US 20160032420A1

(19) **United States**

(12) **Patent Application Publication**

Neylon

(10) **Pub. No.: US 2016/0032420 A1**

(43) **Pub. Date: Feb. 4, 2016**

(54) **METHODS FOR TREATING CARBON MATERIALS INCLUDING CARBONACEOUS ORES**

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(21) Appl. No.: **14/767,192**

(22) PCT Filed: **Feb. 11, 2014**

(86) PCT No.: **PCT/US14/15720**

§ 371 (c)(1),
(2) Date: **Aug. 11, 2015**

Related U.S. Application Data

(60) Provisional application No. 61/763,243, filed on Feb. 11, 2013.

Publication Classification

(51) **Int. Cl.**

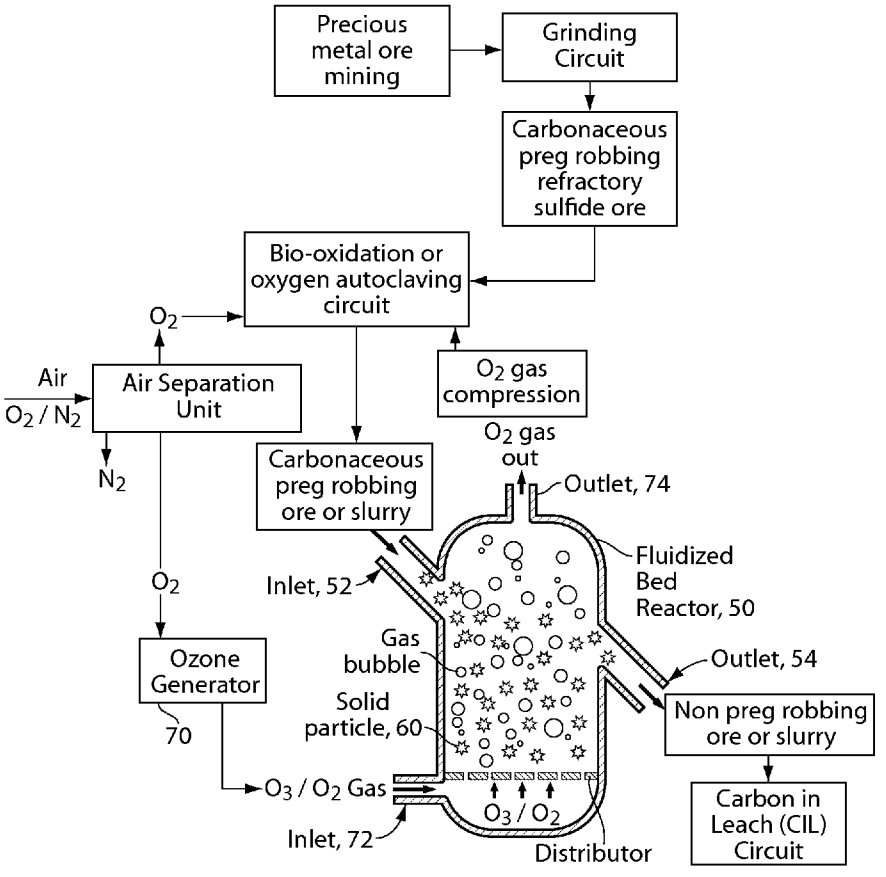
C22B 3/00	(2006.01)
C22B 3/18	(2006.01)
C22B 15/00	(2006.01)
C22B 3/16	(2006.01)
C22B 11/02	(2006.01)
C22B 11/08	(2006.01)

(52) **U.S. Cl.**

CPC ***C22B 11/04*** (2013.01); ***C22B 11/02*** (2013.01); ***C22B 11/08*** (2013.01); ***C22B 15/0065*** (2013.01); ***C22B 15/001*** (2013.01); ***C22B 3/16*** (2013.01); ***C22B 3/18*** (2013.01)

(57) **ABSTRACT**

Methods described herein generally relate to the treatment of carbonaceous materials with ozone to facilitate the subsequent recovery of metal species (e.g., precious metals) from the carbonaceous material. In some cases, the method may involve exposure of a carbonaceous material to a relatively low amount of ozone. In some cases, the carbonaceous material may be subjected to oxidizing conditions, e.g. by autoclaving or bio-oxidation, prior to ozone treatment. Such embodiments may allow for more simplified and cost-effective methods for metal recovery.



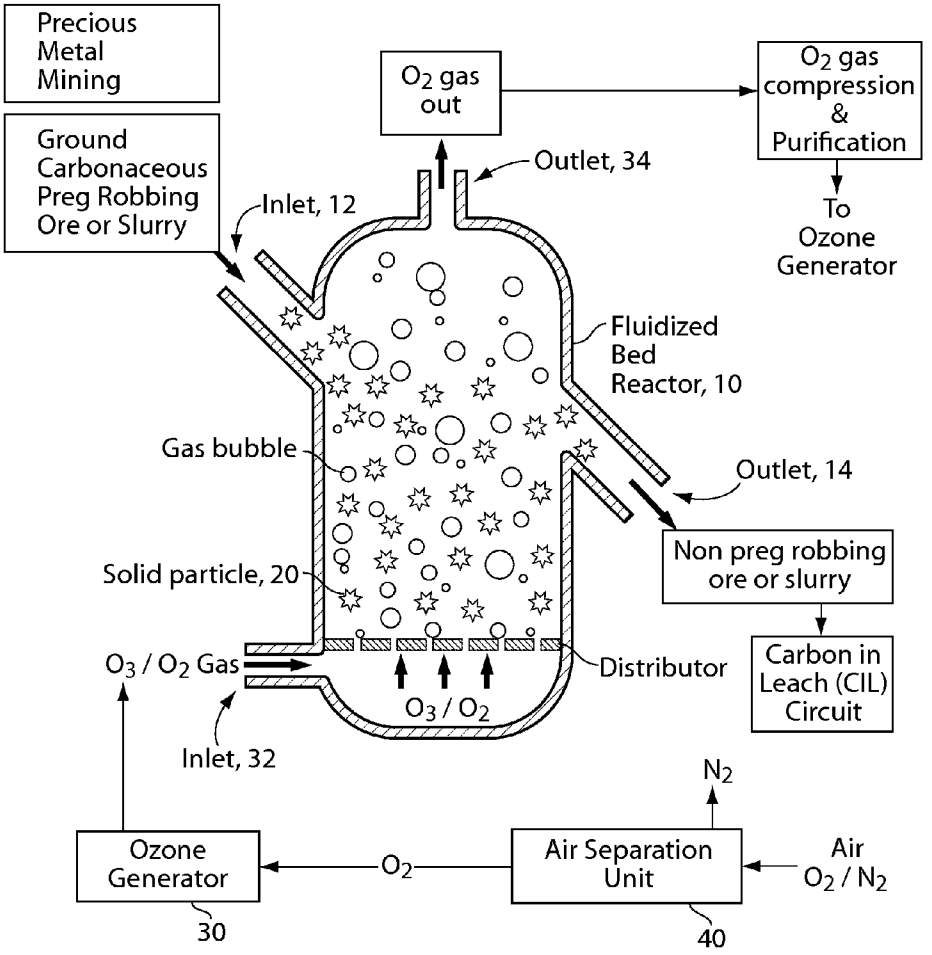

Precious Metal Mining
Ground Carbonaceous Preg Robbing Ore or Slurry
O_2 gas out
O_2 gas compression & Purification
To Ozone Generator
Outlet, 34
Inlet, 12
Fluidized Bed Reactor, 10
Gas bubble
Outlet, 14
Non preg robbing ore or slurry
Solid particle, 20
Carbon in Leach (CIL) Circuit
O_3 / O_2 Gas
Distributor
O_3 / O_2
Inlet, 32
N_2
Ozone Generator
O_2
Air Separation Unit
Air O_2 / N_2
30
40

FIG. 1

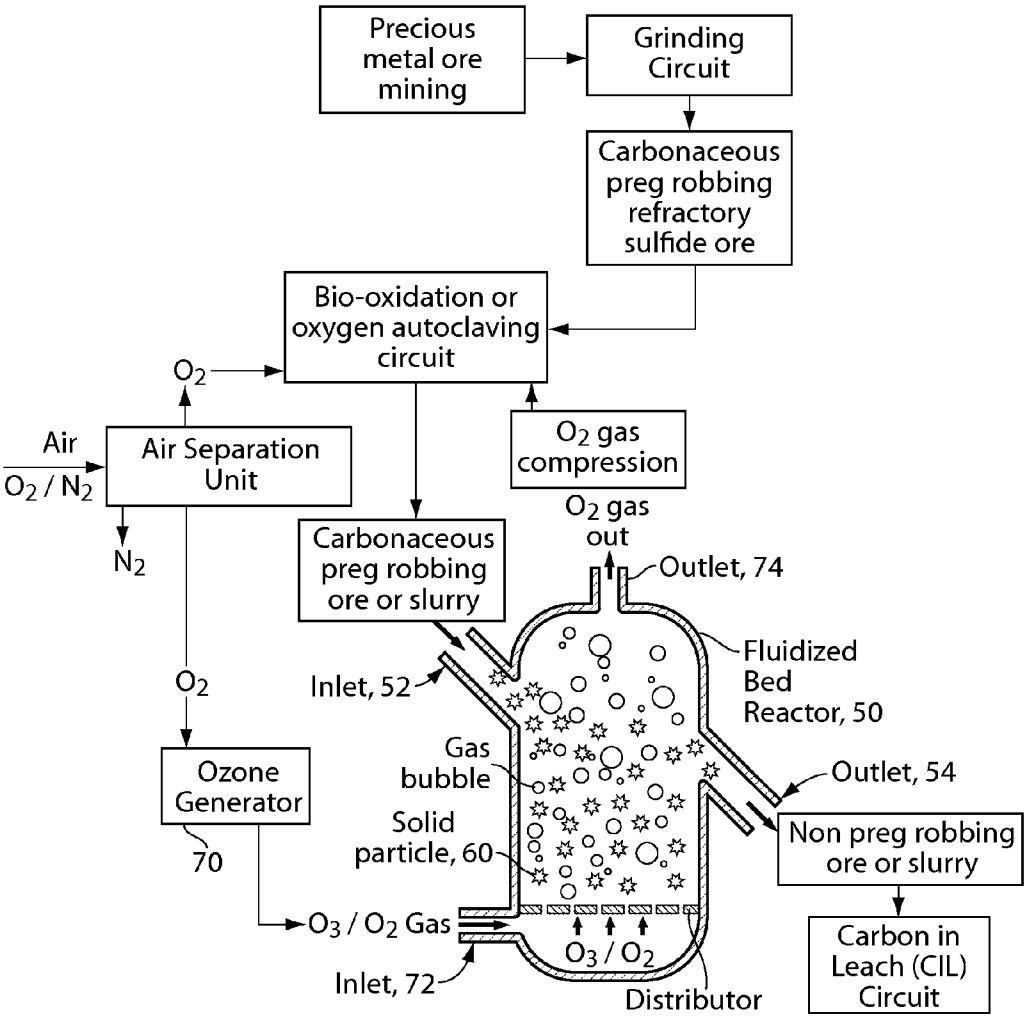

Precious metal ore mining
Grinding Circuit
Carbonaceous preg robbing refractory sulfide ore
Bio-oxidation or oxygen autoclaving circuit
O_2
Air
O_2 / N_2
Air Separation Unit
N_2
O_2 gas compression
O_2 gas out
Outlet, 74
Carbonaceous preg robbing ore or slurry
Inlet, 52
Fluidized Bed Reactor, 50
Gas bubble
Outlet, 54
Solid particle, 60
Non preg robbing ore or slurry
O_2
Ozone Generator
70
O_3 / O_2 Gas
O_3 / O_2
Carbon in Leach (CIL) Circuit
Inlet, 72
Distributor

FIG. 2

METHODS FOR TREATING CARBON MATERIALS INCLUDING CARBONACEOUS ORES

FIELD OF THE INVENTION

[0001] Described herein are methods and systems for treating carbonaceous ores and methods and systems for recovery of metals, including precious metals, from carbonaceous ores.

BACKGROUND OF THE INVENTION

[0002] Recovery of metals from ores is often hindered by the presence of organic carbon within the ore ("carbonaceous ores"), which is capable of physically entrapping or adsorbing metal particles. For example, carbonaceous gold ores tend to adsorb gold(I) cyanide when treated with cyanide from leach solutions. This phenomenon, known as "preg-robbing," can be attributed to the presence of a carbonaceous component (e.g., humic carbon) within the ore that competes with leaching reagents to adsorb metal species.

[0003] One method for reducing the preg-robbing characteristics of carbonaceous ores includes roasting carbonaceous ores at high temperatures (e.g., 750° C. to 900° C.) to convert pyrite and humic carbon into SO_2 and CO_2, respectively. However, such methods can involve considerable economic expense and create environmental difficulties, often requiring additional fuel to be added to the carbonaceous ore since the carbon content (0.5-2.0%) or sulfur content (1-2%) within the ore is often insufficient to sustain autogenous reaction.

SUMMARY OF THE INVENTION

[0004] Methods for treating carbonaceous materials are described. In some embodiments, the method comprises exposing a carbonaceous feed material comprising at least one metal species to oxidizing conditions selected to produce an oxidized carbonaceous material, wherein the preg-robbing index of the oxidized carbonaceous material is substantially the same as the preg-robbing index of the carbonaceous feed material; and treating the oxidized carbonaceous material with ozone to produce an ozone-treated carbonaceous material, wherein the preg-robbing index of the ozone-treated carbonaceous material is lower than the preg-robbing index of the oxidized carbonaceous material.

[0005] In some embodiments, the method comprises exposing a carbonaceous feed material comprising a carbonaceous preg-robbing component and at least one metal species to oxidizing conditions selected to produce an oxidized carbonaceous material, wherein the amount of the carbonaceous preg-robbing component of the oxidized carbonaceous material is substantially the same as the amount of the carbonaceous preg-robbing component of the carbonaceous feed material; and treating the oxidized carbonaceous material with ozone to produce an ozone-treated carbonaceous material, wherein the amount of the carbonaceous preg-robbing component of the ozone-treated carbonaceous material is lower than the amount of the carbonaceous preg-robbing component of the oxidized carbonaceous material.

[0006] In some embodiments, the method comprises treating a carbonaceous material comprising at least one metal species with about 0.10 grams of ozone per gram carbonaceous material or less to produce an ozone-treated carbonaceous material; and treating the ozone-treated carbonaceous material with a chemical reagent to recover the at least one metal species from the ozone-treated carbonaceous material.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] FIG. **1** shows a schematic representation of treatment of a carbonaceous material with ozone in a fluidized bed reactor.

[0008] FIG. **2** shows a schematic representation of biooxidation or autoclaving of a carbonaceous material, followed by treatment with ozone in a fluidized bed reactor.

[0009] Other aspects, embodiments and features of the invention will become apparent from the following detailed description when considered in conjunction with the accompanying drawings. The accompanying figures are schematic and are not intended to be drawn to scale. For purposes of clarity, not every component is labeled in every figure, nor is every component of each embodiment of the invention shown where illustration is not necessary to allow those of ordinary skill in the art to understand the invention. All patent applications and patents incorporated herein by reference are incorporated by reference in their entirety for all purposes. In case of conflict, the present specification, including definitions, will control.

DETAILED DESCRIPTION

[0010] Methods and systems described herein generally relate to the treatment of carbonaceous materials with an oxidant (e.g., ozone) to facilitate the subsequent recovery of metal species from the carbonaceous material. Embodiments described herein may allow for more simplified and cost-effective methods for metal recovery, and may also provide the ability to recover higher amounts of metal species (e.g., gold) from carbonaceous ores, relative to previous methods.

[0011] In some cases, the method involves treatment of a carbonaceous material with ozone. As used herein, a "carbonaceous" material or feed material is given its ordinary meaning in the art and refers to any carbon-containing material. In some cases, the carbonaceous material may be or may be a component of a compound/mixture of compounds, ore, or a mineral, including graphite, pyrite, clays, sulfides, bentonites, carbonates, activated carbons, hydrocarbons, acids (e.g., humic acid), and the like. The carbonaceous material or carbonaceous feed material may include at least one metal species and/or a carbonaceous preg-robbing component (e.g., organic carbon). In some cases, the carbonaceous material is a carbonaceous ore. In some cases, the carbonaceous material is a carbonaceous ore concentrate, often referred to as a "concentrate", i.e., a raw ore that has been ground into particles and/or purified at least in part (e.g., to remove gangue or other waste). In some embodiments, the carbonaceous material is a carbonaceous sulfide ore or carbonaceous ore concentrate (e.g., a refractory carbonaceous sulfide ore or carbonaceous ore concentrate).

[0012] Ozone treatment of a carbonaceous material may involve introduction of the carbonaceous material into a reactor that is in fluid communication with an ozone source (e.g., ozone generator). Ozone may then be introduced into the reactor under conditions which facilitate the reaction of ozone with the carbonaceous material. A wide variety of reactors may be utilized, including, but not limited to, a continuously stirred tank reactor, a fluidized bed reactor, a plug flow reactor, a pipe reactor, or a slurry bubble column reactor. In one set of embodiments, the reactor is a fluidized bed

reactor. For example, the method may involve feeding a carbonaceous material into a fluidized bed reactor, and then introducing ozone to the reactor at a rate which facilitates the reaction between ozone and at least a portion of the carbonaceous preg-robbing component (e.g., organic carbon) present in the carbonaceous material. In some cases, ozone is reacted with the carbonaceous material until the amount of organic carbon present within the carbonaceous ore is reduced to a level at which the carbonaceous material no longer exhibits the preg-robbing characteristics (e.g., when attempting to leach the carbonaceous material with a lixiviant).

[0013] In some cases, the carbonaceous material may be introduced into the reactor in solid form, e.g., as ground particles. In some cases, the carbonaceous material may be introduced into the reactor in combination with a fluid carrier in the form of a solution, suspension, emulsion, slurry, or the like. In some embodiments, the carbonaceous material is introduced into the reactor in the form of a slurry (e.g., an aqueous slurry). During ozone treatment, the slurry may be maintained at a pH range of about 2 to about 10, and in some cases, at a pH range of about 5 to about 8. In some cases, the temperature of the slurry is maintained at a temperature between about 25° C. to about 150° C., between about 25° C. to about 125° C., between about 25° C. to about 100° C., between about 25° C. to about 75° C., or between about 25° C. to about 50° C. (e.g., 25° C., 45° C.), during treatment with ozone. In some embodiments, the temperature of the slurry may be maintained during treatment with ozone without an external source of energy.

[0014] An advantageous feature of certain embodiments described herein is the ability to achieve substantial reduction and/or elimination of preg-robbing components within a carbonaceous material using a relatively low amount of ozone. In some cases, pre-treatment of the carbonaceous material (e.g., prior to ozone treatment) may allow for the use of lower amounts of ozone than would otherwise be need for a given degree of reduction of preg-robbing materials, as described more fully below. In some cases, the carbonaceous material may be effectively treated with about 0.10 grams ozone per gram carbonaceous material or less to produce an ozone-treated carbonaceous material. In some cases, the carbonaceous material is treated with about 0.10 grams ozone per gram carbonaceous material or less, about 0.08 grams ozone per gram carbonaceous material or less, about 0.06 grams ozone per gram carbonaceous material or less, about 0.04 grams ozone per gram carbonaceous material or less, about 0.02 grams ozone per gram carbonaceous material or less, or, in some cases, about 0. 01 grams ozone per gram carbonaceous material or less, to produce an ozone-treated carbonaceous material.

[0015] In some cases, ozone may be utilized without need for additional reagents or components to facilitate the interaction between the carbonaceous material and ozone. For example, the carbonaceous material may be treated with ozone in the absence of an acid, including sulfuric acid, nitric acid, hydrochloric acid, and the like. In some cases, the carbonaceous material may be treated with ozone in the absence of a fluorocarbon, such as a perfluorinated solvent.

[0016] Treatment of a carbonaceous material with ozone may reduce the amount of a carbonaceous preg-robbing component (e.g., organic carbon) within the carbonaceous material. In some cases, the amount of preg-robbing component is reduced by at least 10% within the carbonaceous material. In some cases, the amount of preg-robbing component is reduced by about 20%, about 30%, about 40%, about 50%, about 60%, about 70%, about 80%, about 85%, about 90%, or more, within the carbonaceous material. In some embodiments, at least a portion of the carbonaceous preg-robbing component is chemically converted upon reaction with ozone to, for example, a carboxylic acid species or an oxide species.

[0017] By reducing the amount of a carbonaceous preg-robbing component within the carbonaceous material, the preg-robbing index of the carbonaceous material may also be reduced. The term "preg-robbing index" is given its ordinary meaning in the art and is indicative of the ability of a carbonaceous material to adsorb metal species (e.g., gold) when placed under metal leaching conditions. Methods of determining preg-robbing index, including cyanide leach tests and/or gold-spiked cyanide leach tests, are described in Helm et al., "An investigation of the carbonaceous component of preg-robbing gold ores," World Gold Conference 2009, the Southern African Institute of Mining and Metallurgy, 2009. In some embodiments, the preg-robbing index of a material can be determined by contacting a synthetic gold solution with a carbonaceous material, monitoring the "robbing" of gold from the synthetic solution, and then calculating the percentage of gold loss from the synthetic solution. Typically, a carbonaceous material having a preg-robbing index of 20 or greater (e.g., 20-70) may contain a sufficient amount of organic carbon to be capable of substantially hindering the recovery of metal species from the carbonaceous material.

[0018] Some embodiments described herein involve treating a carbonaceous material having a preg-robbing index of 20 or greater with ozone, to produce a material having a reduced preg-robbing index. In some embodiments, the preg-robbing index is reduced to less than 20 upon treatment with ozone. In some embodiments, the preg-robbing index is reduced to less than 18 upon treatment with ozone. In some embodiments, the preg-robbing index is reduced to less than 16 (e.g., 15) upon treatment with ozone. In some embodiments, the preg-robbing index is reduced to less than 14 upon treatment with ozone. In some embodiments, the preg-robbing index is reduced to less than 12 upon treatment with ozone. In some embodiments, the preg-robbing index is reduced to less than 10 upon treatment with ozone. In some embodiments, the preg-robbing index is reduced to less than 8 upon treatment with ozone. In some embodiments, the preg-robbing index is reduced to less than 6 (e.g., 5) upon treatment with ozone.

[0019] The carbonaceous material may be optionally pre-treated prior to exposure to ozone in order to allow for the use of lower amounts of ozone in subsequent treatment steps than would otherwise be needed to achieve a certain degree of reduction of preg-robbing materials. In some embodiments, the carbonaceous material is treated with a first oxidant prior to treatment with ozone. For example, pre-treatment of the carbonaceous material may involve exposure to a set of non-ozone oxidizing conditions, or a set of oxidizing conditions that may or may not substantially alter the preg-robbing index of the carbonaceous material. In some cases, the set of oxidizing conditions alters the preg-robbing index of the carbonaceous material. In some cases, the set of oxidizing conditions does not substantially alter the preg-robbing index of the carbonaceous material. That is, the preg-robbing index of a carbonaceous material after exposure to the set of oxidizing conditions may be substantially the same as the preg-robbing index of the carbonaceous material prior to exposure to the set

of oxidizing conditions. Similarly, exposure of the carbonaceous material to the set of oxidizing conditions may not substantially alter the amount of carbonaceous preg-robbing component within the carbonaceous material. That is, the amount of carbonaceous preg-robbing component within carbonaceous material after exposure to the set of oxidizing conditions may be substantially the same as the amount of carbonaceous preg-robbing component within the carbonaceous material prior to exposure to the set of oxidizing conditions.

[0020] For example, a carbonaceous feed material can be exposed to a set of oxidizing conditions, including oxidative autoclaving or biooxidative leaching, in a first step that may take place in a first reactor, followed by ozone treatment of the oxidized carbonaceous material as a "polishing" step, which may take place in a second, downstream reactor. In some cases, pre-treatment of the carbonaceous material (e.g., via autoclaving or biooxidation) may produce a material in which substantially all oxidative-consuming materials have been removed except the carbonaceous preg-robbing component (e.g., unoxidized humic carbon). The remaining carbonaceous preg-robbing component may then be exposed to ozone as described herein. In some cases, this two-step method may substantially reduce the amount of ozone needed to decrease or eliminate the preg-robbing character of the carbonaceous material, since, upon autoclaving or biooxidation, substantially the only remaining component within the carbonaceous material that can react with or consume ozone is the carbonaceous preg-robbing component.

[0021] Upon treatment of the carbonaceous ore with ozone, metals can then be recovered by treating the ozone-treated carbonaceous material with a chemical reagent (e.g., lixiviant), or by placing the ozone-treated carbonaceous material under other known conditions for metal recovery. Examples of methods for recovering metal species from ores are described in, for example, U.S. Department of the Interior, Bureau of Mines Report of Investigations, "Leaching Gold-Silver Ores with Sodium Cyanide and Thiourea under Comparable Conditions," Washington: Government Printing Office, 1988; and Srithammavut et al., "Kinetic Modelling of Gold Leaching and Cyanide Consumption in Intensive Cyanidation of Refractory Gold Concentrate," Journal of the University of Chemical Technology and Metallurgy 2011, 46(2), 181-190, the contents of which are incorporated herein by reference in their entireties for all purposes. In some cases, the ozone-treated carbonaceous material is treated with a chemical reagent comprising a cyanide species (e.g., cyanide leaching). In some cases, the ozone-treated carbonaceous material is subjected to carbon-in-leach conditions to recover metal species from the ozone-treated carbonaceous material. That is, the ozone-treated carbonaceous material may be combined with fine carbon to form a slurry, such that metal species from the carbonaceous material are adsorbed onto the fine carbon. In some cases, the ozone-treated carbonaceous material is subjected to carbon-in-pulp conditions to recover metal species (e.g., gold) from the ozone-treated carbonaceous material. That is, the ozone-treated carbonaceous material may be combined with a cyanide-containing species and carbon particles. Typically, the carbon particles are selected to have a larger particle size than that of that of the ozone-treated carbonaceous material for subsequent ease of separation. Metal cyanide (e.g., gold cyanide) formed upon interaction between the carbonaceous material and the cyanide-containing species may be adsorbed onto the carbon, and the carbon-gold particles may then be separated from the slurry (e.g., by screening through a wire mesh). Those of ordinary skill in the art would be capable of selecting the appropriate chemical reagent, or set of conditions, suitable for recovery of a particular metal species.

[0022] One or more metal species may be recovered from the carbonaceous material. In some cases, the metal species is a precious metal, such as gold or silver. In one set of embodiments, the metal species is gold. Other metal species may also be recovered from the carbonaceous material, such as copper. Using methods described herein, a relatively high amount of metal species may be recovered from the carbonaceous material. In some embodiments, about 50% of the metal species within a carbonaceous material may be recovered. In some embodiments, about 60%, about 70%, about 80%, about 90%, about 95%, or more, of the metal species within a carbonaceous material may be recovered.

[0023] Advantageously, the methods disclosed herein may in certain embodiments be performed under ambient conditions. In some cases, ozone treatment of a carbonaceous material is performed under ambient conditions. In some cases, a carbonaceous material is subjected to a set of oxidizing conditions under ambient conditions. In some cases, metal recovery from a carbonaceous material is performed under ambient conditions.

[0024] FIG. **1** shows an illustrative embodiment where ozone treatment of a carbonaceous ore is performed in a fluidized bed reactor. A carbonaceous feed material, for example, obtained from precious metal mining, is introduced to a fluidized bed reactor **10** via inlet **12** as ground particles **20** and/or in the form of a slurry (e.g., an aqueous slurry). Ozone, e.g. as provided by an ozone generator **30** (e.g., which can produce ozone by introducing electric power to oxygen) is introduced into the reactor **10** via inlet **32** and interacts with the carbonaceous ore until a sufficient amount of organic carbon present within the carbonaceous feed is converted into carboxylic acid species and/or oxide species. In some cases, the carbonaceous ore is reacted with ozone until the carbonaceous ore no longer exhibits preg-robbing characteristics. The ozone-treated carbonaceous material may then be removed from the reactor via outlet **14** and subjected to conditions which facilitate the recovery of metals (e.g., gold) present within the carbonaceous material. For example, the ozone-treated carbonaceous material may be introduced into a carbon-in-leach circuit. Optionally, oxygen generated during ozone treatment may exit the reactor **10** via outlet **34** and may be collected, compressed, and/or purified, and may be recycled for use in an associated process. In some embodiments, the recycled oxygen may be reintroduced into the ozone generator **30**. In some embodiments, the recycled oxygen may be utilized in pre-treatment of the carbonaceous material, prior to introduction into the fluidized bed reactor. For example, any recovered oxygen may be used for autoclaving or biooxidative leaching of a carbonaceous feed material, prior to treatment of the material with ozone.

[0025] FIG. **2** shows another illustrative embodiment, in which a carbonaceous material (e.g., a carbonaceous, preg-robbing, refractory sulfide ore) is subjected to a set of oxidizing conditions prior to treatment with ozone. In some cases, the set of oxidizing conditions includes bio-oxidation. Exemplary methods for bio-oxidation are described in, for example, Mxinwa et al., "Process Parameters for Bio-oxidation of Sulphur in the Pre-treatment of Bioleaching Residues Destined for Cyanide Gold Extraction," Proceedings of the

World Congress on Engineering 2012, Jul. 4-6, 2012, London, U.K., pages 1553-1558, the contents of which are incorporated herein by reference in its entirety for all purposes. In some cases, the set of oxidizing conditions involves an oxygen autoclaving circuit. Exemplary methods for oxygen autoclaving are described in, for example, "Delivering the world's largest autoclaves for Barrick Gold," The Hatch Report, July 2012, retrieved from http://www.hatch.ca/News_Publications/Hatch_Report/HR_July2012/barrick.html, the contents of which are incorporated herein by reference in its entirety for all purposes. The carbonaceous feed material may be then introduced to a fluidized bed reactor 50 via inlet **52** as ground particles **60**. Ozone may be introduced into the reactor **50** via inlet **72** and may interact with the carbonaceous feed material until it no longer exhibits preg-robbing characteristics. The ozone-treated carbonaceous material may then be removed from the reactor via outlet **54** and subjected to conditions (e.g., carbon-in-leach circuit) which facilitate the recovery of metals (e.g., gold) present within the carbonaceous material. Optionally, oxygen generated during ozone treatment may exit the reactor **50** via outlet **74** and may be collected, compressed, and/or purified, and may be recycled for use in an associated process. In some embodiments, the recycled oxygen may be reintroduced into the ozone generator **70**.

[0026] Having thus described several aspects of some embodiments of this invention, it is to be appreciated various alterations, modifications, and improvements will readily occur to those skilled in the art. Such alterations, modifications, and improvements are intended to be part of this disclosure, and are intended to be within the spirit and scope of the invention. Accordingly, the foregoing description and drawings are by way of example only.

EXAMPLES AND EMBODIMENTS

Example 1

[0027] The following example describes the ozone treatment of a carbonaceous material. A carbonaceous ore treated containing 0.91 wt % organic carbon was reacted with at least 0.11 g of ozone/g in a fluidized bed. The initial pH of the ore was 7.2, after ozone treatment the pH was 5.8. Upon ozone treatment with 0.10-0.42 g ozone per grams carbonaceous ore, the level of organic carbon within the carbonaceous ore ("C_{org}") was reduced by up to 84.6%. The composition of the carbonaceous ore prior to ozone treatment, as well as the percent by which organic carbon was reduced after ozone treatment, is shown in the tables below.

Original Ore	Wt %
S Total	1.96
S2	1.81
C total	4.77
C org	0.91
C inorg	3.86

		% reduction				
Test	gr O3/gr Ore	S total	S2	C total	Corg	C inorg
	0.00	0.0%	0.0%	0.0%	0.0%	0.0%
3 AOP	0.10	30.1%	32.1%	50.1%	79.1%	43.3%
4 O3	0.11	27.6%	29.6%	50.7%	84.6%	42.7%
1 AOP	0.15	28.1%	24.9%	43.4%	45.1%	43.0%

-continued

		% reduction				
Test	gr O3/gr Ore	S total	S2	C total	Corg	C inorg
5 O3	0.41	33.2%	35.2%	51.2%	84.6%	43.3%
6 AOP	0.42	32.1%	34.2%	51.4%	79.1%	44.8%
7 AOP	0.42	33.2%	35.2%	50.1%	76.9%	43.8%

Example 2

[0028] The following example describes the ozone treatment of a carbonaceous material that has been previously autoclaved.

[0029] A sample of an autoclave discharge that contains gold was introduced as a 40% slurry into the same fluidized bed utilized in Example 1. The natural pH of the discharge was 2.2 and pH adjustments were made with NaOH. The sample was reacted with ozone in the fluidized bed. Upon ozone treatment with 0.007-0.03 g ozone per grams sample (or "discharge"), the level of organic carbon within the carbonaceous ore ("C_{org}") was reduced by up to 88.7%. The composition of the sample prior to ozone treatment, as well as the total percent by which organic carbon (e.g., total organic carbon or "TOC") was reduced after both autoclaving and ozone treatment, is shown in the tables below.

[0030] The use of "ozone polishing" on an autoclave discharge required much lower dosages of ozone to reduce the total organic carbon content by an equivalent amount (80-90%) when compared with ores that have not been previously oxidized prior to ozone treatment, as in Example 1. In economic terms, this experiment presents a comparison of oxidative processes for the precious metal miner who evaluate tradeoffs when considering a given projects flowsheet.

Original Autoclave discharge component	Wt %
S total	2.54
Sulfide S	0.25
C total	0.66
C org	0.55
C inorg	0.11

Test #	g O3/g discharge	pH	% Sulfide S	reduction TOC
1	0.03	6.1	32.8	87.2
2	0.01	5.9	33.4	84.5
3	0.01	9.1	0.1	88.7
4	0.007	2.2	36.3	83.3

What is claimed:

1. A method, comprising:

exposing a carbonaceous feed material comprising at least one metal species to oxidizing conditions selected to produce an oxidized carbonaceous material, wherein the preg-robbing index of the oxidized carbonaceous material is substantially the same as the preg-robbing index of the carbonaceous feed material; and

treating the oxidized carbonaceous material with ozone to produce an ozone-treated carbonaceous material, wherein the preg-robbing index of the ozone-treated carbonaceous material is lower than the preg-robbing index of the oxidized carbonaceous material.

2. A method, comprising:
exposing a carbonaceous feed material comprising a carbonaceous preg-robbing component and at least one metal species to oxidizing conditions selected to produce an oxidized carbonaceous material, wherein the amount of the carbonaceous preg-robbing component of the oxidized carbonaceous material is substantially the same as the amount of the carbonaceous preg-robbing component of the carbonaceous feed material; and
treating the oxidized carbonaceous material with ozone to produce an ozone-treated carbonaceous material, wherein the amount of the carbonaceous preg-robbing component of the ozone-treated carbonaceous material is lower than the amount of the carbonaceous preg-robbing component of the oxidized carbonaceous material.

3. A method as in any preceding claim, further comprising:
treating the ozone-treated carbonaceous material with a chemical reagent to recover the at least one metal species from the ozone-treated carbonaceous material.

4. A method as in claim 3, wherein the chemical reagent comprises a cyanide species.

5. A method as in any preceding claim, wherein the ozone-treated carbonaceous material is subjected to carbon-in-leach conditions to recover the at least one metal species from the ozone-treated carbonaceous material.

6. A method as in any preceding claim, wherein the ozone-treated carbonaceous material is subjected to carbon-in-pulp conditions to recover the at least one metal species from the ozone-treated carbonaceous material.

7. A method as in claim any preceding claim, wherein the carbonaceous material is a carbonaceous ore or carbonaceous ore concentrate.

8. A method as in any preceding claim, wherein the carbonaceous material is a carbonaceous sulfide ore or carbonaceous ore concentrate.

9. A method as in any preceding claim, wherein the at least one metal species is a precious metal.

10. A method as in any preceding claim, wherein the at least one metal species is gold, silver, or copper.

11. A method as in any preceding claim, wherein the at least one metal species is gold.

12. A method as in any preceding claim, wherein about 70% or more of the at least one metal species is recovered.

13. A method as in any preceding claim, wherein about 80% or more of the at least one metal species is recovered.

14. A method as in any preceding claim, wherein about 90% or more of the at least one metal species is recovered.

15. A method as in any preceding claim, wherein about 95% or more of the at least one metal species is recovered.

16. A method as in any preceding claim, wherein, upon treatment with ozone, at least a portion of the carbonaceous preg-robbing component is chemically converted to a carboxylic acid species or an oxide species.

17. A method as in any preceding claim, wherein the oxidized carbonaceous material is treated with ozone in a continuously stirred tank reactor, a fluidized bed reactor, a plug flow reactor, a pipe reactor, or a slurry bubble column reactor.

18. A method as in any preceding claim, wherein the oxidized carbonaceous material is treated with ozone in a fluidized bed reactor.

19. A method as in any preceding claim, wherein, prior to ozone treatment, the oxidized carbonaceous material has a preg-robbing index greater than 20, and, after treatment with ozone, has a preg-robbing index less than 20.

20. A method as in any preceding claim, wherein the steps of treating and/or exposing are performed under ambient conditions.

21. A method as in any preceding claim, wherein a slurry comprising the oxidized carbonaceous material is treated with the ozone.

22. A method as in any preceding claim, wherein the slurry is maintained at a pH range of about 2 to about 10 during treatment with ozone.

23. A method as in any preceding claim, wherein the slurry is maintained at a pH range of about 5 to about 8 during treatment with ozone.

24. A method as in any preceding claim, wherein the slurry is maintained at a temperature between about 25° C. to about 150° C. during treatment with ozone.

25. A method as in any preceding claim, wherein the temperature of the slurry is maintained during treatment with ozone without an external source of energy.

26. A method as in any preceding claim, wherein the set of oxidizing conditions involves autoclaving or biooxidative leaching.

27. A method as in any preceding claim, wherein oxygen produced during treatment of the oxidized carbonaceous material with ozone is recovered and/or used for autoclaving or biooxidative leaching of the carbonaceous feed material.

28. A method as in any preceding claim, wherein the set of oxidizing conditions in the exposing step does not involve exposing the carbonaceous feed material to ozone.

29. A method, comprising:
treating a carbonaceous material comprising at least one metal species with about 0.10 grams of ozone per gram carbonaceous material or less to produce an ozone-treated carbonaceous material;
treating the ozone-treated carbonaceous material with a chemical reagent to recover the at least one metal species from the ozone-treated carbonaceous material.

30. A method as in claim 29, wherein the carbonaceous material is a carbonaceous ore or carbonaceous ore concentrate.

31. A method as in any preceding claim, wherein the carbonaceous material is a carbonaceous sulfide ore or carbonaceous ore concentrate.

32. A method as in any preceding claim, wherein the at least one metal species is a precious metal.

33. A method as in claims 29-31, wherein the at least one metal species is gold, silver, or copper.

34. A method as in any preceding claim, wherein the at least one metal species is gold.

35. A method as in any preceding claim, wherein about 70% or more of the at least one metal species is recovered.

36. A method as in any preceding claim, wherein about 80% or more of the at least one metal species is recovered.

37. A method as in any preceding claim, wherein about 90% or more of the at least one metal species is recovered.

38. A method as in any preceding claim, wherein about 95% or more of the at least one metal species is recovered.

39. A method as in any preceding claim, wherein the carbonaceous material comprises a carbonaceous preg-robbing component and, upon treatment with ozone, the amount of the carbonaceous preg-robbing component is decreased relative to the amount prior to treatment with ozone.

40. A method as in any preceding claim, wherein, upon treatment with ozone, at least a portion of the carbonaceous preg-robbing component is chemically converted to a carboxylic acid species or an oxide species.

41. A method as in any preceding claim, wherein the carbonaceous material is treated with ozone in a continuously stirred tank reactor, a fluidized bed reactor, a plug flow reactor, a pipe reactor, or a slurry bubble column reactor.

42. A method as in any preceding claim, wherein the carbonaceous material is treated with ozone in a fluidized bed reactor.

43. A method as in any preceding claim, wherein, prior to ozone treatment, the carbonaceous material has a preg-robbing index greater than 20, and, after treatment with ozone, has a preg-robbing index less than 20.

44. A method as in any preceding claim, wherein the steps of treating and/or exposing are performed under ambient conditions.

45. A method as in any preceding claim, wherein a slurry comprising the carbonaceous material is treated with ozone.

46. A method as in any preceding claim, wherein the slurry is maintained at a pH range of about 2 to about 10 during treatment with ozone.

47. A method as in any preceding claim, wherein the slurry is maintained at a pH range of about 5 to about 8 during treatment with ozone.

48. A method as in any preceding claim, wherein the slurry is maintained at a temperature between about 25° C. to about 150° C. during treatment with ozone.

49. A method as in any preceding claim, wherein the temperature of the slurry is maintained during treatment with ozone without an external source of energy.

50. A method as in any preceding claim, wherein the chemical reagent comprises a cyanide species.

51. A method as in any preceding claim, wherein the ozone-treated carbonaceous material is subjected to carbon-in-leach conditions to recover the at least one metal species from the ozone-treated carbonaceous material.

52. A method as in any preceding claim, wherein the ozone-treated carbonaceous material is subjected to carbon-in-pulp conditions to recover the at least one metal species from the ozone-treated carbonaceous material.

53. A method as in any preceding claim, wherein the carbonaceous material has been exposed to a set of oxidizing conditions prior to treatment with ozone.

54. A method as in any preceding claim, wherein the set of oxidizing conditions involves autoclaving or biooxidative leaching.

55. A method as in any preceding claim, wherein the set of oxidizing conditions does not include exposure to ozone.

56. A method as in any preceding claim, wherein oxygen produced during treatment of the carbonaceous material with ozone is recovered and/or used for autoclaving or biooxidative leaching of the carbonaceous feed material.

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