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Crystal Plane Anisotropy and the Collection Strengthening of Spodumene

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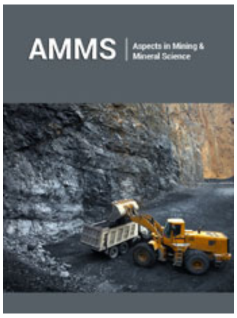

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Abstract

To improve the separation efficiency of spodumene from gangue minerals, the strengthening of the collection of spodumene and the enlarging of the floatability difference between spodumene and gangue minerals are very important. Spodumene is a silicate mineral with chain structure, and its cleavage planes have obvious anisotropy, which affects the adsorption behavior of collector on each crystal plane. Oleate ions mainly adsorbed on the (110) and (100) planes of spodumene, while the combined collector of oleic acid and dodecyl amine promoted the adsorption of collector on the (001) and (010) planes without reducing the adsorption of collector on the (110) and (100) planes of spodumene, and then it strengthens the flotation collection of spodumene.

Keywords: Spodumene; Crystal plane anisotropic; Anionic collector; Anionic/Cationic Collector

Introduction

Lithium was acclaimed as the energy metal for world progress, and it is widely used in pharmaceutical, ceramic, battery, aerospace, and nuclear energy industries. Pegmatite type spodumene ore is one of the important sources for lithium extraction. Flotation is the most common technology for the separation of spodumene from the ores. Because the associated minerals in spodumene ore are feldspar, quartz and beryl, which have similar surface chemical properties as spodumene, so it makes the difficult to separate spodumene from other silicate minerals. Improving the separation efficiency of spodumene is a key issue to realize the efficient utilization and sustainable development of pegmatite lithium resources. It has been found that there is anisotropy of spodumene cleavage planes, and the adsorption behavior of collectors on the different cleavage planes is also different. Strengthening the adsorption of collectors on the different crystal planes of spodumene is an important way to strengthen the flotation of spodumene [1-14]. Based on these research, the crystal plane anisotropy of spodumene and the adsorption behavior of different collectors on crystal planes of spodumene were analyzed and summarized here, in order to provide a new idea for the follow-up research of spodumene flotation.

Crystal Plane Anisotropy of Spodumene

The common exposed cleavage planes of spodumene after the crushing and grinding are (110), (001) and (100), which will lead to the unique surface properties of spodumene. The Al in spodumene is located in the center of octahedron formed by six coordinated o, so the electrostatic strength of each Al-O bond is equivalent to 1/2 valence. As shown in (Figure 1 & Table 1), two Al-O bonds are broken for each aluminum on (110) plane, one Al-O bond is broken for each aluminum on (001) plane, and three Al-O bonds are broken for each aluminum on (100) plane [7].

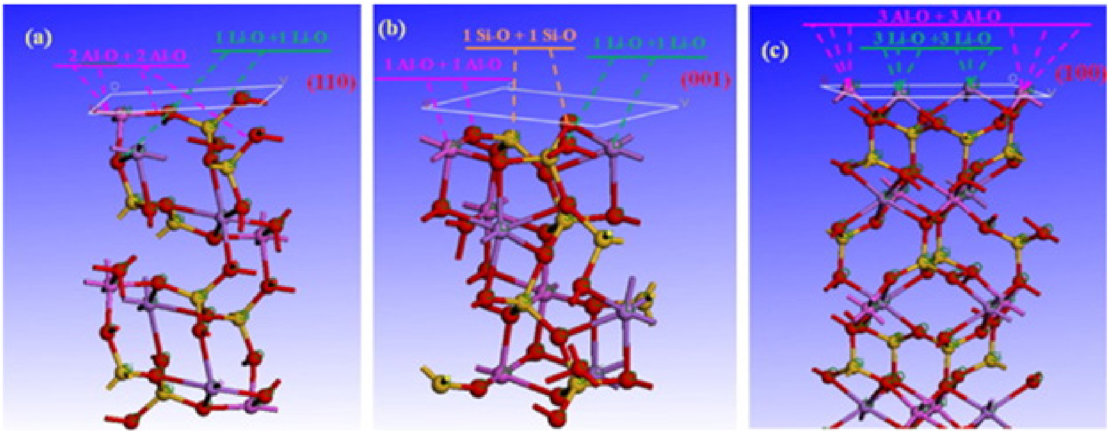

Figure 1: Schematic diagram of bond breaking in different crystal planes of spodumene [7].

(a)-(110), (b)-(001) and (c)-(100). (Color: red-O, white-h, pink Al, lavender Li and yellow Si).

Table 1: Broken bond number of different crystal planes of spodumene [9].

Broken Bond	Crystal Plane	Number of Broken Bond (N_b)	Unit Area of Cell (A/nm^2)	Density of Broken Bond (D_b/nm^{-2})
Li-O	110	2	0.33	6.06
	001	2	0.38	5.26
	100	6	0.44	13.64
Al-O	110	4	0.33	12.12
	001	2	0.38	5.26
	100	6	0.44	13.64
Si-O	001	2	0.39	5.10

Adsorption of anionic collector on crystal plane of spodumene

Different broken bond number of Al-O and Si-O bond on different cleavage planes of spodumene result in the adsorption anisotropy of flotation reagent on different cleavage planes in flotation process. As shown in Figure 2, when sodium oleate (NaOl) is used as collector, sodium oleate has two carboxyl oxygen atoms with -1/2 electrostatic charge, while on the spodumene (110) surface there are two aluminum atoms with +1/2 electrostatic charge that do not meet the coordination valance. (110) and (100) planes are the ideal plane for NaOl chemical adsorption, but there are weak adsorption of sodium oleate on (001) plane [7]. Therefore, it is undoubtedly one of the important ways to improve the flotation of spodumene by regulating the exposure ratio of (110) plane in the process of spodumene crushing and grinding [1,3,6].

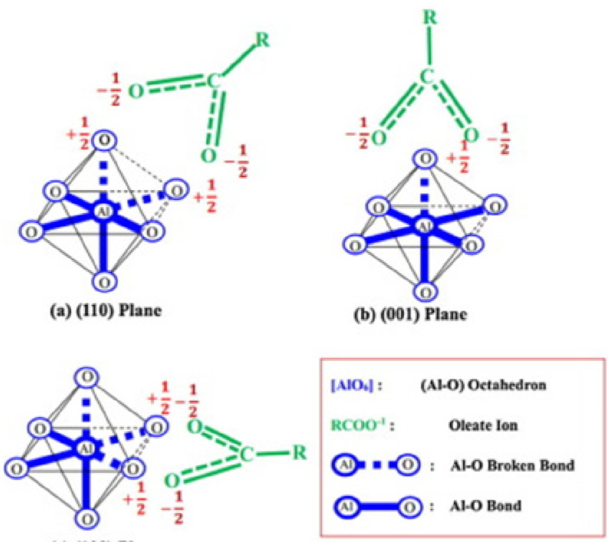

Figure 2: Adsorption model of oleic acid on different cleavage planes of spodumene [9].

Adsorption of anionic/cationic collector on spodumene crystal plane

It has been proved that the combined collector can improve the collecting capacity and selectivity based on the synergism of different collectors, so the combined collector has been widely used in flotation practice. The combination of anionic/cationic collector has shown better collection capacity and selectivity for spodumene flotation and has become a new type of collector with the most application potential in spodumene ore flotation, such as NaOl/DDA [11], NaOl/DTAC [8,10], NaOl/DS [12] and sodium oxide paraffin salt/DDA [13]. The adsorption capacity of collector on spodumene is larger than that of oleic acid using alone instead of the combination collector of oleci acid and dodecyl amine. As shown in Table 2, the adsorption of sodium oleate on the spodumene (110) and (100) planes is mainly observed when sodium oleate is used as collector alone, and the contact angles are significantly higher than that on (001) and (010) planes. When sodium oleate and dodecyl amine were used as the combined collector, the contact angles of spodumene (110) and (100) planes changed slightly, but the adsorption of collector on (001) and (010) planes was significantly increased which results in the significant increase of the contact angles.

Table 2: Contact angles at spodumene crystal planes [5].

Crystal Plane	NaOl	Combined Collector M(NaOl):M(DDA)					
		10:1	5:1	1:1	1:2	1:4	DDA
(110)	73	68	71	68	70	73	70
(001)	37	66	65	60	67	70	75
(010)	35	65	65	61	68	70	70
(100)	80	83	85	75	78	75	70

The same result was also found that oleate adsorbs on (110) plane of spodumene as a dense monolayer in the absence of DDA while its adsorption on (001) plane is weak [6]. As shown in Figure 3, a small amount of DDA can significantly promote the adsorption of collector on (001) plane but has little effect on the adsorption of collector on (110) plane of spodumene. This is an important reason why the combined collector of oleic acid and dodecyl amine can further strengthen the flotation of spodumene [14].

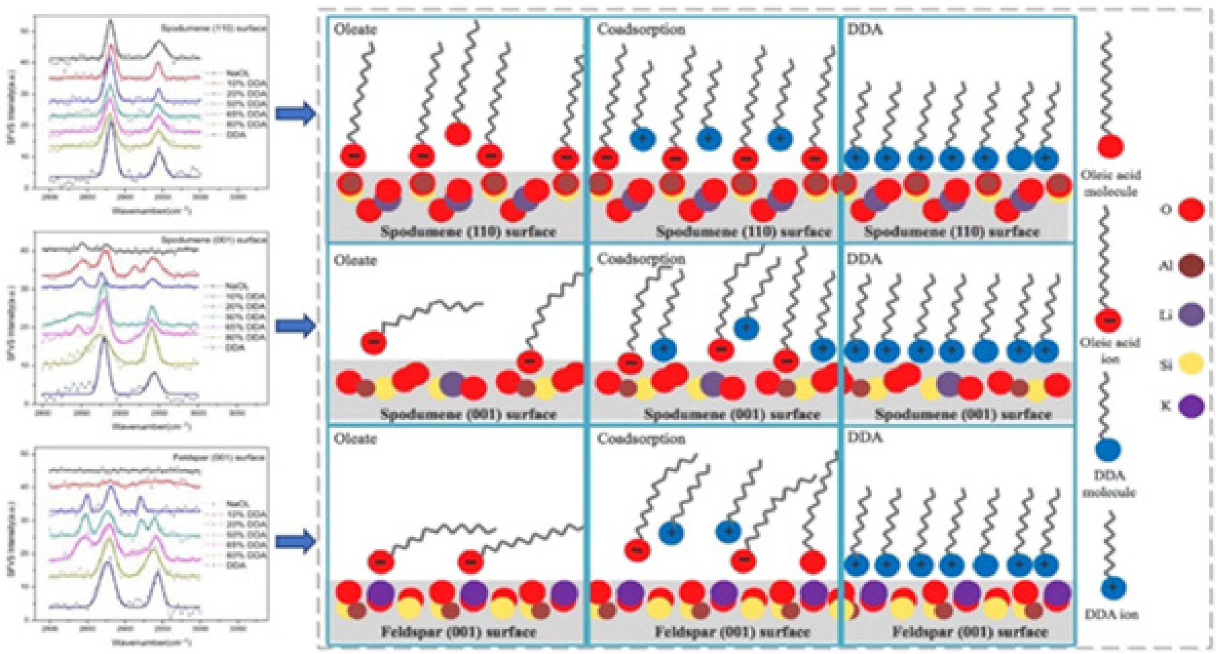

Figure 3: Different adsorption models of dodecylamine and sodium oleate on spodumene and feldspar crystal planes [14].

Conclusion

Spodumene, quartz and feldspar are all silicate minerals and have the similar surface properties, it is difficult to separate spodumene from gangue minerals by flotation. After the crushing, the main cleavage planes of spodumene are (110), (001), (010) and (100), which show differences in physical and chemical properties. It leads to the different adsorption behavior of collectors on different cleavage planes, the more adsorption of sodium oleate on (110) and (100) plane, but the less on (001) and (010) planes, which leads to the limitation of the collector capacity for sodium oleate. However, the combined collector of oleic acid and dodecyl amine can further strengthen the collector adsorption on (001) and (010) planes without affecting the adsorption of collector on (110) and (100) planes. In a result, the adsorption of collector on spodumene was strengthened and the effect of crystal plane anisotropy was also eliminated.

Acknowledgment

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