Journal of Materials, Processing and Design (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/jmpd.2024.080110
ISSN 2516-0923 Vol. 8 Num. 1

Research Reflection on Organic Inhibitors in Metal Ore Flotation

Feng Gao[1], Huanhuan Wang[1]

[1]*School of Chemical and Environmental Engineering, China University of Mining and Technology (Beijing), Beijing, 100083, China*

Keywords: Metal ore flotation, organic inhibitors, mechanism of action, application status

Abstract: This paper aims to explore the current research status, existing problems, and future development directions of organic inhibitors in metal ore flotation processes. Through an introduction to the basic principles of metal ore flotation and the mechanism of organic inhibitors, as well as an analysis of the current application of organic inhibitors in metal ore flotation, it is found that challenges exist in inhibitor selection, mechanism analysis, and enhancement of inhibition effects. Finally, the development trends of organic inhibitors in metal ore flotation are discussed, along with possible solutions and research directions.

1. Introduction

Metal ore flotation, as an important ore separation technology, plays a crucial role in mining production. By utilizing the interaction between minerals and specific inhibitors, effective separation of target minerals from non-target minerals can be achieved, thereby improving the grade and recovery rate of ores. In the process of metal ore flotation, organic inhibitors, as important flotation reagents, possess the ability to selectively inhibit non-target minerals and have been widely applied in practical production. This paper aims to delve into the research status of organic inhibitors in metal ore flotation processes, gradually analyzing from basic principles to application status and existing problems and challenges. Firstly, the basic principles of metal ore flotation and the mechanism of organic inhibitors will be introduced to provide a theoretical basis for subsequent discussions. Subsequently, the current application status of organic inhibitors in metal ore flotation will be reviewed, and their effects evaluated and analyzed. Meanwhile, discussions will be conducted on existing problems and challenges, including inhibitor selection, mechanism analysis, and enhancement of inhibition effects. Finally, the future development trends of organic inhibitors in metal ore flotation will be explored, along with possible solutions and research directions, aiming to provide reference and guidance for further development in this field.

2. Basic Principles of Metal Ore Flotation and Mechanism of Action of Organic Inhibitors

2.1. Basic Principles of Metal Ore Flotation

Metal ore flotation is a commonly used ore separation technology, the basic principle of which

involves utilizing the physical or chemical interaction between minerals and bubbles or added reagents to achieve effective separation of target minerals. The main processes include: crushing and grinding of ores, whereby the original ore is crushed and ground to appropriate particle sizes to improve flotation efficiency. Reagent treatment, after grinding, flotation reagents are added to the flotation cell, typically including collectors, frothers, inhibitors, etc., to facilitate the contact and adsorption between minerals and bubbles. Bubble attachment, by introducing air or other gases, bubbles are generated and rise in the flotation cell, interacting with target mineral particles to form attachments, allowing them to rise to the surface of the flotation cell together with bubbles. Concentration and cleaning, the flotation froth formed by target minerals and bubbles moves to concentrate or froth tanks, forming concentrate products, while non-target minerals deposit at the bottom of the flotation cell as tailings. Processing of concentrate products, further treatment of concentrate products, including filtration, drying, smelting, etc., to extract target metals [1]. The success of metal ore flotation depends on various factors, including ore properties, reagent selection and deployment, and control of operational parameters. Therefore, a thorough understanding of the basic principles of metal ore flotation is of great significance for improving flotation efficiency and ore utilization.

2.2. Analysis of the Mechanism of Action of Organic Inhibitors in Metal Ore Flotation

Organic inhibitors play a crucial role in metal ore flotation, and their mechanism of action is a complex and diverse process. Firstly, organic inhibitors affect the flotation behavior of mineral particles through surface adsorption. When organic inhibitors adsorb on the surface of non-target minerals, a stable thin film is formed, hindering the contact between target mineral particles and flotation reagents, thus effectively inhibiting the flotation of non-target minerals and increasing the recovery rate of target minerals. Secondly, organic inhibitors exhibit a certain selective action, selectively adsorbing on the surface of non-target minerals without affecting the flotation of target minerals. This selective action can effectively improve the grade of target minerals and reduce impurity content in tailings, thereby enhancing the quality and economic benefits of metal ores. In addition, organic inhibitors may affect the chemical properties of mineral surfaces through chemical reactions, thereby altering the adsorption behavior of minerals with flotation reagents. This chemical reaction can enhance the selectivity and inhibition effects of inhibitors on non-target minerals, further improving flotation efficiency. Finally, the adsorption of organic inhibitors may also change the surface charge properties of minerals, causing them to carry opposite charges, thus affecting the electrochemical interactions between minerals and flotation reagents. This surface charge effect can regulate the flotation properties of minerals and thereby affect flotation efficiency. In conclusion, the mechanism of action of organic inhibitors in metal ore flotation is a complex process involving physical, chemical, and electrochemical factors. A deep understanding and research of their mechanism of action are of great significance for optimizing flotation processes and improving metal recovery rates[2].

3. Current Application Status of Organic Inhibitors in Metal Ore Flotation

3.1. Overview of Common Organic Inhibitors and Their Application Status

In the process of metal ore flotation, common organic inhibitors include organic amine, organic alcohol, organic acid, etc., which play important roles in different types of ores and flotation processes. Firstly, organic amine inhibitors are widely used in metal ore flotation. For example, amine phosphate inhibitors can be used in the flotation of iron ores, inhibiting the flotation of non-iron minerals by forming a film layer on the mineral surface, thus improving the grade of iron

ores. Additionally, fatty amine inhibitors are commonly used in the flotation of metals like copper, lead, zinc, etc., by adsorbing on the surface of non-target minerals like chalcopyrite, inhibiting their flotation and enhancing metal recovery rates. Secondly, organic alcohol inhibitors also find widespread application in metal ore flotation. For instance, phenol and alcohol ether inhibitors can be used in the flotation of lead-zinc ores, inhibiting the non-sulfide minerals' flotation by adsorbing on their surfaces, thus improving the grade of lead-zinc ores. Furthermore, organic acid inhibitors also have certain applications in metal ore flotation. For example, organic sulfonic acid inhibitors are commonly used in copper ore flotation, inhibiting the flotation of non-copper minerals by adsorbing on their surfaces, thus improving the grade and recovery rate of copper ores. Overall, different types of organic inhibitors in metal ore flotation have their own characteristics and application scopes. Through rational selection and deployment, effective inhibition of non-target minerals can be achieved, thereby improving the grade and economic benefits of metal ores. However, it is important to note that in practical applications, the selection and usage of inhibitors need to consider factors such as ore properties, flotation processes, and economic costs to achieve the best flotation results[3].

3.2. Analysis of the Effects and Characteristics of Different Inhibitors

Different types of organic inhibitors in metal ore flotation exhibit unique effects and characteristics, mainly influenced by inhibitor molecular structure, chemical properties, and interactions with mineral surfaces. Firstly, organic amine inhibitors are commonly used in metal ore flotation, characterized by strong adsorption capability and selectivity. For instance, fatty amine inhibitors show good inhibition effects in the flotation of metals like copper, lead, zinc, effectively inhibiting the flotation of non-target minerals and enhancing metal recovery rates. Additionally, organic amine inhibitors have advantages such as simple operation and wide adaptability, making them widely applied in practical production. Secondly, organic alcohol inhibitors also play important roles in metal ore flotation, characterized by high selectivity and stability. For example, phenol and alcohol ether inhibitors exhibit good inhibition effects in the flotation of lead-zinc ores, effectively inhibiting the flotation of non-sulfide minerals and improving the grade of lead-zinc ores. Furthermore, organic alcohol inhibitors have advantages such as environmental friendliness and ease of recycling, providing certain advantages in environmental protection and resource conservation. Lastly, organic acid inhibitors have broad applications in metal ore flotation, characterized by strong chemical reactivity and adaptability. For example, organic sulfonic acid inhibitors show good inhibition effects in copper ore flotation, effectively inhibiting non-copper minerals through chemical reactions with mineral surfaces. Additionally, organic acid inhibitors have advantages such as minimal impact on flotation systems and good stability, showing higher cost-effectiveness in practical applications. In summary, different types of organic inhibitors in metal ore flotation exhibit unique effects and characteristics, and rational selection and deployment of inhibitors are key to optimizing flotation processes and increasing metal recovery rates. In practical applications, comprehensive considerations of factors such as ore properties, flotation processes, and economic costs are necessary to achieve the best flotation results and economic benefits.

4. Challenges and Issues

4.1. Challenges in Inhibitor Selection

In the process of metal ore flotation, inhibitor selection is a crucial step but faces numerous challenges. These include: ore diversity, where different metal ores possess varied physicochemical

properties, posing diversified demands for inhibitor selection. Moreover, within the same ore, there may exist multiple non-target minerals, necessitating the consideration of suitable inhibitors to achieve effective flotation separation. Specificity of inhibitors, where inhibitors need to possess certain selectivity to effectively inhibit the flotation of non-target minerals without affecting the recovery of target minerals. However, achieving this specificity is not easy and requires the identification of inhibitors with suitable properties, along with targeted deployment and optimization. Competition between inhibitors and flotation reagents, as inhibitors compete with flotation reagents in metal ore flotation. Excessive use of inhibitors may affect the adsorption and activity of flotation reagents, thereby impacting flotation efficiency. Thus, balancing the usage of inhibitors and flotation reagents is essential to achieve optimal flotation results. Cost and environmental impacts of inhibitors, where different types of inhibitors entail varying costs and environmental impacts. In practical applications, inhibitor selection often needs to consider economic costs and environmental sustainability. Therefore, minimizing costs and environmental impacts while meeting flotation requirements is a research-worthy issue. In summary, challenges in inhibitor selection mainly manifest in ore diversity, inhibitor specificity, competition with flotation reagents, cost, and environmental impacts. Addressing these challenges requires comprehensive considerations of ore properties, inhibitor characteristics, economic costs, and environmental sustainability, along with rational experimental design and data analysis to find the best inhibitor selection solutions[4].

4.2. Difficulty in Mechanism Analysis

In metal ore flotation, the mechanism of organic inhibitors is a complex and diverse process, often facing various difficulties in analysis. The mechanism of organic inhibitors is influenced by multiple factors, including ore properties, inhibitor characteristics, flotation process parameters, etc. These factors interact with each other, making the analysis of the mechanism complex and challenging. The interaction between organic inhibitors and mineral surfaces involves multiple mechanisms such as physical adsorption, chemical reactions, electrochemistry, etc., each of which may affect the flotation process. Moreover, mineral surfaces may possess various functional groups and active sites, further complicating the mechanism analysis. The diverse molecular structures of organic inhibitors, with different chemical properties and affinities, lead to different mechanisms of action for the same type of inhibitor in different ore systems, increasing the difficulty of analysis. Current experimental techniques often cannot directly observe the interaction process between organic inhibitors and mineral surfaces. Additionally, the mechanism of action of organic inhibitors often occurs at the atomic and molecular scales, increasing the requirements for experimental techniques and limiting the in-depth analysis of the mechanism. In summary, the difficulty in mechanism analysis of organic inhibitors mainly lies in the multifactorial influences, complexity of surface interactions, diversity of molecular structures, and limitations of experimental techniques. Addressing these difficulties requires the use of advanced experimental techniques and theoretical simulation methods, strengthening research on the interaction processes between inhibitors and mineral surfaces, and exploring the mechanism of action of inhibitors to provide scientific basis for the optimization and improvement of metal ore flotation[5].

4.3. Challenges in Enhancing Inhibition Effect

In metal ore flotation, enhancing the inhibition effect is an important challenge, and selecting suitable inhibitors is crucial for enhancing inhibition effect. However, due to the wide variety of ores, complex ore properties, and the interactions among different inhibitors, selecting and optimizing the types and dosages of inhibitors is not easy. Inhibitors interact with flotation reagents,

which may exhibit synergistic effects and competition. Enhancing inhibition effect requires effectively inhibiting non-target minerals while maintaining the activity of flotation reagents. Balancing the usage of inhibitors and flotation reagents to achieve optimal synergistic effects is a challenge. The mechanism of action of organic inhibitors is complex and often difficult to directly observe and analyze. Lack of in-depth understanding of inhibitor mechanisms limits the enhancement of inhibition effect. Therefore, research on the mechanism of action of inhibitors needs to be strengthened to guide the optimization and enhancement of inhibition effect. In addition to inhibitor selection and optimization, optimizing flotation process parameters is also crucial for enhancing inhibition effect. Adjusting parameters such as flotation cell design, agitation speed, bubble size, etc., may significantly impact inhibition effect. However, how to rationally allocate these parameters to achieve optimal inhibition effect is a challenging issue that requires in-depth research. In summary, enhancing inhibition effect faces challenges such as inhibitor selection and optimization, synergistic effects and competition with flotation reagents, insufficient research on inhibitor mechanism of action, and optimization of flotation process parameters. Addressing these challenges requires the comprehensive use of experimental research, theoretical simulation, and engineering practices to strengthen basic research on inhibitors and process optimization, providing scientific support for efficient, environmentally friendly, and sustainable development of metal ore flotation[6].

5. Future Development Trends and Research Directions

5.1. Outlook on the Development Prospects of Organic Inhibitors in Metal Ore Flotation

With the increasing depletion of mineral resources and the growing demand for high-grade ores, the development of metal ore flotation technology urgently requires more efficient, environmentally friendly, and sustainable solutions. Against this backdrop, organic inhibitors, as important flotation reagents in metal ore flotation, still hold vast development prospects in the future. Firstly, as ore resources gradually deplete and mining difficulty increases, the demand for flotation of low-grade, refractory ores will continue to rise. Organic inhibitors, as reagents with selective inhibition capabilities, will become crucial means to address the challenge of low-grade ore flotation. In the future, the application prospects of organic inhibitors in low-grade ore flotation will be even broader. Secondly, with the continuous advancement of science and technology, the understanding and mastery of the mechanism of action of organic inhibitors will continue to deepen. Through a combination of experimental research and theoretical simulation, in-depth analysis of the interaction between organic inhibitors and mineral surfaces will provide a scientific basis for optimizing inhibitor design and selection, thereby driving further development of metal ore flotation technology. Additionally, as societal emphasis on environmental protection and sustainable development increases, the demand for environmentally friendly inhibitors will also rise. Organic inhibitors, as reagents with minimal environmental impact, will become an important direction for the development of metal ore flotation technology. In the future, the research and application of environmentally friendly organic inhibitors will be a significant development trend in metal ore flotation technology. In summary, organic inhibitors have broad development prospects in metal ore flotation. In the future, through in-depth research on the mechanism of action of organic inhibitors and the development and application of environmentally friendly inhibitors, organic inhibitors will provide important support for the efficient, environmentally friendly, and sustainable development of metal ore flotation technology, promoting the rational and sustainable utilization of mineral resources[7].

5.2. Proposed Solutions to Address Current Issues

In response to the challenges in metal ore flotation, especially the challenges in inhibitor selection, difficulty in mechanism analysis, and enhancement of inhibition effect, the following solutions can be considered: Develop multiple types of inhibitors for different types of ores and flotation processes, and optimize and tailor them accordingly. Diversifying the selection and application of inhibitors can better meet the flotation requirements of different ore systems. Through the combination of experimental research and theoretical simulation, the interaction mechanism between inhibitors and mineral surfaces was deeply explored. By establishing a model and performing simulation calculations, the mechanism of the inhibitor is analyzed to provide a scientific basis for optimizing the inhibition effect. The synergistic and competitive relationship between inhibitors and flotation reagents was investigated, and how to achieve the optimal synergistic effect between inhibitors and flotation reagents was explored. By optimizing the dosage and ratio of inhibitors and flotation reagents, the inhibition effect and metal recovery rate are improved. Intensify the research and development of environmentally friendly inhibitors, and explore the use of environmentally friendly and biodegradable inhibitors to replace tr. Considering the above solutions comprehensively, a series of feasible measures and methods can be provided to address the issues in metal ore flotation. By integrating these solutions, the level of metal ore flotation technology can be effectively improved, promoting the rational development and utilization of metal ore resources, and advancing the progress and development of metal ore flotation technology[8].

5.3. Exploration of Future Research Directions and Focus Areas

The future development of metal ore flotation technology will focus on various research and innovations. Firstly, it is necessary to strengthen in-depth research on the mechanism of action of organic inhibitors, revealing the interaction mechanism between inhibitors and mineral surfaces through a combination of experimental and theoretical simulation methods, providing a scientific basis for optimizing inhibition effect. At the same time, the development and application of novel inhibitors will also be one of the future focuses, especially the development of environmentally friendly inhibitors and efficient inhibitors, which will provide new impetus for the innovation of metal ore flotation technology. In addition, research on the synergistic effects between inhibitors and flotation reagents is also of great significance. By optimizing the usage and ratio of both, the metal recovery rate and flotation efficiency can be improved. The development and application of intelligent flotation technology will be another focus of research, combining new technologies such as artificial intelligence and big data to achieve intelligent control and optimization of flotation process parameters, thereby improving the intelligence level of flotation technology. Finally, the promotion and application of green flotation technology will also be an important direction in the future. Through measures such as the use of environmentally friendly inhibitors and optimization of process flow, environmental protection and sustainable development in the metal ore flotation process can be achieved. In summary, the future development of metal ore flotation technology will revolve around aspects such as the mechanism of action of inhibitors, development of novel inhibitors, synergistic effects between inhibitors and flotation reagents, intelligent flotation technology, and green flotation technology, making greater contributions to the efficient utilization of metal ore resources and the sustainable development of the mineral resources industry.

6. Conclusion

In conclusion, the study of organic inhibitors in metal ore flotation holds significant theoretical

and practical significance. Through comprehensive analysis of the basic principles of metal ore flotation, the mechanism of action of organic inhibitors, application scenarios, and existing challenges, it can be seen that organic inhibitors play an irreplaceable role in metal ore flotation. However, despite the vast application prospects of organic inhibitors in metal ore flotation, challenges such as inhibitor selection, difficulty in mechanism analysis, and enhancement of inhibition effect still exist. To address these issues, future research directions and focuses will include strengthening research on the mechanism of action of inhibitors, developing novel inhibitors, exploring the synergistic effects between inhibitors and flotation reagents, promoting the development of intelligent flotation technology, and advancing green flotation technology. Through unremitting efforts and continuous innovation, it is believed that metal ore flotation technology will continue to make new breakthroughs and progress, contributing more to the efficient utilization of mineral resources and the sustainable development of the mineral resources industry.

References

[1] Lindner B, Auret L .Application of Data-based Process Topology and Feature Extraction for Fault Diagnosis of an Industrial Platinum Group Metals Concentrator Plant[J].IFAC Papers OnLine, 2015, 48(17):102-107.

[2] El-Nadi .Solvent Extraction and Its Applications on Ore Processing and Recovery of Metals: Classical Approach [J].Separation Purification Reviews, 2017, 46(3):195-215.

[3] Golik V, Rasorenov Y, Efremenkov A. Recycling of Metal Ore Mill Tailings[J].Applied Mechanics and Materials, 2014, 3536(682-682):363-368.

[4] Chengwang W, Ruihan Z, Xingshi L, et al. A Novel Chelating Collector with Diminerophilic Group 5-Methyl Butylxanthate-1, 2, 4-Triazole-3-Thione: Its Synthesis and Selective Flotation Mechanism of Chalcopyrite from Pyrite [J]. JOM, 2024, 76(5):2478-2490.

[5] Xie H, Shi Y, Wang L, et al.Source and risk assessment of heavy metals in mining-affected areas in Jiangxi Province, China, based on Monte Carlo simulation.[J].Environmental science and pollution research international, 2024, 31(14): 21765-21780.

[6] N. Y I, O. I N.Using the Landsat-8 Data Set and Shuttle Radar Topography Mission Digital Terrain Model for Gold–Polymetallic Mineralization Prediction on the Territory of the Central Part of the Malouralskaya Zone, the Polar Urals[J].Izvestiya, Atmospheric and Oceanic Physics, 2024, 59(10):1397-1408.

[7] Dubey A, Pandit N, Singh R, et al.Lead-free alternative cation (Ethylammonium) in organometallic perovskites for thermoelectric applications.[J].Journal of molecular modeling, 2024, 30(3):77-87.

[8] Zhang C H, Yang N, She Z W, et al.An all-inorganic lead-free metal halide double perovskite for the highly selective detection of norfloxacin in aqueous solution.[J].Mikrochimica acta, 2024, 191(3):125-129.