

METHOD TO CONTROL CORROSION OF A METAL SURFACE USING ALKYL SULFAMIC ACIDS OR SALTS THEREOF

BACKGROUND OF THE INVENTION

[0001] This application claims the benefit under 35 U.S.C. §119(e) of prior U.S. Provisional Patent Application No. 61/783,706, filed March 14, 2013, which is incorporated in its entirety by reference herein.

[0002] The present invention relates to the inhibition of corrosion of a metal surface using one or more anti-corrosion agents.

[0003] Corrosion has been the subject of scientific study for more than 150 years. Corrosion is a naturally occurring phenomenon that relates to the deterioration of a material or its properties because of a reaction with its environment. In addition to reduced longevity, corrosion also produces oxides that can further deteriorate a system by erosion, plugging, and fouling. Oxides can deposit on heat transfer surfaces, reducing efficiency, and increasing energy costs. Common sources of corrosion include dissolved oxygen, bacteria, electrolysis (stray current), differential metal (dielectric), and differential cells. Flow, temperature, and pressure can effect the corrosion rate.

[0004] Corrosion inhibitors are used in oil and gas exploration and production, petroleum refining, chemical manufacturing, heavy manufacturing, water treatment, and the product additive industries. As products and manufacturing processes have become more complex and the consequences of corrosion more costly, greater attention is being given to the control and prevention of corrosion. Thus, there is a continued need to identify more effective corrosion inhibitors that minimize financial and environmental costs with better toxicological profiles.

SUMMARY OF THE INVENTION

[0005] A feature of the present invention is to inhibit corrosion of a metal surface.

[0006] Another feature of this invention is to provide methods of using an anti-corrosion agent having low toxicity and/or high efficacy to prevent or minimize the corrosion of metal surfaces.

[0007] Methods of inhibiting the corrosion of metal surfaces located in a variety of different systems and environments are also features of this invention.

[0008] To achieve these and other advantages and in accordance with the purposes of the present invention, as embodied and broadly described herein, the present invention provides a method of inhibiting corrosion of a metal surface including applying at least one alkyl sulfamic acid or salt thereof to the metal surface in an amount effective to inhibit corrosion of the metal surface. At least one alkyl sulfamic acid or salt thereof can be applied in any suitable manner to the metal surface, for example, the application can include one or more of the following: flowing, coating, sponging, wiping, spraying, painting, showering, and misting. The method can further include subjecting the treated metal surface with corrosive agent(s).

[0009] Additional features and advantages of the present invention will be set forth in part in the description which follows, and in part will be apparent from the description, or may be learned by practice of the present invention. The objectives and other advantages of the present invention will be realized and obtained by means of the elements and combinations particularly pointed out in the written description and appended claims.

[0010] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are only intended to provide a further explanation of the present invention, as claimed.

DETAILED DESCRIPTION OF THE PRESENT INVENTION

[0011] The present invention provides a method of inhibiting corrosion of a metal surface including applying at least one alkyl sulfamic acid or salt thereof or a solution containing the alkyl sulfamic acid or salt, to the metal surface in an amount effective to inhibit corrosion of the metal surface. Any type of corrosion can be inhibited as characterized by cause and/or effect. For example, the corrosion can include uniform corrosion that extends evenly across the surface, pitting corrosion that is uneven and has smaller deep areas (pits), exfoliation corrosion that moves along layers of elongated grains, and/or intergranular corrosion that grows along grain boundaries.

[0012] Any suitable or desirable alkylated derivative of sulfamic acid, salt thereof, combinations thereof can be used in the present invention. More than one alkylated derivative of sulfamic acid or salt thereof can be used. Sulfamic acid is also known as amidosulfonic acid, amidosulfuric acid, aminosulfonic acid, and sulfamidic acid. Sulfamic acid is a molecular compound having the formula H_3NSO_3 . Sulfamates can be O-substituted, N-substituted-, or di-/tri-substituted derivatives of sulfamic acid and are also considered to be sulfamic acids or salts thereof for purposes of the present invention. Both tautomers H_3NSO_3 and $\text{H}_2\text{NSO}_2(\text{OH})$ fall within the scope of sulfamic acids or salts thereof in the present invention. Alkylated derivatives of these sulfamic acids can be used.

[0013] The alkylated derivative of sulfamic acid can thus be an alkyl sulfamic acid or salt thereof. The alkyl group can contain any desirable number of carbons in a linear, branched, and/or cyclic configuration. For example, the alkyl group can be methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, dodecyl, isopropyl, isobutyl, sec-butyl, tert-butyl, neopentyl, and the like. The at least one sulfamic acid can have the formula $\text{R}_1\text{R}_2\text{NS}(\text{O})_2(\text{OH})$,

and, for example, R_1 and R_2 are independently a hydrogen, a $C_4 - C_{20}$ alkyl group, or a cycloalkyl group, and R_1 and R_2 are not both hydrogen, and/or R_1 , R_2 , and the N form a 5-8 membered heterocyclic ring including one or more of O, NH, and CH_2 . The at least one alkyl sulfamic acid can have the formula $R_1R_2NS(O)_2(OH)$ and, for example, R_1 and R_2 can independently be a hydrogen, a $C_4 - C_{20}$ alkyl group, or a cycloalkyl group, and R_1 and R_2 are not both hydrogen. The at least one alkyl sulfamic acid can have the formula $R_1R_2NS(O)_2(OH)$, and, for example, R_1 or R_2 , but not both, is a $C_4 - C_{20}$ alkyl group or a cycloalkyl group. The at least one alkyl sulfamic acid can have the formula $R_1R_2NS(O)_2(OH)$ and, for example, both R_1 and R_2 are a $C_4 - C_{20}$ alkyl group or cycloalkyl group. The at least one alkyl sulfamic acid can have the formula $R_1R_2NS(O)_2(OH)$ and, for example, R_1 , R_2 , and the N form a 5-8 membered heterocyclic ring including one or more of O, NH, and CH_2 . The sulfamic acid or salt thereof can be a halide derivative of a sulfamic acid. Examples of sulfamic acids and salts thereof that can be alkylated (if not so already) employed in the method of the present invention include those described in U.S. Patent Nos. 7,576,041; 7,470,652; 7,345,202; 6,983,614; 6,824,668; 6,380,182; 6,110,387; 6,103,131; 5,478,461; 5,431,839; 4,386,060; 4,327,034; 4,049,709; 3,223,704; and 3,536,759, which are incorporated herein by reference in their entireties. Salts include, but are not limited to, alkali metal and quaternary ammonium salts. Methods for the preparation of various sulfamic acids or salts thereof are described in Nickless, Inorganic Sulphur Chemistry, Elsevier Publishing Company, New York; 611-614 (1968), which is incorporated by reference in its entirety.

[0014] The alkyl sulfamic acid or salt thereof can be applied by itself to a metal surface or applied as part of a fluid that can optionally contain one or more additional components, for example, an additional anti-corrosion agent and/or a biocide. When combined with one or

more additional anti-corrosion agents, the resulting corrosion inhibition can be sub-additive, additive, or super-additive (synergistic). The fluid can include a liquid, a vapor (gas), or a combination thereof. The fluid can include H₂O, NH₃, and/or an alcohol. The fluid can be aqueous, non-aqueous, or both. The fluid can include an acid or base in addition to the alkyl sulfamic acid or salt thereof. The fluid can include a salt solution of at least one salt independent of an alkyl sulfamic acid salt.

[0015] The fluid containing the alkyl sulfamic acid or salt thereof can be cooled or heated, or be used at ambient temperature or other temperatures above or below 20 deg C. The pH of the fluid can be neutral or from about 0.0 to about 14, from about 2.0 to about 12, from about 4.0 to about 10, or from about 6.0 to about 8.0.

[0016] The concentration of the at least one alkyl sulfamic acid or salt thereof can be adjusted according to the particular metal surface(s) being treated and the parameters of the system in which it is employed. The concentration of at least one alkyl sulfamic acid or salt thereof in a fluid system can be less than 0.001 ppm, greater than 0.001 ppm, from about 0.001 ppm to about 10,000 ppm from about 0.01 to about 1,000 ppm, from about 0.1 ppm to about 100 ppm, or from about 1.0 ppm to about 50 ppm, or from about 0.5 ppm to about 25 ppm, or from about 1 ppm to about 15 ppm, or from about 1 ppm to about 10 ppm, or from about 1 ppm to about 5 ppm. The alkyl sulfamic acid or salt thereof can be prepared as a stock solution of from about 0.01 wt% to about 100 wt%, from about 0.1 wt% to about 95 wt%, from about 1.0 wt% to about 80 wt%, from about 5.0 wt% to about 75 wt%, from about 10 wt% to about 60 wt%, from about 15 wt% to about 50 wt% from about 25wt% to about 40 wt% alkyl sulfamic acid or salt thereof based on the total weight of the stock solution. The alkyl sulfamic acid or salt thereof can be used in the methods of the invention as a solid, liquid, and/or gaseous

formulation. The methods according to the invention can be part of an overall water treatment regimen. The alkyl sulfamic acid or salt thereof can be used with other water treatment chemicals, such as biocides (e.g., algicides, fungicides, bactericides, molluscicides, oxidizers, etc.), stain removers, clarifiers, flocculants, coagulants, or other chemicals commonly used in water treatment.

[0017] Depending on its use, a composition containing alkyl sulfamic acid or salt thereof according to the present invention can be prepared in various forms known in the art. For example, the composition can be prepared in liquid form as a solution, dispersion, emulsion, suspension, or paste; a dispersion, suspension, or paste in a non-solvent; or as a solution by dissolving the alkyl sulfamic acid or salt thereof in a solvent or combination of solvents. Suitable solvents include, but are not limited to, acetone, glycols, alcohols, ethers, water, or other water-dispersible solvents. The composition can be prepared as a liquid concentrate for dilution prior to its intended use. Common additives such as surfactants, emulsifiers, dispersants, and the like can be used as known in the art to increase the solubility of the alkyl sulfamic acid or its salt as well as other components in a liquid composition or system, such as an aqueous composition or system. The composition of the invention can be solubilized by simple agitation.

[0018] A composition of the present invention can be prepared in solid form. For example, the alkyl sulfamic acid or salt thereof can be formulated as a powder or tablet using means known in the art. The tablets can contain a variety of excipients known in the tableting art such as dyes or other coloring agents. Other components known in the art such as fillers, binders, glidants, lubricants, or antiadherents can be included. These components can be included to improve tablet properties and/or the tableting process.

[0019] The alkyl sulfamic acid, salt thereof, and/or composition including the same can be applied directly or indirectly to a metal surface using any appropriate technique, for example flowing, coating, sponging, wiping, spraying, painting, showering, and/or misting of the at least one alkyl sulfamic acid or salt thereof to the metal surface can be employed. The "applying" can include flowing a fluid containing the at least one alkyl sulfamic acid or salt thereof over the metal surface. The method can comprise forming a protective film on the metal surface including the at least one alkyl sulfamic acid or salt thereof.

[0020] The corrosion of any suitable metal surface can be inhibited using the methods of the invention. Any metal, combination of metals, or alloys can be protected. Even surfaces that contain minor amounts or trace amounts of one or metals can be protected. The metal can be any metal susceptible to corrosion including industrial metals. Examples of metal surfaces include those containing one or more of scandium, titanium, vanadium, chromium, manganese, iron, cobalt, nickel, copper, zinc, yttrium, zirconium, platinum, gold, mercury, niobium, iridium, molybdenum, technetium, ruthenium, rhodium, palladium, silver, cadmium, hafnium, tantalum, tungsten, rhenium, osmium, aluminum, indium, germanium, gallium, antimony, tin, lead, bismuth, cerium, praseodymium, neodymium, promethium, samarium, europium, gadolinium, terbium, dysprosium, holmium, erbium, thulium, and/or ytterbium and/or alloys of one or more of these metals. Alloy metals such as stainless steel, steel, mild steel, bronze, brass, and the like are further examples of metals. The metal surface can be a ferrous or a non-ferrous surface. The surface can have any shape and/or dimensions. The metal surface can be continuous or discontinuous. The metal can be embedded in one or more non-metal media such as a plastic, a rubber, a glass, a ceramic, a composite, or the like. The metal can be

electroplated. The metal can be galvanized. A constant or variable electric current and/or magnetic field can be applied to the metal surface. The metal surface can be heated or cooled.

[0021] The method of the invention can further include contacting the metal surface with at least one corrosive agent from which protection is sought. The applying of the alkyl sulfamic acid, salt thereof, and/or one or more other anti-corrosive agents can be performed before, during, and/or after the contacting of the metal surface with the at least one corrosive agent. The metal surface can be part of a closed fluid system or an open fluid system, or both. Examples of systems that can be treated include, but are not limited to cooling systems, heating systems, cooling towers, boilers, radiators, steam piping, oil transport machinery and piping, oil production machinery and piping, paper and pulp machinery, drinking and tap water treatment plants, plumbing, sewers, waste water treatment plants, and other industrial uses that come in contact with corrosive agents.

[0022] An amount effective to inhibit corrosion is an amount that results in a lower degree of chemical change of the metal surface in the presence of an anti-corrosion inhibitor than in its absence. Corrosion inhibition can be partial inhibition or complete inhibition. The chemical change can be measured, for example, by measuring a change in weight of the metal surface and/or by measuring the concentration of metal, ions thereof, or salts thereof originating from the metal surface in fluid that flows past the metal surface. The weight loss, for example, of a corrosion coupon after exposure to a corrosive environment can be expressed as mils (thousandths of an inch) per year penetration (MPY). The corrosion rate can be calculated with the assumption of uniform corrosion over the entire surface of the coupon. MPY can be calculated by multiplying the weight loss in grams by 22,300 and then dividing by the product of the area of coupon (sq. in.), the metal density of the coupon (g/cm^3), and the time of

exposure in a corrosive environment (days). 1 MPY is equal to 0.0254 mm/y, which is equal to 25.4 $\mu\text{m}/\text{y}$. Accordingly, corrosion rate from metal loss can be calculated as $\text{mm}/\text{y} = 87.6 \times (W/DAT)$ with W (weight loss in milligrams), D (metal density in g/cm^3), A (area of sample in cm^2), and T (time of exposure of the metal sample in hours).

[0023] Metal corrosion can occur via electrochemical reactions at the interface between a metal and an electrolyte solution. A thin film of moisture on a metal surface forms the electrolyte for atmospheric corrosion. Corrosion normally occurs at a rate determined by an equilibrium between opposing electrochemical reactions, anodic (metal oxidation) and cathodic (reduction of a solution species). These reactions can occur on one metal or on two or more dissimilar metals that are in electrical communication. Corrosion current can be used to generate a corrosion rate by assuming an electrolytic dissolution reaction involving a chemical species. Uniform corrosion across a metal surface allows calculation of the corrosion rate in units of distance per year. For an alloy undergoing uniform dissolution, equivalent weight is a weighted average of the equivalent weights of the alloy components. If the dissolution is not uniform, corrosion products can be used to calculate equivalent weight.

[0024] A weight loss can be converted to a corrosion rate with knowledge of the density and the sample area of a sample. ASTM Standard G 102, Standard Practice for Calculation of Corrosion Rates and Related Information from Electrochemical Measurements can be used. An eddy current instrument and probe can be used for measuring corrosion by monitoring a conductivity curve and impedance plane and using one or more techniques such as single layer corrosion detection, two layer corrosion detection, a limited penetration method, dual frequency method, and/or a variable frequency method.

[0025] The following examples are intended to illustrate, not limit, the present invention.

EXAMPLES**Example 1**

[0026] Copper metal sample coupons with a surface area of 3.38 in² were installed in a laboratory-scale liquid recirculating loop equipped with a reservoir capable of holding approximately 11 L total volume. The apparatus was designed to hold metal sample coupons in the path of flowing liquid at a chosen flow rate and temperature for chosen period of time. After exposure for an adequate period of time, the metal sample weight loss resulting from corrosion was used to calculate the corrosion rate. The exact conditions of the tests are listed in the Tables 1-3. For tests shown in all three tables, the temperature was 35°C, linear velocity was 7 gallons per minute (GPM) (3 ft/s), and the mass of treatment was 10 L. Synthetic water was used having 1170 ppm NaCl and 505 ppm NaHCO₃, at pH 8.

[0027] For the purpose of evaluating yellow-metal corrosion inhibitor performance, corrosion rate data was generated for the trial material (hexylsulfamic acid) and a known industry corrosion inhibitor (tolyltriazole) (identified as “TTA” in the Tables) as a control, and in some cases untreated (blank) systems, using copper test coupons in sodium chloride-sodium bicarbonate brine at initial pH 8.8. This aqueous matrix was designed to mimic the pH, alkalinity, and total dissolved solids that might be found in a secondary treated municipal wastewater after four cycles of concentration. The inhibitor dosage range of from 5 ppm to 10 ppm was selected because this is an effective dosage range for the protection of copper with tolyltriazole.

[0028] After exposure to the corrosive environment defined by the testing parameters, corrosion coupons were cleaned with an acidic solution that is capable of removing various chemical and biological deposits and films that might have formed on the coupon surface

during exposure to the test environment. The weight change (and corresponding corrosion rate) determined before a coupon has been chemically cleaned helps the researcher ascertain general material removal and/or deposition process information. The corrosion rate obtained after cleaning is considered the true corrosion rate for the system under evaluation. Comparative data from known corrosion inhibitors and/or untreated systems collected at the time of the subject inhibitor evaluation are advantageous due to variability in experimental factors that otherwise are not easily controlled between different experiments. In the tables, the MPY (milli-inch per year) of corrosion was determined.

[0029] The data presented in Tables 1-3 show that hexylsulfamic acid has corrosion inhibitor properties that result in copper corrosion rates far less than that obtained in untreated systems. The data also show that the copper corrosion inhibition performance of hexylsulfamic acid is similar to that obtained for tolyltriazole. The data also show that hexylsulfamic acid performance as a copper corrosion inhibitor has an inverse relationship with inhibitor concentration under the given test conditions, which is similar to the performance trend obtained with tolyltriazole. Put another way, lower dosages, treatment levels, were more effective in controlling corrosion than higher dosages.

TABLE 1

Treatment	Coupon	Inhibitor Dosage ppm	pH	Weight Loss/Gain grams	MPY	Area in ²	Time hours
5ppm active TTA (before cleaning)	Copper, CDA110	5	8.8	0.0009	0.025	3.38	649
5ppm active TTA (after cleaning)	Copper, CDA110	5	8.8	0.0043	0.118	3.38	649
5ppm Hexyl Sulfamic Acid (before cleaning)	Copper, CDA110	5	8.8	0.0009	0.025	3.38	649
5ppm Hexyl Sulfamic Acid (after cleaning)	Copper, CDA110	5	8.8	0.0043	0.118	3.38	649
10ppm Hexyl Sulfamic Acid (after cleaning)	Copper, CDA110	10	8.8	0.0068	0.186	3.38	649
10ppm Hexyl Sulfamic Acid (after cleaning)	Copper, CDA110	10	8.8	0.0214	0.586	3.38	649

TABLE 2

Treatment	Coupon	Inhibitor Dosage ppm	pH	Weight Loss/Gain grams	MPY	Area in ²	Time hours
Blank (before cleaning)	Copper, CDA110	0	8.8	0.0086	0.097	3.38	1575
Blank (after cleaning)	Copper, CDA110	0	8.8	0.0188	0.212	3.38	1575
5ppm active TTA (before cleaning)	Copper, CDA110	5	8.8	0.0022	0.025	3.38	1575
5ppm active TTA (after cleaning)	Copper, CDA110	5	8.8	0.0056	0.063	3.38	1575
10ppm Hexyl Sulfamic Acid (before cleaning)	Copper, CDA110	10	8.8	0.0044	0.050	3.38	1575
10ppm Hexyl Sulfamic Acid (after cleaning)	Copper, CDA110	10	8.8	0.0111	0.125	3.38	1575

TABLE 3

Treatment	Coupon	Inhibitor Dosage ppm	pH	Weight Loss/Gain grams	MPY	Area in ²	Time hours
5ppm Hexyl Sulfamic Acid (before cleaning)	Copper, CDA110	5	8.8	0.0018	0.174	3.38	184
5ppm Hexyl Sulfamic Acid (after cleaning)	Copper, CDA110	5	8.8	0.0055	0.531	3.38	184
7.5ppm Hexyl Sulfamic Acid (before cleaning)	Copper, CDA110	7.5	8.8	0.0036	0.348	3.38	184
7.5ppm Hexyl Sulfamic Acid (after cleaning)	Copper, CDA110	7.5	8.8	0.0089	0.860	3.38	184
10ppm Hexyl Sulfamic Acid (before cleaning)	Copper, CDA110	10	8.8	0.0033	0.319	3.38	184
10ppm Hexyl Sulfamic Acid (after cleaning)	Copper, CDA110	10	8.8	0.0097	0.937	3.38	184

[0030] The present invention includes the following aspects/embodiments/features in any order and/or in any combination:

1. A method of inhibiting corrosion of a metal surface comprising:
applying at least one alkyl sulfamic acid or salt thereof to the metal surface in an amount effective to inhibit corrosion of the metal surface.
2. The method of any preceding or following embodiment/feature/aspect, wherein said alkyl sulfamic acid is a C₁-C₁₂ alkyl sulfamic acid or salt thereof.
3. The method of any preceding or following embodiment/feature/aspect, wherein the at least one alkyl sulfamic acid has the formula R₁R₂NS(O)₂(OH), and

R₁ and R₂ are independently a hydrogen, a C₄ – C₂₀ alkyl group, or a cycloalkyl group, and R₁ and R₂ are not both hydrogen, and/or

R₁, R₂, and the N form a 5-8 membered heterocyclic ring including one or more of O, NH, and CH₂.

4. The method of any preceding or following embodiment/feature/aspect, wherein R₁ and R₂ are independently a hydrogen, a C₄ – C₂₀ alkyl group, or a cycloalkyl group, and R₁ and R₂ are not both hydrogen.
5. The method of any preceding or following embodiment/feature/aspect, wherein R₁ or R₂, but not both, is a C₄ – C₂₀ alkyl group or a cycloalkyl group.
6. The method of any preceding or following embodiment/feature/aspect, wherein both R₁ and R₂ are a C₄ – C₂₀ alkyl group or cycloalkyl group.
7. The method of any preceding or following embodiment/feature/aspect, wherein R₁, R₂, and the N form a 5-8 membered heterocyclic ring including one or more of O, NH, and CH₂.
8. The method of any preceding or following embodiment/feature/aspect, wherein the alkyl sulfamic acid or salt thereof is present in a fluid applied to the metal surface.
9. The method of any preceding or following embodiment/feature/aspect, wherein the fluid is a liquid.
10. The method of any preceding or following embodiment/feature/aspect, wherein the fluid is a vapor.
11. The method of any preceding or following embodiment/feature/aspect, wherein the fluid comprises at least one of H₂O, NH₃, and an alcohol.
12. The method of any preceding or following embodiment/feature/aspect, wherein the fluid comprises an acid or base in addition to the alkyl sulfamic acid or salt thereof.
13. The method of any preceding or following embodiment/feature/aspect, wherein the fluid comprises a salt solution of at least one salt independent of the alkyl sulfamic acid salt.

14. The method of any preceding or following embodiment/feature/aspect, wherein the applying comprises one or more of flowing, coating, sponging, wiping, spraying, painting, showering, and misting of the at least one alkyl sulfamic acid or salt thereof.
15. The method of any preceding or following embodiment/feature/aspect, wherein the applying comprises flowing a fluid comprising the at least one alkyl sulfamic acid or salt thereof over the metal surface.
16. The method of any preceding or following embodiment/feature/aspect, wherein the metal surface is a non-ferrous surface.
17. The method of any preceding or following embodiment/feature/aspect, wherein the metal surface comprises copper or a copper-containing alloy (e.g., bronze).
18. The method of any preceding or following embodiment/feature/aspect, further comprising contacting the metal surface with at least one corrosive agent.
19. The method of any preceding or following embodiment/feature/aspect, wherein the applying is performed before, during, and/or after the contacting.
20. The method of any preceding or following embodiment/feature/aspect, wherein the metal surface is part of a closed fluid system.

[0031] The present invention can include any combination of these various aspects, features, or embodiments above and/or below as set forth in sentences and/or paragraphs. Any combination of disclosed features herein is considered part of the present invention and no limitation is intended with respect to combinable features.

[0032] Applicants specifically incorporate the entire contents of all cited references in this disclosure. Further, when an amount, concentration, or other value or parameter is given as either a range, preferred range, or a list of upper preferable values and lower preferable values,

this is to be understood as specifically disclosing all ranges formed from any pair of any upper range limit or preferred value and any lower range limit or preferred value, regardless of whether ranges are separately disclosed. Where a range of numerical values is recited herein, unless otherwise stated, the range is intended to include the endpoints thereof, and all integers and fractions within the range. It is not intended that the scope of the invention be limited to the specific values recited when defining a range.

[0033] It will be apparent to those skilled in the art that various modifications and variations can be made to the embodiments of the present invention without departing from the spirit or scope of the present invention. Thus, it is intended that the present invention covers other modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents.

CLAIMS

What is claimed is:

1. A method of inhibiting corrosion of a metal surface comprising:
applying at least one alkyl sulfamic acid or salt thereof to the metal surface in an amount of 1.0 to 50 ppm to inhibit corrosion of the metal surface, wherein the amount of the at least one alkyl sulfamic acid or salt thereof results in a lower degree of chemical change of the metal surface than in its absence.
2. The method of claim 1, wherein said alkyl in said alkyl sulfamic acid is an alkyl group that is pentyl, hexyl, heptyl, octyl, nonyl, decyl, dodecyl, or neopentyl.
3. The method of claim 1, wherein the at least one alkyl sulfamic acid has the formula $R_1R_2NS(O)_2(OH)$, and
 R_1 and R_2 are independently a hydrogen, an alkyl group, or a cycloalkyl group, wherein the alkyl group is pentyl, hexyl, heptyl, octyl, nonyl, decyl, dodecyl, or neopentyl, and R_1 and R_2 are not both hydrogen.
4. The method of claim 3, wherein R_1 or R_2 , but not both, is an alkyl group or a cycloalkyl group, wherein the alkyl group is pentyl, hexyl, heptyl, octyl, nonyl, decyl, dodecyl, or neopentyl.
5. The method of claim 3, wherein both R_1 and R_2 are an alkyl group or cycloalkyl group, wherein the alkyl group is pentyl, hexyl, heptyl, octyl, nonyl, decyl, dodecyl, or neopentyl.
6. The method of claim 1, wherein the alkyl sulfamic acid or salt thereof is present in a fluid applied to the metal surface.
7. The method of claim 6, wherein the fluid is a liquid.

8. The method of claim 6, wherein the fluid is a vapor.
9. The method of claim 6, wherein the fluid comprises at least one of H₂O, NH₃, and an alcohol.
10. The method of claim 6, wherein the fluid comprises an acid or base in addition to the alkyl sulfamic acid or salt thereof.
11. The method of claim 6, wherein the fluid comprises a salt solution of at least one salt independent of an alkyl sulfamic acid salt.
12. The method of claim 1, wherein the applying comprises one or more of flowing, coating, sponging, wiping, spraying, painting, showering, and misting of the at least one alkyl sulfamic acid or salt thereof.
13. The method of claim 1, wherein the applying comprises flowing a fluid comprising the at least one alkyl sulfamic acid or salt thereof over the metal surface.
14. The method of claim 1, wherein the metal surface is a non-ferrous surface.
15. The method of claim 1, wherein the metal surface comprises copper or a copper-containing alloy.
16. The method of claim 1, further comprising contacting the metal surface with at least one corrosive agent.
17. The method of claim 14, wherein the applying is performed before, during, and/or after the contacting.
18. The method of claim 1, wherein the metal surface is part of a closed fluid system.
19. The method of claim 1, wherein the applying forms a protective film on the metal surface including the at least one alkyl sulfamic acid or salt thereof.

20. The method of claim 1, wherein the at least one alkyl sulfamic acid or salt thereof is applied to the metal surface in an amount of 1.0 to 10 ppm.