Influence of Al_2O_3 content on microstructure and oxidation resistance of glass-ceramic coatings for 06Ni9DR alloy steel

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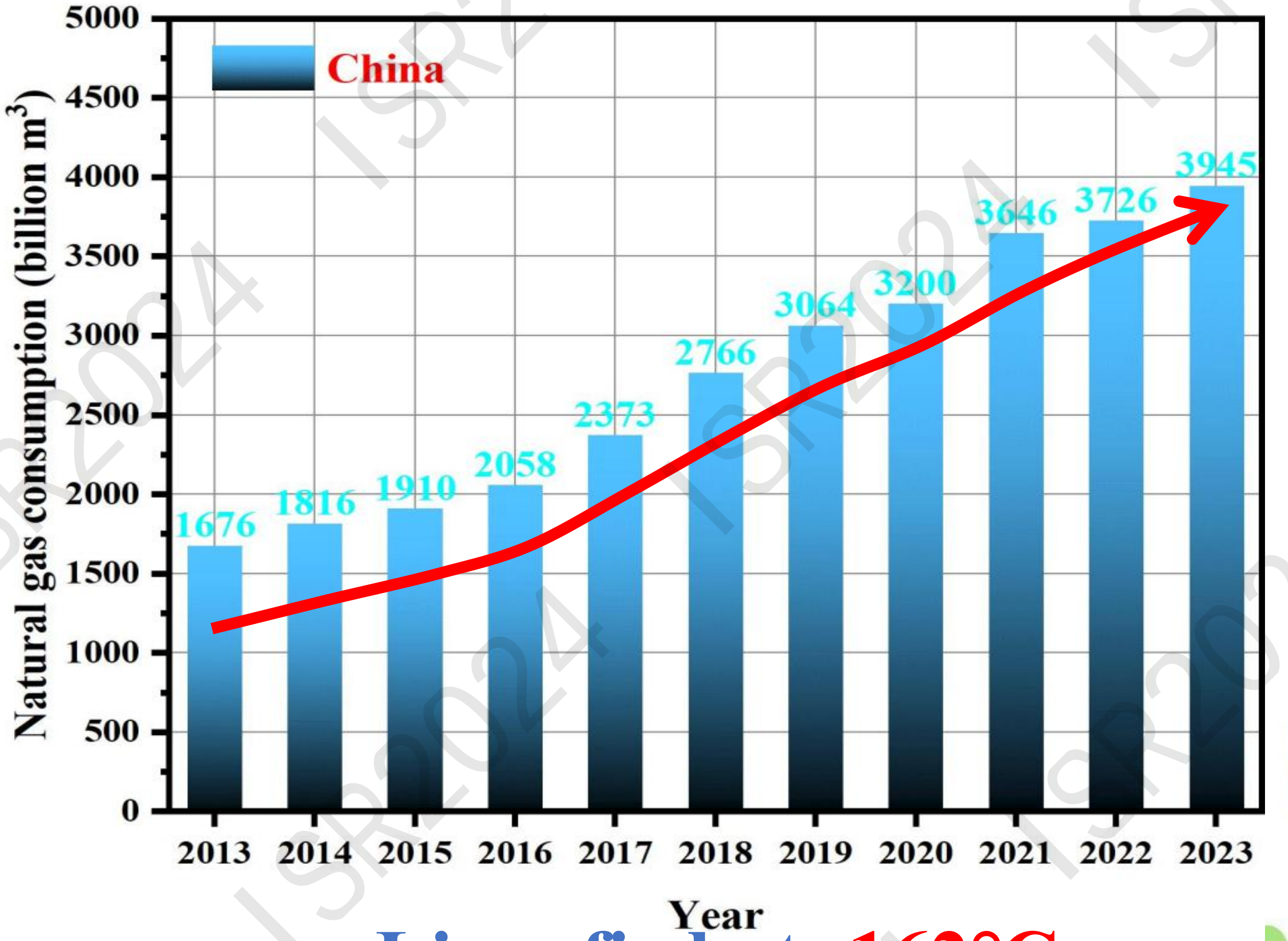
Contents

Natural Gas

Clean primary fossil energy



Liquefied at -162°C

06Ni9DR alloy steel

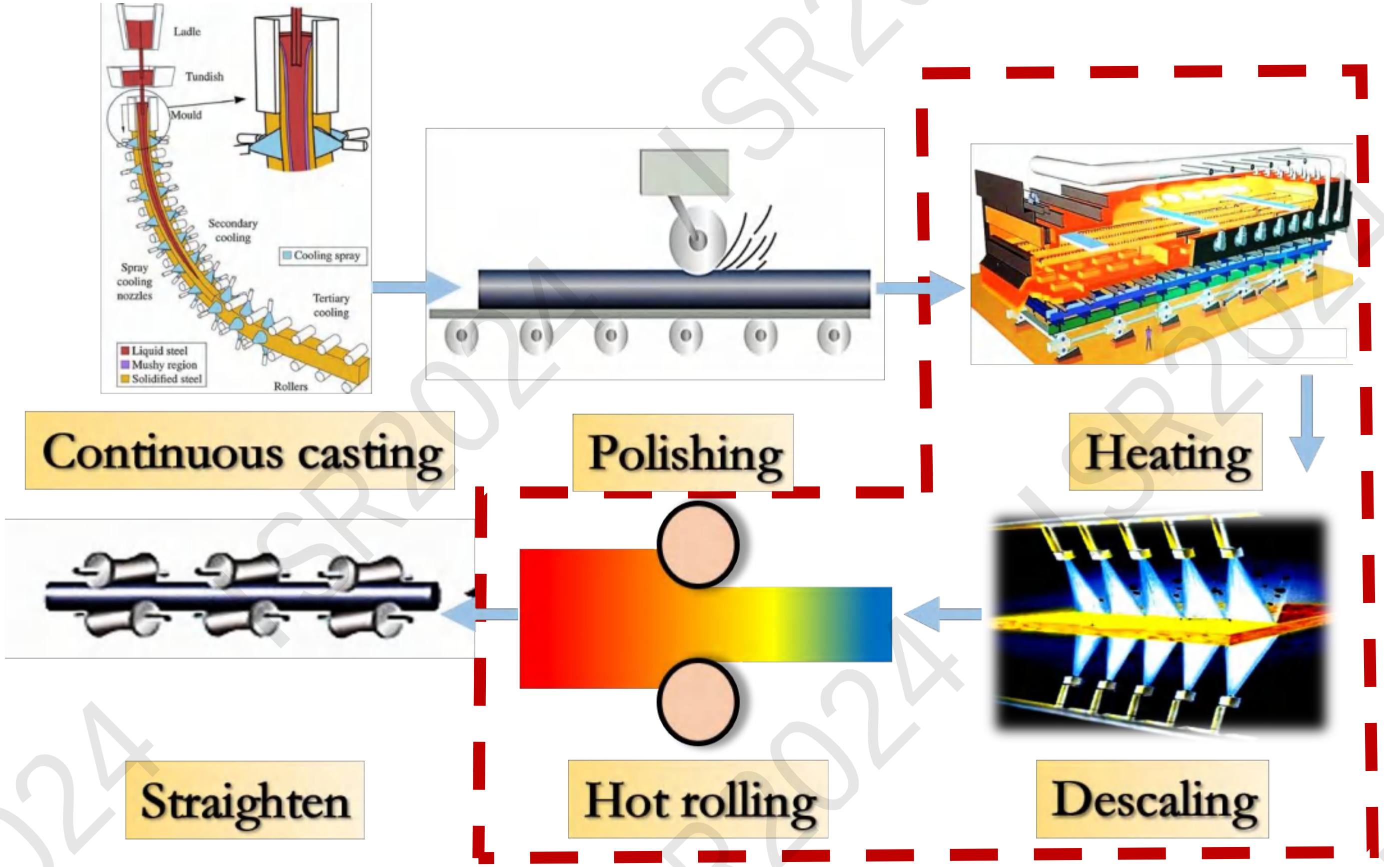
- Resistance to low-temperature shock
- Low coefficient of thermal expansion
- Excellent low-temperature toughness

Exploration of LNG

Transportation of LNG

Storage of LNG

06Ni9DR alloy steel



The production process of alloy steel

Important process

1100~1300°C

Severe Oxidation

Oxidation protection methods

I Low-temperature Rolling

II Vacuum Heating

III Protective Atmosphere

IV Salt Bathing

V Protective Coating

Easy Operation

No Limitation of Shape and Size

Eide Application

Protective Coating

High content of liquid phase

Glass coating

< 1000℃

- **Homogeneous and Dense structure**
- **Excellent self-healing properties**

Good oxidation protection

1100~1300℃

Viscosity ↓↓

Failure

Protective Coating

Ceramic coating

- **Good thermal stability**
- **> 1500℃**
- **Dense structure**

Good oxidation protection

1100~1300℃

Difficult to densify

Glass-Ceramic coating

Oxidation Protection ↑↑

Formulation and composition

Formulation	Glass powder	α-Al_2O_3	CMC	水
GC20	**80**	**20**	0.6	60
GC40	**60**	**40**	0.6	60
GC60	**40**	**60**	0.6	60
GC80	**20**	**80**	0.6	60

Composition of raw materials

Raw material	**Chemical composition**					
	SiO_2	**Al_2O_3**	**CaO**	**MgO**	**K_2O**	**Na_2O**
Glass powder	74.04	1.65	5.43	2.48	1.49	14.91
α-Al_2O_3 micro powder		99.60				0.40

Experiment process

Shape change

XRD

Microstructure

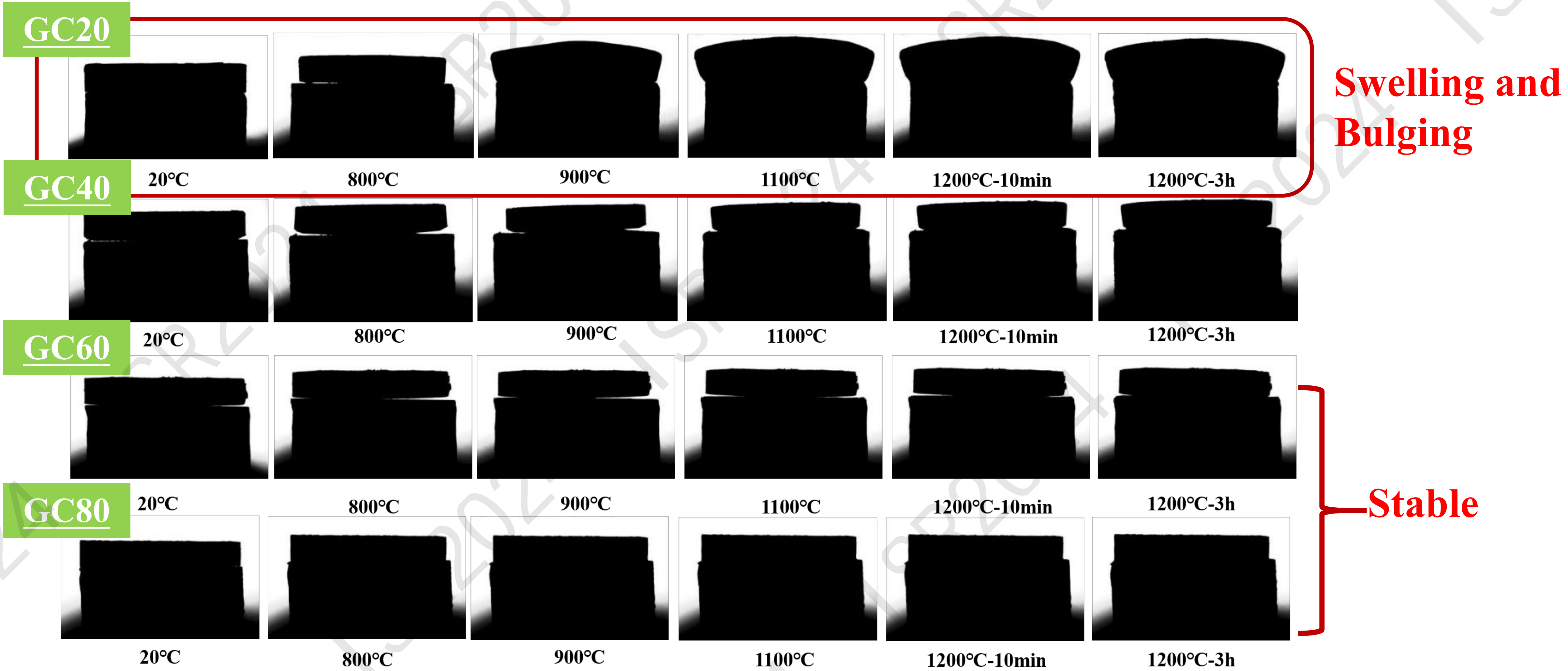
Oxidation test

Coating-steel interaction

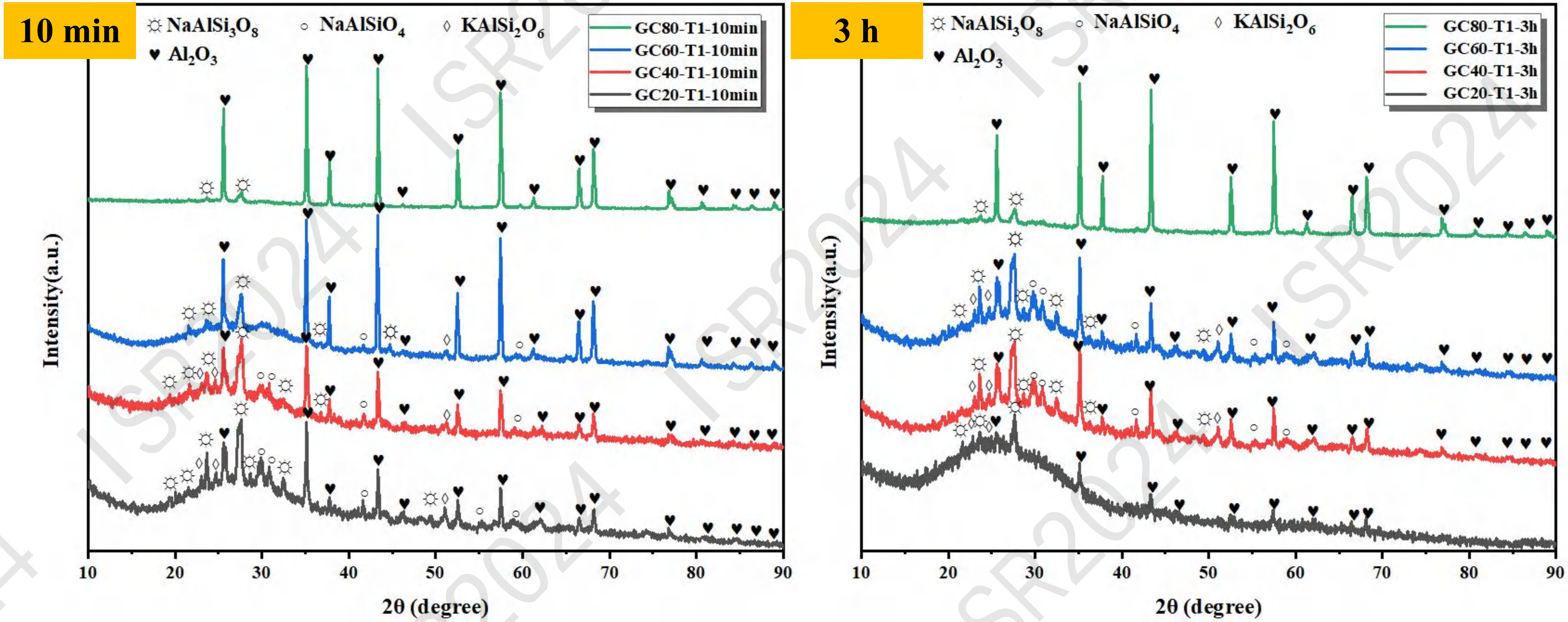
FactSage™

The content and viscosity of Liquid phase

Shape change of GC-T5 coating



XRD of GC-T1 coating

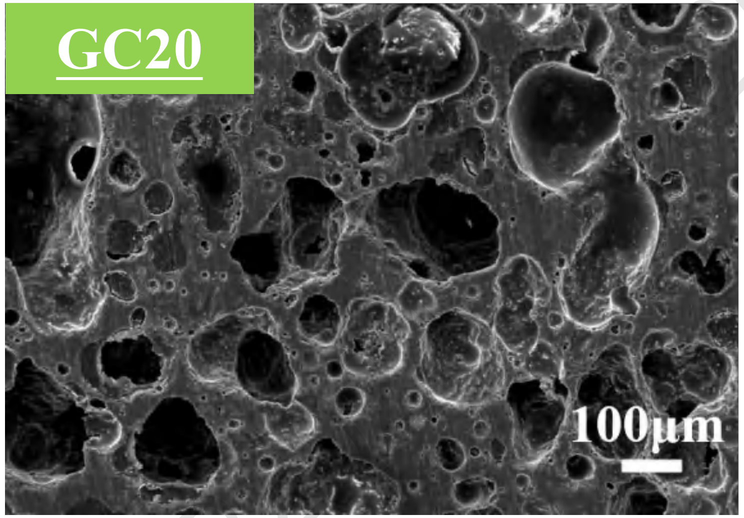


The Al_2O_3 content in the GC20 coating decreases significantly with heating duration, and there is no significant change in the phase composition in the GC80 coating

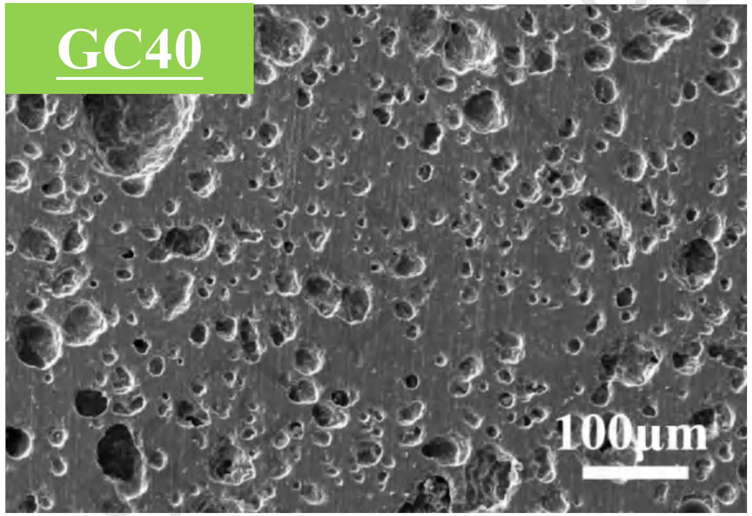
Microstructure of GC-T1 coating

10min

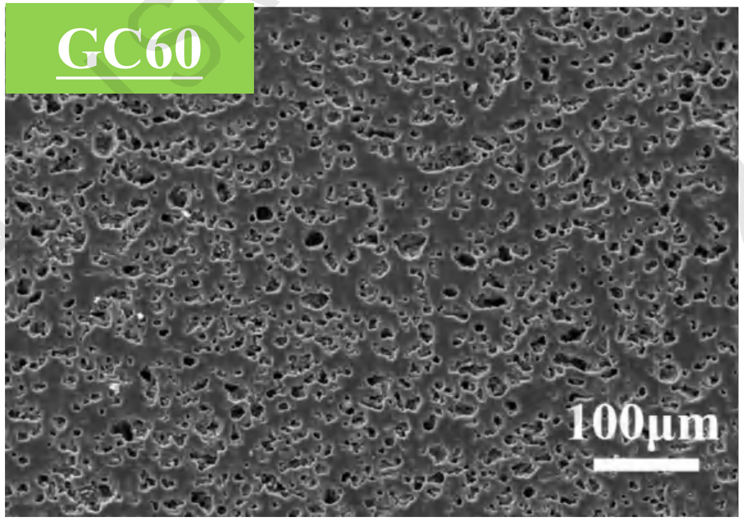
GC20



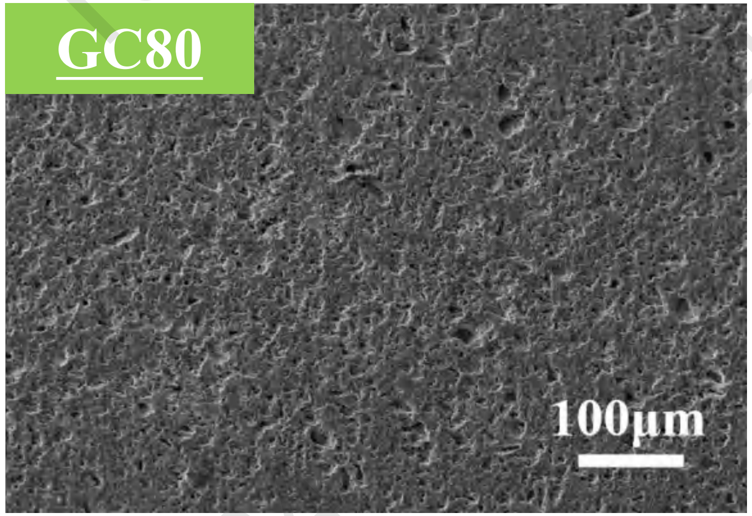
GC40



GC60



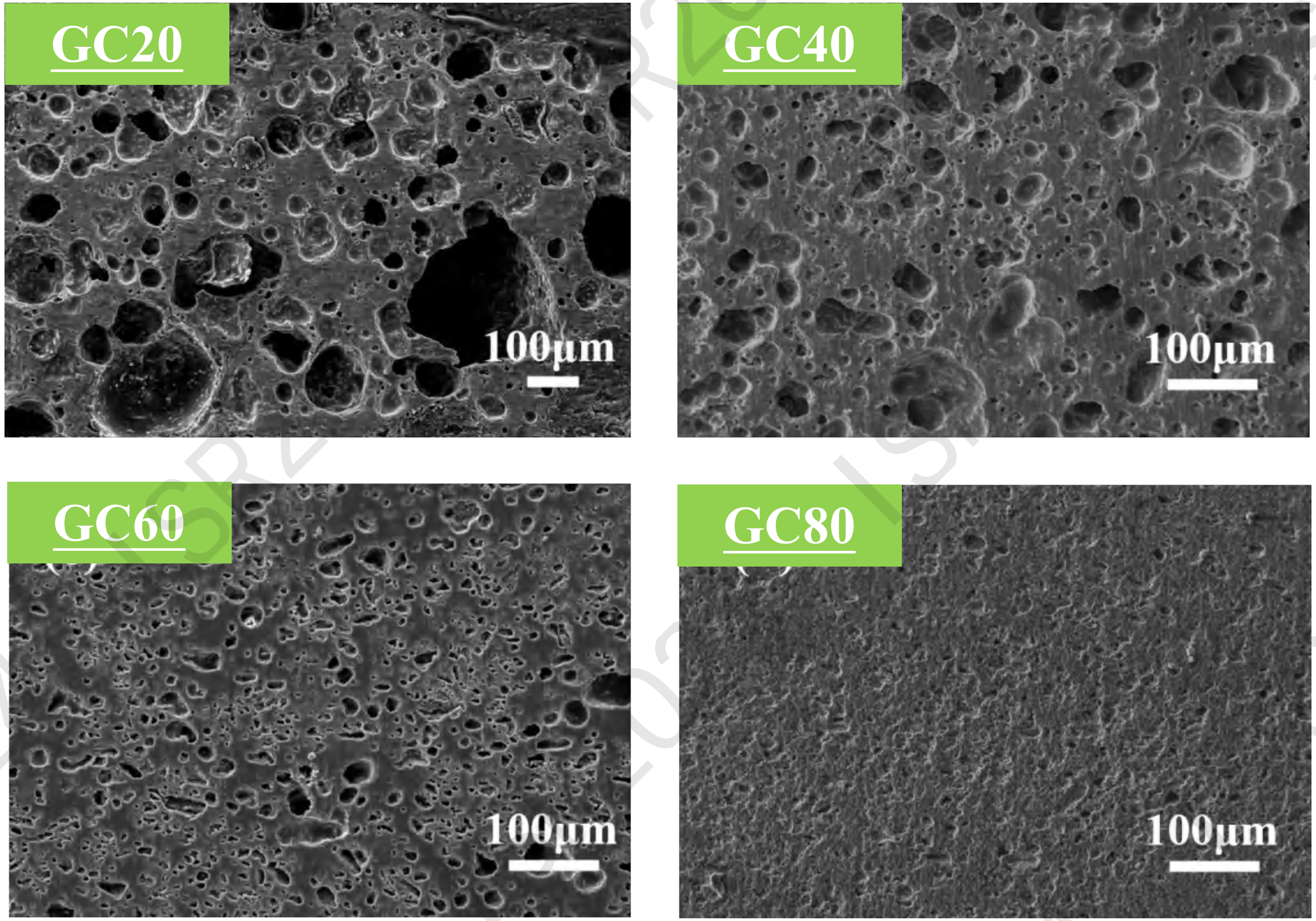
GC80

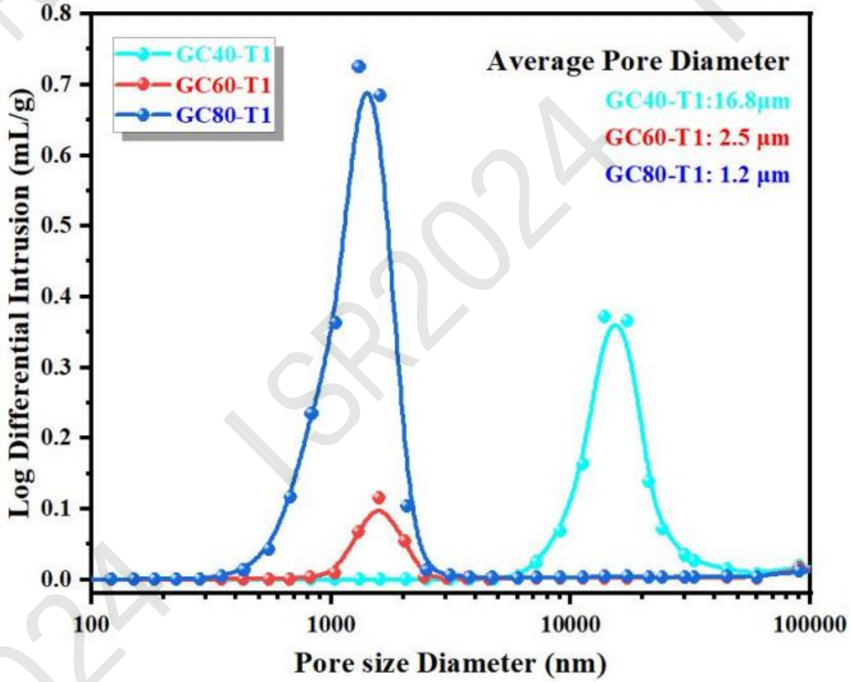


Smaller pore sizes in coatings with higher Al_2O_3

Microstructure of GC-T1 coating

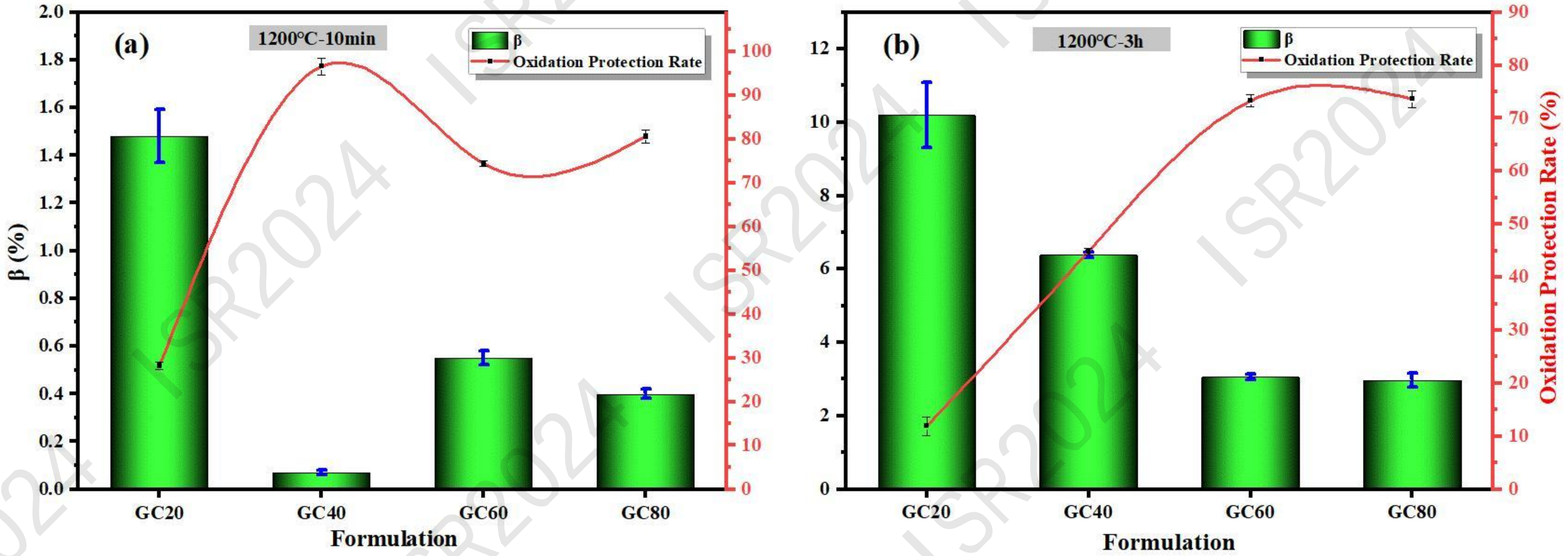
3 h





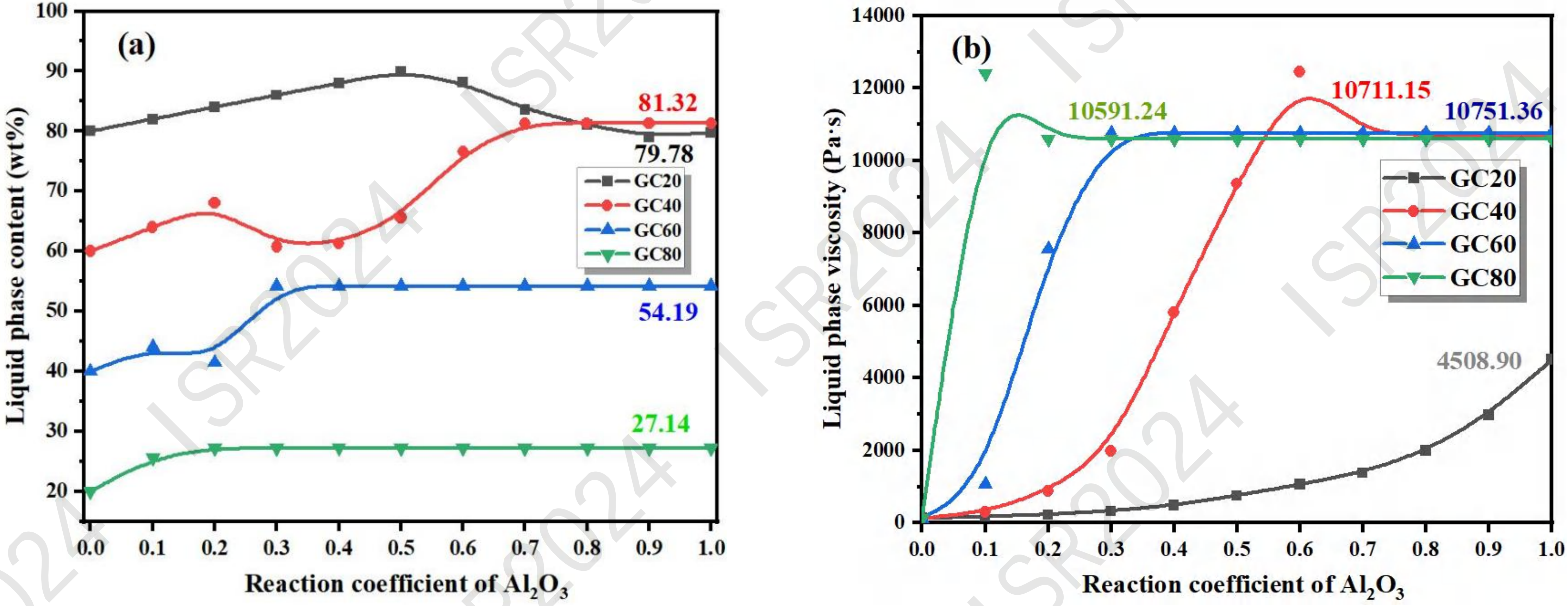
The pore structure of high Al_2O_3 coatings is **more stable** and it is easier to form **tiny pores**

Oxidation protection



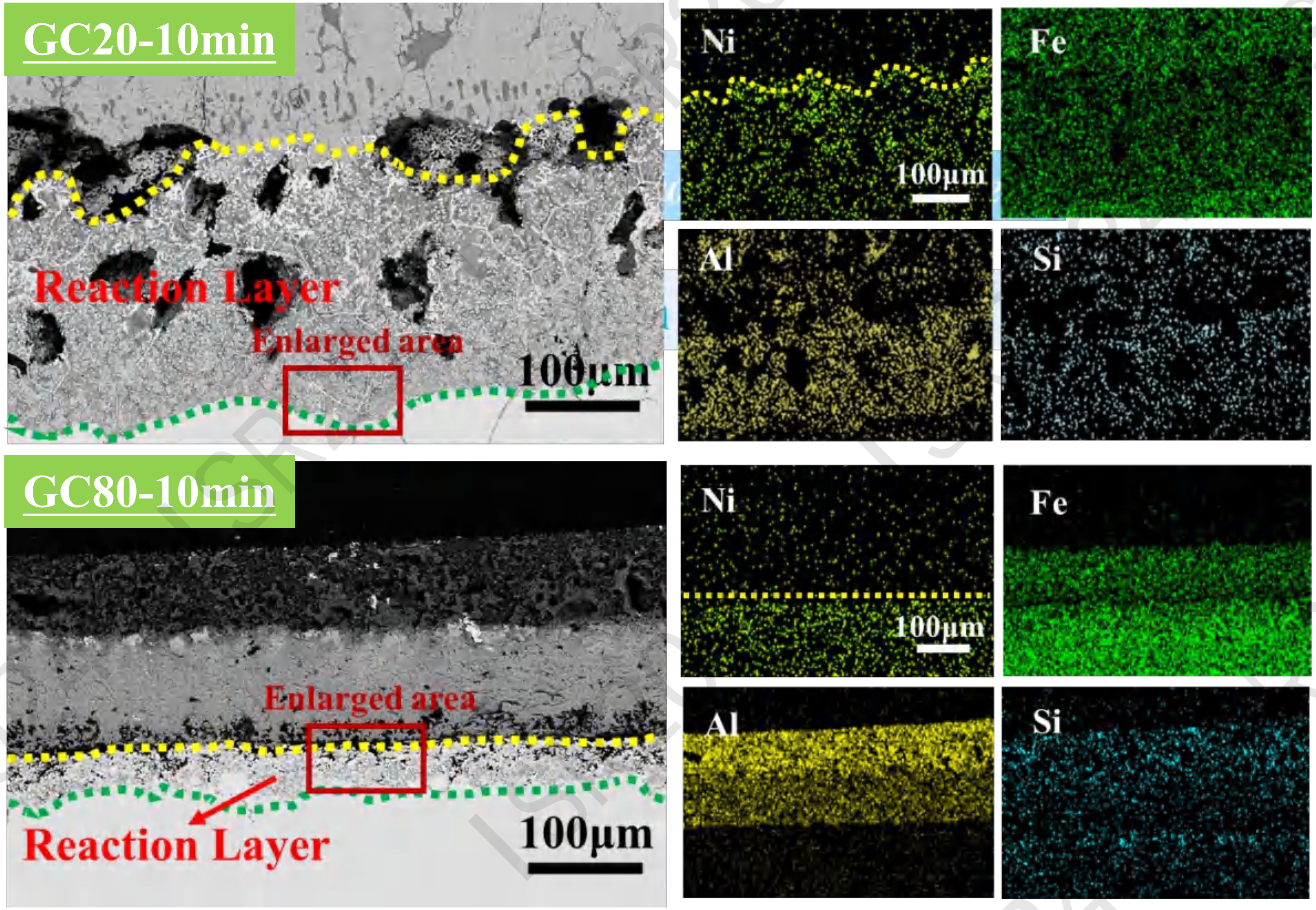
The oxidation protection of GC20 is always worst, the stable and good oxidation protection is provided by GC80

Liquid phase of GC-T1 coating



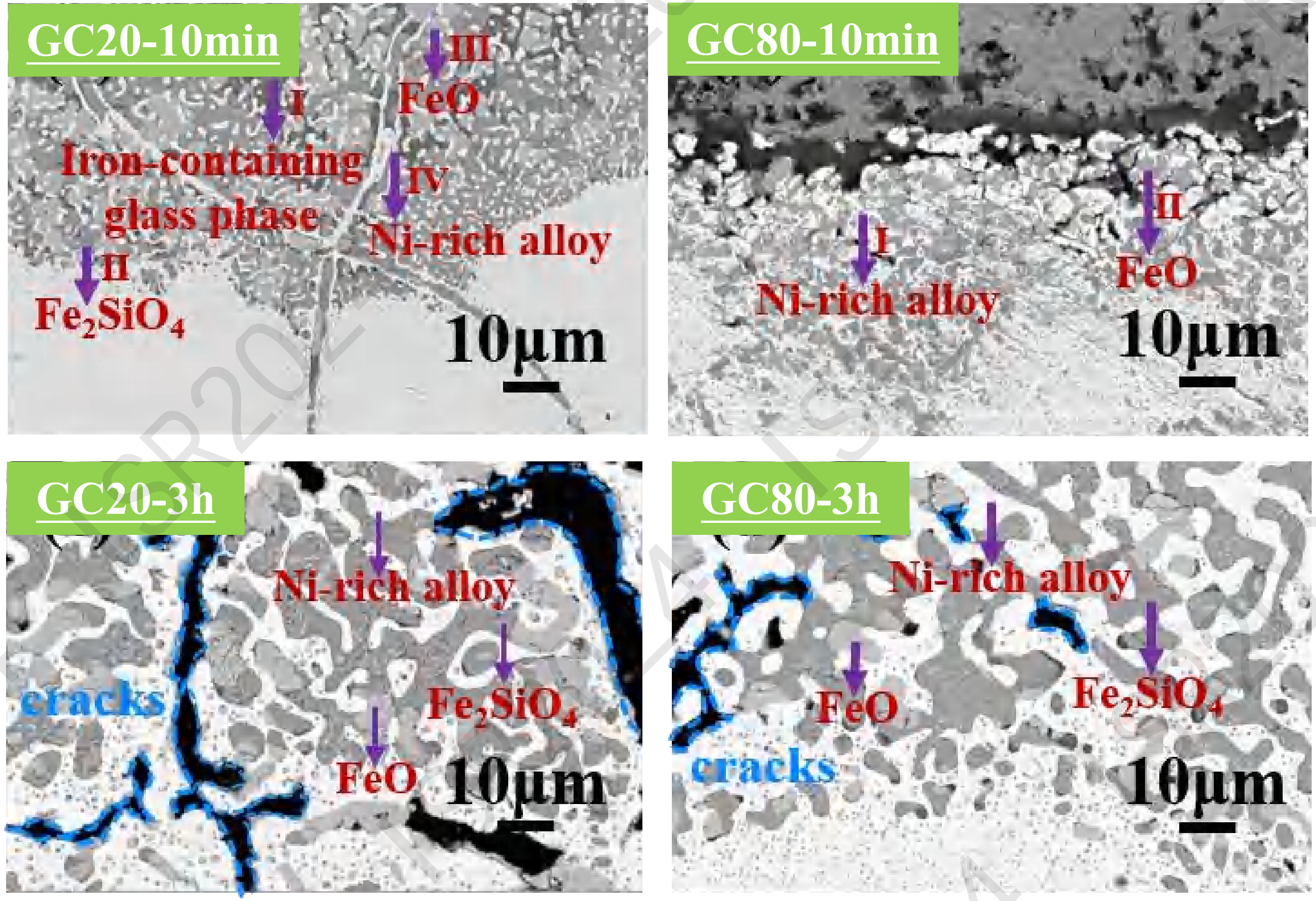
The higher content of Al_2O_3 in coating, high viscosity liquid phase is formed faster, which is more helpful to the formation of a stable structure.

Coating-steel interaction of GC coated samples



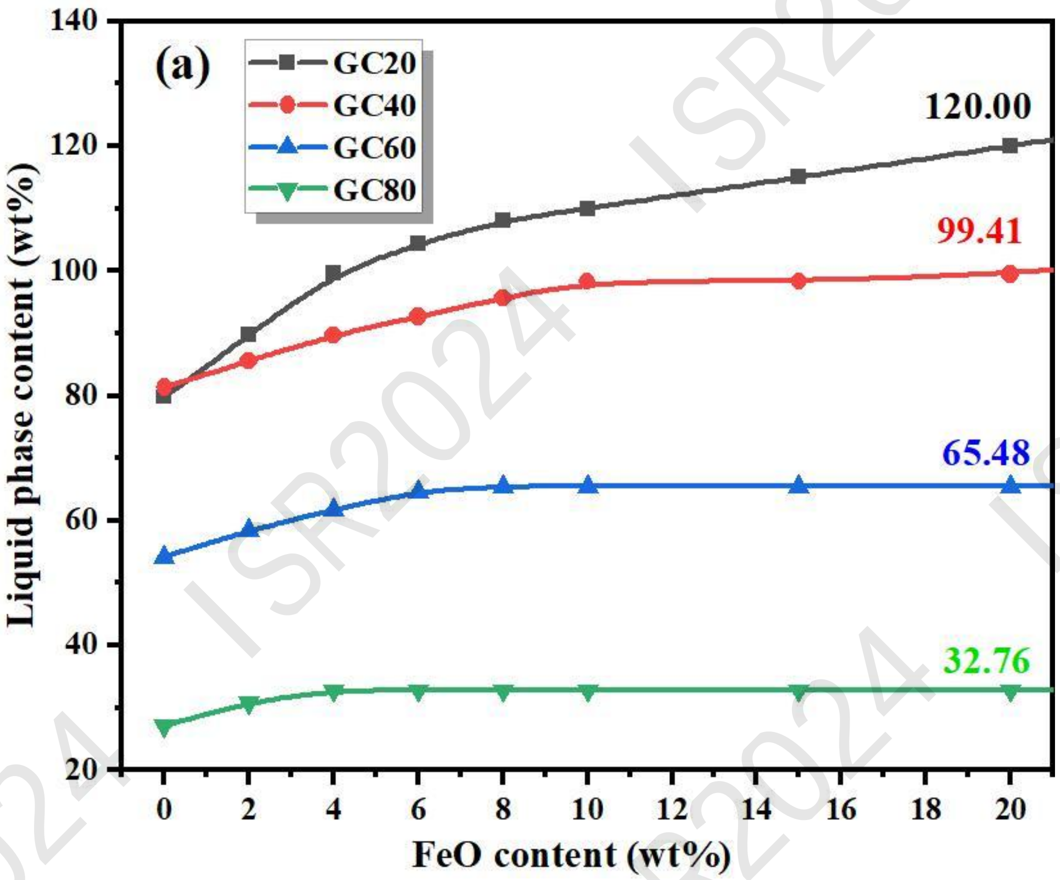
A coating with **a lower Al_2O_3 content** has **a greater depth** of **penetration** of the Si-containing liquid phase into the substrate.

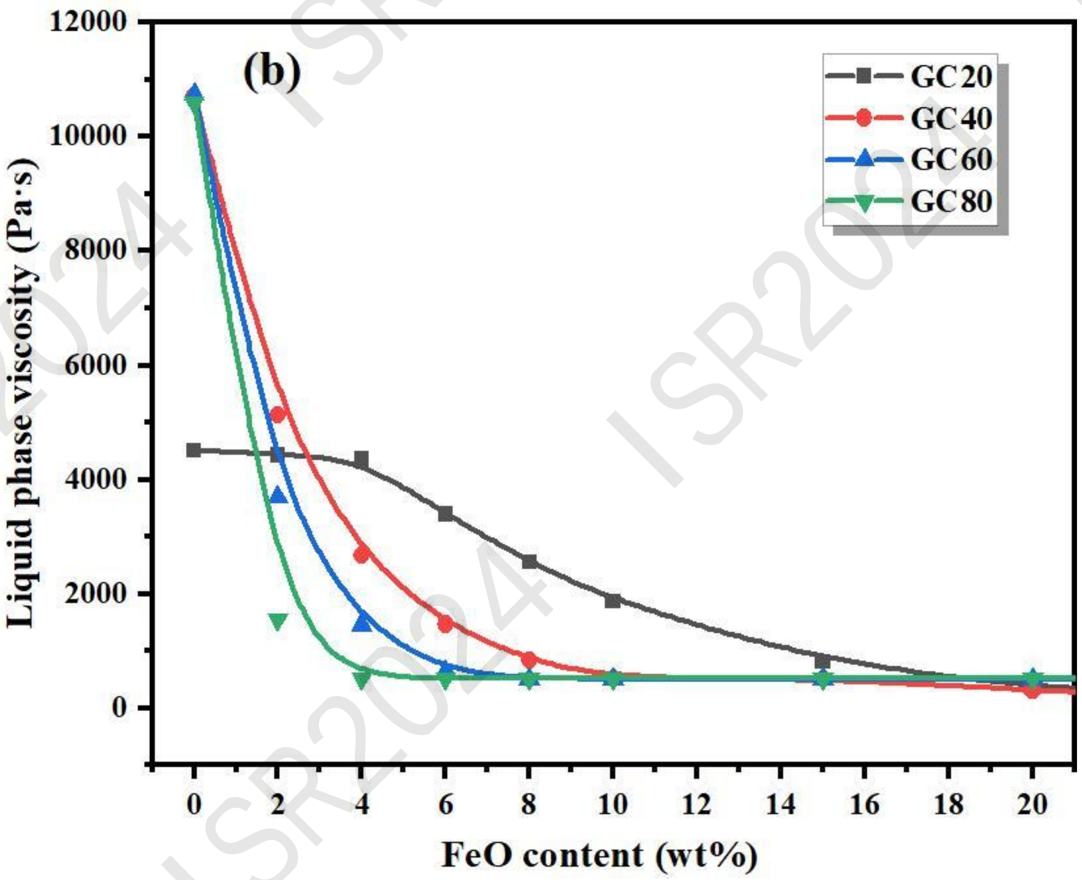
Coating-steel interaction of GC coated samples



Cracks are generated in the coating accelerate penetration with increasing oxidation time

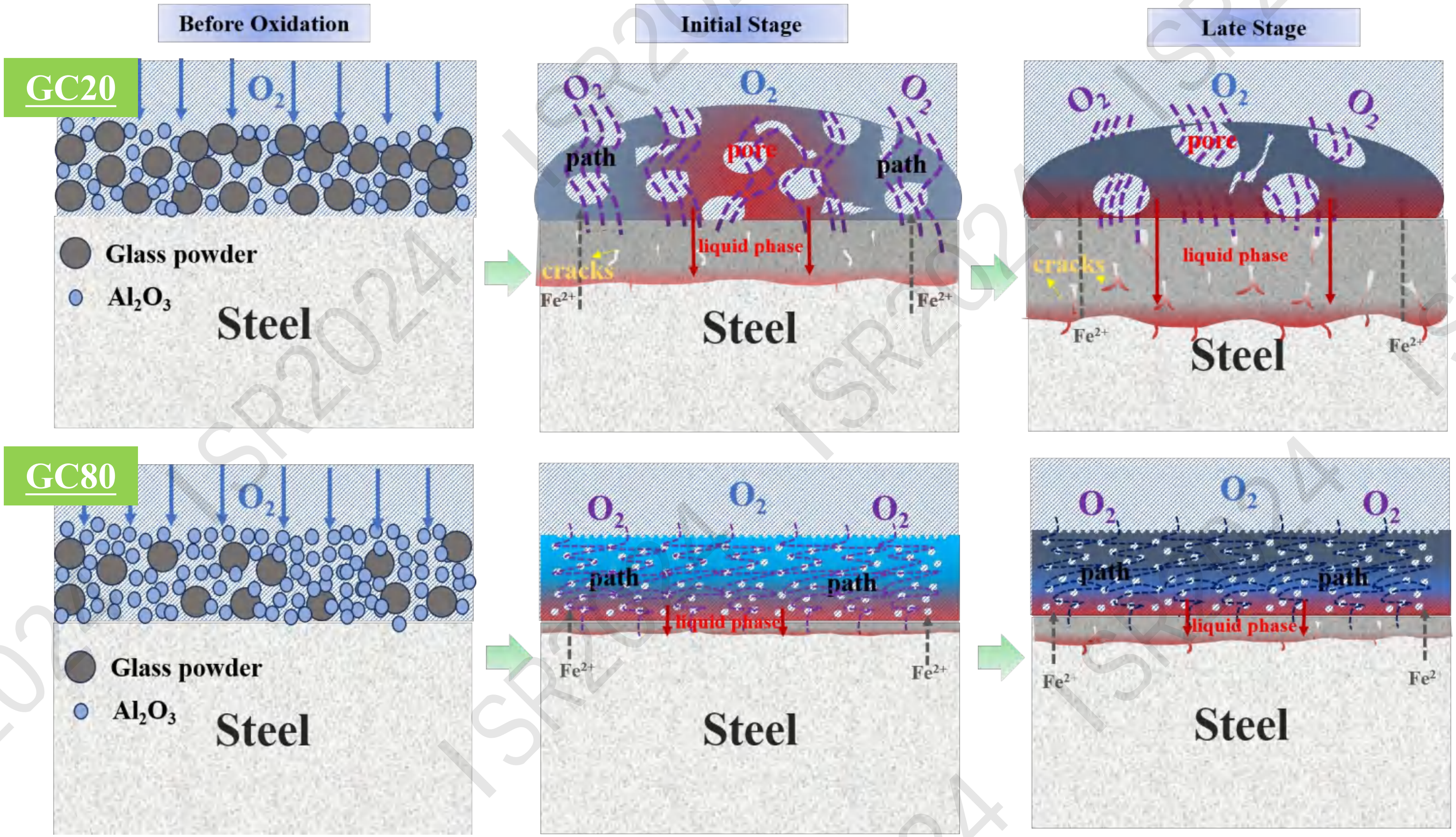
Coating-steel interaction of GC coated samples





FeO is the main oxidation product of nickel-alloyed steel, which reacts with the coating to reduce the viscosity of the liquid phase and make it penetrate into the substrate

Protection mechanism



Large number of **open pores** provide diffusion **channels**

The **tiny pores** greatly extend the diffusion **path**

Conclusion

- The Al_2O_3 content had a significant impact on the microstructure of glass-ceramic coatings. The coating with 20 wt% Al_2O_3 swelled and bulged during heat treatment.
- High Al_2O_3 content was beneficial for quickly obtaining high viscosity liquid phase, and the coating with 60 wt% and 80 wt% Al_2O_3 exhibited good thermal stability
- The glass-ceramic coating with 60 wt% and 80 wt% Al_2O_3 exhibited excellent oxidation protection because there are good thermal stability and a large number of tiny pores with pore sizes in range of 0.5–3 μm led to a very long diffusion path of oxygen.

Acknowledge

Thanks for your attention!