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Technology for Extracting High-Quality Graphite Based on A Combinatorial Processing Scheme

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ABSTRACT

Objective: *This study aims to develop an integrated and environmentally adaptive processing technology for producing high-purity graphite suitable for advanced industrial applications.* ***Method:*** *A combinatorial scheme was implemented, involving multi-stage flotation enrichment, pyrometallurgical treatment at 900–1000°C, and hydrometallurgical leaching using hydrochloric acid.* ***Results:*** *Flotation increased the carbon content to 94%, while subsequent thermal and chemical treatments further enhanced the purity to 98.4% carbon with an ash content of only 0.74%. Comparative analysis revealed that hydrochloric acid was more effective than nitric acid in removing mineral impurities.* ***Novelty:*** *The study introduces a unified technological pipeline that combines flotation, thermal processing, and hydrometallurgical leaching—providing a cleaner and more sustainable alternative to conventional acid-intensive purification methods. This approach not only improves graphite quality but also reduces environmental hazards, offering practical value to the energy, nuclear, and metallurgical industries.*

INTRODUCTION

Due to its unique properties, graphite has become an integral component of products used in energy, chemical engineering, metallurgy, and other fields. The applications of graphite are constantly expanding, indicating its increasing consumption today. According to statistics, graphite dynamics have become a key trend in the market economy[1].

Graphite is considered an excellent construction material. Its use is based on the fact that graphite (in an oxygen-free atmosphere) remains solid at temperatures up to approximately 4000°C due to its very high sublimation point. Moreover, despite its low density, graphite is not only a sufficiently strong material but also easy to machine[2].

Graphite possesses high thermal conductivity and heat capacity. This material increases in strength as temperature rises within its operational range and is resistant to corrosion and erosion during irradiation . The strength of graphite varies significantly depending on its production method, so graphites of the same density but different structures can have varying strengths. Generally, a graphite composite with a finer structure tends to have higher strength and a longer service life . Graphite has been used as both a structural and functional material in high-temperature reactors (in Germany and the USA)[3].

RESEARCH METHOD

One of the quality indicators of graphite for industrial needs in graphite and graphite products is the amount of chemical impurities. Even small amounts of elements such as sulfur, vanadium, titanium, chromium, manganese, iron, and silicon significantly deteriorate the technological and operational characteristics of the final product. Therefore, the carbon content in the graphite raw material and its ash content are of great importance. The ash content is considered the main factor affecting the useful properties and value of graphite, which is why consumers pay special attention to this indicator[4].

The graphite sample was enriched mainly by flotation. This process is based on the hydrophobic properties of dispersed graphite and consists of multi-stage purification flotation in the presence of collecting and foaming reagents. For flotation enrichment, the sample was ground in mills to 70-80% passing 74 μm, which made it possible to increase the carbon content in the concentrate to 94% based on this technological scheme (**Fig. 1**). Traditionally, two technological approaches are used for the purification of graphite concentrate: thermal and chemical. In practice, these methods can be combined. Optimal conditions for obtaining the final product were determined in three stages: flotation, heat treatment, and chemical treatment of the graphite sample[5].

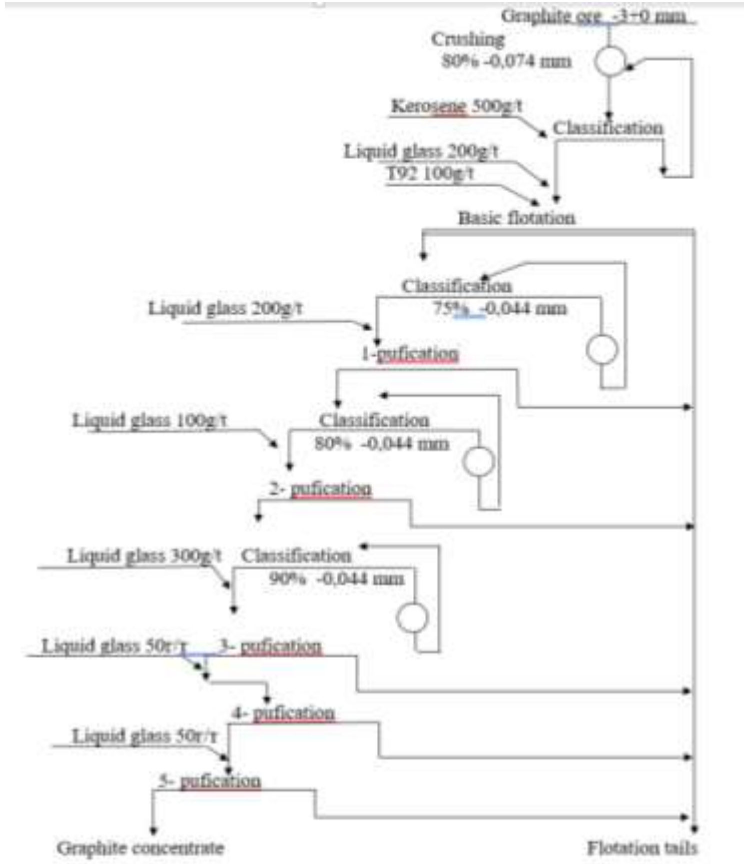

Figure 1. Technological scheme of flotation enrichment

When heating graphite concentrate, the reduction of non-volatile oxides present in the mineral fraction is observed at temperatures above 1000°C. The reduction products either directly transition to the gas phase or form more difficult-to-melt compounds (carbides) with carbon, the evaporation of which occurs at considerably higher temperatures. At temperatures of 2200-2400°C, the ash content of carbonaceous materials can decrease to as low as 0.2% . In practice, the degree of purification is determined by numerous factors: the type of raw material, particle size distribution, furnace design, chemical composition of the lining, processing duration and regime, etc[6].

The graphite flotation concentrate obtained by the flotation method, based on optimal indicator results, was mixed with technical soda (calcined sodium carbonate) in a 40% ratio and roasted in a hermetically sealed container for 2 hours in a SNOL-1200 laboratory furnace at a temperature of 900-1000°C[7].

Figure 2 shows the SNOL-1200 laboratory furnace used in the graphite purification process. The image depicts the furnace in operation, with a visible bright red heating chamber indicating high-temperature firing conditions. The experimental procedure described involves roasting a mixture of graphite flotation concentrate and technical soda (calcined sodium carbonate) in a hermetically sealed container for 2 hours at 900–1000°C within this furnace. The purpose of this thermal treatment is to reduce the ash content of the graphite concentrate by facilitating the removal of mineral impurities. The SNOL-1200 is a laboratory-scale furnace capable of achieving temperatures up to 1200°C and is used for controlled, high-temperature processing in material science experiments. The figure illustrates the setup critical for achieving efficient thermal purification in the multi-stage processing scheme for high-purity graphite production[8].

Figure 2. Firing in the SNOL-1200 laboratory furnace

A significant drawback of chemical methods is the use of dangerous, aggressive acids and the negative impact of these technologies on the environment. It should be noted that acid-based chemical methods are not used in the USA, Canada, and European Union countries[9].

Chemical purification of natural and secondary graphite from impurities through acid leaching is widely used almost worldwide, including in China, Brazil, Australia, and Russia . Most companies carry out such purification at the final stage of graphite concentrate processing. Typically, solutions of NaOH/Na2CO3, HF, HCl, and H2SO4 are used as reagents. Hydrogen fluoride is one of the most commonly used and currently one of the most dangerous acids[10].

Hydrometallurgical processing of the roasted product was initially carried out with water in a high-temperature resistant porcelain container at 85-90°C for 150 minutes with a liquid to solid ratio of 8:1. To transfer the remaining iron and calcium oxides in the product obtained after this process into solution, dissolution of this product was performed using hydrochloric and nitric acids. The mixture was stirred with hydrochloric acid at a liquid-to-solid ratio of 10:1 for 120 minutes at a temperature of 90°C. After the process was completed, it was filtered, and the filtered product was dried[11].

In the second case, nitric acid was mixed with a solid in a ratio of L:S=10:1 for 120 minutes at a temperature of 90°C. After the process was completed, the mixture was filtered, and the filter cake product was dried[12].

RESULTS AND DISCUSSION

Results

The flotation concentrate obtained as a result of numerous flotation studies is not suitable for industrial use; therefore, the concentrate was purified using thermal and chemical treatment methods. Pyrometallurgical studies made it possible to purify graphite from quartz minerals, aluminum oxide, and partially from carbonate minerals, which are considered harmful impurities in the concentrate[13].

The results of numerous studies have shown that treating the calcine of the flotation concentrate with hydrochloric acid is more effective than with nitric acid. From the chemical analysis results of the obtained products, it can be seen that at the end of the graphite concentrate processing, a concentrate with a carbon content of 97.5% and an ash content of 1.7% was obtained. In large-scale laboratory conditions, a product with a carbon content of 98.4% and an ash content of 0.74% was obtained[14].

Discussion

The study demonstrates that obtaining high-purity graphite suitable for industrial applications requires an integrated approach combining flotation, pyrometallurgical, and hydrometallurgical methods. Flotation enrichment increased carbon content to 94%, but this alone was insufficient for high-grade applications, necessitating subsequent thermal and chemical purification. Heat treatment above 1000°C facilitated the removal of non-volatile oxides and partial reduction of harmful impurities such as quartz and aluminum oxide, enhancing graphite purity. The combination of thermal treatment with chemical leaching using hydrochloric acid proved more effective than nitric acid, yielding a graphite concentrate with 98.4% carbon and 0.74% ash content. These results align with global purification trends while addressing local industrial needs in Uzbekistan. However, the study also highlights limitations in environmental sustainability due to the use of aggressive acids, emphasizing the need for greener alternatives in future research. Additionally, factors such as furnace design, temperature regimes, and reagent selection were found to significantly influence purification efficiency, underscoring the importance of optimizing process parameters for industrial scalability. This comprehensive methodology provides a reliable technological pathway to produce high-quality graphite applicable in metallurgy, nuclear technology, and advanced material manufacturing, reinforcing the strategic value of domestic graphite resources in import substitution and technological independence efforts. Future studies should focus on environmentally safe reagent systems, refining temperature-time regimes, and integrating renewable energy sources into thermal purification to enhance sustainability and economic feasibility in large-scale production[15].

CONCLUSION

Fundamental Finding : This study confirms that a combinatorial processing scheme integrating flotation, pyrometallurgical, and hydrometallurgical methods is essential for producing high-purity graphite with 98.4% carbon content and 0.74% ash, meeting the stringent quality standards required for advanced industrial applications. **Implication :** The integrated approach provides a practical and environmentally adaptive alternative to traditional acid-intensive purification methods, thereby enhancing the sustainability and industrial relevance of natural graphite processing, particularly for sectors such as energy, metallurgy, and nuclear technologies. **Limitation :** Despite its effectiveness, the process still relies on significant acid consumption, which poses environmental and operational challenges that may limit large-scale implementation without further optimization. **Future Research :** Subsequent studies should focus on minimizing chemical usage by exploring greener reagents, optimizing energy input during thermal treatment, and developing closed-loop systems for waste acid recovery, thus advancing both the environmental and economic feasibility of high-purity graphite production.

REFERENCES

[1] V. I. Bragina и I. I. Baksheeva, «Development of Graphite Ore Beneficiation Technology», *Min. Inf. Anal. Bull.*, сс. 133–137, 2012.

[2] F. Syarifuddin, F. F. Florena, E. S. Hanam, и others, «Effect of Acid Leaching on Upgrading the Graphite Concentrate from West Kalimantan (Indonesia)», в *AIP Conference Proceedings*, 2016. doi: 10.1063/1.4941905.

[3] W. Xie, Z. Wang, J. Kuang, и others, «Fixed Carbon Content and Reaction Mechanism of Natural Microcrystalline Graphite Purified by Hydrochloric Acid and Sodium Fluoride», *Int. J. Miner. Process.*, сс. 45–54, 2016, doi: 10.1016/j.minpro.2016.08.002.

[4] K. P. Vlasov, *Graphite as a High-Temperature Material*. Mir, Moscow, 1964.

[5] E. I. Zhmurikov, I. A. Bubnenkov, и V. V. Dremov, *Graphite in Science and Nuclear Technology*. Novosibirsk, 2013.

[6] T. Enoki, M. Suzuki, и M. Endo, *Graphite Intercalation Compounds and Applications*. Oxford University Press, 2003.

[7] P. Brodie, *Graphite: Properties, Applications and Future Outlook*. Nova Science Publishers, 2014.

[8] M. O. Oliynyk и A. I. Makachova, «Improvement of the Graphite Raw Material Balancing Technology of Zavallia Deposit», *Min. Bull.*, сс. 210–215, 2014.

[9] W. Peng, Y. Qiu, L. Zhang, и others, «Increasing the Fine Flaky Graphite Recovery in Flotation via a Combined Multiple Treatments Technique of Middlings», *Minerals*, с. 208, 2017, doi: 10.3390/min7110208.

[10] M. S. Dresselhaus и G. Dresselhaus, *Intercalation Compounds of Graphite*. Springer, 2002.

[11] S. V. Belyaev, G. A. Koroleva, S. I. Lytkina, и others, «Promising Methods for Preparing Foundry Graphite», *J. Sib. Fed. Univ. Eng. Technol.*, cc. 462–466, 2014.
[12] K. Zaghiba, X. Song, A. Guerfi, и others, «Purification Process of Natural Graphite as Anode for Li-ion Batteries: Chemical versus Thermal», *J. Power Sources*, cc. 8–15, 2003, doi: 10.1016/S0378-7753(03)00116-2.
[13] S. F. Ding и Y. P. Niu, «Research on Purification Technics of Some Flake Graphite», *Adv. Mater. Res.*, cc. 753–755, 2013, doi: 10.4028/www.scientific.net/amr.753-755.119.
[14] H. T. Thi и N. D. Hong, «Sulfuric Acid Leaching Process for Producing High Purity Graphite from 92.6 % C to 98 % C», *World J. Res. Rev.*, cc. 23–26, 2017.
[15] S. Tambanis и G. Chiappini, «Thermal Processing Achieves up to 99.99994 % Purity of Mahenge Graphite Concentrates». Black Rock Mining Limited, c. 4, 2016 y.

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