The 6th International Symposium on East Asian Resources Recycling Technology
October 23 - 25, 2001, Gyeongju (慶州), Korea
ISBN: 89-952527-0-7 93530

Preparation of Aluminum Hydroxide by Processing of Aluminum Dross

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Abstract: Aluminum dross should be recycled in consideration of characteristics of the dross and its reutilization after processing. In this study, aluminum dross generated in the domestic secondary aluminum industry was processed to use it as raw material for producing aluminum hydroxide. Sample dross was classified according to its size. The dross smaller than 1mm was leached with sodium hydroxide solution to extract the remaining aluminum from the dross into the solution, and then aluminum hydroxide precipitate was recovered from the leach liquor. Purity of the obtained aluminum hydroxide was above 98 percent, and particle size of the sample was in range of 3-39µm. From the result, it was suggested that this process could be applicable to recycling of aluminum dross.

Key Words: Aluminum dross, Recycling, Leach liquor, Aluminum hydroxide,

Introduction

Aluminum dross is formed on molten aluminum due to its great affinity for oxygen. Skimming of dross from the molten aluminum bath invariably results in loss of the underlying metal, and dross is a major waste in the production of aluminum metal. Dross is processed to recover the remaining aluminum by means of physical separation and remelting. and then residue in the dross processing is normally landfilled. In recent years, landfill cost in waste management increases because of increasing local environmental regulations. Also, there arise social needs for recycling of the wastes. Because it becomes difficult to dispose of dross in landfills, recycling of dross is an important issue in the secondary aluminum industries. In the developed countries, some innovative technologies on treatment of aluminum dross have been developed. Several technologies for extracting remained aluminum in dross and reducing amount of dross have been developed and commercialized[1-4]. However, technology for recycling of waste dross has not been reported so many yet[5].

It is assumed that about sixty thousand tons of dross have been generated annually in Korean aluminum industries. The dross has been processed by the secondary aluminum producers in consideration of recovering the remaining aluminum. The hot dross is squeezed by press, or centrifuged to separate molten metal from the dross. In some case, aluminum could be recovered by remelting the dross in crucible with salt flux covering the melt surface. The residues in the dross processing are disposed of in landfills mostly until now. Aluminum production in Korea has been increasing, and social need for environmental preservation is also an important issue nowadays. So, it is necessary that technologies on effective dross treatment should be developed in the domestic secondary aluminum industries.

Two aspects should be considered in dross treatment. One is how to recover remaining aluminum effectively, and the other is how to reduce the amount of the waste residue generated in the dross treatment. In consideration of the second aspect, reuse of the residue would be the best in dross recycling. In this study, remaining aluminum in the waste dross was recovered as aluminum hydroxide precipitate by application of Bayer Process[6], which is a traditional method for manufacturing aluminum hydroxide from bauxite ore. Through the study, an effective method relevant to recycling of the domestic aluminum dross would be suggested.

Experiment

Sample Dross

The sample used in the experiment was confined to black dross generated in the domestic aluminum industries. The sample dross, which was generated in an aluminum scrap smelter, was processed in the smelter to recover the remaining aluminum previously, and was about to disposed of in landfills. Chemical composition of the sample dross was shown in Table 1, and size distribution by use of Taylor sieves was shown in Table 2. Magnesium, sodium, calcium, iron, and potassium were contained as major impurities in the sample. Because amount of salt flux used in the melting of scrap and in the processing of dross at the scrap smelter was small, contents of sodium and potassium were small in the sample dross. Also, metallic aluminum in the dross was about 34% by weight. Main phases of the sample were confirmed as Al_2O_3, metallic Al and $MgAl_2O_4$ by X-ray diffraction method.

Experimental Procedures

Figure 1 schematically shows experimental procedures carried out in this study. The main idea of this process flowsheet is that it could be more effective on recovery of the remaining aluminum from the dross to separate small size dross from large size before melting. When dross is crushed, size of oxide phase in the dross becomes smaller and metallic phase becomes larger. The critical size in the classification was 1mm in this study. The undersize dross at the classification step in Figure 1 was treated as waste dross. This waste dross was leached with 10% sodium hydroxide to extract remained metallic aluminum into the solution as the following equation (1).

$$2Al_{(in\ dross)} + 2NaOH + 2H_2O \rightarrow 2NaAlO_2 + 3H_2\uparrow \quad (1)$$

The hydrogen gas generated in this reaction could be collected. The leached solution was processed to recover the dissolved aluminum as aluminum hydroxide precipitate as the following equation (2) with addition of aluminum hydroxide fines as seed material according to Bayer process.

$$NaAlO_2 + 2H_2O \xrightarrow{Al(OH)_3\ seed} Al(OH)_3\downarrow + NaOH \quad (2)$$

Factors affecting extracting the remained aluminum at the leaching of dross with NaOH solution were concentration of NaOH, pulp density of the solution, and A/C ratio, which describes amont of aluminum to sodium in the solution. Definitions of these factors used in this study were described as following equations (3), (4), (5). Here, C is concentration, W means weight of samples, and P.D. is pulp density of the solution. Also, $W_{(Al)}$ means weight of remained aluminum of the dross sample.

$$C_{(\%,\ NaOH)} \equiv W_{(NaOH)}/\{W_{(NaOH)} + W_{(H_2O)}\} \quad (3)$$

$$P.D. \equiv W_{(dross)}/\{W_{(NaOH)} + W_{(H_2O)} + W_{(dross)}\} \quad (4)$$

$$A/C \equiv W_{(Al)}/W_{(NaOH)} \quad (5)$$

$Al(OH)_3$ was precipitated in the leached liquor according to equation (2). It was washed and dried as shown in Fig. 1. Its phase was analyzed by use of X-ray diffraction, and purity was quantitatively analyzed by ICP method. Recovery of $Al(OH)_3$ was calculated as equation (6). Here, M means molecular weight of the material. The residue at the leaching step was processed through washing, drying, and roasting to reuse it as raw materials for ceramics.

$$R(\%) \fallingdotseq \frac{W_{(Al(OH)_3,\ precipitated)}}{W_{(Al)} \times M_{(Al(OH)_3)}/M_{(Al)}} \times 100 \qquad (6)$$

Results and Discussion

Purity and of the Prepared $Al(OH)_3$

Phase of white precipitates prepared in the experiment was confirmed as $Al(OH)_3$ by use of X-ray diffraction method. Diffraction peaks were shown in Fig. 2, and the peaks were as same as those of aluminum hydroxide denoted as '29-41'. Contents of impurities in the precipitates were shown in Table 3 together with those of a commercial reagent for comparison. Sodium and silicon were major impurities in the sample. From this table, it could be assumed that the purity of the obtained aluminum hydroxide was above 98%. Size of the sample was in range of 3-39μm through scanning electron microscopy. It was considered that the sample of this grade could be used for manufacturing water treatment product such as aluminum sulfate. The filtrate at the precipitation step in Fig.1 could be recycled into the leaching step by adjustment of sodium concentrate. To produce aluminum hydroxide by use of waste dross has some advantages in consideration of saving cost for raw ores and the equipment cost used for traditional process.

Shape of the Sample

Shape of the prepared $Al(OH)_3$ was observed by Scanning Electron Microscopy. It was shown in Fig. 3. Number "1" on the left-upper side in the photo represents shape of precipitates whose precipitate time was twelve hours, and "2" was that of precipitates whose precipitate time was 7 days. Magnification of both photos were same as ×5,000. Fine precipitates were agglomerated in case of number "1" due to insufficient nuclear growth time, and nuclear of precipitate was sufficiently grown in case of number "2". It was shown that shape and size of the precipitates were varied according to precipitating condition. Size distribution of the precipitated sample analyzed by laser beam light scattering was in range of 3-39 μm.

Effect of A/C on recovery of $Al(OH)_3$

The waste dross under 1mm size was leached with variation of A/C ratio. At the leaching step, aluminum reacts with sodium hydroxide with same stoichiometric equivalent as shown in equation (1). Because molecular ratio of aluminum and sodium hydroxide was 27/40, stoichiometric A/C ratio was 0.675 in the reaction. So, experimental range of A/C was 0.3-0.67. Aluminum content of sample dross was estimated as 30 percent for convenience' sake of calculation. The other experimental conditions were listed in Table 4 with result of recovery. Amount of sodium hydroxide and its concentration was varied with variation of A/C. Recovery of precipitated $Al(OH)_3$ shown in Table 4 was graphed as Fig. 4. Precipitation was low in case of low A/C such as 0.3, and precipitation also decreased in case of over A/C 0.6. Maximum 66% of the dissolved aluminum could be recovered as aluminum hydroxide precipitate at A/C 0.5. Fig 5 shows recovery of precipitates near A/C 0.5 in detail. From the results, A/C 0.5 was the most effective in this experimental conditions.

Effect of P.D. on recovery of $Al(OH)_3$

Pulp density(P.D.) of the leaching solution also affects the extraction of aluminum and recovery of $Al(OH)_3$ precipitates. If A/C is constant, relatively dense P.D. would be more advantageous than lower case because large amount of dross could be leached with one batch. However, loss of leached solution, which is due to pore of solid particle, would be relatively larger at filtration step. Recovery of $Al(OH)_3$ was investigated with range of P.D. 8-16. A/C was fixed as 0.5 in this experiment. The other experimental conditions were listed in Table 5 with result of recovery. Result shown in Table 5 was graphed as Fig. 6. Precipitation occurred little in case below P.D. 8%. When it increased over 10%, precipitation of $Al(OH)_3$ increased with increase of P.D. Maximum 67% of the dissolved aluminum could be recovered as aluminum hydroxide precipitate in case of P.D. 16%. From the results, it was considered that P.D. 14-16 was the most effective in this experimental conditions.

Conclusion

Aluminum dross should be treated in consideration of characteristics of the dross and its reutilization after processing. Through the experimental study for recycling of aluminum dross, the waste dross could be recycled for recovering the remained aluminum in the form of aluminum hydroxide through leaching with sodium hydroxide, and the waste residue could be reused as raw material for ceramics. Purity of the prepared aluminum hydroxide was above 98 percent, and particle size of the sample was in range of 3-39μm. At conditions that A/C 0.5 and pulp density 14-16 at the leaching step, maximum 67 percent of the dissolved aluminum could be recovered as aluminum hydroxide precipitate. It is considered that this process could be a good suggestion for recycling and minimization of waste aluminum dross.

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<Table List>

<Figure List>

Table 1. Chemical composition of the sample dross

Chem. Comp.	Ca	Fe	K	Mg	Mn	Na	Ti	Zn
Average	1.70	1.28	0.99	3.28	0.16	1.93	0.34	0.39

Table 2. Particle size distribution of the sample dross

Sieve Mesh	+20	20/40	40/50	50/70	70/100	100/200	200/325	-325
Average, wt%	3.1	25.7	12.2	8.2	13.8	26.7	8.2	2.1

Table 3. Chemical composition of the aluminum hydroxide sample

\Composition Sample\	Na, %	Si, %	Ca, ppm	Fe, ppm	Mg, ppm	Mn, ppm	Cu, ppm	Ni, ppm	K, ppm
Prepared	0.77	0.56	13	18	<1	<1	<1	<1	210
Commercial	0.09	0.052	7.9	23	<1	<1	<1	<1	26

Table 4. Recovery of $Al(OH)_3$ with variation of A/C ratio

P.D.(%)	Water (ml)	NaOH (g)	C_{NaOH} (%)	Amount of Dross (g)	A/C	Recovery (%)
14	1000	194.5	16.28	194.5	0.3	12.35
		139.1	12.21	185.5	0.4	46.77
		108.3	9.77	180.5	0.5	66.50
		88.6	8.14	177.3	0.6	58.17
		77.1	7.15	175.4	0.67	47.76

Table 5. Recovery of $Al(OH)_3$ with variation of pulp density

A/C	Water (ml)	NaOH (g)	C_{NaOH} (%)	Amount of Dross (g)	P.D. (%)	Recovery (%)
0.5	1000	55.0	5.20	91.7	8	1.4
		71.4	6.66	119.0	10	41.8
		89.1	8.18	148.5	12	57.0
		108.3	9.77	180.5	14	66.5
		129.0	11.42	215.0	16	67.2

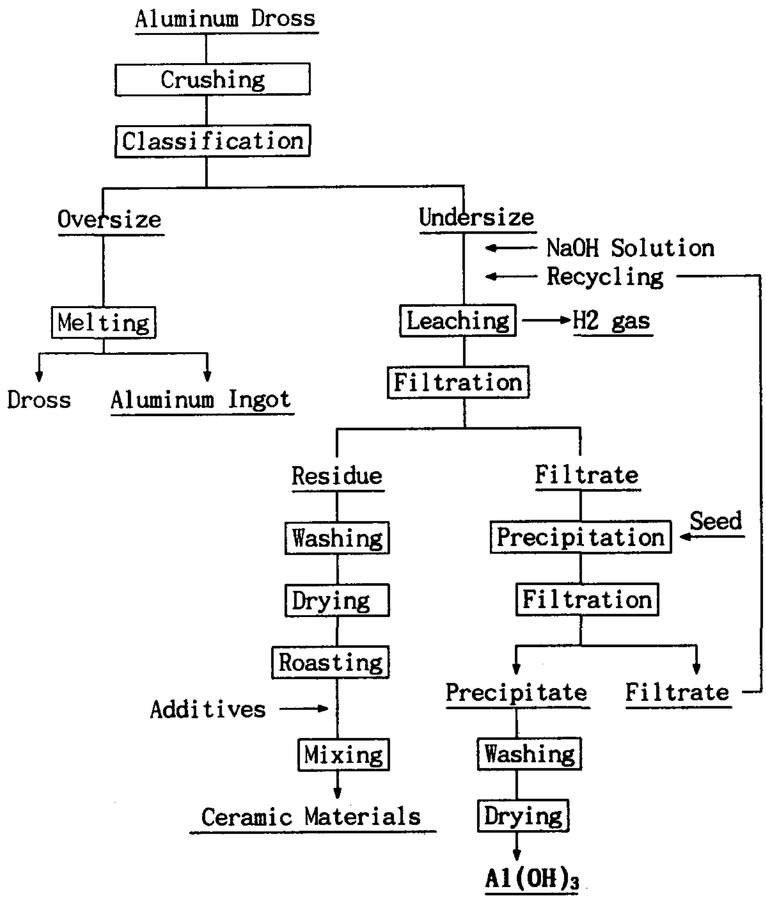

Fig. 1. Schematic diagram of the process for recycling of aluminum dross

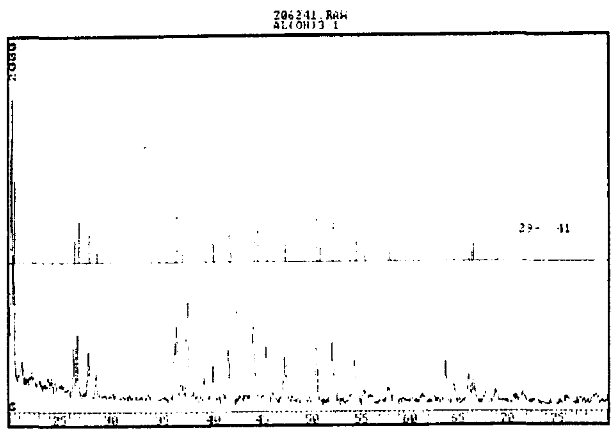

Fig. 2. X-ray diffraction curve of the aluminum hydroxide sample.

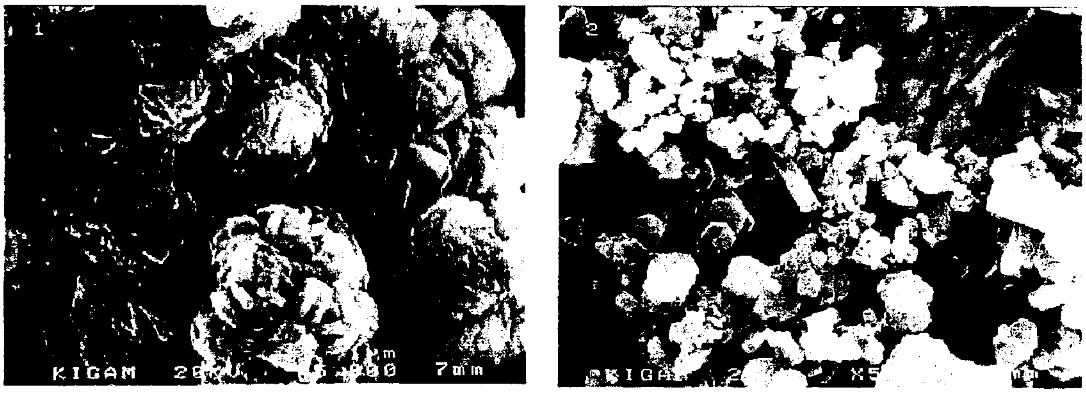

Fig. 3. Photos by SEM of the aluminum hydroxide sample ($\times$5,000).

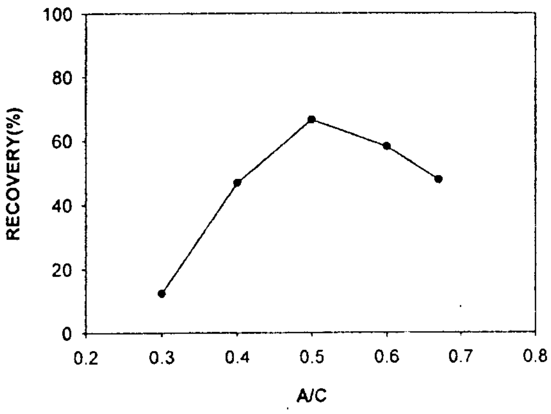

Fig. 4. Recovery of $Al(OH)_3$ with variation of A/C ratio.

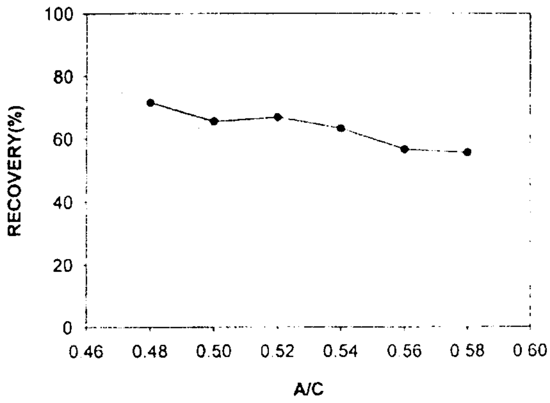

Fig. 5. Recovery of $Al(OH)_3$ with variation of A/C near 0.5.

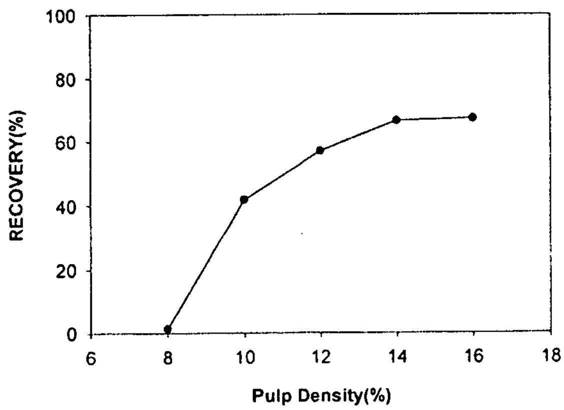

Fig. 6. Recovery of $Al(OH)_3$ with variation of pulp density.