion

Low creep

Low thermal conductivity

Good electrical conductivity

Good thermal shock performance

Excellent high temperature strength

Application area

Building materials

Refractory used in cement kiln, glass kiln

Ferrous metallurgy

Refractory used in steel and iron

Nonferrous metallurgy

Refractory for aluminum melting furnace

New energy

Saggar for Lithium battery

The current development bottleneck of mullite

1. Industrial production is difficult to control chemical composition precisely.

→ Excessive SiO_2 creates higher liquid phase content and reduces the comprehensive performance

→ Excessive Al_2O_3 increases the thermal expansion and reduces the thermal stability

2. Incomplete conversion

→ Silicates that have not converted to mullite crystals during sintering, which is glass phase

→ The impurity phase and/or incomplete mullite crystal is formed, which affects the high temperature performance of the material.

3. Incomplete development of mullite crystals

→ Grain size

→ Grain Density and arrangement

4. Quality can still be improved

Part 03 Performance comparison of different grades mullite

M50

M60

M65

M70

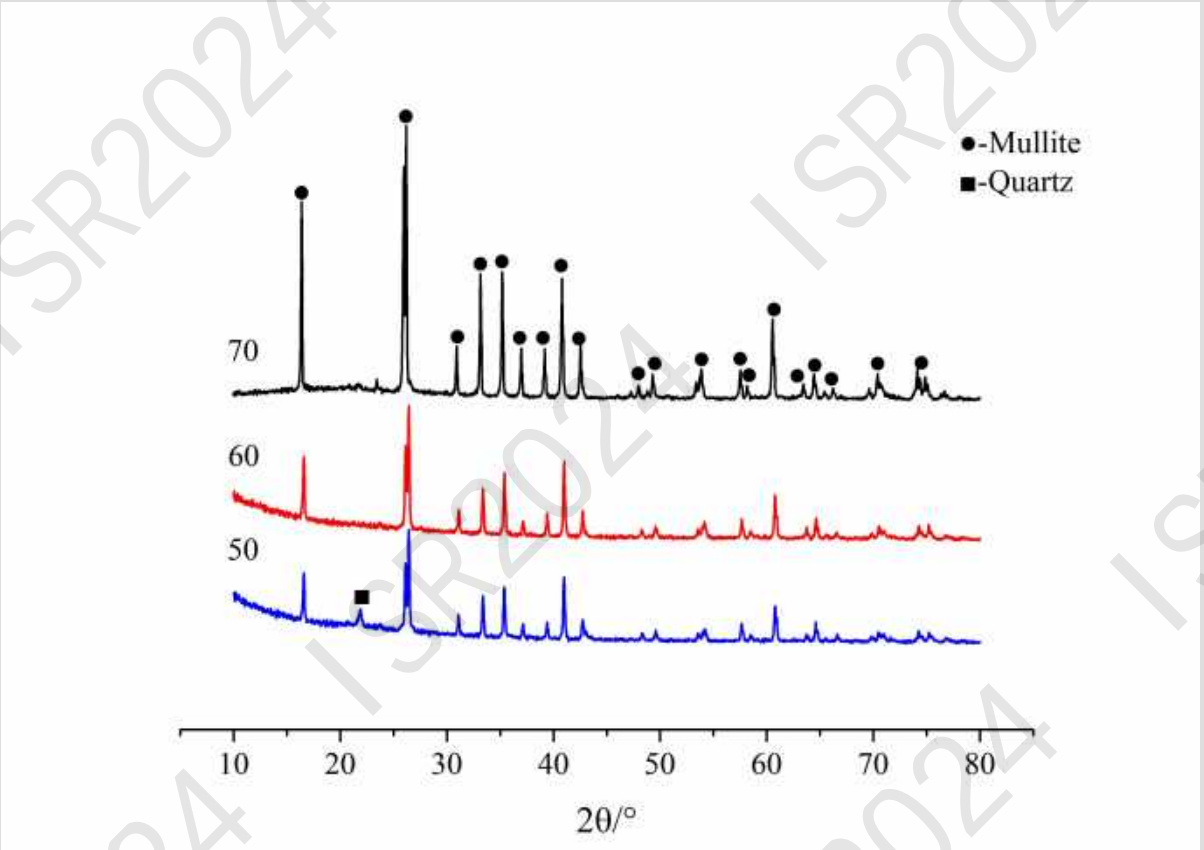
Chemical Composition

Chemical component (%)	Sintered mullite							
	M70		M65		M60		M50	
	Control value	Typical value	Control value	Typical value	Control value	Typical value	Control value	Typical value
Al_2O_3	≥68.0	68.5	≥65.0	65.5	≥60.0	61.0	≥50.0	51.0
Fe_2O_3	≤1.70	1.55	≤1.70	1.55	≤1.70	1.55	≤1.7	1.55
TiO_2	≤3.20	3.10	≤3.2	2.60	≤2.80	2.75	≤2.60	2.50
CaO+MgO	≤0.60	0.50	≤0.60	0.50	≤0.60	0.50	≤0.60	0.50
Na_2O+K_2O	≤0.50	0.40	≤0.50	0.40	≤0.50	0.40	≤0.50	0.40

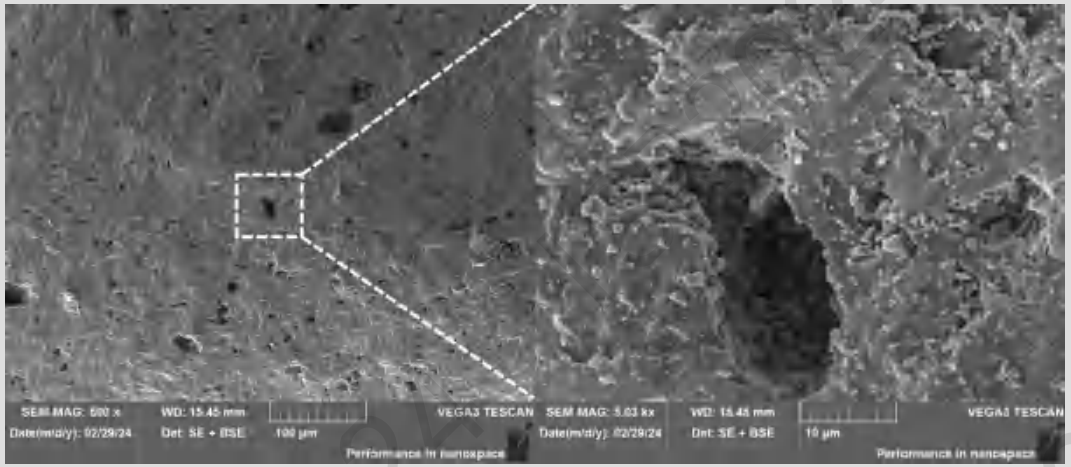
Physical properties

Physical index	Sintered mullite							
	M70		M65		M60		M50	
	Control value	Typical value	Control value	Typical value	Control value	Typical value	Control value	Typical value
Bulk density (g/cm^3)	>=2.82	2.83	>=2.73	2.75	>=2.68	2.73	>=2.56	2.62
Apparent porosity (%)	<=2.5	1.60	<=2.5	2	<=2.5	1.60	<=2.50	1.60
Water absorption (%)	<=0.80	0.55	<=0.80	0.7	<=0.80	0.55	<=0.8	0.55

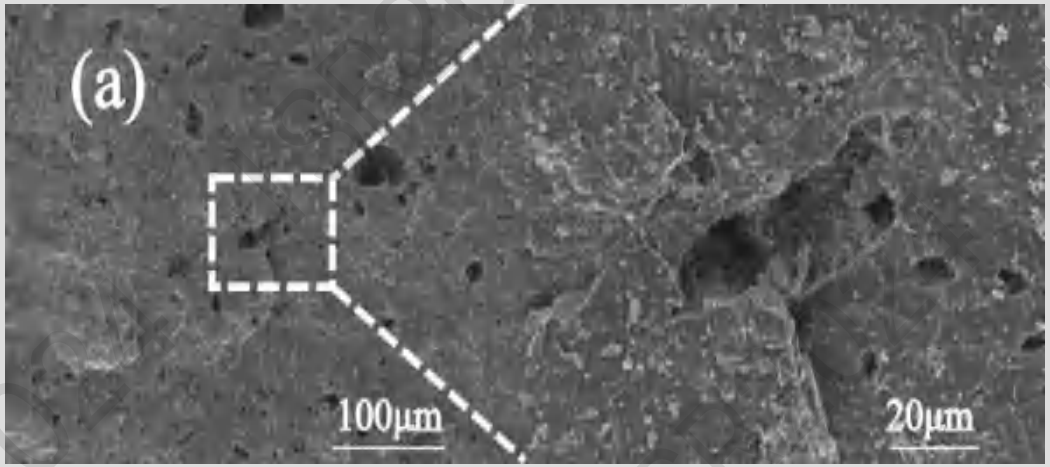
Different grades of mullite



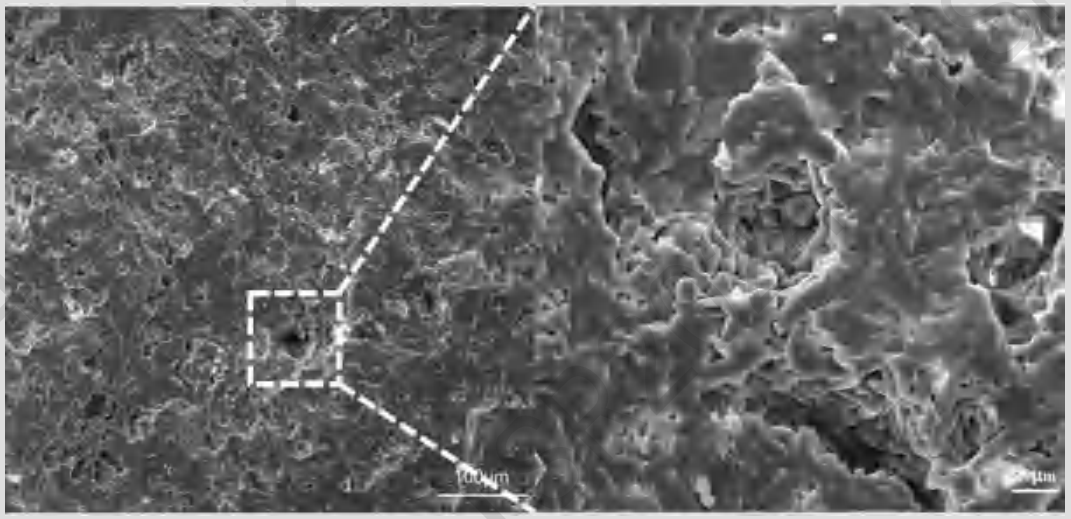
SEM



M60 Microstructure



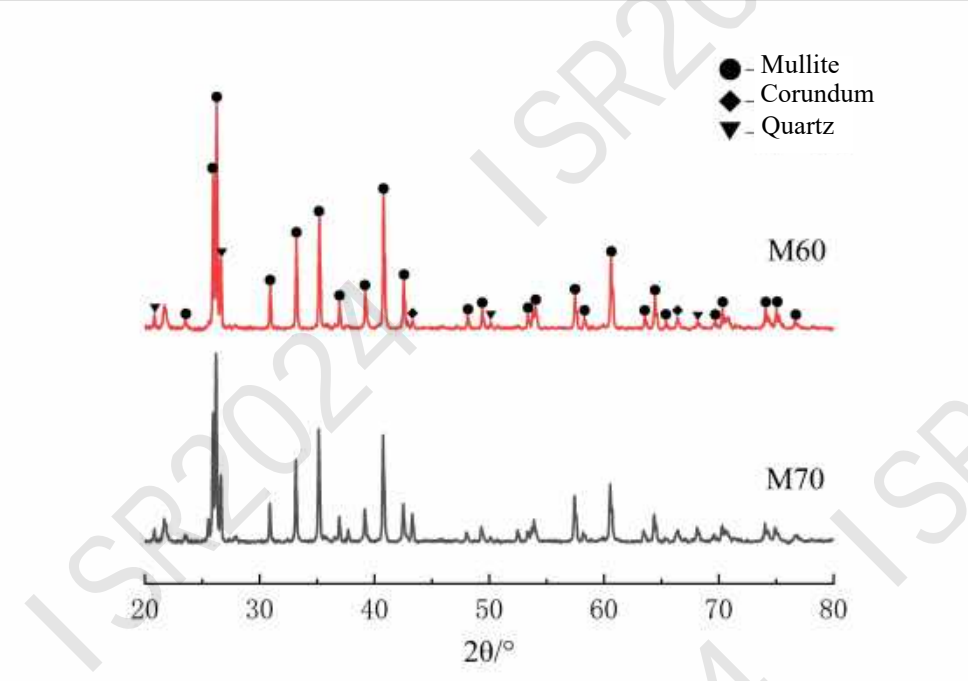
M50 Microstructure



M70 Microstructure

Compared with M70 mullite , M60 mullite has a smoother surface, a relatively small number of pores but a larger pore size. Both mullite and M60 mullite are short columnar. The size of short columnar mullite is about 3.1 μm, and the size of short columnar mullite is about 7.2 μm.

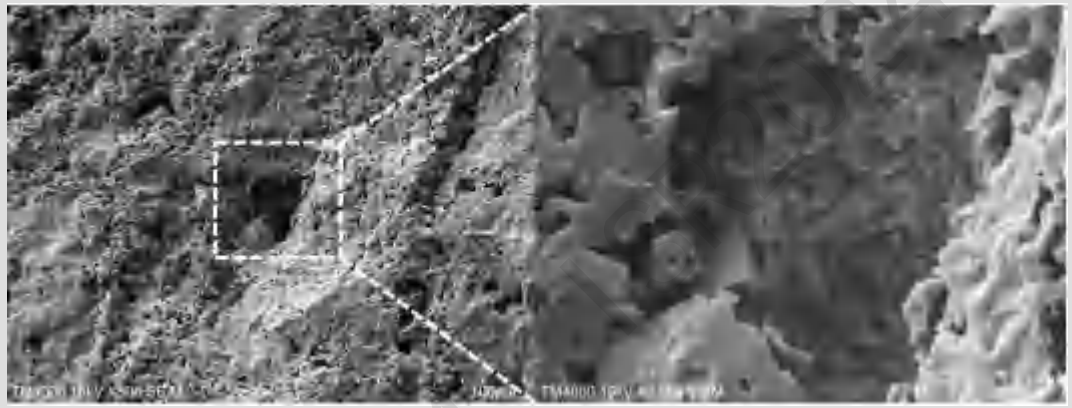
Comparison of M70/60



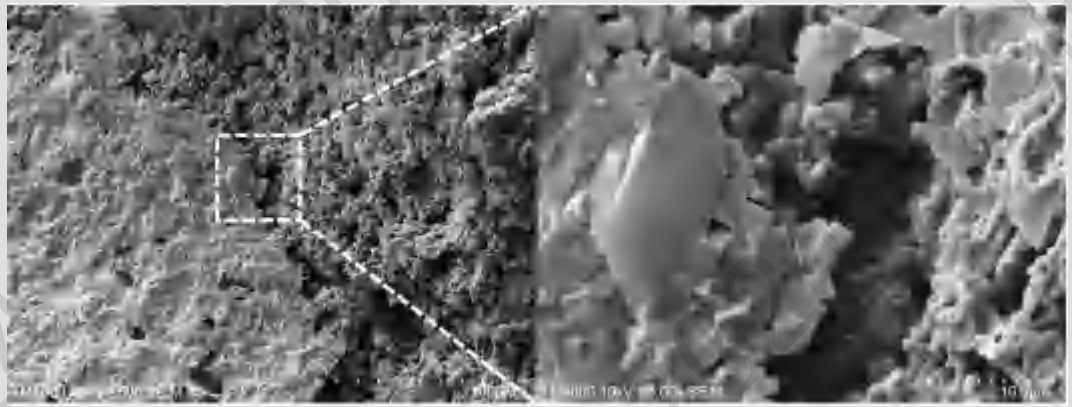
XRD patterns of different grades of mullite castables

This is XRD patterns of different grades of mullite castables firing at 1500 °C. As shown in the figure, the XRD diffraction peaks of the mullite castable samples made of M60 and M70 mullite raw materials are similar, indicating that the phase composition is basically the same. Through phase analysis, it can be seen that mullite is the main crystalline phase and corundum and quartz are subcrystalline phases. The mullite diffraction peak of M60 mullite sample is higher than that of M70 mullite sample, indicating that the crystal development of M60 mullite sample is relatively good.

M70/60 castables comparison



Microstructure of M60 mullite castable sample



Microstructure of M70 mullite castable sample

M60 mullite sample has more pores than M70 mullite sample. At the joint of fine and aggregate material, M60 mullite sample is more tightly bound and the internal structure is more dense, while M70 mullite sample has a large gap and a relatively loose structure.

	Linear change	Bulk density	Apparent porosity	Flexural strength	Compressive strength
	(%)	g/cm³	(%)	MPa	MPa
M60	-0.94	2.52	12.6	32.1	157.7
M70	-0.64	2.60	12.2	23.5	86.9

The M60 mullite and M70 mullite samples both shrink after firing. Since there is more SiO_2 in the M60 mullite sample, more liquid phase can be formed during sintering, which promotes liquid phase sintering and improves the density of the sample, resulting in greater shrinkage of the M60 mullite sample than that of the M70 mullite sample. The remaining SiO2 in the M60 mullite sample undergoes an in-situ synthesis reaction with Al2O3, which caused the sample to expand, resulting in the decrease of the bulk density of the sample and the increase of the apparent porosity. The liquid phase sintering phenomenon of M60 mullite sample is more obvious, which leads to the generation of more mullite phase, and the microstructural bonding of M60 mullite sample is closer, which improves the mechanical properties of M60 mullite castable and makes it have higher flexural strength and compressive strength.

Part 04 Application prospect analysis of different grades of mullite

1. Some low-temperature refractory application, such as the aluminum industry, Saggar industry, and the industry with high thermal shock performance requirements, can use some low-grade mullite to replace high-grade mullite, which may improve the service life of its products.

2.Some industries with refractory application in bauxite are facing problems of unstable supply of bauxite and instable quality control. They are eager to learn how to use mullite in replacing bauxite. It is a topic that need to be studied in the future.

Part 05 Conclusion

1. Besides chemical difference between different grade mullite , difference in the phase content and microstructure also leads to the difference in its performance.
2. In order to ensure the stability of end-products, most of the current users are using M70 mullite as raw materials. But some applications do not require M70 mullite and cause unnecessary over-performance and waste of resources.
3.The vast majority of foreign-funded enterprises have used M65/M60/M50 for replacement of 70 mullite. The service life of product has not been reduced but improved sometimes and it is cost saving.
4.With the increasingly tight resources supply, how to use low-grade raw materials reasonably to make high-quality product is the future trend.

Thanks for very much!

Wechat

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