XVI International Mineral Processing and Recycling Conference
28-30 May 2025, Belgrade, Serbia

DOI: 10.5937/IMPRC25208A Original research article

THE SELECTION OF APPLICATION MODES OF AGENTS MODIFYING DIAMOND SPECTRAL CHARACTERISTICS IN THE PROCESS OF X-RAY LUMINESCENCE SEPARATION

Valentin Alexeyevich Chanturia[1], 0000-0002-4410-8182,
Valeriy Valentinovich Morozov[2#], 0000-0003-4105-944X,
Galina Petrovna Dvoichenkova[1], 0000-0003-3637-7929,
Elena Leonidovna Chanturia[2], 0000-0002-5757-4799,
[1]Institute of Comprehensive Exploitation of Mineral Resources of Russian Academy of Sciences, Moscow, Russian Federation
[2]National University of Science and Technology “MISIS”, Moscow, Russian Federation

ABSTRACT – The problem of choosing the optimal composition and conditions for processing diamond-kimberlite products with phosphor-containing reagents and modifiers has been solved. To solve the problem, the patterns of interaction of the organic collector with the surface of diamond crystals and kimberlite grains were determined and the necessary reagents – regulators were selected. The optimal phase composition and temperature conditions for the use of modifier reagents have been determined. The approbation of the selected processing modes has shown their effectiveness, providing increased diamond recovery during X-ray luminescent separation.

Keywords: Diamonds, Kimberlite, X-Ray Luminescence, Luminophores, Modifier.

INTRODUCTION

A promising way to solve the problem of recovery weakly and anomalously luminescent diamonds in X-ray luminescence separation is the use of state-of-the art technologies for optimizing the spectral characteristics of diamonds with luminophore-containing modifying agents [1]. The condition for the effectiveness of the applied technology is the maintenance of maximum differences in the level of luminophores fixation on diamonds and kimberlite minerals [2].

The purpose of this study was to increase the selectivity of fixing the modifier reagent on diamonds and kimberlite. To solve this problem, it is necessary to determine and maintain the optimal composition of the organic collector, to select the temperature conditions of modifying agent application and to use agent-regulators of interaction between the organic collector and the surface of diamond crystals and kimberlite grains [3].

[#] corresponding author: dchmggu@mail.ru

EXPERIMENTAL

Natural diamond crystals lost in the process of X-ray luminescence separation and kimberlite grains with a grain size of 1.5 to 3 mm, which correspond to the industrial range (Fig.1 a, b), were used for the research and testing.

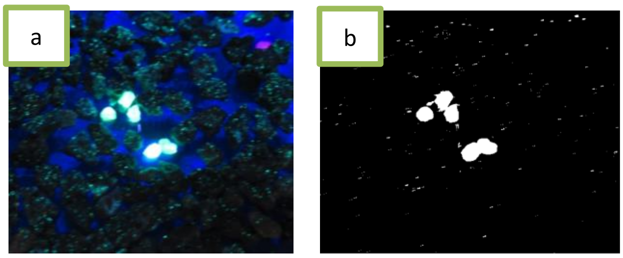

Figure 1 Natural weakly luminescent diamonds testing after treatment with agent in a) ultraviolet range; b) by visiometric analysis

In the preparation of the modifying agent, a hydrophobized inorganic luminophore was mixed with an organic collector. The obtained composition was dispersed in industrial water with additives of special dispersing agents. The obtained emulsion of the luminophore composition was fed into the installation for treatment of diamond-containing material (Fig. 2).

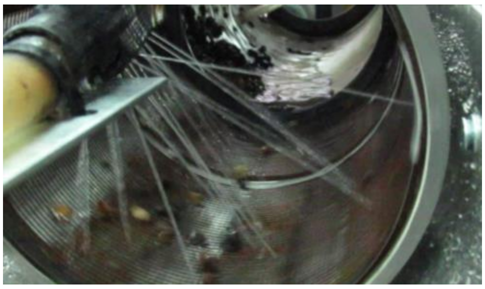

Figure 2 Installation for treatment of diamond-containing material with luminophore-containing composition (view from the side of material washing and unloading)

Excess emulsion after regeneration was returned to the emulsion preparation unit. The diamond-kimberlite product after removal of the emulsion was washed with industrial water (Fig. 2). After treatment and washing, the diamond-containing material was sent to a separator for diamond extraction using the amplitude-kinetic separation method. The luminophore-containing composition fixed on the diamond surface generates an optical signal in the range of 400-580 nm with the required spectral and kinetic characteristics, which ensures the extraction of weakly luminescent diamond crystals into the concentrate. To assess the luminophore fixation selectivity, we used the method of visiometric analysis of mineral surface coverage with luminophores using images obtained with a Renishaw InVia Raman confocal microscope with a 365 nm laser.

RESULTS AND DISCUSSION

Substantiation of methods for increasing the effectiveness of luminophore fixation on diamonds

Media temperature control is commonly used to regulate the fixation of organic apolar collectors on minerals [4]. Another technique to improve the stability of luminophore fixation on diamond surface is combining a high-viscosity collector and low molecular weight solvents. The mechanism of improving luminophore fixation is the increase in viscosity and the hysteresis component of the holding force after the low molecular weight solvent is transferred to the aqueous phase.

The studies of the effect of the modifying agent application temperature conditions included heating of the water-agent emulsion with maintaining the temperature of 35-40 °C in the medium of the diamond-containing material treatment and subsequent washing of the material at the temperature of 15-20 °C. Heating of the emulsion strengthens of the luminophore composition fixation on diamonds for all compositions of an organic collector and decreases the concentration of luminophore on the kimberlite mineral surface.

Table 1 Results of visiometric analysis of the effect of temperature conditions and collector composition on the effectiveness of luminophore fixation

No.	Organic collector composition	Temperature, °C					
		15	20	25	30	35	40
		Coverage of diamond surface with luminophore, %					
1	CCHGO (Cat cracking heavy gas oil)*	27.0	29.2	31.5	32.0	31.5	29.7
2	DTF	22.0	24.2	27.5	28.0	26.9	25.7
3	CCHGO (85%), DTF (15%)	27.4	31.4	33.0	32.1	31.2	28.7
4	CCHGO (90%), EMK (10%)	30.5	33.4	33.5	31.7	30.8	29.4
Kimberlite minerals surface coverage with luminophore, %							
1	CCHGO	3.0	3.8	4.3	4.0	2.1	1.5
2	DTF	4.6	5.3	5.0	4.6	2.8	2.3
3	CCHGO (85%), DTF (15%)	3.1	3.5	3.3	2.8	2.0	1.5
4	CCHGO (90%), EMK (10%)	2.7	2.9	3.0	2.9	2.5	2.1

*CCHGO is catalytic cracking heavy gas oil; DTF is diesel technical-grade fraction, EMK - ethyl methyl ketone

The selected temperature conditions with the emulsion heating and temperature decrease in washing process stage, as well as the use of compound collectors of the proposed composition provide stable fixation of luminophores on diamonds (the surface concentration more than 15%) while ensuring the selectivity of the separation (the surface concentration on the kimberlite mineral surface was less than 3%).

The basic process parameters of the diamond spectral and kinetic characteristics selective modification modes are the characteristics of a modifying agent: the ratio of luminophore/collector; the ratio of collector/aqueous phase, and the concentration of a dispersing agent. To determine the optimal composition of a modifying agent, the second-order factorial experiment method was used. The initial factorial experiment matrix (second-order orthogonal central composite design) was compiled according to the standard technique with the addition of zero and star points. The experimental array consisted of 15 experiments.

To reduce the optimization problem to a one-parameter one, the criterion "Selectivity of luminophore fixation on diamonds and kimberlite" (SLF_{DK}) was applied, calculated by the following equation:

$$SLF_{DK} = (C_{LD})/15 - (C_{LK})/3 \qquad (1)$$

where C_{LD} - surface concentration of luminophores on diamond; C_{LK} - surface concentration of luminophores on kimberlite. The physical essence of the criterion is the uniform accounting of the deviations of the surface concentrations from the boundary values (3 and 15%).

The results of the mathematical processing of the experimental results in Excel environment using the second-order factorial experiment allowed determining the area of optimal ratios between the components of the MLA-3 modifying agent in the working emulsion: the ratio of water/collector of 80:1 - 100:1, the ratio of collector/ luminophore of 9:1.

The optimal concentration of sodium hexametaphosphate (HMF) at the selected values of the modifying agent emulsion parameters is 1.5 g/l.

Tests of X-ray luminescence separation with the use of modification with luminophore-containing agents

The effectiveness of the selected mode was tested using aqueous emulsion of modifying agents based on luminophores (FL-530), anthracene (MLA-1 and MLA-2), and E-515–115-G5 (MLA-3) [3] with the addition of sodium hexametaphosphate (as dispersing agent) to the aqueous phase with the selected ratios of the luminophores, a collector, and aqueous phase.

The testing results demonstrated high selectivity of the RLS of diamond-containing products in the tests of all modifying agents and treatment modes, confirmed by high recovery (ε) of diamonds (90 - 100%) with complete yield of kimberlite into the tailings (Table 2).

The visiometric method confirmed intensive fixation of the luminophore-containing compositions on both types of diamonds (the coverage degree of 15.5 - 17.0 %) when using a composition based on FL-515-125 luminophore (Fig. 3).

Table 2 Spectral and kinetic characteristics and recovery of diamonds and kimberlite in the testing separation process

Conditions	Mineral	kinetic parameters of the signal				ε, %
		Convolution	Tau, ms.	A_{SC}, mV	K_A	
No treatment	A1	0	50	56	0	0
	A2	0.01	0.8	422	35.6	0
	K	n.m.	n.m.	<50	n.m.	0
With treatment (average of six tests)	A1	0.13	2.33	305.67	8.10	90
	A2	0.17	2.33	902.50	6.03	100
	K	n.m.	n.m.	<50	n.m.	0.9

A1 - weakly luminescent diamonds, A2 - anomalously luminescent diamonds, K - kimberlite; n.m. - parameter is not measured due to A_{SC} value is beyond the measurement range

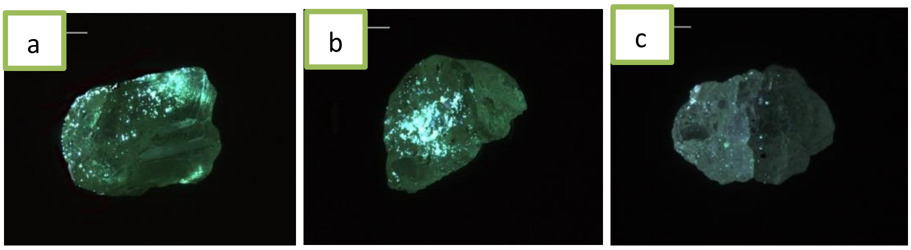

Figure 3 Fixation of luminophore-containing composition MLA-3 (E-515-115+CCHGO+DTF) on weakly luminescent (a), anomalously luminescent (b) diamonds, and a kimberlite grain (c)

The obtained results of the tests and the analysis of recovered diamonds fully correspond to the data of laboratory studies and show the feasibility of achieving the degree of diamonds coating with luminophores of more than 15% and their complete recovery in the process of X-ray luminescence separation.

CONCLUSION

The optimal phase composition and temperature conditions for the use of reagents modifiers of spectral and kinetic characteristics of diamonds have been determined. Testing of the selected modes has shown the possibility of increasing diamond extraction during X-ray luminescent separation.

REFERENCES

1. Chanturiya, V.A., Morozov, V.V., Dvoichenkova, G.P., Chanturiya, E.L. (2023) Selection of reagent compositions for modifying spectral characteristics of weakly and anomalously luminescent diamonds in the process of x-ray luminescence separation. Journal of Mining and Metallurgy, 59 A (1), 49-60.

2. Morozov, V.V., Chanturia, V.A., Dvoichenkova, G.P., Chanturia, E.L., Podkamenny, Y.A.. (2023) Selecting Organic Collectors for Luminophore-Bearing Modifying Agents to Extract Weakly Fluorescent Diamonds. Journal of Mining Science. 59, 292-301.
3. Chanturia, V.A., Morozov, V.V., Dvoichenkova, G.P., Podkamenny, Yu.S., Timofeev, A.S. (2023) Optimization of composition and conditions of application of means/agents for modifying spectral characteristics of diamonds in the process of X-ray luminescence separation. Gornye Nauki I Tekhnologii [Mining Sciences and Technologies], 8 (4), 313-326 (in Russian).
4. Morozov, V.V., Kovalenko, E.G., Dvoichenkova, G.P., Pestryak, I.V., Lezova, S.P. (2022) Selection of collector composition and temperature conditions for diamond foam separation. Journal of Mining and Metallurgy, 58 A (1), 21 – 28.