SORBENT POLYMER COMPOSITES INCLUDING PHOSPHONIUM HALIDES, FLUE GAS TREATMENT DEVICES AND FLUE GAS TREATMENT METHODS UTILIZING THE SAME

FIELD

[1] Some embodiments of the present disclosure relate to sorbent polymer composites that include phosphonium halides. The sorbent polymer composites of such embodiments may be utilized in devices and methods as described herein.

BACKGROUND

[2] Coal-fired power generation plants, municipal waste incinerators, and oil refinery plants generate large amounts of flue gases that contain substantial varieties and quantities of environmental pollutants, such as sulfur oxides (SO_2, and SO_3), nitrogen oxides (NO, NO_2), mercury (Hg) vapor, and particulate matter (PM). In the United States, burning coal alone generates about 27 million tons of SO_2 and 45 tons of Hg each year.

[3] There is an ongoing need to provide systems that can remove multiple flue gas pollutants such as, but not limited to, SO_x, Hg vapor, and particulate matter at low cost.

SUMMARY

[4] The subject matter should be understood by reference to appropriate portions of the entire specification, any or all drawings, and each claim.

[5] ~~Some aspects of t~~The present disclosure relates to a device comprising a sorbent polymer composite, wherein the sorbent polymer composite comprises: a sorbent, a polymer, and at least one phosphonium halide. In some ~~such aspects~~examples, the phosphonium halide has a very high thermal stability. Accordingly, in such examples~~aspects~~, the phosphonium halide can be relevant for high temperature application(s). In some examples~~such aspects~~, the at least one phosphonium halide may be disposed on the sorbent polymer composite, disposed within the sorbent polymer composite, or any combination thereof. In some examples~~aspects~~, the at least one phosphonium halide may be disposed within the sorbent polymer composite. In some examples~~aspects~~, the device may also be configured to treat a flue gas stream.

[5a] One aspect of the present disclosure relates to a device comprising: a sorbent polymer composite; wherein the sorbent polymer composite comprises: a sorbent; and a polymer; and at least one phosphonium halide, wherein the at least one phosphonium halide is: disposed on the sorbent polymer composite, disposed within the sorbent polymer composite, or any combination thereof; and wherein the device is configured to treat a flue gas stream.

[6] In some examples~~aspects~~, the at least one phosphonium halide comprises a compound with a formula: $P(R_1R_2R_3R_4)X$, wherein $X=I^-$, Br^-, I_3^-, BrI_2^-, Br_2I^-, or Br_3^-, and wherein at least one of R_1, R_2, R_3 or R_4 is a hydrocarbon having from 1 to 18 carbon atoms. In some examples~~aspects~~, the hydrocarbon is chosen from an alkyl, an aryl, or a cyclic alkyl. In some examples~~aspects~~, the at least one

phosphonium halide comprises a quaternary phosphonium iodide. In some examplesaspects, the at least one phosphonium halide comprises a quaternary phosphonium bromide. In some examplesaspects, the at least one phosphonium halide comprises a quaternary phosphonium triiodide. In some examplesaspects, the at least one phosphonium halide comprises a quaternary phosphonium tribromide. In some examplesaspects, the at least one phosphonium halide comprises ethyltriphenylphosphonium iodide (ETPPI). In some examplesaspects, the at least one phosphonium halide comprises tetrabutylphosphonium iodide (TBPI), ethyltriphenylphosphonium triiodide ($ETPPI_3$), tetrabutyl phosphonium bromide (TBPBr), ethyltriphenylphosphonium bromide (ETPPBr), or any combination thereof.

[7] In some examplesaspects, the at least one phosphonium halide is thermally stable, such that the at least one phosphonium halide retains a single molecular formula, at temperatures in excess of 180°C. In some examplesaspects, the at least one phosphonium halide is thermally stable, such that the at least one phosphonium halide retains a single molecular formula, at temperatures from 180°C to 400°C. In some examplesaspects, the at least one phosphonium halide is thermally stable, such that the at least one phosphonium halide retains a single molecular formula, at temperatures from 200°C to 400°C. In some examplesaspects, the sorbent of the sorbent polymer composite has a surface area in excess of 400 m^2/g. In some examplesaspects, the sorbent of the sorbent polymer composite has a surface area ranging from 400 m^2/g to 2000 m^2/g. In some examplesaspects, the sorbent of the sorbent polymer composite is chosen from: activated carbon, silica gel, zeolites, or any combination thereof. In some examplesaspects, the polymer of the sorbent polymer composite has a surface energy of less than 31 dynes per cm. In some examplesaspects, the polymer of the sorbent polymer composite has a surface energy ranging from 15 dynes per cm to 31 dynes per cm. In some examplesaspects, the polymer of the sorbent polymer composite comprises a fluoropolymer. In some examplesaspects, the fluoropolymer is expanded polytetrafluoroethylene (ePTFE). In some examplesaspects, the at least one phosphonium halide is disposed within the sorbent polymer composite.

[8] Some aspects of tThe present disclosure also relates to a method of treating a flue gas stream. In some examplessuch aspects, the flue gas stream may comprise oxygen, water vapor, at least one SO_x compound, and mercury vapor. In some examplessuch aspects, the method may comprise passing the flue gas stream over a device, where the device comprises a sorbent polymer composite, and where the sorbent polymer composite comprises a sorbent, a polymer, and at least one phosphonium halide. In some examplesaspects, the at least one phosphonium halide is disposed on the sorbent polymer composite, disposed within the sorbent polymer composite, or any combination thereof. In some examplesaspects, the method may further comprise reacting the oxygen and water vapor with the at least one SO_x compound on the sorbent polymer composite, so as

to form sulfuric acid. In some examples~~aspects~~, the method may further comprise reacting the mercury vapor with the at least one phosphonium halide, so as to fix molecules of the mercury vapor to the sorbent polymer composite. In some examples~~aspects~~, the method further comprises, prior to the treating step, obtaining the flue gas stream from at least one combustion process. In some examples~~aspects~~, the at least one SO_x compound comprises sulfur dioxide (SO_2), sulfur trioxide (SO_3), or any combination thereof.

[8a] Another aspect of the present disclosure relates to a method comprising: treating a flue gas stream, wherein the flue gas stream comprises: oxygen, water vapor, at least one SO_x compound, and mercury vapor; wherein treating the flue gas stream comprises: passing the flue gas stream over a device, wherein the device comprises: a sorbent polymer composite; wherein the sorbent polymer composite comprises: a sorbent; and a polymer; and at least one phosphonium halide, wherein the at least one phosphonium halide is: disposed on the sorbent polymer composite, disposed within the sorbent polymer composite, or any combination thereof; reacting the oxygen and water vapor with the at least one SO_x compound on the sorbent polymer composite, so as to form sulfuric acid; and reacting the mercury vapor with the at least one phosphonium halide, so as to fix molecules of the mercury vapor to the sorbent polymer composite.

DRAWINGS

[9] Some embodiments of the disclosure are herein described, by way of example only, with reference to the accompanying drawings. With specific reference now to the drawings in detail, it is stressed that the embodiments shown are by way of example and for purposes of illustrative discussion of embodiments of the disclosure. In this regard, the description taken with the drawings makes apparent to those skilled in the art how embodiments of the disclosure may be practiced.

[10] FIG. 1 is an illustration of a device, in the form of a flue gas treatment unit, according to some embodiments of the present disclosure.

[11] FIGS. 2A and 2B are simplified illustrations of sorbent polymer composites in accordance with some embodiments of the present disclosure.

[12] FIG. 3 is a chart showing Langmuir Adsorption isotherms of various exemplary phosphonium halides in accordance with some embodiments of the present disclosure.

[13] FIG. 4 is a chart showing the stability of ethyltriphenylphosphonium iodide (ETPPI) as a function of temperature in a thermal gravimetric analysis in accordance with some embodiments of the present disclosure.

[14] FIG. 5 is a chart showing the stability of tetrabuylphosphonium iodide as a function of temperature in a thermal gravimetric analysis in accordance with some embodiments of the present disclosure.

[15] FIG. 6 is a chart showing the stability of ethyltriphenylphosphonium bromide (ETPPBr) as a function of temperature in a thermal gravimetric analysis in accordance with some embodiments of the present disclosure.

[16] FIG. 7 is a chart showing the stability of tetrabuylphosphonium bromide (TBPBr) as a function of temperature in a thermal gravimetric analysis in accordance with some embodiments of the present disclosure.