GOLD RECOVERY FROM CHALCOPYRITE CONCENTRATES IN THE HYDROCOPPER® PROCESS

by

P Sinisalo and K Hietala*

Outotec Research Oy, Finland
*Outotec Oyj, Finland

Presented by

Pia Sinisalo
pia.sinisalo@outotec.com

CONTENTS

ABSTRACT

Outotec HydroCopper® process is developed for treating chalcopyrite copper concentrates in an atmospheric chloride environment. Gold is commonly associated with these concentrates. Gold is recovered as by-product of copper to enhance economy of the production plant. Copper and gold are leached in a multistage counter-current circuit.

Copper is leached first. Dissolved copper is precipitated as copper(I)oxide from the copper chloride solution after solution purification. Copper(I)oxide is reduced to metallic copper in hydrogen atmosphere at a reduction furnace. Copper is melted and cast to end product e.g. copper wire rod.

Gold is leached after most of the copper is leached, when the oxidation-reduction potential (ORP) increases. Bromide is used in gold leaching stage to aid gold dissolution. Gold is adsorbed onto activated carbon for further gold refining. This paper features the latest improvements tested for the gold recovery within the Outotec HydroCopper® process.

1. INTRODUCTION

Gold is commonly associated with copper sulphide minerals. Gold grades in copper concentrates are usually rather low. In most cases this value is < 5 g/t. Gold is preferably produced as by-product of copper to enhance the economics of the deposit. About 80 % of by-product gold comes from copper ores [1].

McCaughey found in the early 1900's that gold dissolves in cupric chloride leaching of gold-containing copper ores [2]. Outotec benefited from this fact in its HydroCopper® process that treats copper concentrates in atmospheric chloride environment [3].

This paper presents the HydroCopper® process with emphasis on gold leaching and recovery. The use of bromide for gold leaching in the HydroCopper® process is discussed. Gold recovery from solution using activated carbon is also discussed.

2. HYDROCOPPER® PROCESS

The HydroCopper® process can be divided into seven parts (Fig. 1): countercurrent leaching of copper concentrate, gold recovery, oxidation of leach solution, solution purification, precipitation of copper(I) oxide (Cu_2O), regeneration of chemicals and fabrication of copper products.

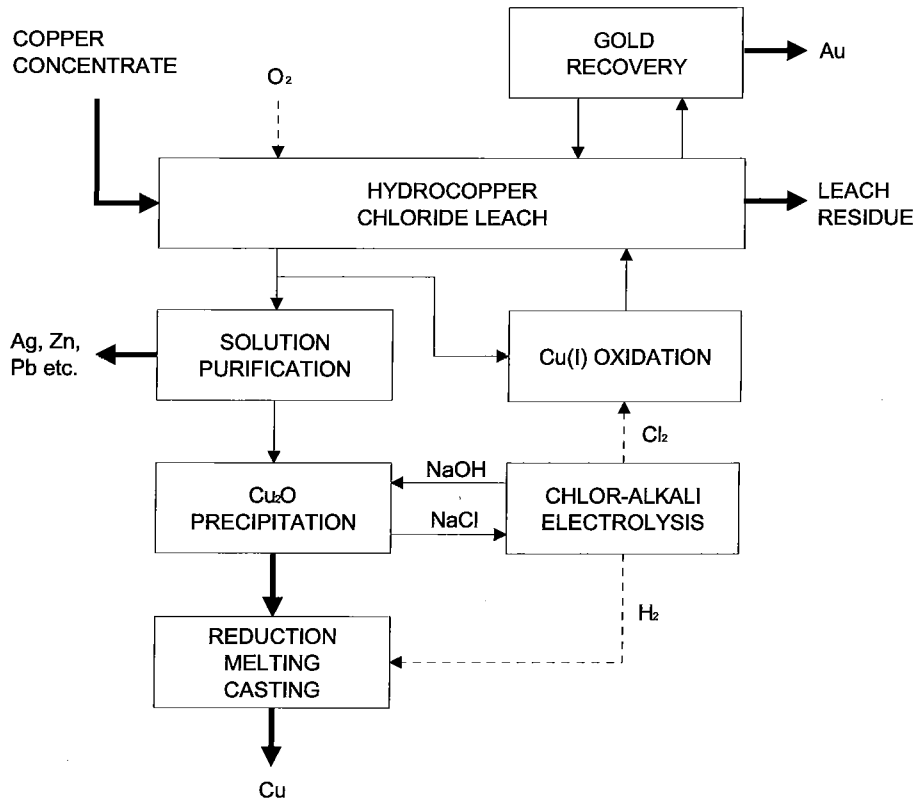

Figure 1: Simplified flowsheet of the Outotec HydroCopper® process.

Copper concentrate is leached under atmospheric pressure in strong chloride solution using cupric ions as oxidant in agitated reactors. The leaching temperature is 85-95 °C. Oxygen is blown into the reactors in order to oxidise the iron and to precipitate it as hydroxide or oxide at pH 1.5-2.5. Most sulphide minerals are dissolved and elements such as Au, Zn, Pb, Ni and Ag end up in the leach solution along with Cu.

Chalcopyrite, the most significant but slowly soluble copper mineral, is leached in the chloride media with the help of Cu^{2+} according to the basic reaction:

$$CuFeS_2 + 3\ Cu^{2+} \rightarrow 4\ Cu^{+} + Fe^{2+} + 2\ S^0 \qquad (1)$$

Ferrous iron is further oxidised by oxygen to ferric that precipitates as goethite or hematite, resulting in the following sum reaction:

$$CuFeS_2 + Cu^{2+} + \tfrac{3}{4}\ O_2 \rightarrow 2\ Cu^{+} + \tfrac{1}{2}\ Fe_2O_3 + 2\ S^0 \qquad (2)$$

Gold dissolution is enhanced using some alkali bromide, such as sodium bromide, in the last leaching stage. Gold bromo-complex is formed according to following sum reaction:

$$Au + 3\ Cu^{2+} + 4\ Br^{-} \rightarrow AuBr_4^{-} + 3\ Cu^{+} \qquad (3)$$

The gold-containing solution is pumped through columns or agitated reactors where gold is adsorbed onto activated carbon. The bromide-containing solution is circulated back to gold leaching after gold recovery to reduce sodium bromide consumption (Fig. 2).

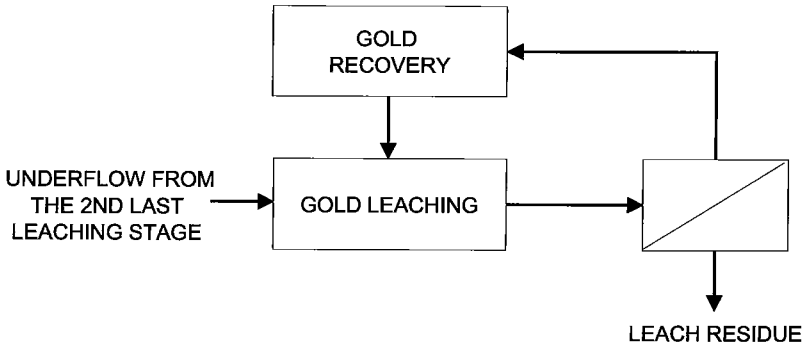

Figure 2: Schematics of the gold leaching and gold recovery stages.

The main components of the leach residue are iron oxides and elemental sulphur. In addition, it contains silicates, pyrite and some gypsum. During leaching, 5-10 % of the sulphur in the sulphide is oxidised to sulphate that is removed as gypsum by adding limestone.

After solution purification, copper is recovered as Cu_2O by precipitation with sodium hydroxide. The oxide is reduced with hydrogen gas to copper sponge that is melted and cast into copper products. The copper produced meets the requirements of LME A+ purity for high-quality copper.

The key factor in the HydroCopper® process is the use of chlor-alkali electrolysis to regenerate the chemicals from sodium chloride solution recovered from Cu_2O precipitation. The chlor-alkali electrolysis produces NaOH for the precipitation of Cu_2O, hydrogen gas for the reduction of Cu_2O and chlorine gas for the oxidation of Cu^+ to Cu^{2+} in the oxidation stage.

3. EXPERIMENTAL

3.1. LEACHING OF GOLD-CONTAINING COPPER CONCENTRATE

The laboratory scale leaching tests were carried out in an agitated reactor at typical HydroCopper® leaching environment. Solution was nearly saturated with sodium chloride. NaBr concentration used was 0 and 15 g/L. Temperature was kept constant at 95 °C.

ORP was measured using a platinum electrode and a silver-silver chloride reference electrode. This scale is also used in this paper. Oxygen was used as an oxidant and applied after 2 h of leaching. The retention time for solids was 30 h and samples were taken at regular intervals.

Tests were carried out with a chalcopyritic copper concentrate containing 27 % Cu and 4 g/t Au. Chalcopyrite carried over 80 % of the copper in the concentrate and the rest was in bornite. The concentrate contained also 18 % pyrite and some quartz. Gold in the copper concentrate was not refractory.

3.2. GOLD RECOVERY FROM SOLUTION USING ACTIVATED CARBON

The laboratory-scale kinetic test was carried out in an agitated reactor at 90 °C. Authentic HydroCopper® leach solution with bromide and coconut shell activated carbon were employed. The retention time for solids was 2 h and samples were taken at regular intervals.

The solutions and solids were analysed for Au using GFAAS and fire assay respectively. Br was analysed from solutions using titration. Sulphur was analysed from solids using S/C analyser. Base metals were analysed using ICP.

4. RESULTS AND DISCUSSION

4.1. GOLD LEACHING FROM COPPER CONCENTRATE

Copper leaching yield achieved in the HydroCopper® is typically 98 %. Leaching is controlled by blowing oxygen and monitoring the pH and ORP. Most of the copper is leached in the middle stage(s) of the countercurrent leaching.

ORP is high and gold is leached with the help of bromide in the last leaching stage. The underflow feed to this stage contains typically 2-8 % copper in solids that are leached as well. Total retention time for solids is 10-20 h.

Gold concentration in solution is typically from 0.2 to 1.5 mg/L after gold leaching due to relatively low gold grade of copper concentrates. The target for gold leaching is less than 1 g/t gold in the leach residue.

In the laboratory test with bromide, ORP rose from 450 to 600 mV and 98 % of the copper was leached in 15 h (Fig. 3). Gold leaching followed the trend of copper leaching. Gold leaching yield achieved was 90 % in 15 h. Gold concentration in solution was 0.3 mg/L. Bromide had no effect on copper leaching.

The presence of bromide helps to get more gold leached already at lower ORP, as the solids in contact with the solution react faster than without the presence of bromide. In the laboratory test, gold yield without bromide was only 65 % compared to 90 % with bromide in 15 h (Fig. 4). This is attributed to the greater stability of the $AuBr_4^-$ complex compared to the $AuCl_4^-$ complex.

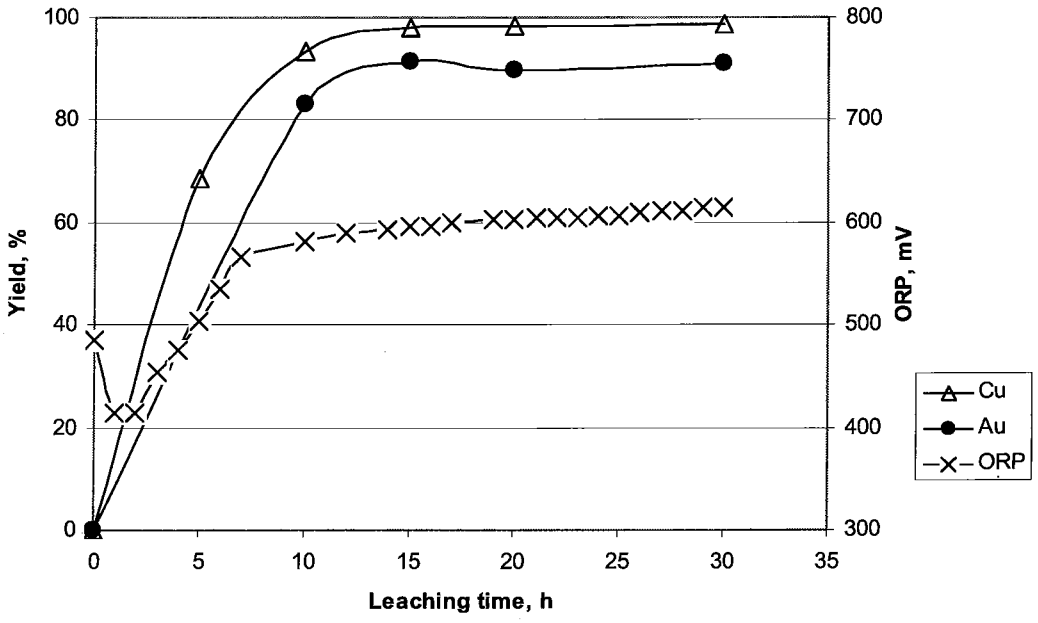

Figure 3: Copper and gold leaching in the presence of bromide.

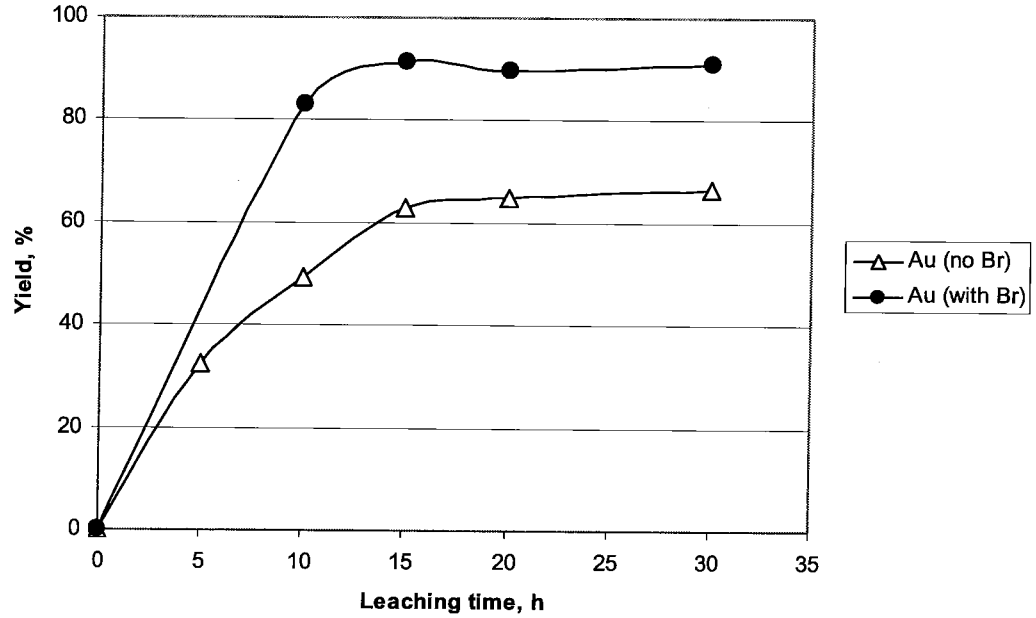

Figure 4: The effect of bromide addition on gold leaching.

4.2. GOLD RECOVERY FROM SOLUTION

Gold can be recovered from solution using activated carbon. Carbon loading has an adsorption type mechanism involving mass transfer of gold complex from solution onto the carbon. The adsorption behaviour is similar to gold recovery in the cyanidation process.

Dissolved gold is adsorbed onto activated carbon typically at 0.5-1 % w/w in the HydroCopper® process. Gold loading capacity increases with increasing gold concentration in solution. On the other hand, some organic compounds in solution can foul the carbon and cause less gold to be adsorbed.

Gold adsorption on activated carbon is fast. Results from the laboratory test demonstrate this. Steady state was reached practically in 2 h and over 85 % of the gold in solution was adsorbed in 30 min using 0.3 g/L activated carbon and 1 mg/L gold initially at the temperature of 90 °C (Fig. 4).

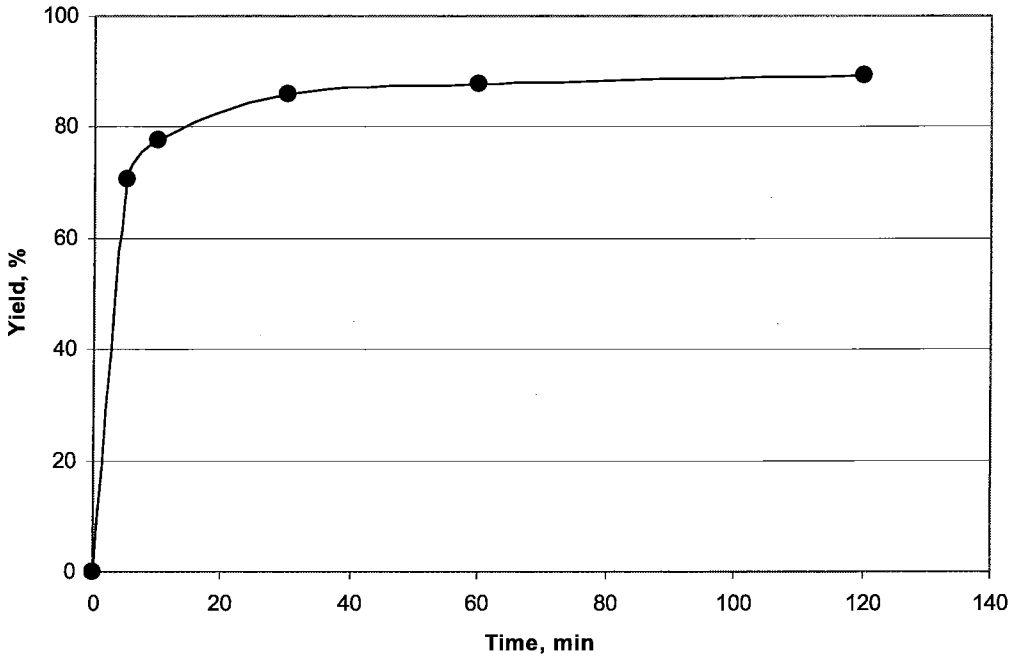

Figure 4: Gold adsorption on activated carbon.

5. TECHNO-ECONOMIC ASPECTS

HydroCopper® provides an economically competitive non-cyanide process option for gold recovery from copper concentrates. Gold leaching takes place in connection with copper leaching in the HydroCopper® process and hence only minor additional investment and operating costs are associated with the gold recovery.

Refractory gold associated with pyrite cannot be leached in the conditions typical to the HydroCopper® process. If the gold is leached, pyrite needs to be decomposed, which forms sulphur acid that has to be neutralised. Limestone cost associated with the neutralisation is significantly higher than those of copper concentrates.

6. CONCLUSION

Gold can be leached in association with copper from copper concentrates in the HydroCopper® process. The countercurrent leaching mode allows elevation of ORP for effective gold leaching in chloride media with the help of some bromide. Gold is recovered onto activated carbon that can be further refined to produce metallic gold.

7. REFERENCES

1. Marsden, J., House, I., The Chemistry of Gold Extraction, Ellis Horwood, London, 1992.

2. McCaughey, W. J., The Solvent Effect of Ferric and Cupric Salt Solution Upon Gold, J. Am. Chem. Soc., Vol. 10, 1909, 1261-1270.

3. Hyvärinen, O., Hämäläinen, M., Leimala, R., Outokumpu HydroCopper Process: A Novel Concept in Copper Production, Chloride Metallurgy, Montreal, Canada, October 19-23, 2002.