Conference Paper

Gold Allocation Forms in Sulfide Ore and Products of their Processing Enrichment

Alexey Mironovich Amdur[1], Sergei Andreevich Fedorov[2], and Anna Nikolaevna Matushkina[1]

[1]Ural State Mining University, 30, Kuybysheva street, Ekaterinburg, Russian Federation, 620144
[2]Institute of Metallurgy of the Ural Branch of the Russian Academy of Sciences, 101, Amundsen street, Ekaterinburg, Russian Federation, 620016

Abstract

Gold in sulfide ores and technogenic formations after their processing is concentrated in the form of micro-dispersed particles. This article presents a study on the composition of the ultrafine gold particles, their size distribution, and some predicted gold properties. The studies were carried out using copper pyrite ore as an example. It was found that the content of metallic impurities in Au particles, which may appear during their formation under natural conditions, increases with a decrease in their size. The presence of copper in gold particles significantly lowers the melting point of the alloy. The data obtained are used to develop a technology for utilizing gold from technogenic formations of a similar type.

Keywords: gold particles, copper, metallic impurities, alloy, radius of particle.

Corresponding Author:
Alexey Mironovich Amdur
engineer-ektb@rambler.ru

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1. Introduction

A significant part of the world’s gold reserves is concentrated in sulfide ores and technogenic formations after their processing: tailings and other. In them, gold is represented by microdispersed particles, the size of which usually does not exceed 10 microns. Such gold is extracted on modern processing equipment only after enlargement, which is possible in the process of heating and melting of technogenic raw materials [1].

To develop a technology for the extraction of microdispersed gold from sulfide materials, it is necessary to study the composition of microdispersed particles, their size distribution, and on this basis to predict Au properties that differ from those of bulk samples.

2. Material and Method

The problem was solved by the example of copper-pyritic ore of the Urupsky deposit as a model system. According to mineralogical studies, the main minerals are (wt.%): Pyrite (80), quartz (8), chalcopyrite (5), sphalerite (2), chlorite (3). The gold content is 1.2 g/t.

The sizes of gold particles and their chemical composition were determined using an Axio Imager 2 optical microscope (Carl Zeiss, Germany) and a Zeiss EVO-MA 15 scanning electron microscope with an X-max X-ray attachment (Carl Zeiss). The prefix made it possible to determine the chemical composition of the particles. The relative error of this device with a mass fraction of the element of 2–5% was 10%, with higher contents of the element, the error decreased to 1–2%. In this case, the general error of determination consisted of the error of the device and the error associated with the preparation of samples for analysis.

We used a scanning electron microscope control program for preset search and data processing — INCA Wave (Oxford Instruments, Great Britain). Search parameters were set by the maximum density of the substance and particle size. Particles with a diameter of more than 0.01 μm were analyzed, which is due to the resolution of the microscope. Due to the low concentration of gold particles in the initial ore, it is difficult to find using optical and electron microscopy. Based on the obtained data on the mineralogical and chemical composition, reagents-solvents of mineral phases were selected. All rock-forming minerals were transferred to the solution. A representative sample weighing about 4×10^{-5} g was taken from the residue, which was placed on the surface of the sample holder of the scanning electron microscope in the form of a monolayer.

As a criterion for the presence of Au, a color template for the image of a standard gold sample was used. Based on the study, basic data were obtained on the chemical composition, length, width, perimeter, area and shape of gold particles.

3. Results and Discussions

The size distribution of gold particles is shown in Fig. 1. The predominant fraction is 0.5-1.0 μm. Existing enrichment methods do not allow the concentration of gold with such particle sizes.

The analysis of more than 150 of the gold particles found that most of them contain metallic impurities. The predominant impurity found in every part of gold - copper. Its contents range from 3.32 to 46.97 wt%. Single particles are admixtures of platinum (up to 40 wt.%) and silver (up to 19 wt.%). The main part of the particle has a shape close

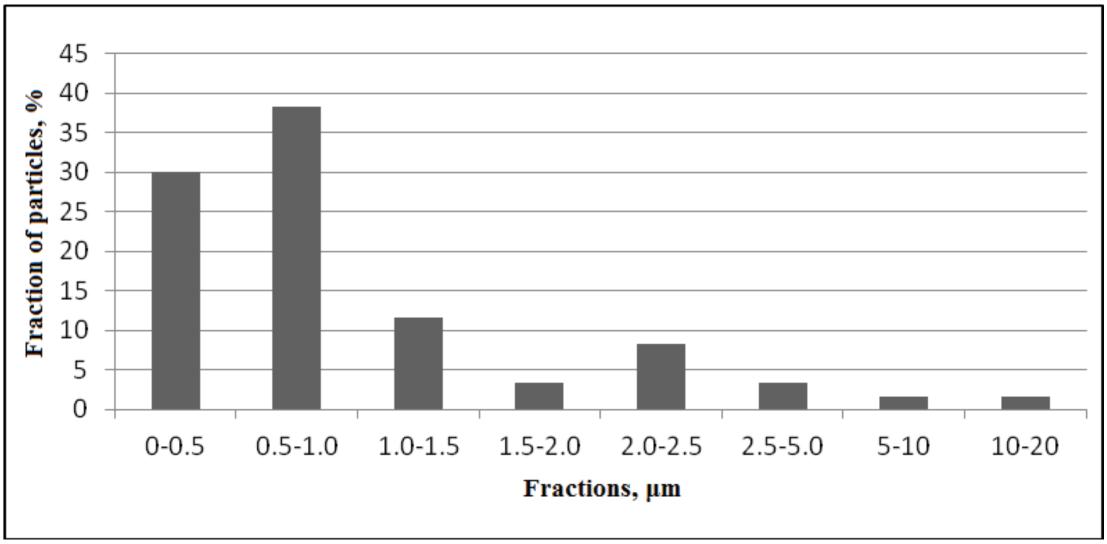

Figure 1: Size distribution of gold particles (0 - 20 microns).

to the sphere. In this regard, the evaluation of the particle sizes was made according to its radius R.

The content of impurities increases with decrease in the size of the gold particles, Fig. 2. A similar dependence established previously for the carbonate-silicate ores [2]. For particles, R is greater than 1 μm, the gold content in the particles did not depend on the linear size and area. When $R < 1$ μm and it decreases with decreasing particle size, and in this region increased the dispersion of the data. The latter suggests that the composition of the particles is strongly influenced by random factors.

In dispersed systems, the particle size influences many properties. This influence is shown when reducing the size to a certain critical value. This way depends on the strength of thin steel wires and glass fibers to their diameter, the viscosity of the liquid films of the thickness, strength of steel and the size of the inclusions during its dispersion hardening [2].

Thus, it was established experimentally that the content of metallic impurities in a separate particles of gold ore is only slightly dependent on the linear size and area, if R is greater than 1 μm. When $R < 1$ μm, the content of impurities increases with decrease of their size. Probably, the increased solubility is due to the loss of faceting and erosion of the crystal lattice for small particles, which is accompanied by the increase in Gibbs energy.

It can be assumed that the formation of alloys and compounds of gold with copper occurs in natural conditions when the nuclei of gold. It is believed [3] that the gold is recovered from hydrothermal solutions at temperatures up to 450, which contains copper. In the process of recovery from these solutions the copper according to the phase diagram of Cu-Au along with found the content of Cu in the particles of gold

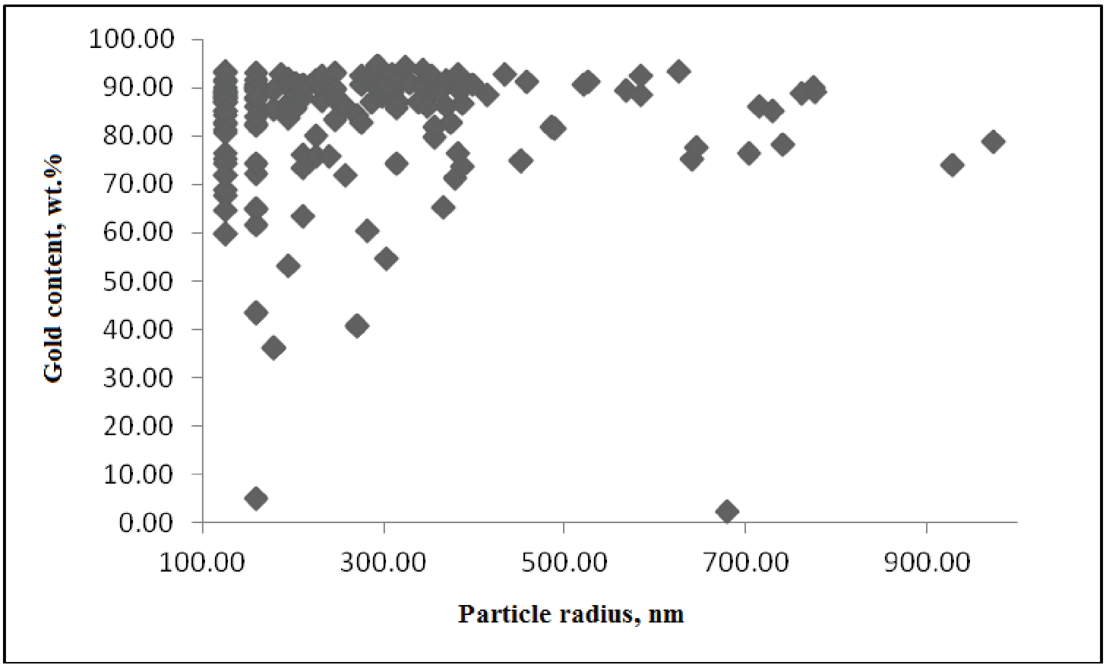

Figure 2: The dependence of the gold content on the particle size.

Urupsky deposits may form the following compounds with gold: $AuCu_3$, AuCu, Au_3Cu. To substantiate the possibility of the formation of alloys of gold with copper in the natural conditions of hydrothermal solutions conducted a simulation of these processes using the Equilibrium Compositions module of the HSC Chemistry package 9.0. Analyzed major known reactions of recovery of gold and copper from solutions. From Fig. 3 it is seen that in equilibrium conditions at temperatures above 100°C can indeed form the intermetallic compound AuCu. It replaces Au, the amount of which decreases. Also at temperatures above 400°C produces compound $AuCu_3$, but in very small quantities.

Thus, the appearance of impurities of copper in micro-particles of gold in sulfide ores is possible at the stage of formation of these metals in the natural environment.

The liquidus temperature of gold alloys with copper and their chemical compounds is significantly lower than the melting point of pure gold (1063°C). According to the Au-Cu state diagram [4], for the predominant small gold particles containing 18 wt.% Copper, the liquidus temperature is 910°C, for particles greater than 3 microns (6 wt.% Cu) - 980°C. Also, for small gold particles (0.1-0.5 microns), the size factor will affect in accordance with the Thomson equation, and the melting temperature will decrease by another 3-6°C.

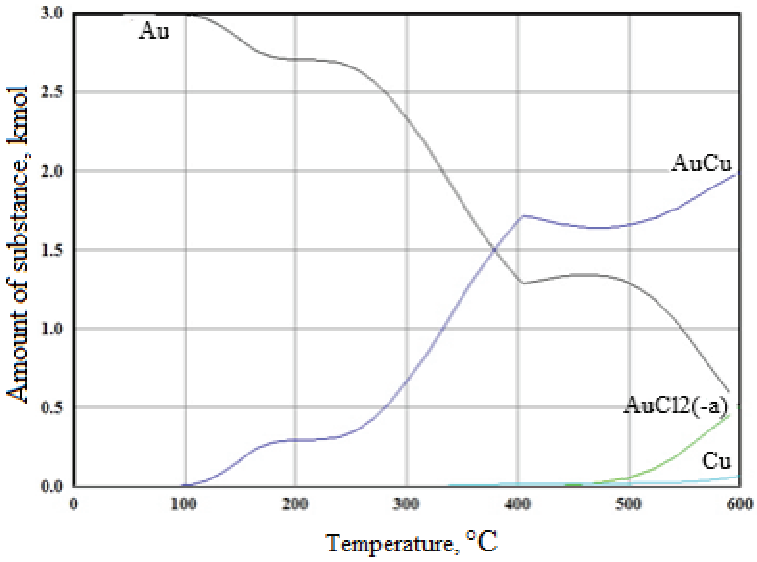

Figure 3: The equilibrium phase composition during the formation of gold and copper from hydrothermal solutions.

4. Conclusion

The conducted studies using the example of copper-pyritic ore revealed the size distribution of gold particles; the content of metallic impurities in Au particles, which may appear during their formation under natural conditions, increases with decreasing size; the presence of copper significantly lowers the melting point of the alloy. The data obtained are used to develop a technology for utilizing gold from technogenic formations of a similar type.

Acknowledgments

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