IRON ORE ON FORMATION AND FLOW OF LIQUID PHASE[1]

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Abstract

The high temperature characteristics of iron ore, such as assimilation characteristic, fluidity of liquid phase, could well reflect behaviors of iron ores during sintering process, and the mineralogical characteristic of iron ores would influence the high temperature sintering characteristics further. Taking eight kinds of iron ores from Brazil, Australia, and South Africa as the objects, the chemical composition, mineral types, particle morphology, and gangues dispersity of the selected iron ores were investigated respectively. Meanwhile the influence rules between the mineralogical characteristics and the high temperature characteristics were measured and analyzed. The results showed that the effect of SiO_2 on assimilation characteristic of iron ores was relatively complex, Al_2O_3 and LOI of iron ores had negative correlation with assimilation temperature of iron ores, the dense slab-flaky mineral granule restrained to the assimilation characteristics of iron ores; liquid phase of iron ores with high SiO_2 content and low Al_2O_3 content had high fluidity, and the higher dispersity of gangue minerals in iron ores was good to the fluidity of liquid phase.

Key words: Iron ore; Mineralogical characteristics; Assimilation characteristics; Fluidity of liquid phase.

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1 INTRODUCTION

Iron ore particle is important raw material for sintering, its basic characteristics would influence the yield and quality of sintering product. Therefore, it's necessary to study fundamental features of iron ore to improve the quality of sinter. The basic characteristics of iron ore include the mineralogical characteristics of iron ore (e.g. the row material condition, micro- characteristic) and the high temperature characteristics of iron ore (e.g. assimilation, liquid phase fluidity).

Research shows that the high temperature properties of iron ore fines, such as assimilation characteristics and liquid phase fluidity, played an important role in behaviors at high temperature during sintering and had important influence on quality of sinter.[(1-3)] There is evidence of a relationship between the mineralogical characteristics of iron ore and its high temperature characteristics. And through these researches, can summarize some influence rules to guide the sintering manufacturing practice. However, few of researchers study the micro-characteristics of iron ore particle influence the high temperature properties.

Therefore, in this paper, based on mini-sintering test experiments, the high temperature characteristics of eight import iron ore fines which common used in china were measured. Then compared and analyzed the effect of mineralogical properties of iron ore fines, particularly the micro-characteristics, on the assimilation characteristics and liquid phase fluidity.

2 EXPERIMENTAL MATERIALS AND EXPERIMENT METHOD

2.1 Experimental Materials

2.2

The chemical composition of the eight kinds of import iron ore powders are shown in Table 1. Among ,IOA~IOD were imported from Brazil, IOE~IOG were from Australia, IOH was a kinds of South African iron ore.

Table 1. Chemical compositions of iron ore powders(mass fraction)

Ore	TFe	FeO	SiO_2	CaO	Al_2O_3	MgO	LOI
IOA	63.42	0.59	5.64	0.01	1.34	0.06	1.81
IOB	63.10	0.73	5.56	0.06	0.97	0.27	1.86
IOC	64.14	0.58	5.19	0.02	0.86	0.07	1.68
IOD	64.81	0.17	2.77	0.02	1.24	0.06	2.12
IOE	58.60	0.20	4.44	0.04	1.63	0.07	10.07
IOF	61.44	0.29	3.68	0.03	2.26	0.08	5.45
IOG	60.77	0.32	4.19	0.02	2.28	0.06	6.07
IOH	64.44	0.32	5.21	0.11	1.33	0.03	0.55

2.2 Experiment Method

In this experiment, XRD and SEM methods were employed to analyze mineral composition, micro-structure of iron ore. The mini-sintering test equipment (as shown in Figure 1) was used to research assimilation temperature and liquid phase fluidity of the iron ore, the concrete steps are as follows.

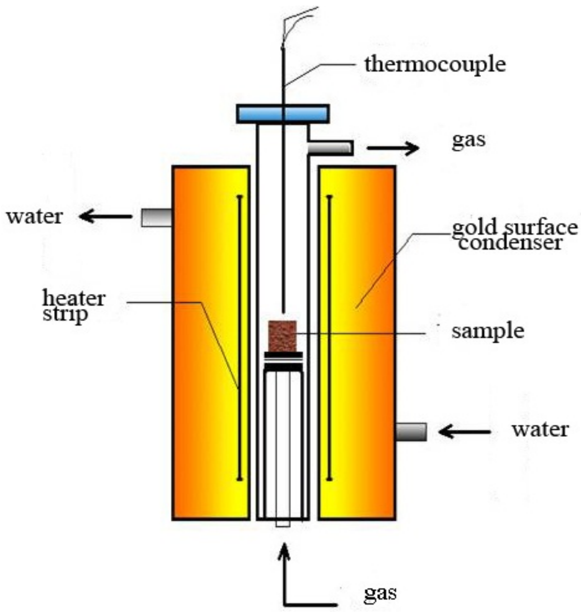

Figure 1. Mini-sintering test equipment.

2.2.1 Assimilation characteristics

The lowest assimilation temperature(LAT) in the interface of the iron ore fines and analytical grade CaO reagents was measured to evaluate the assimilation capacity of different iron ore. The lower the lowest assimilation temperature (LAT), the stronger the assimilation characteristics. The CaO and ore fines were extruded to two cakes respectively, and the ore cake was positioned on the CaO cake. Then the sample was heated in air according to the sintering temperature variation curve. The start of melting was taken as the start of assimilation, and the lowest start reaction temperature of different iron ore were measured. The sketch map of the test for assimilation capacity is shown in Figure 2.

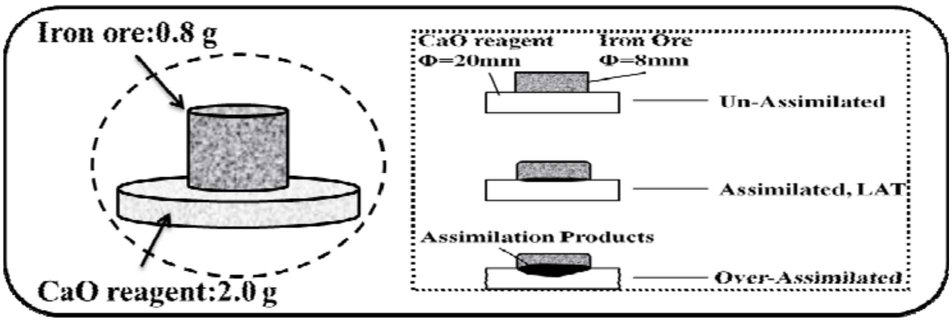

Figure 2. Schematic diagram of the assimilation capacity experiment.

2.2.2 Fluidity of liquid phase fluidity

In this work, the index of fluidity of liquid phase(IFL)of the sample composed of different iron ore fines and CaO reagents was used to evaluate the liquid phase fluidity. The lower the index of fluidity of liquid phase (IFL), the poorer the liquid phase fluidity. The ore and CaO were mixed according to binary basicity was 4.0, and then extruded into a cylindrical cake sample. The sample was heated in nitrogen according to the sintering temperature variation curve. The vertical projected area of the cake after the test was measured to calculate the index of fluidity of liquid phase (IFL). The sketch map of the experiment for the liquid phase fluidity is shown in Figure 3.

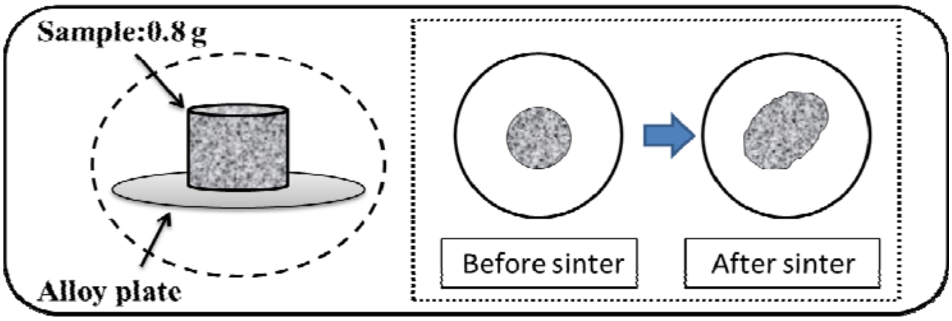

Figure 3. Schematic diagram of the fluidity experiment.

The IFL is the data which the projected area of the sample after heated decrease the projected area of the sample before heated, divide the projected area of the sample being before heated.

3 RESULTS

The results of XRD (shown in Figure 4), assimilation and liquid phase fluidity of the 8 kinds of iron ore are shown in Table 2.

Table 2. Results of XRD,LAT and FI of iron ore fines

Ore	**Iron-containing minerals**	**Gangue minerals**		**LAT/℃**	**IFL/-- (1280℃)**
		Si	Al		
IOA	Hematite and few goethite	Quartz	Gibbsite	1263	1.949
IOB	Hematite and few goethite	Quartz	Gibbsite	1290	2.183
IOC	Hematite and few goethite	Quartz	Gibbsite	1285	1.917
IOD	Hematite and few goethite	Quartz	Gibbsite	1270	0.000
IOE	Goethite and few hematite	Quartz	kaolinite	1215	1.824
IOF	Hematite and goethite	Quartz	kaolinite	1235	1.123
IOG	Hematite and goethite	Quartz	Gibbsite	1225	1.656
IOH	Hematite	Quartz	kaolinite	1237	2.859

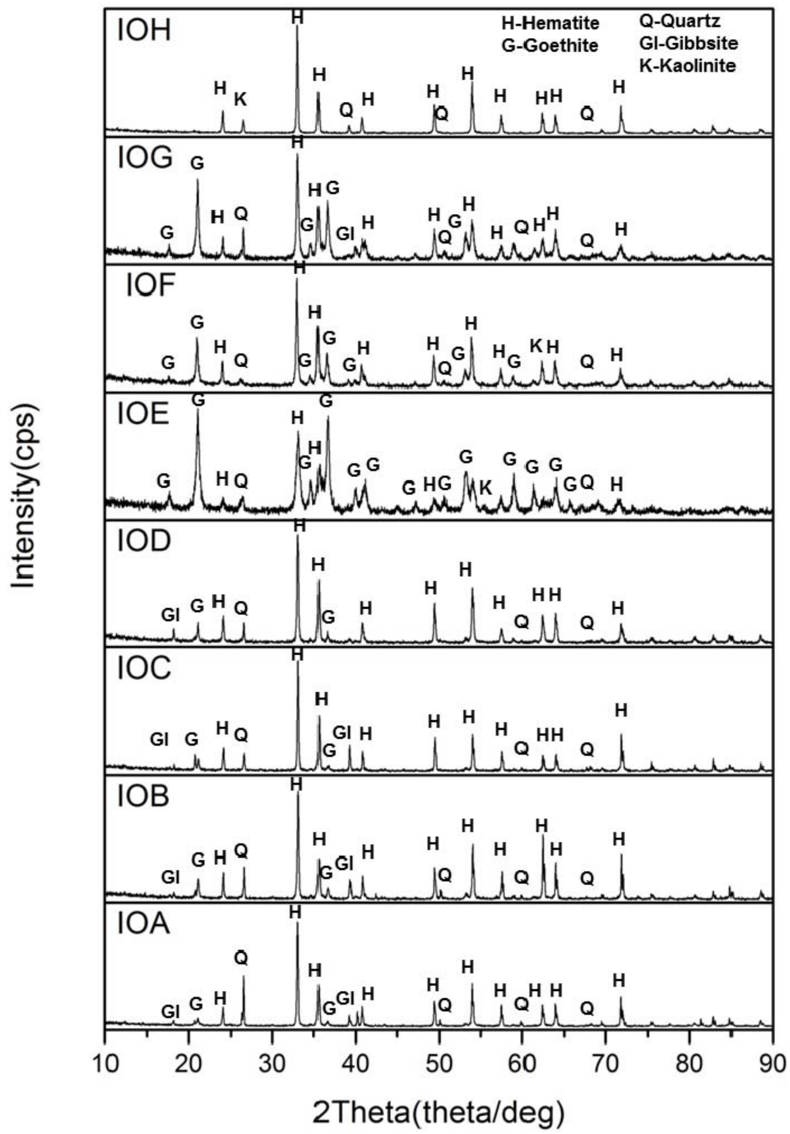

Figure 4. Results of XRD of iron ores.

4 DISCUSSION

4.1 Influence of Mineralogical Characteristics on Assimilation Characteristics

4.1.1 Chemical composition of iron ore

The main chemical composition factors which influence the assimilation temperature were the content of SiO_2, Al_2O_3 and LOI. According to the previous research,[4] the more SiO_2, the higher assimilation temperature the ore was. However, this law was adapted when the SiO_2 less than 4.5 mass%. With the resources of iron ore become inferior grade, gangue content ascend, the content of SiO_2 of some iron ore have climbed around to 6 mass%. Figure 5 shows the relationship between SiO_2 content and LATs of iron ores.

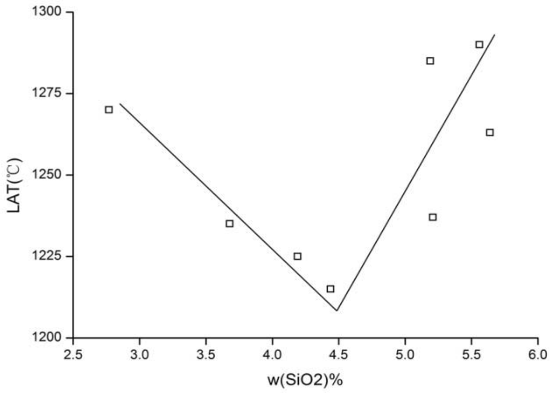

Figure 5. Relationship between the SiO_2 and the LATs

As shown in Figure 5, the SiO_2 of iron ores were not a simple line relationship with LATs. In the condition of SiO_2 content under a value (e.g.w (SiO_2)≈4.5%),the LATs become higher with more SiO_2 in ores; When exceed the value, the law was contrasted to the previous. Because the increased SiO_2 content has benefit to produce low melting point substances, such as the series of Fe_2O_3-CaO-SiO_2 eutectic mixture, its melting point is 1192℃. But with the content of SiO_2 continued to increase and reached a higher level, the SiO_2 was relative excess, and then produced higher melting point substances, such as the series of CaO-SiO_2. Moreover, SiO_2 elevated the melting point of the system, as SiO_2 was a high melting point substance.

The relationship between the content of Al_2O_3, LOI of iron ore and the LATs was shown in Figure 6 and Figure 7. With them increase, the LATs of iron ore dropt down.

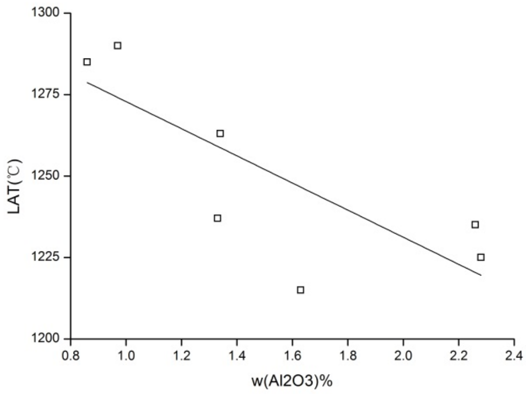

Figure 6. Relationship between the Al_2O_3 and the LATs.

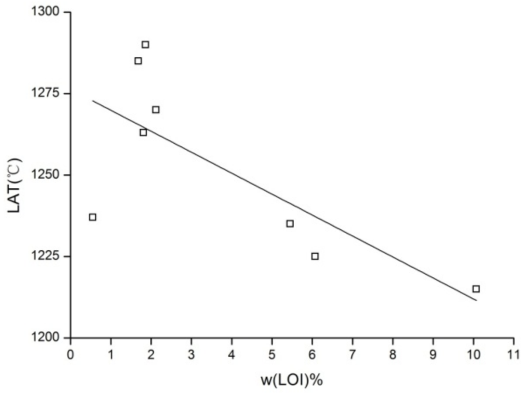

Figure 7. Relationship between the LOI and the LATs.

The increased of Al_2O_3 promoted to produce low melting point substance, SFCA, moreover, the primary SFCA enhanced the contact between CaO cake and ore particles, improved the chemical kinetic parameters. So it reduced the LATs. The iron ore of high LOI become loosen structure and higher porosity,(5) after the crystal water and carbonate resolved. Therefore, it improve dynamic condition of the diffuse of Ca^{2+} by increased reaction contact area, promoted to produce low melting point materials, lessened the LATs.

4.1.2 Mineral types

- **Influence of iron-containing minerals on assimilation of iron ore**

Iron-containing mineral types largely influence its assimilation characteristics.(6) Different types of minerals have obvious distinct of assimilation temperature , as shown in Figure 8. The research shown, because of the limonite has loosen and porosity structure, the assimilation reaction dynamic condition was better than hematite. The sort of assimilation capacity of iron mineral types: Limonite> Half-Limonite> Hematite.

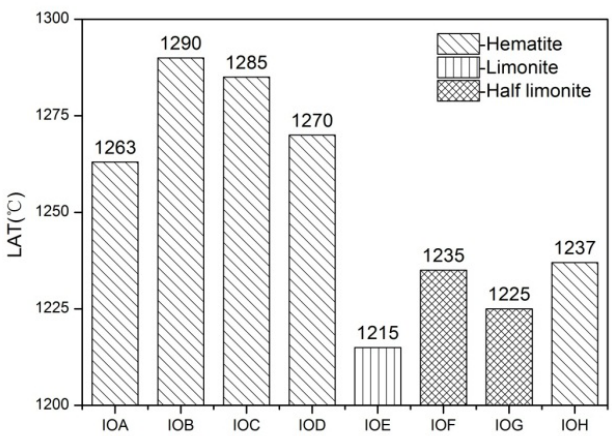

Figure 8. Comparison of the LATs of iron-containing minerals.

- **Influence of gangue minerals on assimilation of iron ore**

Figure 9 indicated gangue mineral types have some influences on assimilation characteristics, though it’s not notable as iron-minerals. In general, the assimilation temperature of iron ore fines which gangue minerals are quartz and gibbsite were higher than gangue minerals are quartz and kaolinite. The kaolinite' reactivity is higher than gibbsite,[6] so the LATs are lower. In addition, IOG was a special case which needed to be researched further.

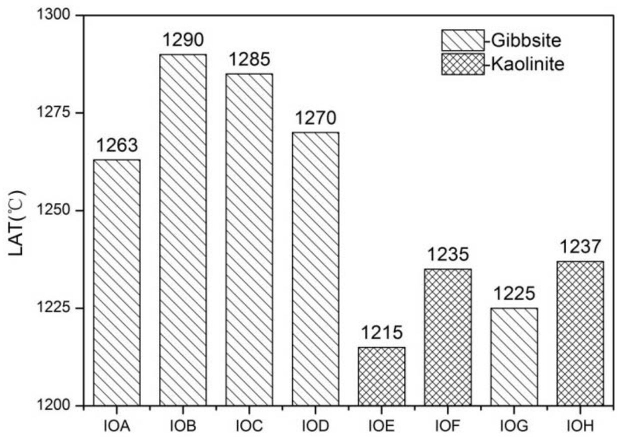

Figure 9. Comparison of the LATs of gangue minerals.

4.1.3 Particle morphology

Through microscopy observed the particle morphologies of iron ores, as shown in Figure 10 indicated that granules of IOB and IOC have dense slab-flaky structure. Compared IOB, IOC with IOA, have similar chemical composition and same mineral types, but LAT of IOA was obviously lower than IOB and IOC. It indicated the dense slab-flaky granules have inhibition function to assimilation characteristics. Not only because the dense and glazed surfaces of particles dropped down kinetics condition of the reaction with CaO, but also they could cause more void in iron ore fines cake, influenced the contact of iron ore granules, the primary melted liquid couldn't father developed. So influence the assimilation temperatures of ores. The results shown the iron ore granules have bulk or pisolitic structure which have good uniformity would have better assimilation characteristics.

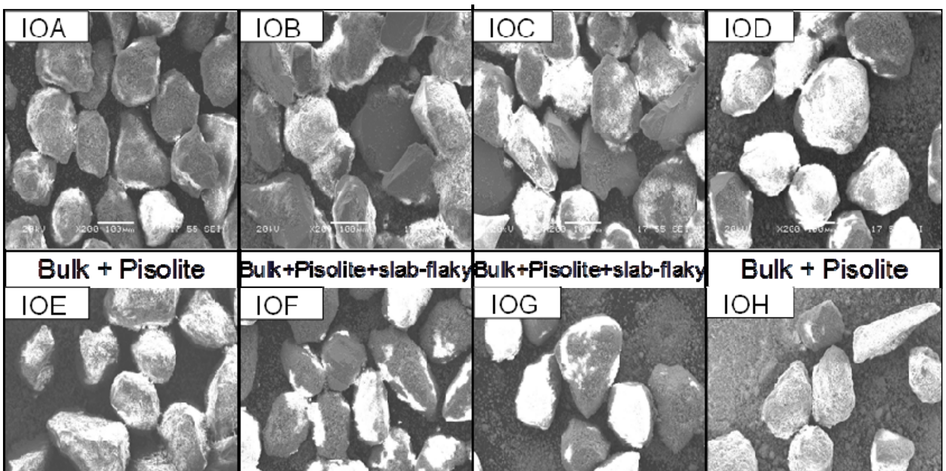

Figure 10. Images of particle morphologies of iron ore fines.

4.2 Influence of Mineralogical Characteristics on Liquid Phase Fluidity

4.2.1 Chemical composition of iron ore

Figure 11 to Figure 13 shown the influence trend of SiO_2, Al_2O_3 and LOI on liquid phase fluidity.

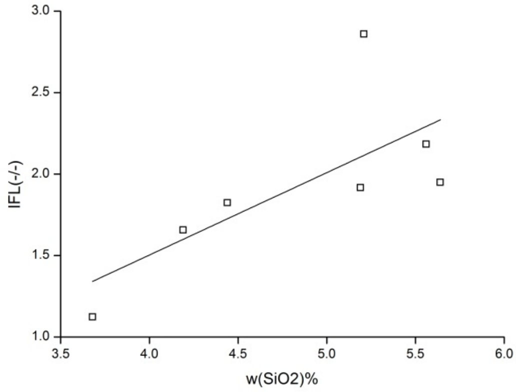

Figure 11. Relationship between SiO_2 and the IFLs.

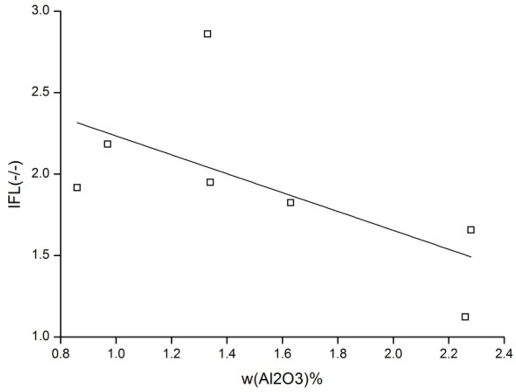

Figure 12. Relationship between Al_2O_3 and the IFLs.

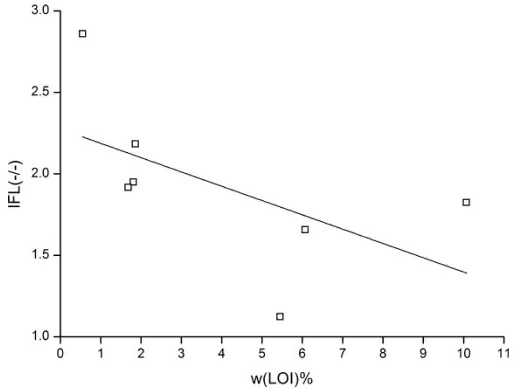

Figure 13. Relationship between LOI and the IFLs.

According to Figure 11 shown the IFLs ascend with the increase of SiO_2. Because a certain amount of SiO_2 were benefited to produce low temperature substances, such as a series of Fe_2O_3-CaO-SiO_2 mixture or SFCA, accelerated to liquid phase generate, enhanced the IFLs. For another, in the situation of fixed binary basicity, the additive amount of CaO was proportional to SiO_2 content. The increased content of CaO promoted to produce low melting point materials, thus it arose liquid phase fluidity.[7,8]

With Al_2O_3 content increased, IFLs descended, as shown in Figure 12. The content of Al_2O_3 has dual function to liquid phase fluidity. On a hand, Al_2O_3 is benefit to produce SFCA which is low melting point, enhanced the liquid phase fluidity capacity. On the other hands, Al_2O_3 is a high melting substance, with the content ascended, the melting point of liquid phase also arose, meanwhile, increased the viscosity of liquid phase.

In addition, the content of LOI also influenced the fluidity of iron ore. As the Figure 13 indicated that the IFLs descend with the LOI content ascend. Because of the iron ore fines formed new gaps and holes after calcination process. Primary liquid generated and penetrated into cracks, decreased the volume of outflow liquid phase, descended the fluidity index.[9,10]

4.2.2 Influence of gangue minerals on liquid phase fluidity of iron ore

In this experiment, SiO_2 of iron ore fines main exist modes was quartz, and Al_2O_3 was gibbsite or kaolinite. The previous researches shown,[2,11,12] the gangues in the form of clay minerals have higher reactivity. It could enhance the liquid phase fluidity. Kaolinite belongs to clay minerals. It has higher reactivity and easier produced low melting point liquids than gibbsite. Compared with the 4 ores (IOA, IOB, IOC, IOH) which have similar content of SiO_2 (shown in Figure 14), the results correspond with this law.

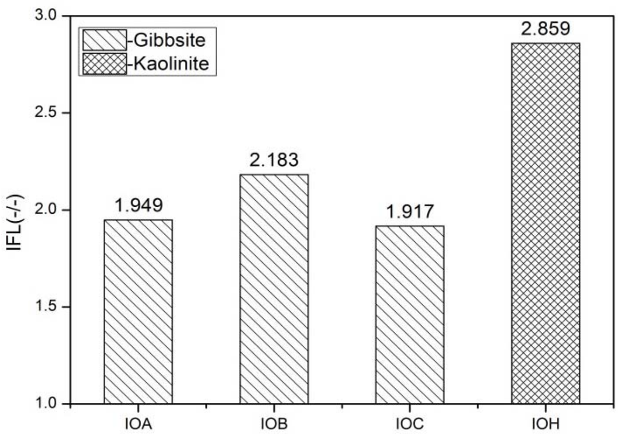

Figure 14. Comparison of the IFLs of gangue minerals.

4.2.3 Influence of gangue dispersity on liquid phase fluidity of iron ore

Adopted iron ore of IOA, IOB and IOC which own the similar chemical component and the same mineral types to compare to the influence of gangue dispersity on liquid phase fluidity. The research founded that the gangues of IOA and IOC were relatively concentrated and the sizes were bigger. The gangues of IOB were tiny and tight integrated with iron minerals, as shown in Figure 15. The quartz granules could obviously find in ore of IOA and IOC.

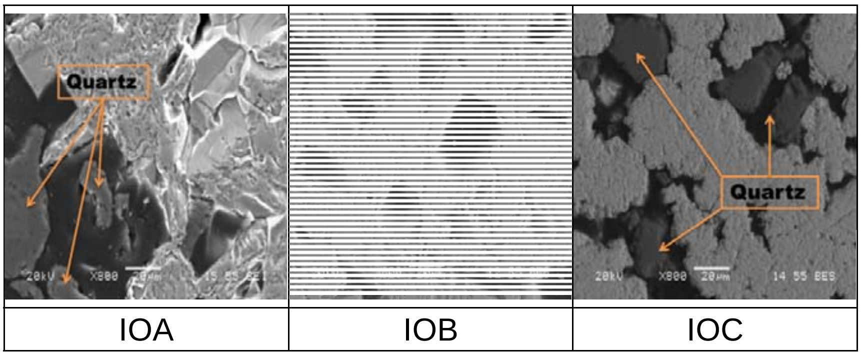

Figure 15. SEM images of IOA, IOB and IOC.

According to the results of LATs and IFLs of the iron ores, IOB has the highest LAT, it's 1290℃. It indicates the ore of IOB begin to melting and produce liquid phase need a higher temperature condition. Under the same heating mechanism, it should have produced less liquid phases. But the IFL of IOB is the highest in these ores. Even though the LATs of IOA and IOC were lower than IOB, and they would produce more liquid phases than IOB, but the gangues of IOA and IOC were concentrated and the sizes were bigger. The gangue granules could not completely dissolve into liquid phase in the relative short time. These gangue particles in the liquid phase would ascend the viscosity of liquid phase,[13] hindered the flowing.

5 CONCLUSIONS

The research were conducted to discuss the influence of mineralogical characteristics of iron ore especially micro-characteristics on assimilation characteristics and liquid phase fluidity. The results are as follows:

1) The main factors which influence of mineralogical characteristics of iron ore on assimilation characteristics and liquid phase fluidity were chemical composition, mineral types, particle morphology and gangue dispersity.

2) In this experiment, $w(SiO_2)\%<4.5$,the assimilation characteristics of iron ores arose with the increased of SiO_2, but the excessive content of SiO_2 dropped down the assimilation characteristics.

3) Al_2O_3 and LOI were conducive to assimilation characteristics, but were bad for fluidity of liquid phase.

4) The mineral types of Al-containing gangues influence liquid phase fluidity. Gangues exited mainly in the form of kaolinite would better than gibbsite to liquid phase fluidity capacities.

5) In the micro-characteristics of iron ores aspect, the dense slab-flaky granules of iron ores restrained the assimilation capacities from dynamics constitutions; independent enrichment gangue particles which have digger sizes, restrained the liquid phase fluidity.

Acknowledgment

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