MICROWAVE ELECTROMAGNETIC PROCESSING OF ORE CONCENTRATES FOR EXTRACTION OF METALS

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The energy of microwave (MW) electromagnetic field (EMF) is used in extraction metallurgy of precious metals during last decades[1]. In this work the extraction of elements in the samples from “tailings”, concentrates of gold-sulfide-quartz ores and molybdenum concentrate with the use of MW field were studied. The effectiveness of interaction of EMF energy depends on matter properties, EMF frequency and MW chamber construction where the heating of the matter is done. The amount of excretion heat is proportional to the square of electric field strength of electromagnetic wave, that is the power of microwave generator. Therefore the physical-chemical process (temperature) may be regulated by varying the generator power during constant irradiation time in MW chamber or by varying irradiation time the generator power being constant or by both methods simultaneously.

The temperature dependence of dissociation of FeS on MW generator magnetron current is presented on Fig.1. One may conclude from the picture that FeS dissociation reaction is possible at lower temperatures in comparison with convection heating but at sufficient electromagnetic MW field strength. The studies of oxidation process of sulfur excretion during irradiation of gold and silver containing sulfide ores show that the more high MW EMF strength the lower dissociation temperature. Physical-chemical reactions implemented on account of EMF energy occur at temperatures 20-30% lower than during traditional heating.

The investigation and discussion

The characteristics of main ore and rock-forming minerals of studied samples determine magnetic and electric conductivity of MW field. The interaction effectiveness of EMF energy depends on such minerals as pyrite, hematite, chalcopyrite, magnetite, hydroxides of iron, sulfur, quartz. This minerals are responsible for dielectric losses. The main rock-forming minerals are quartz, carbonate, sulfurite and there are some minor amounts of volastonite, epidote and feldshpar. The ores are characterized by vein texture and it is important for the distribution of dielectric losses in the volume of irradiated ore mineral. The main ore minerals are pyrite, chalcopyrite, chalcozine, magnetite and hydroxide of iron.

The experimental research were conducted on specially elaborated MW stands. The stands comprise the following parts: 1) MW chamber; 2) the system of measurement and control of temperature; 3) the measurement system of absorbed MW power; 4) MW generators with 0.915 GHz and 50kW; 2.45 Hz and 5 kW.

The element analyses were done by radiochemical neutron activation method.

The initial samples of “tailings” with gold contents 0.1 g/ton and silver 3.9 g/ton were put for irradiation into MW chamber. MW power was monitored by calorimetric method. The temperature was measured at MW power shut down directly in the sample.

The following results were obtained.

Table 1.

gold concentration	silver concentration	probes
0,10 g/ton	3,9 g/ton	initial probe, “tailings”
1,20 g/ton	32,5 g/ton	magnetic fraction after microwave treatment, “tailings”

From table 1 one may see that in “tailings” magnetic fraction after microwave treatment contains the gold ~ 10 times more than initial probe. Magnetic fraction was extracted in magnetic field with 1.2T strength. The set of experiments with concentrates from sulfide gold containing ores was done.

Probe 1 - gold-sulfide-quartz ore.

Contents of gold 256,7 g/ton, silver 2787 g/ton (in vitro analisis). Mineral contents of probe: quartz - 85%, carbon shale - 3%, ancerit - 1-2%, nugget gold (probeness from 770 till 795 , average 781 (14K)). Gold forms accretings with quartz and sulfides. Unopened accretings in 1-2 mm fractions are 40%. The nugget silver is 70% of total silver contents in probe. The remained part enters into the composition of freibergite, akantite, oviheite; pyrite in the probe is - 5%, sphalerite - 2%, halenite - 1,5%, burnonite - 1,5%; there are also famatenite, bulangerite, pyrrotine, the total amount not exceeding 0,1%.

Probe 2 - oxidized gold-quartz ore.

Contents of gold 165,9 g/ton, silver 718,9 g/ton (in vitro analisis). Gold is extracted in nugget accretions with quartz and iron. Probeness is in range from 850 till 928. Silver is in the form of chlorides - embolite (0,1%) and bromirite (low), which form accretions with iron hydrooxides (3%). The main components of ore are quartz (93%), hydro-micas (4%) and pyrite (less than 0,1%). The experimental results on gold extraction in probes described above are presented in table 2. The analyses were done by atomic-absorption method.

The heating of sulfide ores in microwave field has definite advantages in comparison with ordinary heating: during microwave irradiation a heating takes place inside the material contrary to the grain surface during traditional annealing. In the temperature range 300-400°C the sharp increasing of gold extraction is due to some reasons, one of them is cracking of minerals (sulfides, quartz) and revealing of gold. The decomposition of sulfides occurs at

temperature near 700°C. The extraction of gold is increased from 59,7% in initial probe till 92,0%. In the case oxidized ore the gradual extraction increasing (from 84,34% to 99,0%) takes place because of cracking of quartz where gold is confined.

Table 2

The treatment in microwave field, temperature, °C	Gold extraction degree, %
Initial probe	59,7
300	92,00
400	84,48
600	76,66
700	84,24
1000	83,87
Initial probe	84,34
600	88,58
1000	99,00

The results on gold extraction from “tailings” after their treatment in microwave field have shown that as results of phase transition $Fe_2O_3 \rightarrow Fe_3O_4$ in temperature range 350-400°C the magnetic conductivity of gold containing sulfides increased.

The discussion of experimental results for molybdenum concentrate

Molybdenum industrial concentrate contains (%) molybdenum - 26, rhenium - 0.09, copper - 6.45, iron - 10.6, arsenic - 0.033, moisture and oil - 5.43. And magnetic compounds are 4.6% of molybdenum concentrate. The main mineral containing molybdenum is molybdenite MoS_2. Molybdenum is also contained in molybdite, povelite and others. The extraction of molybdenum is done from molybdenum and copper-molybdenum ores. The ores are of two types - sulfide and oxidized ones. The main ore minerals of sulfide ores are chalkopyrite, pyrite, magnetite, molybdenite. The last one contains rhenium admixtures in the form of isomorphous intrusions. Sulfide ores have high electromagnetic conductivity and one may expect fast heating and active participation of MW field in initiated physical-chemical reaction. The extraction of rhenium from molybdenum concentrate is based on volatility of Re_2O_7 oxides at the temperature of oxidation annealing 500-600°C. The experiments have been done in air ambiance and without it. The heating of material up to 400-500°C in microwave chamber without air was done during 3-5 min. Then the temperature was maintained on this level by decreasing the generator operation time (pulse generator operation with on-off time ratio ~2). The white transparent smoke appeared at 150-200°C which was collected by sublimation capture system. The heating of multi-component system of molybdenum concentrate elements occurred on account of conductivity currents. The constituents having high values of dielectric

losses angle tangent (tgδ) are heated first. In definite points of phase transitions the ordering of domain structure of magnetic moments takes place. For example, sufficiently strong magnetization(>90%) of Mo concentrate (in comparison with ~5-10% before irradiation) i.e. the material becomes magnetic one. The magnetization phenomenon means the probability of phase transitions in 400-500°C region. It was established by neutron activation method that the rhenium amount remained in material after MW treatment is ~ 20g/ton. Therefore the rhenium yield in sublimates is 91%. The hydrogen containing impurities transform into carbon(soot) and the oil contents decreases from 5.43% up to 0.2-0.3%. In MW chamber the MW breakdowns, ionization and plasma excitation are observed during the exceeding of electromagnetic field strength.

Before the annealing the sample presents itself black color powder (with specific glitter) where there are rather big “granules” (up to 6-7 mm) which remain black traces on the paper.

After the annealing the sample may be divided into two parts. The inner part, where oxygen access is hampered, presented itself also black, dispersion, homogeneous powder having glitter. The outer part - irradiated in the oxygen presence is very non-homogeneous, brown powder having both black and yellowish and almost white scruples.

For phase analysis of samples X-ray diffraction and neutron diffraction methods were used. X-ray analysis was done at the diffractometer with the use of CuK_α and then (with account for possible presence of Fe - containing minerals) - CoK_α - radiation. Neutron diffractograms were measured at neutron diffractometer set at the reactor thermal column and provided with 10 detectors neutron registration system with λ=1,085 Å wavelength. The sample was located into 8 mm diametre vanadium capsule.

On X-ray and neutron-diffractograms of initial material the most sharply the group of reflexes belonging to molybdenite [2] is displate and basal reflections are considerably magnified probably due to textureness of the preparation. Moreover, there are reflections specific for talc-type silicate with ~9,4 Å hight layers; the presence of chalkopyrite as well as quartz and calcite is not excluded. The background character on the neutron diffractogram indicates to the presence of large amounts of bound hydrogen due to oil impurity.

The material irradiated without oxygen access, according X-ray and neutron diffraction data, presents itself almost pure molybdenite, and the sharpness of reflexes even at the big 2 Θ angles certifies the high degree of far order. The silicate lines practically are absent. In the separated magnetic fraction on Co-radiation, besides main phase - molybdenite, Fe-containing impurities (probably magnetite, pyrotine and modified sulfide of chalkopyrite type). The behaviour of background indicates to the absence of bound hydrogen, i.e. to the oil removal.

For analysis of non-homogenious outer part of material (irradiated in the presence of oxygen) the samples were prepared not only from the total powder mass but from visually selected black

and white scruples. It happened that both present themselves multi-phase mixtures and molybdenite prevails in black scruples and is absent practically in white ones where prevailing phase is talc-type silicate (with slightly increased layer hight) which presents also in black particles. As it was shown in [3] the structure of such silicate may remain during annealing above 650°C. Besides, there are lines of α - quartz and MoO_3 at all diffractograms, α - pyrrotine and powellite are possible (the reliable diagnostics is hampered because of the overlaping of reflexes).

The measurements of integral intensity of molybdenite reflex 1013 have shown that on X-ray diffractogram of inner part of material this reflex is reduced very little (about 10%) and at the outer layer - more than order. Hence, the decomposition of molybdenite and its oxidation till MoO_3 occurs mainly in the outer layer of molybdenum concentrate in the oxygen presence. Magnetic separation of outer layer material has shown that the black particles posess magnetic properties (the white scruples are not magnetic). So, the treatment of molybdenum concentrate in MW field leads to sharp increase of material magnetic susceptibility.

The results obtained permit to analyze and extract hard-separable elements more effectively comparing with traditional methods.

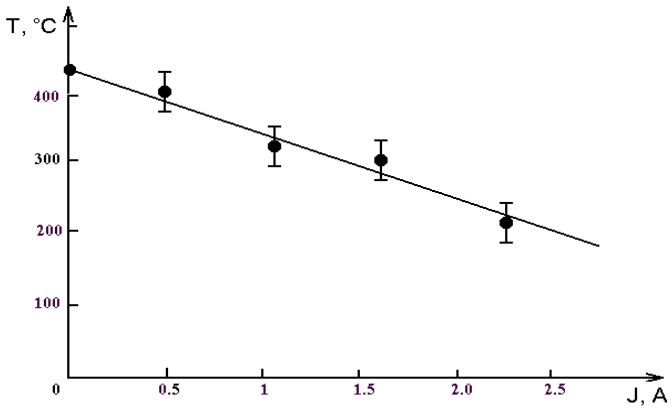

Fig. 1. The temperature dependence of FeS dissociation on magnetron current

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