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(21) Inventors/Applicants:

(74) Agents:

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(54) Title: OPTICAL METHODS AND SYSTEMS FOR DETECTING A CONSTITUENT IN A GAS CONTAINING OXYGEN IN HARSH ENVIRONMENTS

(55) Abstract: A method for detecting a gas phase constituent such as carbon monoxide, nitrogen dioxide, hydrogen, or hydrocarbons in a gas comprising oxygen such as air, includes providing a sensing material or film (20, 120) having a metal embedded in a catalytically active matrix such as gold embedded in a yttria stabilized zirconia (YSZ) matrix. The method may include annealing the sensing material at about 900°C, exposing the sensing material (20, 120) and gas to a temperature above 400°C, projecting light onto the sensing material (20, 120), and detecting a change in the absorption spectrum of the sensing material due to the exposure of the sensing material to the gas in air at the temperature which causes a chemical reaction in the sensing material compared to the absorption spectrum of the sensing material in the absence of the gas. Systems (700) employing such a method are also disclosed.
AMENDED CLAIMS

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CLAIMS:

1. A method for detecting a constituent in a gas containing oxygen, the method comprising:
   providing a sensing material (20, 120) comprising a metal embedded in a catalytically active matrix;
   exposing the sensing material (20, 120) and the constituent in the gas to a temperature above about 400°C;
   projecting light onto the sensing material (20, 120); and
   detecting the constituent in the gas by a change in the absorption spectrum of the metal due to the exposure of the sensing material to the constituent in the gas at the temperature which causes a chemical reaction in the sensing material compared to the absorption spectrum of the metal in the absence of the constituent in the gas.

2. The method of claim 1 further comprising detecting comprises determining a concentration of the constituent in the gas based on an amount of the change in the absorption spectrum.

3. The method of claim 1 wherein the detecting comprises subtracting the absorption spectrum of the metal in the gas from the absorption spectrum of the metal in the gas containing the constituent, determining the peak to peak difference therebetween, and determining a concentration of the constituent in the gas based on the amount of the peak to peak difference.

4. The method of claim 1 further comprising comparing the change in the absorption spectrum to a database (760) of absorption spectrum changes.

5. The method of claim 1 wherein the detecting comprises detecting a "blue shift" to shorter wavelengths in the absorption spectrum.

AMENDED SHEET (ARTICLE 19)
6. The method of claim 1 wherein the detecting comprises detecting carbon monoxide in the gas.

7. The method of claim 1 wherein the detecting comprises detecting hydrogen in the gas.

8. The method of claim 1 wherein the detecting comprises detecting hydrocarbon in the gas.

9. The method of claim 1 wherein the detecting comprises detecting a "redshift" to longer wavelengths in the absorption spectrum.

10. The method of claim 1 wherein the detecting comprises detecting nitrogen dioxide in the gas.

11. The method of claim 1 wherein the metal comprises gold and the catalytically active matrix comprises a yttria stabilized zirconia matrix.

12. The method of claim 1 wherein the providing comprises providing the sensing material (20, 120) annealed at about 900°C.

13. The method of claim 1 wherein the exposing the sensing material (20, 120) and the constituent in the gas comprises exposing the sensing material (20, 120) and the constituent in the gas to a temperatures between about 500°C to about 800°C.

14. The method of claim 1 wherein the detecting further comprises filtering the light to permit identification of a wavelength of the absorption spectrum of the metal.
15. The method of claim 1 wherein the providing the sensing material comprises providing the sensing material having a grain size of the metal about equal to the grain size of the catalytically active matrix.

16. The method of claim 1 wherein the providing the sensing material (20, 120) comprises providing the sensing material (20, 120) having a grain size of the metal and the grain size of the catalytically active matrix of about 19 nanometers.

17. The method of claim 1 wherein the providing the sensing material (20, 120) comprises providing the sensing material on a sapphire substrate.

18. The method of claim 1 wherein the providing the sensing material (20, 120) comprises providing the sensing material on an optical fiber.

19. A method for detecting a plurality of constituents in a gas containing oxygen, the method comprising:
   providing a plurality of sensing materials (200, 210, 220) comprising a metal embedded in a catalytically active matrix;
   exposing the plurality of sensing materials (200, 210, 220) and the plurality of constituents in the gas to a temperature above about 400°C;
   projecting light onto the sensing materials (200, 210, 220); and
   detecting the constituents in the gas by a change in the absorption spectrum of the metal in the plurality of sensing materials (200, 210, 220) due to the exposure of the plurality of sensing materials (200, 210, 220) to the constituents in the gas at the temperature which causes a chemical reaction in the plurality of sensing materials (200, 210, 220) compared to the absorption spectrum of the metal in the plurality of sensing materials (200, 210, 220) in the absence of the constituent in the gas.
20. The method of claim 19 further comprising tailoring each of the plurality of sensing materials (200, 210, 220) to a different one of the plurality of constituents.

21. The method of claim 19 further comprising tailoring each of the plurality of sensing materials (200, 210, 220) to a different one of the plurality of constituents to by varying the grain size of the metal in the catalytically active matrix.

22. A system for detecting a constituent in a gas containing oxygen, said system comprising:
   a sensing material (20, 120) comprising a metal embedded in a catalytically active matrix;
   a light source for directing light on to said sensing material (20, 120);
   a light detector for detecting light reflected from the sensing material(20, 120);
   and
   a processor (750) operable to detect the constituent in the gas by a change in the absorption spectrum of the metal due to the exposure of the sensing material (20, 120) to the constituent in the gas at the temperature which causes a chemical reaction in the sensing material (20, 120) compared to the absorption spectrum of the metal in the absence of the constituent in the gas.

23. The system of claim 22 wherein said processor (750) is operable to determine a concentration of the constituent in the gas based on an amount of the change in the absorption spectrum.

24. The system of claim 22 wherein said processor (750) is operable to subtract the absorption spectrum of the metal in the gas from the absorption spectrum of the metal in the gas containing the constituent, determine the peak to peak difference therebetween, and determine a concentration of the constituent in the gas based on the amount of the peak to peak difference.

AMENDED SHEET (ARTICLE 19)
25. The system of claim 22 wherein said processor (750) is operable to compare the change in the absorption spectrum to a database (760) of absorption spectrum changes.

26. The system of claim 22 wherein said processor (750) is operable to detect a "blue shift" to shorter wavelengths in the absorption spectrum.

27. The system of claim 22 wherein said processor (750) is operable to detect carbon monoxide in the gas.

28. The system of claim 22 wherein said processor (750) is operable to detect hydrogen in the gas.

29. The system of claim 22 wherein said processor (750) is operable to detect hydrocarbon in the gas.

30. The system of claim 22 wherein said processor (750) is operable to detect a "redshift" to longer wavelengths in the absorption spectrum.

31. The system of claim 22 wherein said processor (750) is operable to detect nitrogen dioxide in the gas.

32. The system of claim 22 wherein the metal comprises gold and the catalytically active matrix comprises a yttria stabilized zirconia matrix.

33. The system of claim 22 wherein the sensing material (20, 120) is annealed at about 900°C.

34. The system of claim 22 further comprising a filter (70) for filtering the light to permit identification of a wavelength of the absorption spectrum of the metal.
35. The system of claim 22 wherein the sensing material (20, 120) comprises a
grain size of the metal about equal to the grain size of the catalytically active matrix.

36. The system of claim 22 wherein the sensing material (20, 120) comprises a
grain size of the metal and the grain size of the catalytically active matrix of about 19
nanometers.

37. The system of claim 22 wherein the sensing material is disposed on a
sapphire substrate.

38. The system of claim 22 wherein the sensing material is disposed on an optical
fiber.

39. A system for detecting a plurality of constituent in a gas containing oxygen, the
system comprising:
   a plurality of sensing materials (200, 210, 220) comprising a metal embedded in a catalytically active matrix;
   a light source for directing light onto said plurality of sensing material (200, 210, 220);
   a light detector for detecting light reflected from said plurality of sensing materials (200, 210, 220); and
   a processor (750) operable to detect the plurality of constituents in the
gas by a change in the absorption spectrum of the metal in the plurality of sensing
materials (200, 210, 220) due to the exposure of said plurality of sensing material
(200, 210, 220) to the plurality of constituent in the gas at the temperature which
causes a chemical reaction in the plurality of sensing materials (200, 210, 220)
compared to the absorption spectrum of the metal in the plurality of sensing materials
(200, 210, 220) in the absence of the constituent in the gas.

AMENDED SHEET (ARTICLE 19)
40. The system of claim 39 further comprising tailoring each of the plurality of sensing materials (200, 210, 220) to a different one of the plurality of constituents to optimize the change in the absorption spectrum for a particular constituent.

41. The system of claim 40 wherein each of the plurality of sensing materials (200, 210, 220) comprises a metal having a different grain size.

42. The system of claim 40 wherein said processor (750) is operable to compare the change in the plurality of absorption spectrums to a database (760) of a plurality of absorption spectrum changes.

AMENDED SHEET (ARTICLE 19)