CLAIMS

What is claimed is:

1. A instrumented cutting element for an earth-boring drilling tool, the instrumented cutting element comprising:
a cutting element body having a cutting surface thereon; and
at least one sensor located proximate the cutting surface, the at least one sensor oriented and configured to determine resistivity of one of a contacting formation and the cutting element.

2. The instrumented cutting element of claim 1, wherein the at least one sensor includes a plurality of electrodes coupled with a control circuit, the plurality of electrodes configured to sense at least one of a voltage and a current.

3. The instrumented cutting element of claim 2, wherein the plurality of electrodes includes two terminals configured as voltage electrodes, and two terminals configured as current electrodes.

4. The instrumented cutting element of claim 2 or claim 3, wherein the plurality of electrodes includes an outer electrode extending around an inner electrode.

5. The instrumented cutting element of claim 4, wherein the sensor and at least a portion of the cutting surface are not coplanar.

6. The instrumented cutting element of claim 4 or claim 5, wherein an inner region of the cutting surface between the outer electrode and the inner electrode is a recessed region.

7. An earth-boring drilling tool, comprising:
a bit body; and
an instrumented cutting element as recited in any of claims 1 through 8.

8. The earth-boring drilling tool of claim 7, further comprising a control circuit operably coupled with the at least one sensor, the control circuit configured to energize the at least one sensor and detect a return signal from the at least one sensor.

9. The earth-boring drilling tool of claim 8, wherein the cutting body includes a diamond table disposed on a substrate, and wherein a conduit passes through the diamond table and the substrate coupling the at least one sensor to the control circuit.

10. The earth-boring drilling tool of claim 9, wherein the bit body includes:
a pocket in which the instrumented cutting element is disposed; and
wiring passing through the pocket coupling the instrumented cutting element and the control circuit.

11. The earth-boring drilling tool of any of claims 7 through 10, further comprising a plurality of instrumented cutting elements, each of the instrumented cutting elements configured as a single terminal device.

12. The earth-boring drilling tool of claim 11, wherein the instrumented cutting elements of the plurality are grouped such that a first group of instrumented cutting elements are arranged on at least one of a gauge and shoulder of the bit body, and a second group of instrumented cutting elements are arranged on at least one of a nose and cone of the bit body.

13. The earth-boring drilling tool of claim 11, wherein at least two single terminal devices form a circuit with the control circuitry.

14. The earth-boring drilling tool of any of claims 7 through 10, further comprising another instrumented element coupled with the drill bit at a location that actively engages the subterranean formation if the drilling operation is in a dragging mode or rubbing mode.

15. A method of determining resistivity of a subterranean formation during a drilling operation, the method comprising:

energizing a sensor of an instrumented element of a drill bit;

sensing a return signal flowing on or through the subterranean formation; and

determining a resistivity of the subterranean formation based, at least in part, on the return signal.

16. The method of claim 15, wherein energizing the sensor includes at least one of applying a voltage to the sensor and injecting a current into the subterranean formation through the sensor, and sensing the return signal occurs through the sensor of an instrumented cutting element.

17. The method of claim 15, wherein energizing the sensor and sensing the return signal includes generating current flowing between an instrumented cutting element and another instrumented cutting element.

18. The method of claim 15, wherein generating current flowing between the instrumented cutting element and another instrumented cutting element includes generating current flowing between the instrumented cutting element and the another instrumented cutting element positioned at a location on one of a drill string and a surface of the subterranean formation.

19. The method of any of claims 15 through 18, wherein determining a resistivity of the subterranean formation includes determining a horizontal resistivity and a vertical resistivity of the subterranean formation.

20. The method of claim 19, further comprising determining porosity of the subterranean formation using the determined horizontal resistivity and vertical resistivity.

Claims

1. An earth-boring drilling tool, comprising:

a bit body having at least one blade formed thereon; and

a cutting element at least partially disposed within a pocket of the at least one blade of the bit body, the cutting element comprising:

a cutting element body having a cutting surface thereon; and

at least one sensor disposed within the cutting element body and having at least one exposed surface, the at least one exposed surface being recessed relative to at least a portion of the cutting surface of the cutting element, the at least one sensor oriented and configured to sense resistivity of one of a contacting formation and the cutting element.

2. The earth-boring drilling tool of claim 1, wherein the at least one sensor of the cutting element includes a plurality of electrodes coupled with a control circuit.

3. The earth-boring drilling tool of claim 2, wherein the plurality of electrodes includes two terminals configured to measure voltages, and two terminals configured to measure currents.

4. The earth-boring drilling tool of claim 2, wherein the plurality of electrodes includes an outer electrode extending around an inner electrode.

5. The earth-boring drilling tool of claim 4, wherein the outer electrode has a ring shape.

6. The earth-boring drilling tool of claim 1, wherein at least a portion of the cutting surface of the cutting element is recessed relative to the at least one exposed surface of the at least one sensor.

7. The earth-boring drilling tool of claim 5, wherein an outer periphery of the cutting surface protrudes beyond the outer electrode in a direction orthogonal to a plane including the ring shape.

8. The earth-boring drilling tool tool of claim 5, wherein an inner region of the cutting surface between the outer electrode and the inner electrode is recessed relative to the outer electrode and the inner electrode.

9. An earth-boring drilling tool, comprising:

a bit body; and

an instrumented cutting element coupled with the bit body, the cutting element including: a substrate;

a cutting body disposed on the substrate and having a cutting surface thereon;

at least one sensor disposed within the cutting body, at least one surface of the at least one sensor being at least substantially flush with the cutting surface of the cutting element, wherein the at least one sensor is oriented and configured to sense resistivity of one of a contacting formation and the instrumented cutting element; and

at least one conduit coupled to the at least one sensor and extending through the cutting body and through the substrate in a direction at least substantially orthogonal to the cutting surface of the cutting body of the cutting element.

10. The earth-boring drilling tool of claim 9, further comprising a control circuit operably coupled with the at least one sensor via the at least one conduit, the control circuit configured to energize the at least one sensor through the at least one conduit and detect a return signal from the at least one sensor through the at least one conduit.

11. The earth-boring drilling tool of claim 10, wherein the cutting body includes a diamond table.

12. The earth-boring drilling tool of claim 11, wherein the bit body includes:

a pocket in which the instrumented cutting element is at least partially disposed; and

wiring passing through the pocket coupling the at least one conduit of the instrumented cutting element to the control circuit.

13. The earth-boring drilling tool of claim 10, further comprising at least one non-instrumented cutting element coupled with the bit body.

14. The earth-boring drilling tool of claim 10, wherein the at least one sensor includes a plurality of electrodes configured to sense at least one of a voltage and a current.

15. The earth-boring drilling tool of claim 10, further comprising a plurality of instrumented cutting elements, each of the instrumented cutting elements including a single terminal of a circuit.

16. The earth-boring drilling tool of claim 15, wherein the instrumented cutting elements of the plurality are grouped such that a first group of instrumented cutting elements are arranged on at least one of a gage and shoulder of the bit body, and a second group of instrumented cutting elements are arranged on at least one of a nose and cone of the bit body.

17. The earth-boring drilling tool of claim 15, wherein at least two single terminal devices form the circuit with the control circuitry.

18. The earth-boring drilling tool of claim 10, further comprising another instrumented cutting element coupled with the drill bit at a location that actively engages the subterranean formation if the drilling operation is in a dragging mode or rubbing mode.

19. A method of determining resistivity of a subterranean formation during a drilling operation, the method comprising:

contacting a sensor disposed within a cutting body of a cutting element at least partially disposed within a pocket of a blade of a body of an earth-boring drilling tool with the subterranean formation, an exposed surface of the sensor being recessed relative to at least a portion of a cutting surface of the cutting element;

energizing the sensor of the cutting element while the sensor is in contact with the subterranean formation;

sensing a return signal flowing on or through the subterranean formation; and

determining a resistivity of the subterranean formation based, at least in part, on the return signal.

20. The method of claim 19, wherein energizing the sensor comprises applying a current into the subterranean formation through the sensor using a voltage source of a current source, and wherein sensing the return signal occurs through the sensor of the instrumented cutting element.

21. The method of claim 19, wherein energizing the sensor and sensing the return signal includes generating current flowing between the instrumented cutting element and another instrumented cutting element.

22. The method of claim 21, wherein generating current flowing between the instrumented cutting element and another instrumented cutting element includes generating current flowing between the sensor of the instrumented cutting element and another sensor of the another instrumented cutting element.

23. The method of claim 19, wherein determining a resistivity of the subterranean formation includes determining a horizontal resistivity and a vertical resistivity of the subterranean formation.

24. The method of claim 23, further comprising determining porosity of the subterranean formation using the determined horizontal resistivity and vertical resistivity.