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(54) Title: A METHOD FOR THE TREATMENT OF ORE MATERIAL

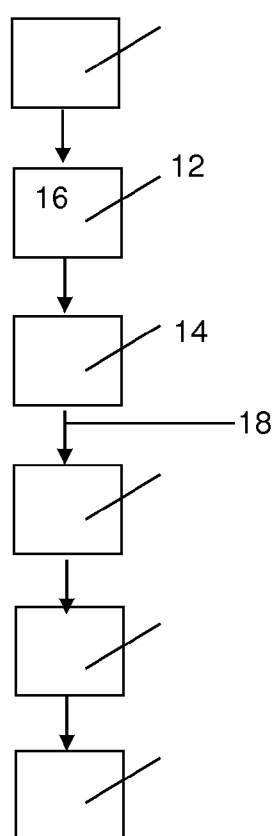


Figure 1

(57) Abstract: A method for treating an ore material with electromagnetic energy, the method comprising at least the steps of: agglomerating the ore material; irradiating the ore material with electromagnetic energy; thereby heating the liquid in the ore material; vapourising at least a portion of the liquid in the ore material; forming micro-channels in the ore material, and acid leaching the ore material.



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“A Method for the Treatment of Ore Material”

FIELD OF THE INVENTION

[0001] The present invention relates to a method for treating ore material with electromagnetic energy to form micro-channels.

BACKGROUND ART

[0002] In mineral processing microwave heating has been used for the pre-treatment of ore materials in order to increase valuable mineral recovery. Microwave heating offers a number of advantages over conventional heating such as, rapid heating, material selective heating and volumetric heating. However, the problem with the use of microwave energy in mineral processing arises from the fact that uncontrolled levels of microwave exposure causes unwanted changes in the minerals and undesirable changes in the ore materials themselves.

[0003] For example, WO 03/102250 proposes the use of pulsed microwave energy treatment of ores to facilitate the subsequent processing of ores based on the differences in thermal expansion of the minerals within the ore, to form micro-cracks throughout the ore structure. However, one of the main problems of micro-crack formation within the ore materials is that the micro-cracks tend to weaken the ore materials. Weakening of the ore materials can lead to unstable heaps for heap leaching. Structurally weak ore materials are also problematic with respect to heap leaching, as the potential for the ore material to break into smaller particles exists. These small particles affect the percolation of the leach solution through the heap, as they can collect in the spaces between the larger particles, preventing the flow of leach solution through the entire heap.

[0004] The use of pulsed microwave energy as disclosed in WO 03/102250 requires significantly high electric field strengths due to very short durations of microwave energy exposure. The use of high electric field strengths may result in a situation where excessive microwave energy causes dielectric breakdown or arcing of the heated ore materials.

[0005] The preceding discussion of the background art is intended to facilitate an understanding of the present invention only. This discussion is not an acknowledgement

or admission that any of the material referred to is or was part of the common general knowledge as at the priority date of the application.

[0006] Each document, reference, patent application or patent cited in this text is expressly incorporated herein in their entirety by reference, which means that it should be read and considered by the reader as part of this text. That the document, reference, patent application or patent cited in this text is not repeated in this text is merely for reasons of conciseness.

[0007] Throughout the specification and claims, unless the context requires otherwise, the term "microwave energy" is understood herein to mean electromagnetic radiation that has frequencies in the range of 100-10,000 MHz.

[0008] Throughout the specification and claims, unless the context requires otherwise, the term "radio frequency energy" is understood herein to mean electromagnetic radiation that has frequencies in the range of 1-100 MHz.

[0009] Throughout the specification and claims, unless the context requires otherwise, the word "comprise" or variations such as "comprises" or "comprising", will be understood to imply the inclusion of a stated integer or group of integers but not the exclusion of any other integer or group of integers.

DISCLOSURE OF THE INVENTION

[0010] In accordance with the present invention, there is provided a method for treating an ore material with electromagnetic energy, the method comprising the steps of:

agglomerating the ore material;

irradiating the ore material with electromagnetic energy;

thereby heating the liquid in the ore material;

vapourising at least a portion of the liquid in the ore material;

forming micro-channels in the ore material; and

acid leaching the ore material.

[0011] Advantageously, irradiation of the ore material results in localised heating of the liquid present within the ore material, forming micro-channels. Without being limited by theory, it is believed that the radiation heats the liquid volumetrically forming vapour. The vapour forces its way to the surface of the ore material resulting in the formation of the micro-channels.

[0012] Advantageously, the micro-channels assist the percolation of the leach solution through the ore material and increases leaching rates and recoveries.

[0013] In the context of this invention, the term electromagnetic energy, is understood to mean electromagnetic radiation that has frequencies in the range of 1-10,000 MHz, being either microwave energy or radio frequency energy.

[0014] Advantageously, the use of radio frequency energy may provide increased heating efficiency compared to microwave energy due to higher electrical conductivity in the water at lower frequencies.

[0015] The term ore material may encompass unprocessed or processed ores including crushed ore particles, cakes of crushed ore particles or agglomerated ore particles.

[0016] It will be appreciated that the method of the present invention is particularly suited to multiphase ore material wherein the phases have different dielectric properties and wherein the bulk of the ore material has low dielectric property.

[0017] It will be appreciated that the ore material contains liquid. Preferably, the liquid contains ions.

[0018] Preferably, the liquid content within the ore material is about 5 w/w% to about 30 w/w%.

[0019] In one form of the invention, the method comprises the further step of:

crushing the ore material to provide ore particles,

prior to the step of:

agglomerating the ore material.

[0020] The step of crushing the ore material may be performed using tools known in the art including ball mills, crushers, hammer mills.

[0021] Preferably, the ore particles have an average diameter of less than 5 cm.

[0022] Preferably, the step of agglomerating the ore material is carried out in a solution of acid and water.

[0023] In one form of the invention, the method comprises the further step of:

agglomerating the ore material in a solution of acid and water;

prior to or after the step of;

irradiating the ore material with electromagnetic energy.

[0024] Without being limited by theory, it is believed that the step of agglomerating the ore material in the solution of acid and water causes the particles to bind together to form larger particles termed herein, agglomerates.

[0025] Advantageously, agglomerating the ore material in the solution of acid and water results in retention of some liquid within the agglomerates.

[0026] Preferably, the liquid content in the agglomerates is +/- 10% w/w.

[0027] By careful control of the step of irradiating the ore material with electromagnetic energy, it is possible to heat the liquid in the ore material in preference to the ore particles. Advantageously, this results in little or no change to the structural integrity of the ore material, despite the formation of the micro-channels.

[0028] Advantageously, both heap stacking and leaching benefit from the structural integrity of the ore materials with micro-channels remaining substantially unaltered. The Applicant envisages that, advantageously, this can result in agglomerates of increased strength and integrity, enabling heaps to be stacked higher and with greater stability than under conventional practise.

[0029] Preferably, the acid is provided in the form of sulphuric acid.

[0030] Preferably, the solution of acid and water used in the step of;

agglomerating the ore particles in a solution of acid and water,

contains up to 50 kg of sulphuric acid per dry tonne of ore particles.

[0031] It will be appreciated that the amount of sulphuric acid in the solution of acid and water may vary depending on the actual mineral composition of the ore particles, the moisture content of the ore particles and other factors.

[0032] The ore particles preferably are agglomerated for an amount of time that may vary from an hour to several days, depending on the extent of agglomeration required. It will be appreciated that the amount of time required to achieve suitable agglomerates will be dependent on the ore composition, agglomerate size, liquid content within the agglomerates and other factors.

[0033] Without being limited by theory, it is believed that as the agglomerate is made smaller higher power densities (Watts/m^3 in the liquid phase) will be required due to greater heat losses and easier mass transport behaviour due to the fact that surface area to volume ratio is much higher in smaller particles than larger ones. The larger the agglomerate, the more resistance there is to mass transport, therefore the higher the temperature reached in the liquid phase (superheating) and the greater the number of channels. In small agglomerates the liquid gets to the surface more easily so it needs to be heated much more quickly than in larger agglomerates. However, if the power density is too high, the agglomerate may blow apart. Consequently, power density must be controlled depending on the agglomerate size and also the liquid content.

[0034] In one form of the invention, the method comprises the further step of:

curing the ore material;

after the step of:

agglomerating the ore particles in a solution of acid and water;

or during the step of:

irradiating the ore material with electromagnetic energy.

[0035] Without being limited by theory, the curing step gives the agglomerates strength even with the included micro-channels. The heating of the agglomerates during microwave treatment and consequent drying effectively result in a degree of curing of the agglomerates. The strengthening of the agglomerates through curing enables higher heap stacking and compensates for any loss in strength due to the micro-channels which are formed.

[0036] Preferably, the ore material that includes the agglomerates formed in the step of:

agglomerating the ore particles in a solution of acid and water,

are fed as a bulk flow of material down a pipe to a troughed or flat conveyor to an electromagnetic treatment assembly to be irradiated with electromagnetic energy.

[0037] The electromagnetic treatment assembly is any assembly that can support a homogenous electric field distribution that is sufficiently high to heat the liquid content contained within a sufficient portion of the ore material. Preferably 'sufficient portion' in this context refers to >90 % of the ore material. The assembly will comprise an electromagnetic generating source, such as a microwave generator.

[0038] In one form of the present invention, the step of:

irradiating the ore material with electromagnetic energy,

comprises the movement of the ore material through an applicator or cavity.

Alternatively, the step of:

irradiating the ore material with electromagnetic energy,

comprises exposing the ore material to the electromagnetic energy in batch mode.

[0039] Advantageously, the movement of the agglomerates past an electromagnetic energy zone as a bed on a conveyor or a moving bed of agglomerates in a tube, pipe or other enclosed structure, facilitates the homogenous irradiation of the agglomerates with electromagnetic energy.

[0040] Preferably, the agglomerates pass the electromagnetic energy zone on a conveyor as a bed of agglomerates.

[0041] The step of:

irradiating the ore material with electromagnetic energy,

comprises exposure with a continuous or pulsed source of radio frequency energy.

[0042] Irradiating the ore material preferably comprises creating a power density ranging between 1×10^5 to 1×10^{12} w/m³ in the liquid phase of the ore material. It will be

appreciated that the power density employed will be dependent on at least the form of the ore material, liquid content in the ore material, the size of the ore material, the mass in any cavities of the ore material, the dielectric properties or conductivity of the liquid, the frequency of the applied electromagnetic energy radiation and the duration of electromagnetic energy irradiation.

[0043] It will be appreciated that the step of;

irradiating the ore material with electromagnetic energy,

includes controlling the electric field strength of the electromagnetic energy and/or the duration of electromagnetic energy irradiation to ensure the ore material is not overly exposed to electromagnetic energy, to minimise undesirable heating of the agglomerates. Undesirable heating of the agglomerates may result in, the formation of micro-cracks that will weaken the agglomerates and/or sintering of the agglomerates that will alter the chemical properties of the minerals present with the agglomerates.

[0044] Preferably, the ore material is irradiated with continuous source of electromagnetic energy for less than about 10 seconds.

[0045] Preferably the average diameter of the ore material is substantially unaltered by the step of;

irradiating the ore material with electromagnetic energy.

[0046] The step of:

acid leaching the ore material,

is preferably conducted using at least one of the following, sulphuric acid (H_2SO_4) or ferric acid (H_2FeO_4) or a combination of both.

[0047] In one form of the present invention, the step of;

acid leaching the ore material,

is followed by a further step of;

recovering metal values from the pregnant liquor solution from the step of acid leaching the ore material with electromagnetic energy.

[0048] In accordance with the present invention, there is provided an ore material comprising micro-channels, wherein the micro-channels are formed by the preferential heating of the liquid in the ore material.

[0049] Preferably the ore material comprising micro-channels is a copper, nickel or uranium-containing ore.

[0050] Preferably, the ore materials comprising micro-channels may be made from a starting material that includes the ore, ore particles, agglomerates formed from ore particles or any other form of ore material that has a liquid content.

BRIEF DESCRIPTION OF DRAWINGS

[0051] The present invention will now be described, by way of example only, with reference to the following figure in which:

[0052] Figure 1 is a schematic flow sheet of a method for treating an ore material with electromagnetic energy, in accordance with the first embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0053] Figure 1 shows a schematic flow sheet of a method for treating an ore material 10 with electromagnetic energy in accordance with the first embodiment of the present invention, comprising the steps of:

crushing 14 of the ore 12;

agglomerating 16 the crushed ore particles;

irradiating 18 the agglomerates with electromagnetic energy;

acid leaching 20 the agglomerates irradiated with electromagnetic energy; and

recovering 22 the metal values.

[0054] In one embodiment of the invention, a uranium ore 12 is supplied to a primary crusher and is crushed 14 to a particle size less than 5 cm.

[0055] In an agglomeration step 16, the crushed uranium ore particles are mixed with a solution of sulphuric acid and water to agglomerate the particles, as known by those

skilled in the art. The agglomerates after leaching have a liquid content in the range of about 5 w/w% to about 30 w/w% and more specifically a liquid content of +/- 10% w/w.

[0056] The agglomerates are fed as a bed to an electromagnetic energy treatment assembly to be irradiated with electromagnetic energy 18, by way of a conveyor or chute under vertical flow 24. The electromagnetic energy treatment assembly may be provided in the form of a microwave treatment assembly. The microwave treatment assembly includes a source in the form of a microwave generator that generates microwaves. The bed of agglomerates on the moving conveyor pass a microwave energy zone, which is created by the microwave generator. The moving agglomerates are exposed to a continuous source of microwave energy with electric field strength sufficient enough to create a power density ranging between 1×10^5 to 1×10^{12} w/m³ in the liquid phase of the ore material for 10s or less. The operating conditions, such as the electric field and the duration of microwave energy exposure, are selected to ensure that the microwave treatment causes only localised heating of the liquid content within the agglomerates.

[0057] The microwave energy exposure cures the agglomerates and heats the liquid in the agglomerates, forming vapour. The vapour forces its way to the surface of the agglomerates resulting in the formation of micro-channels in the agglomerates.

[0058] The agglomerates irradiated with microwave energy are stacked in heaps with heights ranging between 20 m to about 50 m for subsequent leaching 20. The leach solution, which is a sulphuric acid solution is applied to the top or upper surface of the heaps and allowed to percolate through the heap. The micro-channels formed during the irradiation step assist the percolation of the leach solution through the agglomerates, thereby to increase leaching rates and recoveries. The percolated solution is collected at the bottom of the heaps as the pregnant leach solution (PLS). The PLS may be recycled to the heap, collected for the recovery of metal values or a combination of both. For the recovery 22 of metal values standard processes that are known in the art are employed.

Modifications and variations such as would be apparent to the skilled addressee are considered to fall within the scope of the present invention.

Claims

1. A method for treating an ore material with electromagnetic energy, the method comprising the steps of:
 - agglomerating the ore material;
 - irradiating the ore material with electromagnetic energy;
 - thereby heating the liquid in the ore material;
 - vapourising at least a portion of the liquid in the ore material;
 - forming micro-channels in the ore material; and
 - acid leaching the ore material.
2. A method for treating an ore material according to claim 1, wherein the method comprises the further step of:
 - crushing the ore material to provide ore particles,prior to the step of:
 - agglomerating the ore material.
3. A method for treating an ore material according to claim 2, wherein the ore particles have an average diameter of less than 5 cm.
4. A method for treating an ore material according to any one of the proceeding claims, wherein the step of:
 - acid leaching the ore material,is conducted using sulphuric acid (H_2SO_4) or ferric acid (H_2FeO_4) or a combination of both.
5. A method for treating an ore material according to any one of the preceding claims, wherein the step of:
 - agglomerating the ore material.

is carried out in a solution of acid and water:

6. A method for treating an ore material according to claim 5, wherein the acid is sulphuric acid.
7. A method for treating an ore material according to any one of the preceding claims, wherein the step of:

agglomerating the ore material,

is carried out for a period ranging between about an hour to several days.

8. A method for treating an ore material according to any one of the preceding claims, wherein the method comprises the further step of:

curing the ore material;

after the step of:

agglomerating the ore material;

or during the step of:

irradiating the ore material with electromagnetic energy.

9. A method for treating an ore material according to any one of the preceding claims, wherein the liquid content within the ore material is about 5 w/w% to about 30 w/w%.
10. A method for treating an ore material according to any one of the preceding claims, wherein the ore material is fed as a bulk flow of material down a pipe to a troughed or flat conveyor to be supplied to an electromagnetic treatment assembly for irradiating with electromagnetic energy.
11. A method for treating an ore material according to claim 10, wherein the electromagnetic treatment assembly is an assembly that can support a homogenous electric field distribution that can heat the liquid content contained within 90% of the ore material.
12. A method for treating an ore material according to any one of the preceding claims, wherein the step of:

irradiating the ore material with electromagnetic energy,

comprises the movement of the ore material through an applicator or cavity.

13. A method for treating an ore material according to any one of the previous claims, wherein the step of:

irradiating the ore material with electromagnetic energy,

comprises exposing the ore material to the electromagnetic energy in batch mode.

14. A method for treating an ore material according to any one of the preceding claims, wherein the ore material passes an electromagnetic energy zone on a conveyor as a bed of ore material.
15. A method for treating an ore material according to any one of the preceding claims, wherein the ore material is exposed to a continuous source of electromagnetic energy.
16. A method for treating an ore material according to any one of the preceding claims, wherein the ore material is exposed to a pulsed source of electromagnetic energy.
17. A method for treating an ore material according to any of the preceding claims, wherein irradiating the ore material forms a power density ranging between 1×10^5 to 1×10^{12} w/m³ in the liquid phase of the ore material.
18. A method for treating an ore material according to claim 16, wherein the ore material is irradiated with continuous source of electromagnetic energy for less than about 10 seconds.
19. A method for treating an ore material according to any one of the preceding claims, wherein the electromagnetic energy is electromagnetic radiation having frequencies in the range of 1-10,000 MHz.
20. A method for treating an ore material according to claim 19, wherein the electromagnetic radiation is either microwave energy or radio frequency energy.
21. A method of treating an ore material according to any one of the proceeding claims, wherein the method comprises the further step of:

recovering metal values

prior to the step of:

acid leaching the ore material with electromagnetic energy.

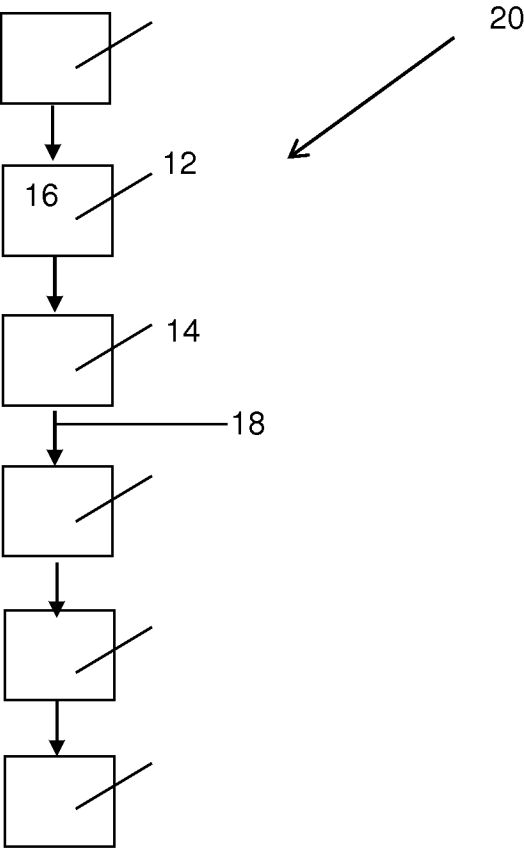


Figure 1

INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU2012/001363

A. CLASSIFICATION OF SUBJECT MATTER

B01J 19/12 (2006.01) B01J 19/08 (2006.01) C22B 3/00 (2006.01) C22B 3/04 (2006.01) C22B 3/06 (2006.01) C22B 3/08 (2006.01)

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI, EPODOC databases (EPOQUE): C22B3/00/IC/EC OR C22B3/04/IC/EC OR C22B3/06/IC/EC OR C22B3/08/IC/EC OR C22B3/10/IC/EC OR B01J19/08/IC/EC OR B01J19/12/IC/EC OR H05B6/IC/EC; +RADIAT+ OR MICRO_WAV+ OR ELECTRO_MAGNETIC+ OR RADIO+; (LEACH+ OR SOLUB+ OR DISSOL+ OR LIXIVI+); (+CHANNEL+ OR CRACK+ OR FRACTUR+ OR PATH+); (VAPOUR+ OR VAPOR+ OR EVAPORAT+ OR HEAT+). **Esp@cenet, Google Patents, and General Internet Keyword Search:** Search terms used such as: microwave; electromagnetic; radiation; leach; channels; cracks; fracture; vapour; vapour; gas;evaporate; heat; thermal; and similar keywords.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
	Documents are listed in the continuation of Box C	



Further documents are listed in the continuation of Box C



See patent family annex

* "A"	Special categories of cited documents: document defining the general state of the art which is not considered to be of particular relevance	"T"	later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E"	earlier application or patent but published on or after the international filing date	"X"	document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L"	document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O"	document referring to an oral disclosure, use, exhibition or other means	"&"	document member of the same patent family
"P"	document published prior to the international filing date but later than the priority date claimed		
Date of the actual completion of the international search 12 December 2012		Date of mailing of the international search report 12 December 2012	
Name and mailing address of the ISA/AU AUSTRALIAN PATENT OFFICE PO BOX 200, WODEN ACT 2606, AUSTRALIA Email address: pct@ipaustalia.gov.au Facsimile No.: +61 2 6283 7999		Authorised officer Peter Ellis AUSTRALIAN PATENT OFFICE (ISO 9001 Quality Certified Service) Telephone No. 02 6225 6106	

INTERNATIONAL SEARCH REPORT		International application No.
C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		PCT/AU2012/001363
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010/0263482 A1 (LIUBAKKA et al.) 21 January 2010 See whole document.	1- 21
A	WO 2008/147420 A1 (CLIFTON MINING COMPANY (UTAH CORPORATION) [US]) 04 December 2008 See whole document.	1- 21
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Form PCT/ISA/210 (fifth sheet) (July 2009)

INTERNATIONAL SEARCH REPORT		International application No.	
Information on patent family members		PCT/AU2012/001363	
This Annex lists known patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.			
Patent Document/s Cited in Search Report		Patent Family Member/s	
Publication Number	Publication Date	Publication Number	Publication Date
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End of Annex			
Due to data integration issues this family listing may not include 10 digit Australian applications filed since May 2001.			