Improvement of Al_2O_3-SiC-C castable by Si-N-O composite micropowder

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Background

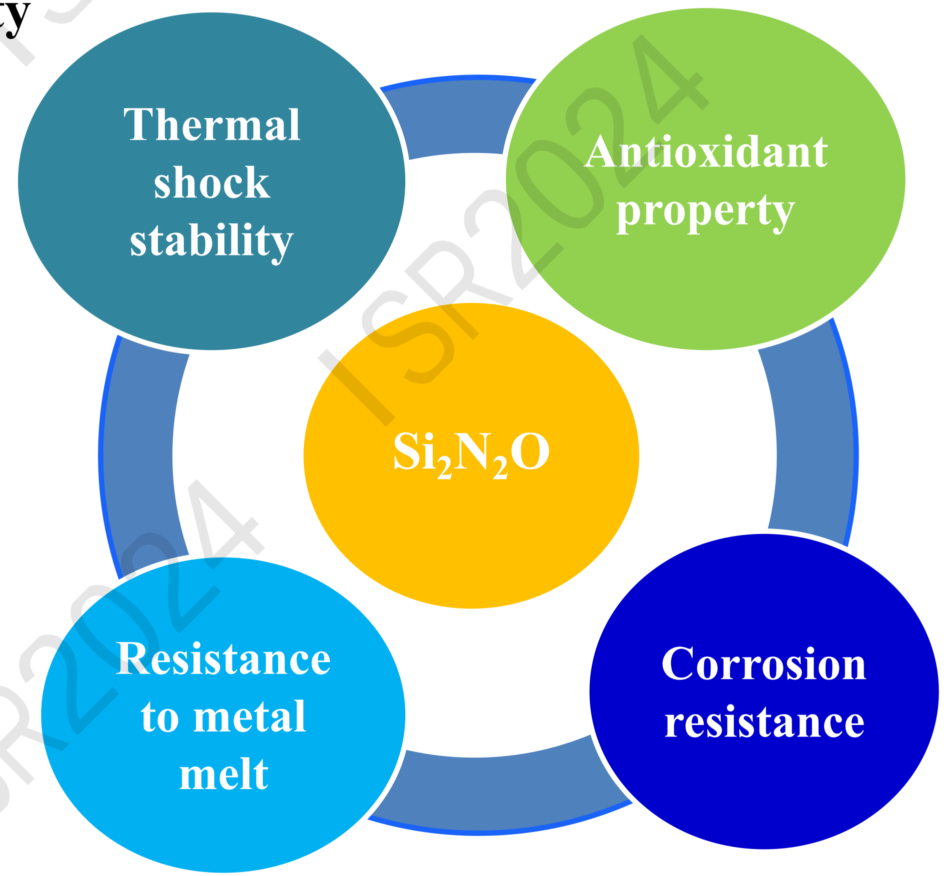
- Advances in modern blast furnace smelting technology: larger blast with higher temperatures, higher pressures, increased hot-metal temperatures, larger hot-metal outputs, and faster hot-metal flow velocities, etc.
- Al_2O_3-SiC-C (ASC) castables used as blast furnace iron runners require excellent resistance to erosion, slag corrosion, thermal shock, and oxidation.

Background

Si_3N_4(Silicon Nitride)

Good corrosion resistance **Excellent thermal conductivity**

Low thermal expansion



Experimental procedures

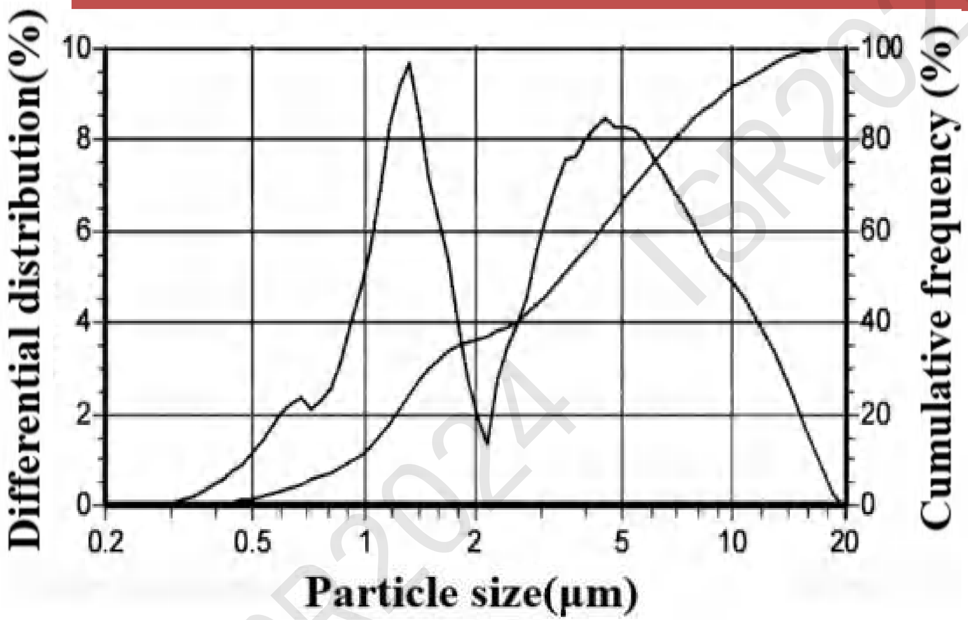


Fig.1 Particle size distribution of Si-N-O composite powder

The ground multiphase powder exhibited a bimodal distribution characteristic. Most of the particle sizes were less than 20 μm, and its D10, D50 and D90 were 0.68 μm, 3.20 μm and 18.86 μm respectively.

Table1 Experimental proportioning table

Raw materials	ω/%				
	SN0	SN1	SN2	SN3	SN5
Brown corundum	55	55	55	55	55
Silicon carbide	18	18	18	18	18
Tabular corundum	**13**	**12**	**11**	**10**	**8**
Ball pitch	3	3	3	3	3
Silicon powder +SiO_2 micropower +α-Al_2O_3 micropower	9	9	9	9	9
Pure calcium aluminate cement	2	2	2	2	2
Composite powder	**0**	**1**	**2**	**3**	**5**
Other additives	0.5	0.5	0.5	0.5	0.5

Results and discussion

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The Si-N-O composite powder were Si_3N_4 and silicon oxynitride phases, as well as a trace amount of metal Si phase. The mass percentages of Si_2N_2O, α-Si_3N_4, β-Si_3N_4 and Si phases were 46.9 %, 15.9 %, 33.3 % and 3.9 %

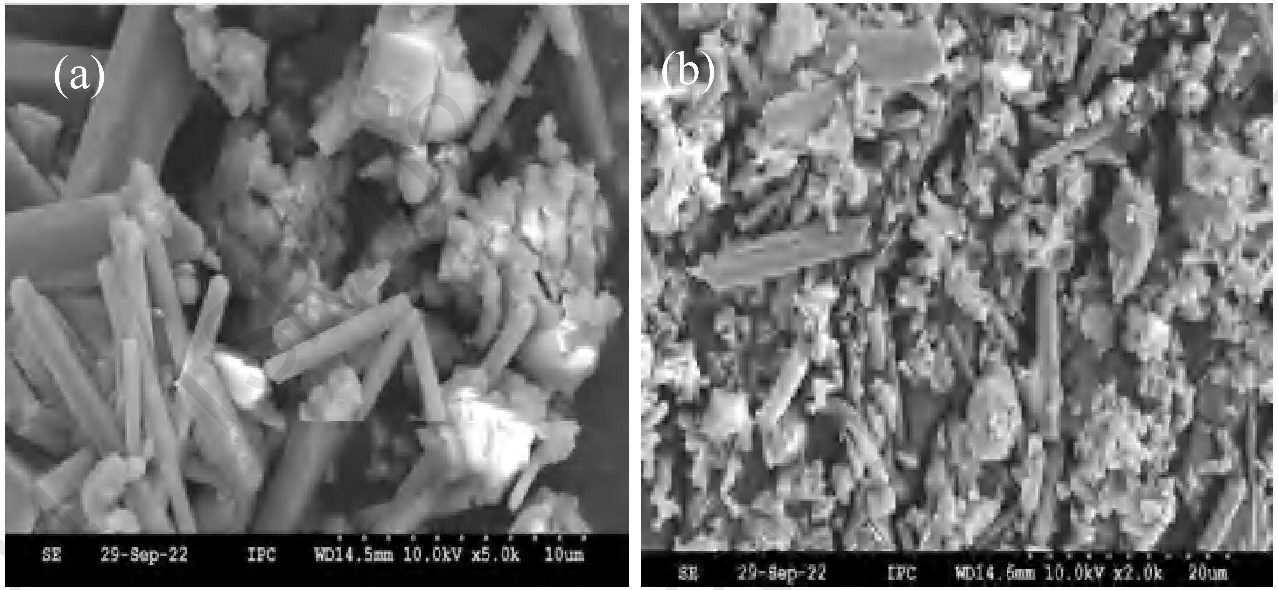

Fig.3 SEM pictures Si-N-O composite powder

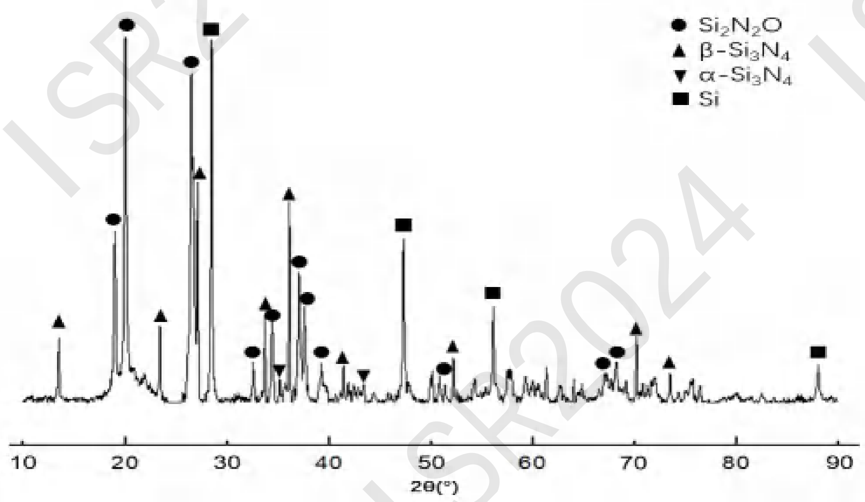

Fig.2 XRD patterns of Si-N-O composite powder

From the photos of different magnifications, the composite powder was mainly rod-shaped, short-columnar and irregular granular. Combined with EDS spectrum and XRD analysis results, the rod-like and columnar crystals were β-Si_3N_4 phase and silicon oxynitride phase, and the agglomerated irregular granular phase is α-Si_3N_4 phase.

Results and discussion

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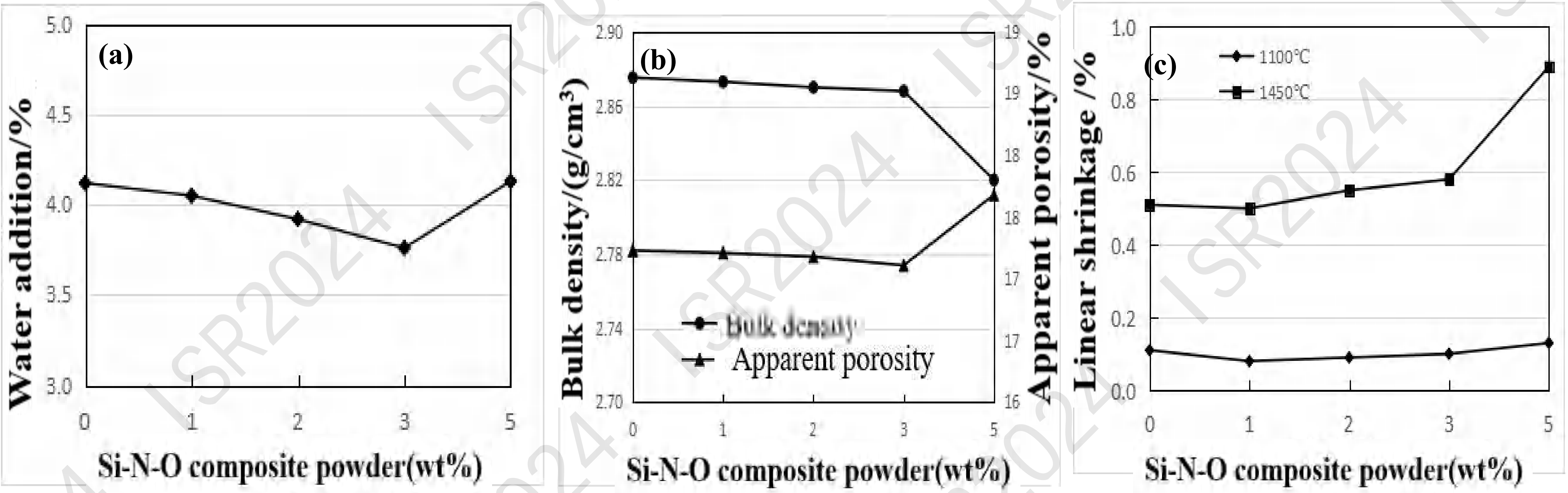


Fig.4 Influence of the addition amount of composite powder on the samples: (a) Water addition, (b) Density and porosity, (c) Temperature.

Results and discussion

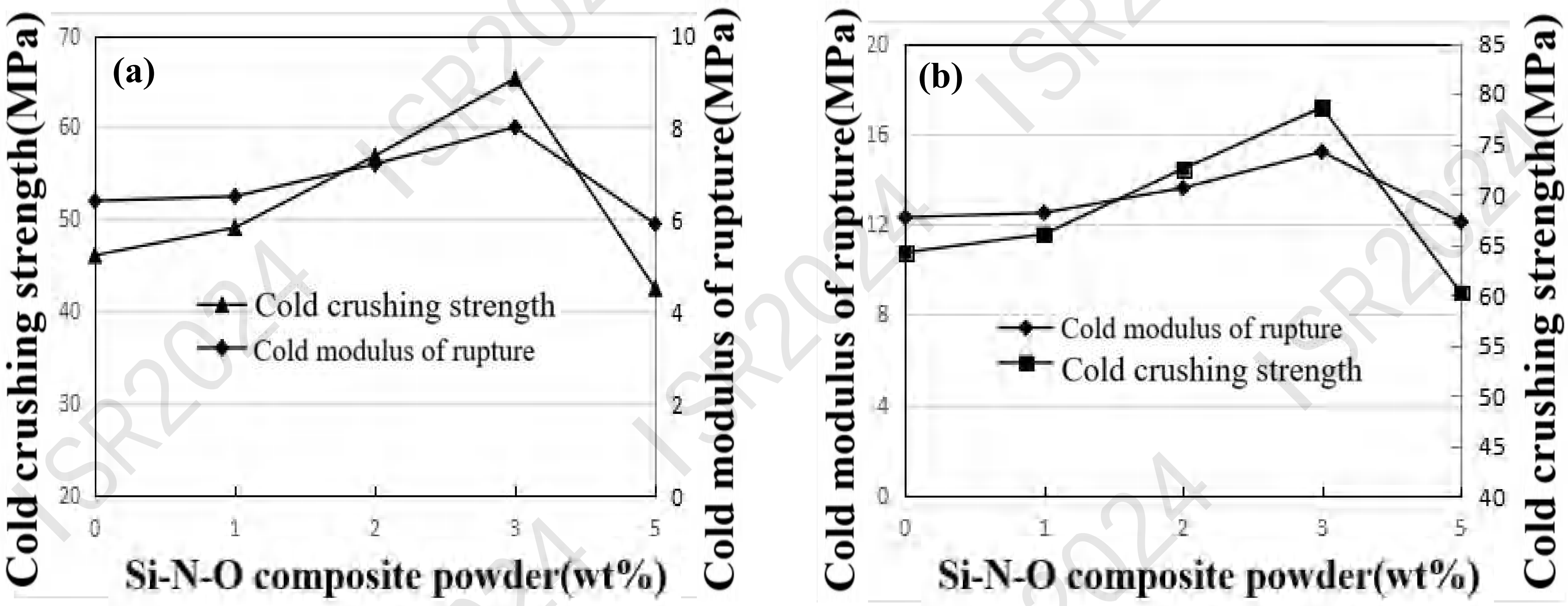
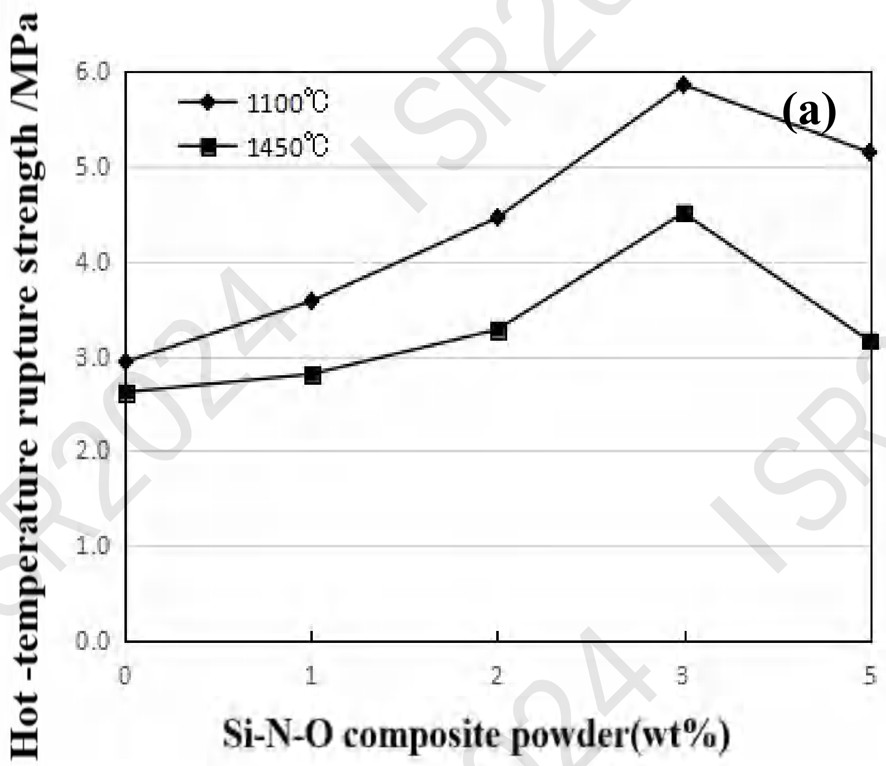


Fig.5 (a)1100 °C，(b)1450 °C

Results and discussion



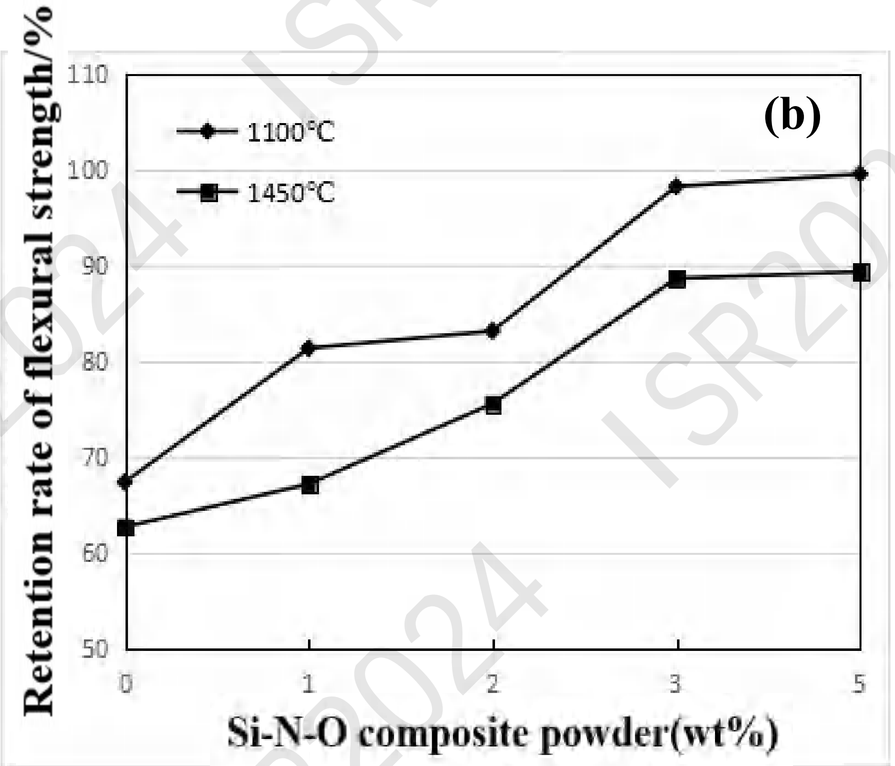


Fig.6 The influence of the addition amount of composite powder on the samples: (a) Hot - temperature rupture strength; (b) Retention rate of flexural strength

Results and discussion

1000 ℃

1450 ℃

Fig.7 The antioxidant properties of the samples after treatment at different temperatures.

The addition of composite powder hindered the further entry of oxygen. Si_2N_2O and Si_3N_4 in the system were more likely to be oxidized thermodynamically, so the addition of the composite powder as an antioxidant could significantly improve the antioxidant capacity of the sample.

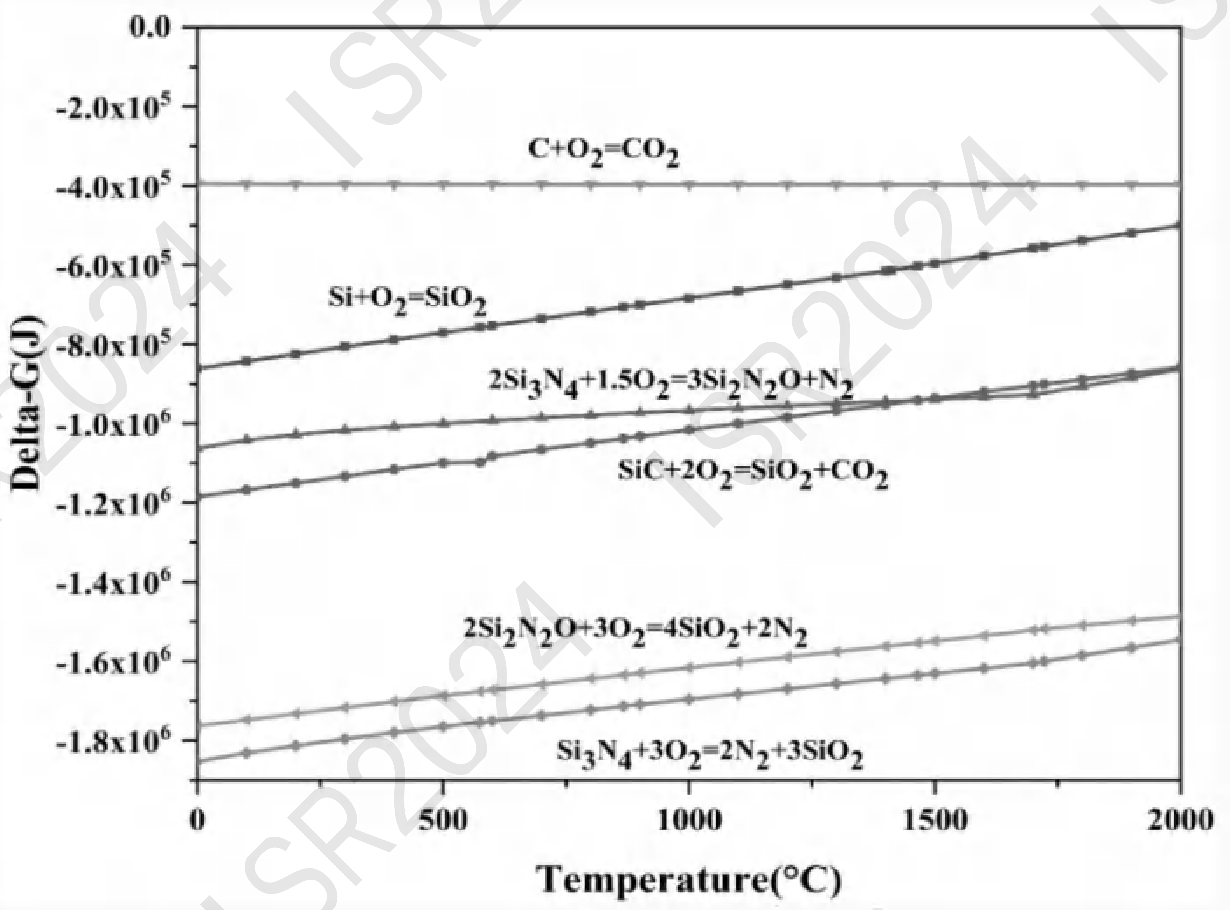


Fig.8 The relationship between △G and temperature of material oxidation reaction

Results and discussion

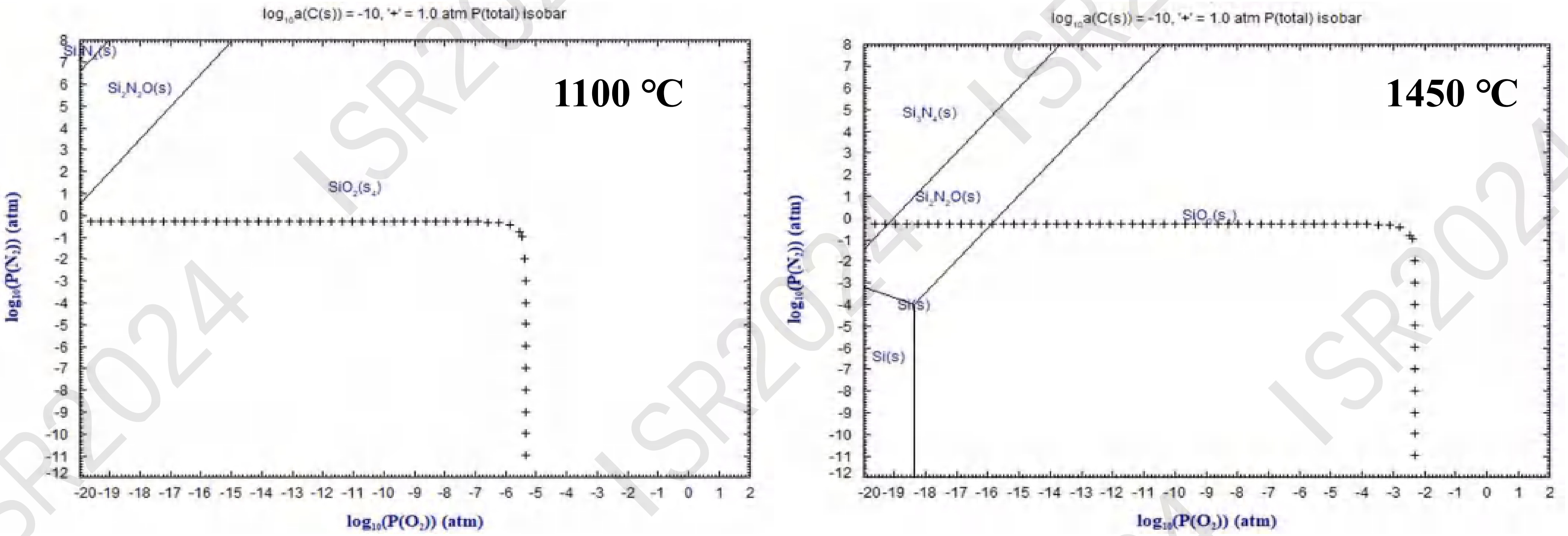


Fig.9 Phase diagram of the dominant regions in Si-C-N-O.

$$4Si_3N_4(s)+3O_2(s) = 6Si_2N_2O(s)+2N_2(g)$$
$$Si_3N_4(s)+3O_2(g) = 3SiO_2(s)+2N_2(g)$$
$$Si_3N_4(s)+1.5O_2(g) = 3SiO(g)+2N_2(g)$$
$$3Si_2N_2O(g) = 3\ SiO(g)+N_2(g)+Si_3N_4(s)$$

Results and discussion

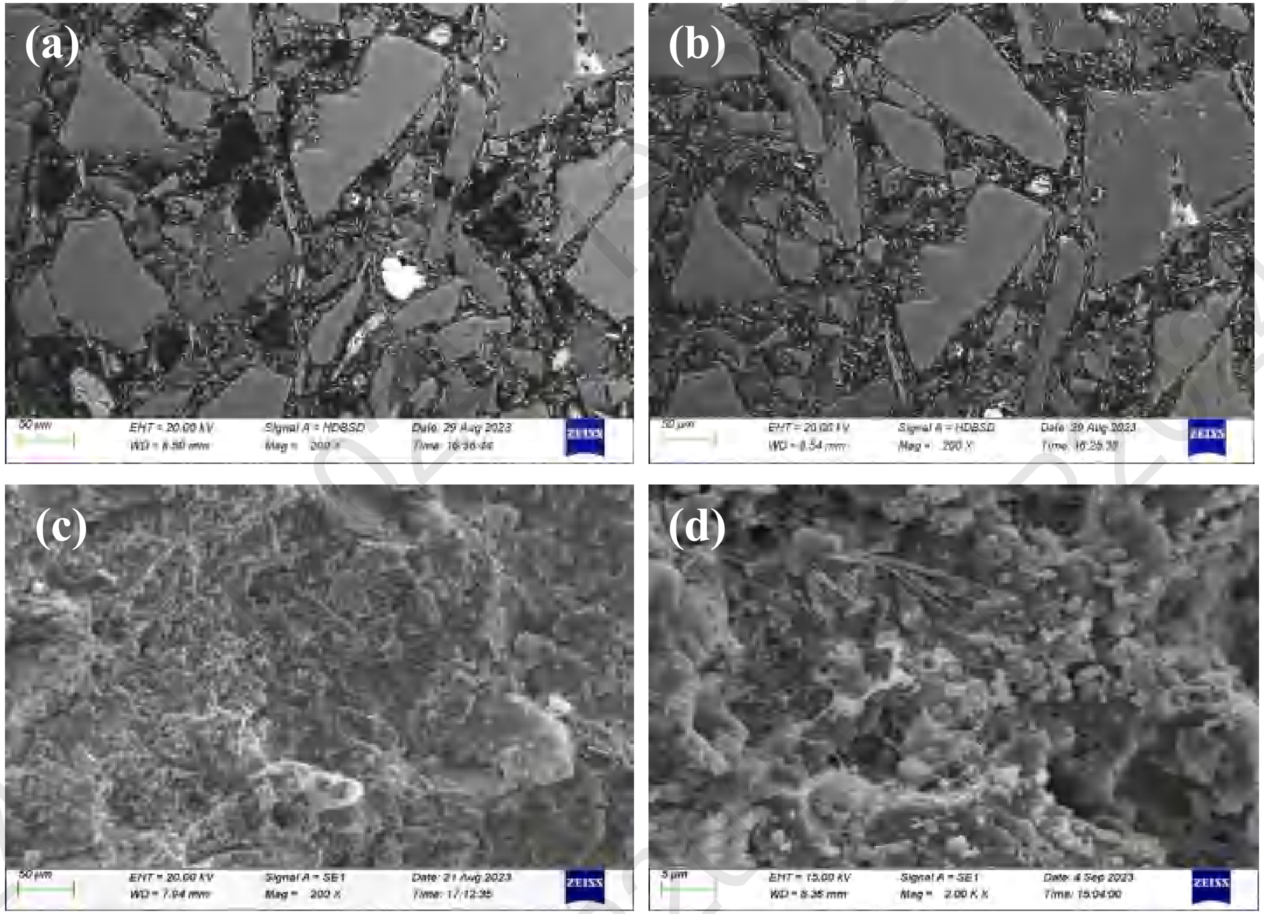


Fig.10 1100 °C:(a)SN0,(b)SN3; 1450 °C: (c)SN0,(d)SN3

1000℃: SN0 was poorly sintered, and there were pores in the matrix part. SN3 was sintered densely. The multiphase powder filled part of the matrix, promoted reaction sintering and improved the density of the material.

1450℃： The “Cementing phase” appeared in SN0. A large number of whiskers appeared in SN3.

Results and discussion

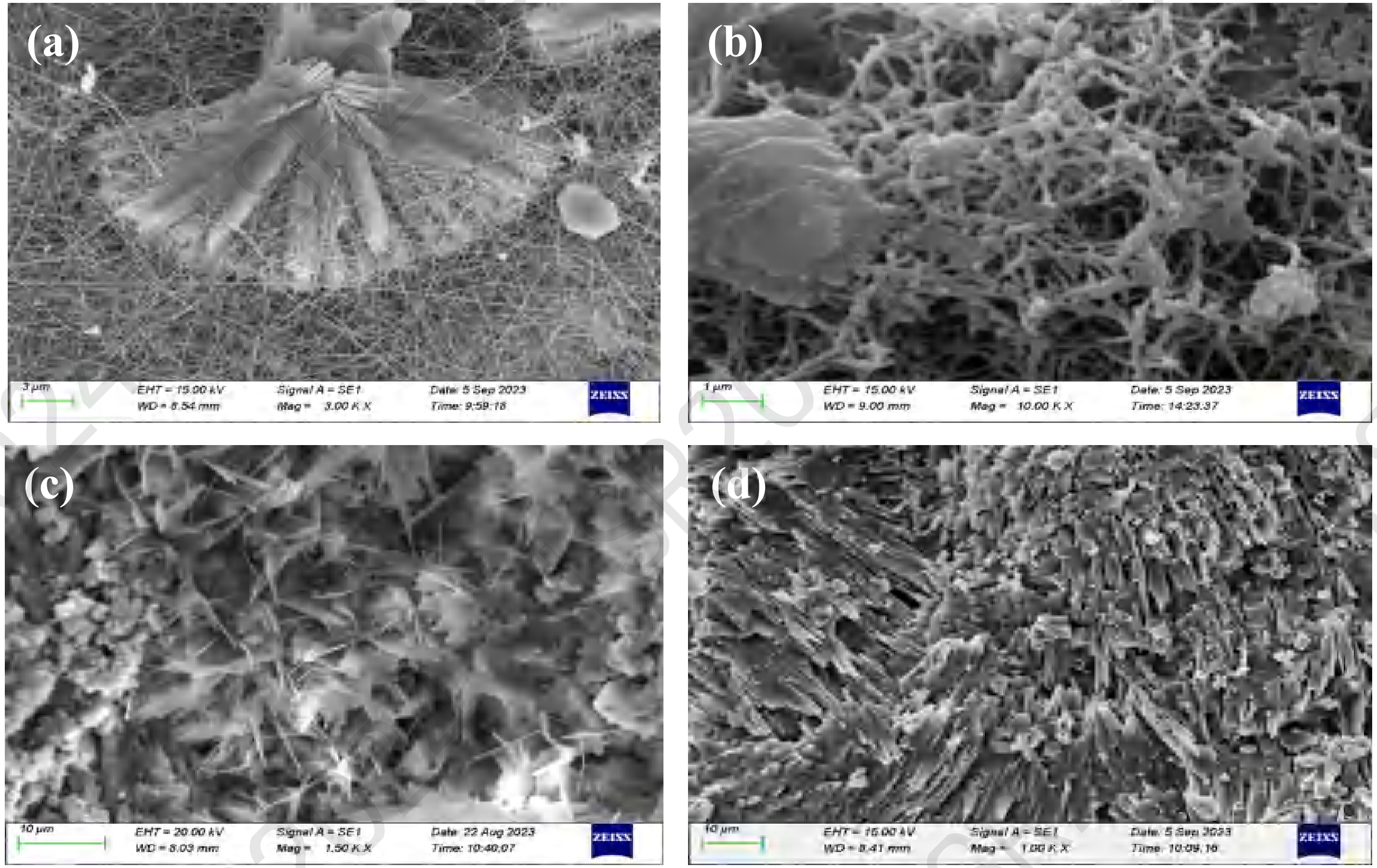


Fig.11 The typical characteristics of the matrix part of the sample after adding the composite powder SEM photos

Conclusions

1. The addition of microcrystalline Si-N-O could significantly improve the cold strength, thermal shock stability and HMOR of the castables. Due to the addition of composite powder, it could react to form fibrous, feathery, flaky, and columnar phases. The formation of these phases could effectively improve the microstructure of the sample, and greatly improve the strength and toughness of the sample.
2. The addition of multiphase powder could significantly improve the oxidation resistance of the castables, and the antioxidant effect was optimal when the addition amount was about 3 wt%. Because the main component in the composite powder can be oxidized prior to the carbon in the material, which reduced the internal oxygen partial pressure of the material and alleviated the oxidation of carbon; at the same time, the composite powder itself and the oxidation products could fill the pores, hinder the diffusion of oxygen, and improve the density and oxidation resistance of the material.

Thanks for your attention!