Claims

1. Apparatus for use in sensing temperature in a wellbore, comprising:

tubing comprising a plurality of temperature sensor modules provided at locations along the inside of the tubing, said temperature sensor modules comprising temperature sensors provided at least in part by at least one semiconductor element having electrical properties that vary with temperature;

an electrical network configured to electrically connect to the semiconductor elements to in use allow measuring of the respective electrical properties of the semiconductor elements to infer a thermal characteristic of the semiconductor element; and

at least one control module electrically connected to multiple temperature sensor modules, via the electrical network, and configured to receive and process an electrical signal associated with the temperature sensor modules to enable inference of the temperature of the semiconductor elements and the environment to which the tubing is exposed at the location of that semiconductor element,

wherein the control module further comprises a common reference signal generator used as a reference for the measurement of the voltage and/or current of at least two or each of the temperature sensor modules.

2. Apparatus as claimed in claim 1, wherein the tubing is metallic.
3. Apparatus as claimed in any preceding claim, wherein the tubing outer diameter is in the range of 3 mm to 14 mm at the location in the tubing of at least one of the temperature sensor modules.
4. Apparatus as claimed in any preceding claim, wherein the outer diameter of the tubing remains substantially constant along the tubing.
5. Apparatus as claimed in any preceding claim, wherein the apparatus is configured to use only the temperature sensitivity of the semiconductor element to infer a temperature of the semiconductor element.
6. Apparatus as claimed in any preceding claim, wherein the tubing is filled with and encapsulates a non-conducting liquid, wherein the tubing comprises a pressure balancing means, configured to act to equalise internal pressure in the tubing with the ambient environment.
7. Apparatus as claimed in claim 6, wherein the pressure balancing means includes a bellows or a flexible bladder.

8. Apparatus as claimed in any preceding claim, wherein the temperature sensor modules in the tubing are encased in a potting compound.
9. Apparatus as claimed in any preceding claim, wherein the tubing comprises at least 6 temperature sensor modules along its length.
10. Apparatus as claimed in any preceding claim, wherein the semiconductor elements are diodes.
11. Apparatus as claimed in any preceding claim, further comprising calibration means configured to compensate for the resistance of wires in the line that connect the semiconductor elements of the temperature sensors to the at least one control module, and also for the temperature dependence of the resistivity of those wires.
12. Apparatus as claimed in claim 1, wherein the common reference signal generator is a reference voltage source.
13. Apparatus as claimed in any preceding claim, wherein multiple control modules are provided, wherein individual control modules control sets of temperature sensor modules, and the control modules are linked to one or more master control modules.
14. Apparatus as claimed in claim 13, further comprising communication means within the tubing to enable data communication along the tubing to enable communication between control modules, or to enable communication with other devices within the well.
15. Apparatus as claimed in any preceding claim, wherein the tubing containing the temperature sensor modules is arranged as a ring or helix to extend around a tubular element of a well apparatus.
16. Apparatus as claimed in any preceding claim, further comprising a power source configured to provide operational power to the apparatus for sensing temperature in the wellbore in use, wherein the power source is arranged to be provided as an in-well power source in use, wherein the power source is replaceable in the well.
17. Apparatus as claimed in claim 16, wherein the power source is a battery or power generator may be replaced using wireline, or coiled tubing.
18. Apparatus as claimed in claim 16, wherein the power source comprises one or more primary cells, secondary cells and/or downhole power generators.
19. Apparatus as claimed in any of claims 1 to 15, wherein the apparatus is configured to be powered in use from a position higher in the well via inductive or capacitive coupling.
20. Apparatus as claimed in any preceding claim, further comprising a wireless data communication module coupled, wirelessly, by a separate wireless connection, or

electrically by wired connection, to the apparatus for use in sensing temperature in a wellbore and arranged to, in use:

wirelessly transmit along the well signals indicative of a temperature sensed in the wellbore by the apparatus, using relays or repeaters.

21. Apparatus as claimed in claim 20, wherein the wireless data communication module is configured to wirelessly receive control signals for controlling the operation of the apparatus, for control of data acquisition, data transmission, and/or to control heating or cooling of the sensors.

22. Apparatus as claimed in claim 20 or 21, wherein the wireless data communication module is configured to transmit said signals acoustically and/or electromagnetically.

23. Apparatus as claimed in any preceding claim, wherein the semiconductor elements are provided in integrated circuit temperature sensors configured to vary a current or a voltage with a temperature of the sensor.

24. Apparatus as claimed in claim 23, wherein the integrated circuit temperature sensors are configured as silicon bandgap temperature sensors each having two p-n junctions that, in use, are operated a different current densities to infer a temperature by determining a voltage difference between the two p-n junctions at the different current densities, which is proportional to absolute temperature.

25. Apparatus as claimed in any preceding claim, wherein the apparatus is configured such that, in use, at least one temperature sensor module is selected by the control module digitally addressing the temperature sensor module, and wherein the selected temperature sensor module enables a voltage or current output representative of the temperature of a semiconductor element to be connected to the control module.

26. Apparatus as claimed in any preceding claim, wherein at least one, or each temperature sensor module comprises a single electronic component.

27. Apparatus as claimed in any of claims 1 to 22, wherein at least one, or each temperature sensor module comprises a single passive electronic component.

28. Apparatus as claimed in any of claims 26 to 27, wherein the maximum physical extent of the single electronic component in any axis is less than 7mm.

29. Apparatus as claimed in any preceding claim, wherein the control module is configured to measure an analogue current and/or voltage associated with the temperature sensor modules to enable inference of the temperature of the semiconductor elements and the environment to which the tubing is exposed at the location of that semiconductor element.

30. A well comprising a well apparatus having apparatus for use in sensing temperature in a wellbore as claimed in any of claims 1 to 29 arranged to sense a temperature in a wellbore of the well.
31. A well as claimed in claim 30, wherein the well apparatus comprises an annular sealing device provided at least 100m below a surface of the well, and between a wellbore or a casing of the wellbore and a tubular.
32. A well as claimed in claim 31, wherein the apparatus for use in sensing temperature in a wellbore is provided entirely below the annular sealing device.
33. A well as claimed in claim 31, wherein the tubing of the apparatus for use in sensing temperature in a wellbore does not extend across the annular sealing device.
34. A well as claimed in any of claims 30 to 33, wherein the well apparatus comprises a tubular element and wherein the tubing of the apparatus for use in sensing temperature in a wellbore extends along and/or around the tubular element.
35. A well as claimed in claim 34, wherein the tubular element is a drill string, and wherein the drill string comprises a drill bit or mill.
36. A well as claimed in any of claims 34 to 35, wherein the tubing is clamped to the tubular element in the well.
37. A well as claimed in any of claims 30 to 33, wherein the apparatus is deployed in the well on wireline, or coiled tubing, and set and/or suspended in the well.
38. A well as claimed in any of claims 30 to 36, wherein the tubing is clamped to and extends across a perforating gun or guns.
39. A well as claimed in any of claims 30 to 33, wherein the apparatus is configured to monitor the temperature at a barrier in the well.
40. A well as claimed in any of claims 30 to 38, wherein the apparatus is configured to monitor the well during a well test or drill stem test.
41. A well as claimed in any of claims 30 to 40, wherein the well is a production and/or injection well.
42. A well as claimed in any of claims 30 to 41, wherein the apparatus is configured to monitor an exothermic reaction associated with a fluid treatment of the well.
43. A well as claimed in any of claims 30 to 42, where the well is in a suspended or abandoned phase, and the apparatus is configured to monitor the well.