A Novel Process of Heap Leaching Extraction of Sc, Zr, Ti, Al, Na from Bauxite Residue with Carbon Footprint Reduction

Alexander Kozyrev[1], Alexander Suss[2], Nataliya Kutkova[3], Tatiyana Gabrielyan[4], Alexander Damaskin[5] and Andrey Panov[6]
1. Chief Researcher
2. Department Director
3. Engineer
4. Engineer
5. Senior Researcher
6. Director R&D Alumina
RUSAL Engineering and Technology Center, Saint Petersburg, Russia
Corresponding author: Aleksandr.Suss@rusal.com

Abstract

A novel process of valuable elements extraction from bauxite residue (BR) with a sodium hydrocarbonate solution using cold "heap" leaching (HL) has been proposed and evaluated in this study. Recovery of Sc, Zr, Ti, Al, Na using the HL process from BR from 2 Russian refineries was studied. Heap leaching provides for extraction of ~ 30 % of scandium from BR. At optimum process conditions, Sc_2O_3 content in the product solution amounted to 5–20 mg/dm^3 and ZrO_2 content amounted up to 0.25 g/dm^3. The obtained concentration of Sc_2O_3 in the solution is higher as compared with "hot" sodium bicarbonate leaching of bauxite residue. With the established technology Sc-concentrate, as well as zirconium, titanium, aluminum are extracted from Sc-containing solution. After Sc, Zr, Ti, and Al have been precipitated the recirculated solution is treated with CO_2 containing exhaust gas of the refinery to convert part of soda to sodium bicarbonate preparing these liquors to be returned to the head of the process to heap leaching. Aluminum removed from BR as pseudoboehmite (AlOOH) or gibbsite-bayerite $Al(OH)_3$ is returned to alumina production or used as special grade products.

Gravity filtration of the sodium bicarbonate ($NaHCO_3$) solution through a BR layer promotes several processes, i.e. caustic alkali sorbed on BR surface is converted to liquid phase sodium carbonate; sodium aluminate is washed from the residue. Alkali from BR and alkali used to obtain Sc-concentrate promote the HL process. Part of tricalcium hydroaluminates (TCA) and hydrogarnets (HG) from bauxite residue react with sodium bicarbonate to form calcium hydrocarboaluminates and low-temperature calcium carbonates thus binding CO_2. Part of alkali in desilication products (DSP) is replaced with CO_2, and DSP partially decomposes. In HL process bauxite residue binds a significant amount of the refinery emitted carbon dioxide thus reducing carbon footprint of alumina production. After completion of heap leaching both liquid and solid phases of bauxite residue have almost neutral pH values and therefore are of lower hazard class.

Keywords: Bauxite residue, Heap (cold) leaching, Carbon dioxide, Sodium bicarbonate, Carbon footprint.

1. Introduction

Bauxites from the deposits located in the north of European Russia, i.e. North Urals (SUBR), Middle-, South-, and North-Timan (STBR), North Onega (SOBR) bauxites, are characterized by high scandium content (60–350 ppm Sc_2O_3equiv.). Explored reserves of these bauxites amount to > 1.5 Gt thus containing a significant part of the world's supply of available scandium. Due to the mineral and geochemical features of these bauxites a major part of scandium is present in boehmite and diaspore as well as in chamosite, zircon $ZrSiO_4$, and pyrite FeS_2, while a lesser amount occurs in iron-containing minerals (hematite Fe_2O_3 and goethite FeOOH) [1].

The RUSAL Kamensk Uralsky and RUSAL Krasnoturyinsk refineries (UAZ and BAZ respectively) produce alumina from a mixture of boehmitic and diasporic bauxites (SUBR and STBR bauxites) using a parallel combined Bayer-sintering process. Scandium is leached from boehmite, diaspore, zircon, and pyrite at a high temperature (≈ 230 °C) and sorbed on the surface of the bauxite residue (BR) in the form of $Sc(OH)_3$ or ScOOH. Scandium oxide concentration increases in UAZ and BAZ residues by two or more times compared with bauxite. Sc_2O_3 content increases to 140÷160 ppm (UAZ) and 180÷210 ppm (BAZ). Moreover, ≥ 60 % of scandium in these BRs are present in the form that can be easily leached with alkaline solution at a pH of ≤ 9 [1].

The results of pilot tests at the Urals refinery (UAZ pilot plant) proved the possibility of leaching up to 35 % scandium with a sodium bicarbonate solution (consisting of the mixture of Na_2CO_3 and $NaHCO_3$) at the atmospheric pressure [2, 3].

With sodium bicarbonate leaching (SBL) a significant part of zirconium and some titanium are leached from BR with scandium. If added to the aluminium alloy in a specific amount with scandium, zirconium and titanium serve as alloying elements for production of Al-Sc alloys. The addition of zirconium and titanium allows reducing specific consumption of scandium while maintaining the properties of Al-Sc alloy.

RUSAL Engineering and Technology Center has developed a method for direct production of Sc-containing smelter grade alumina from a Sc-containing sodium bicarbonate solution [4]. Use of Sc-containing alumina comprising a specific amount of Zr and Ti enables to directly produce Al-Sc alloys excluding the following stages: 1) deep purification of scandium concentrate from impurities; 2) producing Al-Sc2% master alloy. RUSAL's technology reduces scandium losses and decreases the production cost of Al-Sc alloys.

To treat the larger residue volumes and to enable the in-situ treatment of BR disposal areas, it was decided to develop the technology of so-called cold heap leaching to extract Sc, Zr, and Ti from the bauxite residue. Cold heap leaching is widely applied in gold and uranium industries. The present paper discusses the results obtained.

2. Experimental - Cold Heap Leaching Tests

Aprox. 450±25 g (on a dry basis) samples of bauxite residue from different alumina refineries were placed into gravity columns (with an inner diameter of Ø 45 mm) (Figure 1). In all tests the BR layer was ≈ 350±3 mm. Then the BR samples were processed as follows:

- aprox. 450±25 g (on a dry basis) sample of the bauxite residue was reslurried using 1 dm^3 of cold water;
- the obtained BR slurry was placed into the gravity column;
- the flow rate of the water passing through the BR layer reduced to ~ 0.5÷0.1 cm^3/h after 4–5 hours that is typical for the formed but not compacted BR layer in the BRDA (hydraulic conductivity $K \approx n \times 10^{-5} \div n \times 10^{-6}$ cm/s). Yield differences depend on the specifics of phase and mineral composition and particle size distribution of BRs from different alumina refineries;
- when the BR layer in the gravity columns is formed, sodium bicarbonate solutions of following compositions are introduced into the columns;
- the composition of the sodium bicarbonate solution used for heap leaching was specified by a sum of ΣNa_2O_{total} in Na_2CO_3 and $NaHCO_3$ as well as a pH value. Na_2O_{total}

of no more than 10.2. Under these conditions a high content of Sc_2O_3, i.e. ≥ 5 mg/dm^3 in the product solution can be maintained over a long period of time (6 months or more).

The area of a heap leach cell of 1 hectare will yield minimum 80–100 kg Sc_2O_3 per a year. As the concentration of Na_2O in the leaching solution increases due to replacement of the alkali and self-evaporation from the surface, scandium production will increase.

The process allows to extract alkali both from solid and liquid phases of stored BR and also to bind CO_2 with BR solid phase providing sustainable solution for disposal of treated bauxite residue in alumina refining.

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7. References

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