Gold Extraction to Ferrosilicium, Production of Foam Silicate from Processing Tails of the Olimpiada Mining and Processing Complex Gold Processing Plant (Russia, Krasnoyarsk Territory)

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Abstract. The paper describes the studies of processing tails of the Olimpiada Mining and Processing Complex with the methods of chemical, mineralogical, electronic microscope, deep reductive melting with division of the melt into a silicate and metal parts. It is demonstrated that 85% of the processing tails consist of the oxides: SiO₂, CaO, Al₂O₃, Fe₂O₃, H₂O and CO₂. The distribution of gold and silver is provided by the size classes of the initial blend, after melting of which in reduction conditions re-distribution of gold to the metal phase of the melt occurs. The silicate part of the melt when released into water in the “thermal shock” mode forms a light porous X-ray amorphous material “foam silicate”, which also serves as a resource for stable chemical composition for production of a wide range of import substituting ceramic materials.

Keywords: Pyrometallurgy · Processing tails · Ferrosilicium · Gold extraction

1 Introduction

The development of the methods of flotation, gravity and metallurgic processing of gold bearing ores and man-made products today is aimed at increase of the recovery of the valuable product (Pavlov 2005; Pavlov et al. 2015; Meimanova and Nogayeva 2014; Bogdanovich et al. 2013; Tselyuk and Tselyuk 2013; Algebraistova et al. 2017; Amdur et al. 2015). There are almost no technologies for comprehensive use of processing tails to produce an additional marketable product both for task of comprehensive use of processing tails for production of foamed resources for ceramic items production with associated gold recovery to the ferrosilicium matrix is vital.

2 Methods

The paper proposes the pyrometallurgic approach to the solution of the problem of comprehensive wasteless processing of man-made gold-bearing resources with the method of deep reductive melting with division of the melt into the defferrized silicate

part with its further chilling in the thermal shock mode (Pavlov et al. 2015) and the metal part with associated re-distribution of gold in the ferrosilicium matrix. The specimens of the silicate part of the melt were prepared for study using the powder technology; the metal specimens were covered with epoxy resin with subsequent polishing. The chemical phase composition was studied with the use of an X-ray fluorescent S2 RANGER analyzer and the scanning electronic microscope (SEM) Hitachi S-3400N with EMF Bruker.

3 Samples

The input material for pyrometallurgic extraction of gold is represented by the tails of the gold processing plant of the Olimpiada Mining and Processing Complex, which is the leader in Russia in terms of the ore processing volumes and marketable gold production. The gold-antimony and gold-arsenic ores of the Olimpiada deposit have a complex mineral composition and are extremely refractory for gold recovery from them. Most of gold is in the form of thin dissemination in sulfides (Kirik et al. 2017; Novozhilov et al. 2014). No more than 50% of gold is extracted by direct cyanation. At the gold processing plant the flotation concentrates of the ores are exposed to biooxidation using the BIONORD® technology and subsequent leaching to release gold capsuled in sulfides.

The processing tails have loose consistence, mainly sand-aleuritic-clayey size, with the content of (-0.071) mm fraction of about 25%. The chemical composition is dominated by SiO_2 , CaO , Al_2O_3 , H_2O and CO_2 , the share of which is about 90 wt.%. The concentrations of S are 0.69%, C—2.35%, Sb—0.11%, As—0.19%, and Ag — < .1%. The gold grade in individual samples as per the fire assay data varies from 0.2 to 0.97 g/t, with the average metal grade in the bulk sample received for study of 0.6 g/t. The main minerals of tails are quartz, calcite and stratified silicates making 98–99%. Sulfides, oxides, hydroxides and sulfates of iron, arsenic, antimony and tungsten are the impurities. In addition to the native highcarat gold, aurostibite (AuSb_2) and jonassonite (AuBi_5S_4) are present in single grains. Copper, antimony and mercury impurities are noted in some gold particles. Native gold particles are less than 0.045 mm in size (90%). Most of gold is noted in the form of micron inclusions in sulfides, quartz, carbonate and micas. Successive chemical leaching in the tail material using the method (Antropova et al. 1980) identified about 20% of mobile gold forms (water-soluble, sorbed, ferri-forms) and sulfide and telluride forms ~ 15%.

4 Results

In the process of the experiment the flotation tails sample with the weight of 400 g was mixed with lime (Ca(OH)_2) and brown coal. The blend was exposed to reductive melting at the temperature of 1500–1550 °C, in the process of which melt division into a metal and silicate parts occurred. The silicate part of the melt was poured into water

with production of foamed amorphous material (foam silicate). The recovery of foam silicate was 150 g. The metal phase recovery was 26 g (4.4%). Phase composition of the metal aggregate (wt.%): ferrosilicum (FeSi) 82.8; xifengite (Fe_5S_3) 8.97; wustite ($\text{Fe}_{0.974}\text{O}$) 0.79; wollastonite (CaSiO_3) 4.24; calcic clinoferrosilite ($\text{Fe}_{1.5}\text{Ca}_{0.5}(\text{SiO}_3)_2$) and elemental iron (Fe) 0.49. Chemical composition of the produced foam silicate (wt.%) – SiO_2 —43.7; TiO_2 —0.7; Al_2O_3 —7.79; Fe_2O_3 —0.19; MgO —2.22; CaO —42.5; K_2O —1.5; SO_3 —0.77; Cl—0.27, and metal phases: Si—23.5; Al—1.6; Fe—66.2; Mn—2.22; Mg 0.47; Ca—1.97; S—0.42; As—0.68; Cl—0.14; P—1.0; Co—0.35; V—0.28; Cu—0.21; Au—0.2; and Cr—0.18. The optical research of the metal alloy showed non-uniform aggregate composition. Six individualized metal phases of more complex composition have been identified in the iron and silicon alloy matrix. Gold is a part of the alloy consisting of (wt.%): Au—0.25–5.11; Sb—0.4–0.7; Sn—0.57–3.30; As—up to 9.47; Cu—4.51–32.07; Fe—59.8–33.8; Mn—7.2–1.33; Ga—0.24–9.38; and Si—14.53–12.96.

5 Conclusions

Therefore, silicate and metallic semi-finished products have been produced as the result of deep reductive melting of processing tails: (1) ferrosilicum, which is a gold collector; (2) foam silicate material as an additional product of the main production, can be used for production of ceramic materials for different purposes. The use of the method of pyrometallurgic processing of processing tails allows mitigating their adverse effect on the environment.

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