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A STUDY ON THE EFFECT OF γ-RAY IRRADIATION ON THE SELECTIVE FLOCCULATION OF FINE CASSITERITE AND ITS ASSOCIATED MINERALS

The paper is concerned with the study of the flocculation properties of fine-grained cassiterite, hematite and quartz, irradiated by γ-ray. First, we irradiated the minerals by Co-60. Then we performed a selective flocculation experiment. We also studied the mechanism of the process. The outcome of the research shows that -ray irradiation can improve the effectiveness of separating cassiterite, hematite and quartz. As a new process of ore-dressing, it would find a wide application in production.

Introduction

Nearly six years have passed since the International Conference on Fine Mineral Processing was held, yet the mineral processing of fine-grained ores remains a problem demanding a prompt solution.

Processing fine minerals by means of selective flocculation was a breakthrough in ore-dressing technology in the 1970s (Read and Hollick, 1976), and has already been successfully applied to hematite processing at the Tilden Mineral-Processing Plant in the United States (Paananen, 1978). Up to the present, however, it is still at the experimental stage in the treatment of other minerals. The technique of nuclear physical mineral processing began in 1950s, but so far it has not been widely put into use in production. Thus, it is still a new method and needs to be studied further (Tatarhukof, 1983).

Our research is aimed at combining the two new technological processes, trying to use irradiation to change the character of the

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surface of minerals, make the difference in the surface character of different minerals more distinct, and separate several kinds of fine minerals by means of selective flocculation. The investigation can be said to be a bold attempt.

The technique of using high-energy irradiation to intensify the flotation process has frequently been studied at home and abroad, but mainly for doing research for separating minerals, for controlling equipment and for the automation of the process. The objects that are subjected to irradiation include dried minerals, mineral pulps, flotation reagents and flotation water (Jian, 1981). The minerals used in research and experiment are galena, blende, cassiterite, iron ore, apatite, etc. However, there are few reference materials available on treating high-energy irradiated minerals with flocculation.

Of more than ten kinds of γ-ray sources, Co-60 is relatively cheap and easily available. It is produced on a fairly large scale at home and abroad, so there could be a steady supply for industrial production. It provides powerful energy and has a long half-life. Besides, the minerals thus irradiated have no harmful radioactivity, and the process can be conveniently controlled from far away. We have therefore chosen Co-60 with an energy of 1.25 MeV as the γ-ray source for our experiment.

Materials, reagents, equipment and method

Materials

Cassiterite, hand-picked coarse-grained crystal mineral, produced in Wenshan County, Yunnan Province. Composition: 74% Sn, 4.7% SiO_2, 0.1% CaO, 0.04% MgO.

Hematite, produced in Wang Jia Tan Mine of Kunming Iron-Steel Corporation. Composition: 67.2% Fe, 3.7% SiO_2, 0.1% Al_2O_3, 1.0% CaO, 0.2% MgO.

Quartz, supplied by Yunnan Iron-Alloy Plant. Composition: 97.8% SiO_2, 0.23% CaO, 0.2% MgO.

All these minerals were ground separately in the pebble mill to -200 mesh (over 95%).

To increase the purity, the sample of cassiterite was treated in hydrochloric acid, and then purified in distilled water until the pH was neutral.

Reagents

Polyacrylamide 3#, made in China. Hydrolyzability, 30%.

Aerofloc flocculants, ACCOFLOC Type A100, A110, A130, 0575, 0581, N100, made by CYNAMID, U.S.A. Concentration: 1/1000.

Equipment

Zeta-potential Analyzer, Type ZP-10B, manufactured by SHIMADZU Corporation, Japan.

Transmissivity-Measuring Meter, 581-G Photoelectric colorimeter made by Shanghai Analysis Instrument Factory.

Irradiation Source; Co-60 Medico-Irradiation Meter, made by Shanghai No2 Medical Instrument Factory.

Method

The experiment was done in a deep beaker. The reagents were added at a fixed solid-liquid ratio. The mixture was stirred and allowed to settle for a set period of time. A sample of the suspended liquid was then taken from the mixture and its transmissivity measured with a photoelectric colorimeter. The flocculated and unflocculated parts were separately collected, dried and weighed, and their flocculation results were compared.

The test of the effect of the selective flocculation was made in a deep beaker, using a mixture of irradiated and unirradiated minerals in a set proportion.

The choice of flocculants

The reagent property test showed that among the three different kinds of imported reagents, A100, C581 and N100 were most effective. Home-made polyacrylamide 3# was also used in the test and compared with the imported reagents under the same conditions.

It can be seen from Fig 1 that 3#, C581 and A110, when used in small amounts (below 5 mg/l), have a good flocculation effect. With an increase in the dosage, the effect of C581 and A110 decreases, while that of N100 and 3# increases. After the dosage exceeds 20 mg/l, the effect of N100 and 3# drops to a certain degree.

Although in small amounts the effect of polyacrylamide 3# is poorer than that of C581 and A110, there may be a recovery of over 90% when the dosage is larger (about 20 mg/l). Since we are quite clear about the structure and properties of the reagents made in other countries, we decided to use polyacrylamide 3# (with a dosage of 20 mg/l) as the flocculant for our experiment (Yang Ao, 1981, 1982)

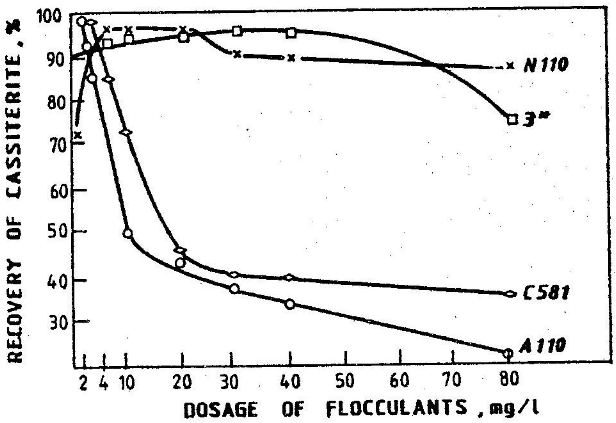

Fig. 1. The effect of the amount of the four flocculants on the flocculation result of cassiterite

It is to be noted that the cationic flocculant C581 and the anionic flocculant A110, when used in very small amounts (C581 —— 5 mg/l, A110 —— 2 mg/l), have an extraordinary binding power with cassiterite and can promote its flocclation. It should be particularly noted that C581 is uneffectived. When used in large dosages, the flocculability of both C581 and A110 decreases, while that of the neutralmolecule N100 and anionic 3# increases.

The effect of γ-ray irradiation on the flocculation of cassiterite and its associated minerals, quartz and hematite

The effect of the amount of irradiation on the flocculation of cassiterite

γ-ray is a high-energy beam of photoelectrons. When it is irradiating the mineral, all or part of it is absorbed by the mineral, giving rise to a change in the structure of the mineral, a change in electrons and a change in crystal defects (Yu, 1981). Therefore, the amount of γ-ray irradiation is an essential factor that affects the changes in the character of the mineral. The results of the investigation of the effect of irradiation on the flocculation of the minerals are shown in Fig. 2.

From Fig. 2. we can see that curves 3 and 5 give the same result. The recovery of cassiterite is not affected by irradiation and its amount. It is affected only by whether or not the cassiterite has been activized. That means the flocculation of cassiterite is not affected by its being irradiated or not, or by the irradiation amount.

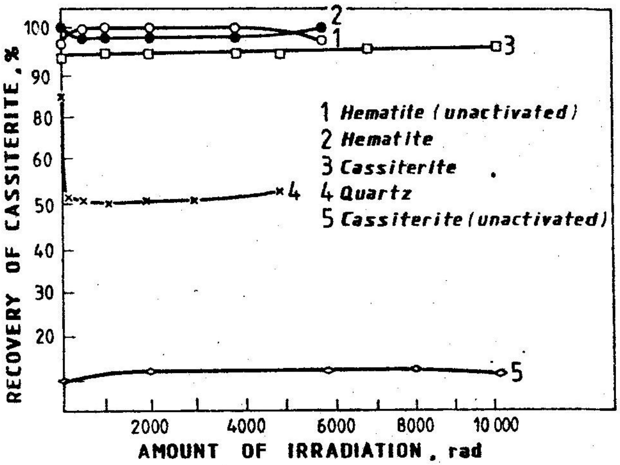

Fig. 2. Effect of amount of irradiation on the flocculation of the minerals

Curve 2 shows that after being irradiated in small amounts, the recovery of hematite increases by 4.1% and it remains the same with further increases in irradiation. The optimum irradiation amount is 500 rad.

Curve 4 shows that the recovery of quartz falls rapidly when it is irradiated in small amounts, and there is a very slight change when irradiated in large amounts. This indicates that a small amount of irradiation depresses the quartz.

The effect of irradiation amount rate on the flocculation of the minerals

Irradiation amount rate is the irradiation amount within a definite period of time. In our experiment, the irradiation amount is changed by adjusting the distance from the Co-60 source to the irradiated minerals. The fixed amounts are 2000 and 4000 rad, the adjusting distance being 45, 50, 55, 60, 65, 70 cm. Using the relevent formulae, we can work out the corresponding irradiation amount rate for each distance.

The irradiation amount rate has different effects on the flocculation of different minerals. The flocculation curves of cassiterite, hematite and quartz under different irradiation amount rates are illustrated in Fig. 3.

It can be seen from Fig. 3 that changes in the irradiation amount rate (within the range of 18-169 rad/min.) have little or no effect on the selective flocculation of the minerals. This shows that the changes of irradiation amount rate do not bring about any changes in the mineral structure and electron state and hardly influence the flocculation character of the minerals.

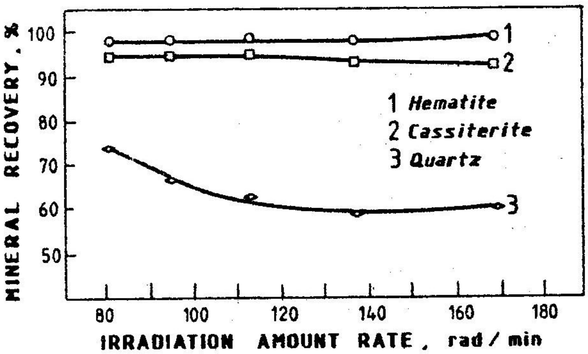

Fig. 3. Effect of irradiation amount rate on mineral recovery

The effect of the lay-aside time after irradiation on the flocculation

Irradiation brings about ionization effect in the external sphere of atoms, damage in the internal part of the mineral and defects in crystals. Such effects differ from mineral to mineral and may become stronger or weaker as time passes on (Horn. 1974).

The results of the test of the time effect on the selective flocculation are shown in Fig. 4.

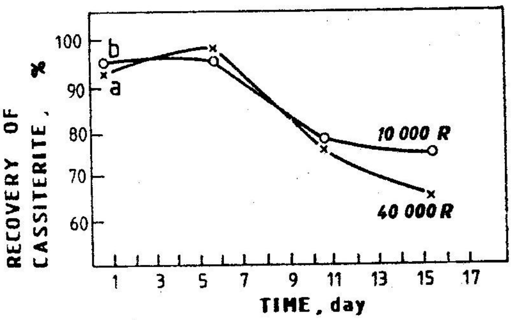

Fig. 4. The relation between time effect and recovery of cassiterite

It can be seen from Fig. 4 that within the two above-mentioned ranges of irradiation amount, the recovery of cassiterite varies with the length of the lay-aside time of the mineral after its being irradiated. If the lay-aside time is five days or less, the recovery of cassiterite increases. If it is laid aside for ten days, the recovery decreases remarkably (18-23%). This tells us that we'd better perform our flocculation experiment in 5-6 day's time after the mineral is irradiated. Prolonged lay-aside time would lower the recovery of cassiterite.

Compared with Curve 3 in Fig. 2, the above results show that γ-ray irradiation does not cause immediate changes in the structure, character and free electron concentration of the cassiterite. These changes take place slowly. Unirradiated cassiterite has the same recovery as that irradiated with a half-day lay-aside time (93.8%). A five-day lay-aside raises the recovery of cassiterite by 5%, but a ten-day lay-aside lowers the recovery by 23%. This also shows that, unlike hematite, cassiterite is not sensitive to γ-ray irradiation. It has a slow effect, which helps separation of Fe from Sn.

Investigation of the functional mechanism of γ-ray irradiation and flocculation of minerals

In order to reveal the functional mechanism of γ-ray irradiation and the flocculation of the minerals, we measured the amount of absorbed flocculants on the surface of the minerals, the zeta-potential and the specific magnetization coefficient before and after irradiation.

Determination of specific magnetization coefficient

The specific magnetization coefficient is the magnetic moment produced by one gram of substance in the outer sphere in a magnetic field with an intensity of one oersted. The magnetism is bound to be affected by the changes in electrons before and after irradiation.

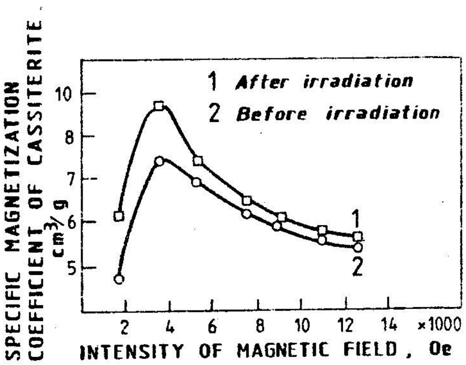

Fig. 5. Changes in the specific magnetization coefficient of cassiterite before and after irradiation

It can be seen from Fig. 5 that, before and after irradiation, specific magnetization coefficient varies regularly with increases in magnetic field intensity. The specific magnetization coefficient of cassiterite after irradiation is higher than before irradiation. When the magnetic field intensity is below four, there is a remarkable difference (over 1.5). When it is over six, there is a minor difference (below 0.5).

This result shows that after irradiation, the magnetism of cassiterite (which is a mineral with weak magnetism) increases; and when the intensity of the magnetic field is four, the increase in magnetism is most remarkable. It shows that, owing to the motion of electrons around the nucleus and their rotation, a magnetic moment is generated in the molecules, thus magnetizing the substance. The irradiation causes excitation and ionization in the outer sphere of atoms and changes the way in which the electrons move, thus increasing the magnetism and raising the specific magnetization coefficient.

The changes in zeta-potential of cassiterite before and after irradiation

The measured-results are listed in Tab. 1.

Table 1

The zeta-potential of cassiterite before and after irradiation

Irradiation amount (rad)	2000	4000	6000	0
Zeta-petential (mV)	6.99	5.23	4.45	7.11

(Proceeding in pH 5.3 distilled water)

It is shown in Tab. 1 that the negative value of zeta-potential for every irradiation amounts is smaller than that of non irradiated cassiterite. This indicates that irradiatin increases the zeta-potential of cassiterite, which makes it more active in reaction with the anionic flocculants.

Within the Co-60 source range which we have chosen, the photons in the photoelectricity effect or Compton effect can excite electrons and pass energy to them, thus freeing them from atoms (Yu, 1981). The surface of the irradiated cassiterite undoubtedly has less negative charge. Even with cassiterite with a negative charge, the irradiation on its surface strengthens the positive charge or weakens the negative charge. Besides,there is an influence of pH pulp on the cassiterite, so the electric charge of irradiated cassiterite is quite different from that of unirradiated cassiterite. Tab. 1 shows that the difference is also affected by the irradiation amount rate —— the larger the amount, the smaller the negative value of zeta-potential, and vice versa.

The determination of the absorbed amount of hydrolyzed polyacrylamide on the surface of the cassiterite

The results measured are listed in Tab. 2.

Table 2

The absorbed amount of reagent before and after irradiation

Dosage of reagents (mg)	After irradiation	Before irradiation
Reagent amount in liquid	4.17	4.47
Absorbed reagent amount on cassiterite	5.83	5.53
Washable amount	2.27	2.54
Unwashable amount	3.56	2.99

From Tab. 2 we can see that the absorbed amount of hydrolyzed polyacrylamide on the irradiated cassiterite increases, including a larger chemically absorbed part (Hu, 1983). This indicates that irradiation enhances the electrical charge on the surface of cassiterite and raises the absorbility of anionic flocculant. Therefore, irradiation can increase the absorption rate of the reagent by the mineral, strengthen the stability of absorption and improve the floatability of the mineral.

Separation test of the two products

In order to further investigate the effectiveness of separating the two products from each other, we carried out a separation test on the cassiterite-hematite mixture sample, in which $SnO_2:Fe_2O_3 = 2:3$. The flocculation test was done by adding 20 mg/l hydrolyzed polyacrylamide to the pulp with pH = 8.

It can be seen from Tab. 3 that the flocculation effect of irradiated minerals is much better than that of unirradiated ones. Though the recovery of iron from iron concentrate and cassiterite concentrate before and after irradiation is the same, β Sn in cassiterite concentrate before and after irradiation is quite different. there is a striking difference in the content of β Sn in iron concentrate before and after irradiation. All this shows that

Table 3

The results of separating the two products

Amount of irradiation (rad)	Mineral recovery (%)	Products	Sn %	Fe %	Sn %	Fe %
500	79.6	Iron concentrate	13.2	45.1	49	89
	20.4	Cassiterite concentrate	54.2	21.2	51	11
0	82.3	Iron concentrate	18.2	41.1	66	89
	17.7	Cassiterite concentrate	44.5	23.3	34	11

irradiation offers a good flocculation effect. If depressants had been used, there could have been a better separation of Sn from Fe.

As our experiment was only aimed at comparing the effect of irradiation with that of unirradiation, we did not use any other kinds of reagent in our experiment.

Summary

The whole experiment shows that γ-ray irradiation is beneficial to the separation of fine-grained cassiterite from hematite and quartz. Irradiation and its amount have no influence on the flocculability of cassiterite. After irradiation, the recovery of quartz decreases sharply, while that of hematite increases (When the irradiation amount reaches 500 rad, the increase is especially remarkable).

The above conclusion was proved by the test of separating cassiterite-hematite mixtire samples.

The irradiation amount rate has relatively little effect on the flocculation of cassiterite and hematite, but has a striking effect on that of quartz. The time effect after irradiation indicates that short lay-aside time doesn't affect the flocculation of cassiterite, while a long lay-aside time (over ten days, for example) can cause a significant drop in the recovery of cassiterite.

Irradiation can increase the amount of absorption of hydrolyzed polyacrylamide, decrease the zeta-potential on the surface of the cassiterite, and raise the specific magnetization coefficient of the mineral. The probable reason for this is that the combining energy of photons is much higher than that of electrons under Compton effect when the electrons are free. After irradiation, the excited and

ionized electrons on the surface leave the atoms of the mineral, so that there is more positive charge on the surface, which strongly attracts the negatively-charged flocculant, forming physical (and even chemical) absorption. As a result, irradiation improves the flocculation process and increases the floatability of the mineral.

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Participants in this investigation included Shi Dao-ming, Na Zhong-hui and Wang Jing-ling.

STRESZCZENIE

Yang Ao, 1987. Wpływ napromieniowania promieniami γ kasyterytu i towarzyszących mu minerałów na ich selektywną flokulację. Fizykochemiczne Problemy Mineralurgii 19; 165-176.

W pracy opisano wpływ napromieniowania Co-60 na właściwości flokulacyjne drobnych ziarn kasyterytu, hematytu i kwarcu. Badano również mechanizm tych procesów. Stwierdzono, że napromieniowanie badanych minerałów podwyższa efektywność rozdziału kasyterytu od hematytu i może

także zwiększyć selektywność rozdziału kwarcu wraz z hematytem od kasyterytu. Napromieniowanie jako nowy proces w przeróbce kopalin może znaleźć szerokie zastosowanie w praktyce przemysłowej.

СОДЕРЖАНИЕ

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В работе описано влияние облучения Co-60 на флокуляционные особенности мелких зерен каситерита, гематита и кварца. Исследован также механизм этих процессов. Определено, что облучение исследованных минералов повышает эффективность раздела каситерита от галенита, а также может увеличивать селективность раздела кварца вместе с гематитом от каситерита. Облучение, как новый процесс в обогащении полезных ископаемых должен найти применение в промышленности.