

CLAIMS

1. 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.
2. The device of claim 1, wherein 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.
3. The device of claim 2, wherein the hydrocarbon is chosen from an alkyl, an aryl, or a cyclic alkyl.
4. The device of any of claims 1 to 3, wherein the at least one phosphonium halide comprises a quaternary phosphonium iodide.
5. The device of any of the preceding claims, wherein the at least one phosphonium halide comprises a quaternary phosphonium bromide.
6. The device of any of the preceding claims, wherein the at least one phosphonium halide comprises a quaternary phosphonium triiodide.
7. The device of any of the preceding claims, wherein the at least one phosphonium halide comprises a quaternary phosphonium tribromide.
8. The device of any of the preceding claims, wherein the at least one phosphonium halide comprises ethyltriphenylphosphonium iodide (ETPPI).
9. The device of any of the preceding claims, wherein the at least one phosphonium halide comprises tetrabutylphosphonium iodide (TBPI), ethyltriphenylphosphonium triiodide (ETPPI₃), tetrabutyl phosphonium bromide (TBPBr), ethyltriphenylphosphonium bromide (ETPPBr), or any combination thereof.
10. The device of any of the preceding claims, wherein 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.

11. The device of Claim 10, wherein 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.
12. The device of Claim 11, wherein 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.
13. The device of any of the preceding claims, wherein the sorbent of the sorbent polymer composite has a surface area in excess of 400 m²/g.
14. The device of claim 13, wherein the sorbent of the sorbent polymer composite has a surface area ranging from 400 m²/g to 2000 m²/g.
15. The device of any of the preceding claims, wherein the sorbent of the sorbent polymer composite is chosen from: activated carbon, silica gel, zeolites, or any combination thereof.
16. The device of any of the preceding claims, wherein the polymer of the sorbent polymer composite has a surface energy of less than 31 dynes per cm.
17. The device of claim 16, wherein the polymer of the sorbent polymer composite has a surface energy ranging from 15 dynes per cm to 31 dynes per cm.
18. The device of any of the preceding claims, wherein the polymer of the sorbent polymer composite comprises a fluoropolymer.
19. The device of claim 20, wherein the fluoropolymer is expanded polytetrafluoroethylene (ePTFE).
20. 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.

21. The method of claim 20, further comprising, prior to the treating step, obtaining the flue gas stream from at least one combustion process.
22. The method of any of claims 20 to 21, wherein the at least one SO_x compound comprises sulfur dioxide (SO_2), sulfur trioxide (SO_3), or any combination thereof.
23. The device of any of claims 1-19, wherein the at least one phosphonium halide is disposed within the sorbent polymer composite.