

PRESENTATION OF RESOURCE-SAVING TECHNOLOGY FOR PRODUCING SCANDIUM COMPOUNDS FROM DIOPSIDE

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Abstract

As part of the work, a low-waste resource-saving technology for processing diopside with the extraction of scandium compounds and the associated production of a wide range of large-tonnage mineral products has been developed. The technology of solid-phase extraction of scandium compounds using solid impregnates based on macroporous activated carbons modified with phosphonic acids has been proposed. The main directions of neutralization and processing of mother liquors and solid products formed in the process of extracting scandium compounds are proposed. Samples of magnesium fertilizers, red pigments for building mixtures, as well as precursors of titanium compounds were obtained as commercial products.

Keywords: Scandium, diopside, extraction, magnesium, titanium

1. INTRODUCTION

The development of industry leads to the need to search for and develop new materials with improved performance characteristics. Steel structures, despite their reliability and durability, cannot always be used in certain industries. Such exceptions include space, aviation and other industries. To the materials used in these directions, in addition to the strength factor, the condition of minimizing the weight is applied, since the use of heavy and dense materials significantly increases the cost and operating costs of the device produced.

To solve such problems, materials based on compounds of magnesium, titanium and aluminum have become widespread; however, in their pure form, these metals do not provide the required strength. To improve this characteristic, alloying additives are introduced into the composition of materials. From the data of various sources [1] it is known that the addition of scandium compounds significantly increases the strength of aluminum alloys and makes it possible to use the resulting alloy in the directions described above.

Scandium is a scattered element, the content of which in rocks rarely exceeds 0.01% of the mass. The scandium mining process is usually combined with the processes of large-scale mineral concentrates to obtain various products. To date, hydrolytic sulphuric acid, a product of processing titanium minerals by the sulphuric acid method [2], uranium mining solutions [3,4], as well as solid ash and slag waste [5] and red mud - waste of overgrowth of bauxite by the method Bayer [6,7].

Liquid extraction processes are used to extract scandium from acid solutions of processing various mineral components. A traditional extractant for solving such problems is a mixture of Di (2-ethylhexyl) phosphoric acid and tributyl phosphate in kerosene [8-10]. The use of a flammable liquid, as well as significant losses of the extractant in the form of an emulsion, significantly increase the cost of the process, which is why the task of developing an effective technology for extracting scandium remains urgent. An equally urgent task is the search for new sources of raw materials for the production of scandium compounds, while the products formed in the process of processing will be in demand on the market.

The authors of the work within the framework of preliminary studies [11,12] put forward an assumption about the possibility of using diopside, a mineral from the pyroxene group, as a raw material for the production of scandium, which at the same time is a valuable source of magnesium compounds.

The main purpose of this work is to present the results of work on the development of an integrated energy and resource-saving, environmentally friendly and safe production technology for processing diopside with the extraction of scandium and for the production of a wide range of mineral products.

2. MATERIALS AND METHODS

The starting point was a sulphuric acid solution of the process of opening diopside [11,12], which is already successfully used at the present time. Sodium-silicon fluoride in an amount of up to 20 g / l was used as an additive to increase the efficiency of opening. The solution was filtered through a polymer vacuum filter to separate unreacted ore and insoluble silicon and calcium-containing sediments.

The study of the chemical composition of acidic solutions was carried out using a Spectroskai atomic emission spectrometer with magnetic plasma (Korolev, Russia) [13]. The study of the chemical composition of solid samples was carried out on a scanning electron microscope with a 1610LV with an energy dispersive spectrometer for electron probe microanalysis SSD X-Max Inca Energy (JEOL, Japan; Oxford Instruments, Great Britain).

Samples of impregnates for the extraction of scandium compounds were obtained by impregnating macroporous coals (MAC, AF3, BCK grades) with a mixture of tributyl phosphate (hereinafter TBP) and di (2-ethylhexyl) phosphoric acid (hereinafter D2EHPA).

3. RESULTS AND DISCUSSION

The chemical composition of sulphuric acid solutions is presented in **Table 1**.

Table 1 Chemical composition of sulphuric acid solutions of diopside leaching

Elements	Sc (mg/l)	Ti (g/l)	Ca (g/l)	Fe (g/l)	Mg (g/l)	Al (g/l)
Concentrations	12.1	0.65	0.42	17.0	15.9	6.15

From the data in **Table 1**, it can be seen that in the process of opening diopside, 20% sulphuric acid solutions with an extremely high content of various metals (titanium, aluminum, iron) are formed. Significant concentrations of magnesium compounds were found in the composition of solutions, which makes it possible to theoretically organize their extraction to obtain magnesium sulphate (fertilizer). In addition to metal salts, the solution contains a fluoride ion (up to 10 g/l), the return of which to the opening stage will significantly reduce the cost of the products obtained.

At the next stage of the experiments, the process of extraction of scandium compounds on samples of impregnates was investigated. Data on the dynamic exchange capacity of impregnates with respect to scandium are presented in the diagram in **Figure 1**.

From the data of the diagram in **Figure 1** that the samples of impregnates have a relatively high capacity in relation to scandium compounds and allow them to be extracted with high efficiency and selectivity from the sulphuric acid solution of diopside processing. Compounds of titanium, iron, aluminum and other impurities almost completely remain in the mother liquor. The residual concentration of scandium compounds in the solution was at the level of 0.001 mg/l (the detection limit of the device). Re-extraction of scandium compounds was carried out with a mixture of ammonium hydrofluoride and sulphate, with the degree of scandium re-extraction exceeding 80%. To isolate solid scandium-containing concentrates, precipitation is carried out in the form of fluorides, oxalates or hydroxides.

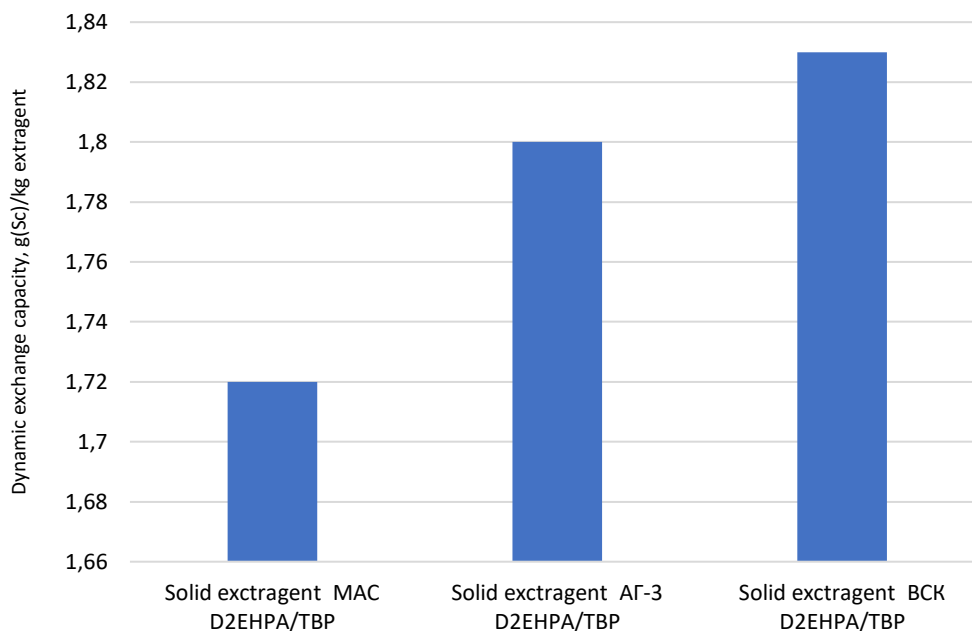


Figure 1 Dynamic exchange capacity

Magnesium oxide was introduced into the mother liquor containing free fraction in the form of a suspension. In the process of neutralization and increase in pH, fluorides and hydroxides of titanium, iron, aluminum and other impurities were precipitated from the solution, and magnesium sulphate remained in the solution due to its good solubility. Data on the chemical composition of solutions obtained in the neutralization process are presented in **Table 2**.

Table 2 Chemical composition of solutions of the process of neutralization of free sulphuric acid

	Concentration (g/l)					pH after neutralization
	Ti	Ca	Fe	Mg	Al	
Alkaline reagent MgO	<0.001	0.16	<0.001	42.3	<0.001	8.54

From the data in **Table 2**, it can be seen that the use of magnesium oxide (147 g/l) allows with high efficiency to remove impurities of heavy metals from the mother liquor. Most of the fluorides have also passed into the sediment and can be returned to the ore opening stage.

The solution that has passed the drying stage is a mixture (in terms of oxides):

94.6 wt% MgO, 2.1 wt% Na₂O, 1.7 wt% SiO₂, 0.8 wt% CaO, 0.9 wt% TiO₂, Fe₂O₃, Al₂O₃

Comparing the data on the chemical composition of the solid product and the requirements of regulatory documents, we can conclude that the obtained magnesium sulphate can be used as a fertilizer [14].

The precipitate of hydroxides and fluorides of aluminum, iron, titanium and other elements obtained in the process of neutralization was calcined at a temperature of 950 °C for 60 minutes. The composition of the resulting product: iron 25.3 wt%, aluminum 10 wt%, magnesium 11 wt%, titanium 1.3 wt%, calcium 0.6 wt%, oxygen 51.8 wt%. This product can be used as an inexpensive pigment for the production of building products, as well as an iron ore raw material for the production of metallic iron.

An enlarged scheme of diopside processing, considering the technological solutions described in the work, is shown in **Figure 2**.

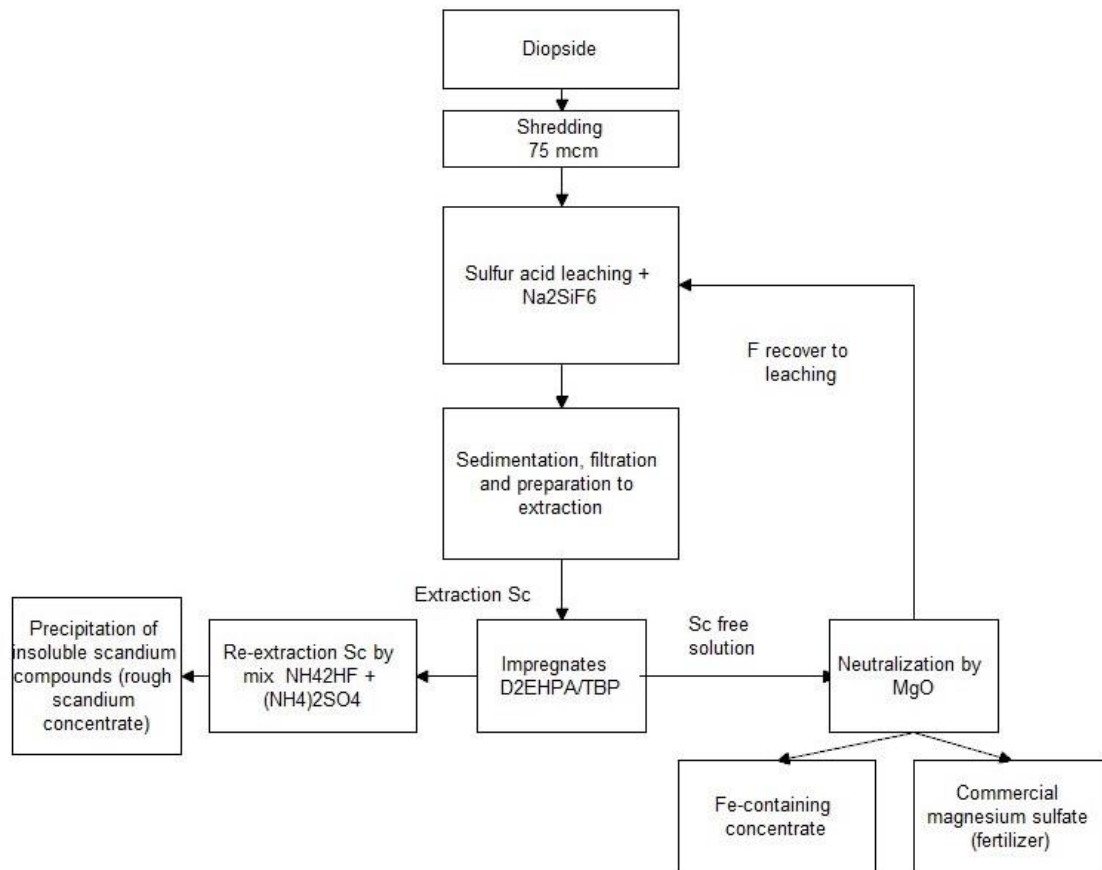


Figure 2 Schematic diagram of energy- and resource-saving technology for processing diopside

4. CONCLUSION

The presented data demonstrate innovative approaches to organizing the diopside processing process to obtain scandium compounds and large-tonnage mineral products (fertilizers, pigments). A technology for the extraction (extraction) of scandium compounds using impregnates based on macroporous coals impregnated with a mixture of tributyl phosphate (hereinafter TBP) and di(2-ethylhexyl) phosphoric acid (hereinafter D2EHPA) has been proposed. A high exchange capacity of impregnates with respect to scandium compounds is noted. The possibility of re-extraction of scandium compounds using a binary mixture of ammonium hydrofluoride and sulphate is proposed. In this case, the efficiency of this mixture in the process of scandium re-extraction exceeds 80%.

A technology has been proposed for the neutralization of sulphate mother liquors by neutralization with magnesium oxide, while magnesium sulphate, a fertilizer for the needs of agriculture, is obtained as products with the extraction of compounds of iron, aluminum and titanium, which can be used as iron ore raw materials or pigments for building materials.

A conceptual diagram of an energy- and resource-saving, environmentally safe production technology for processing diopside with obtaining scandium concentrates and a wide range of large-tonnage mineral products is proposed.

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