CLAIMS

1. A semiconductor device, comprising:

a source;

a drain;

a channel comprising a nanostructure, the nanostructure comprising an unmodified portion and a modified portion including a localized dopant species, the modified portion having an increased trap state density relative to the unmodified portion, and the modified portion being functionalized with an active moiety; and

a gate terminal in electrical communication with the nanostructure.

2. The semiconductor device of claim 1, wherein the nanostructure comprises at least one of: a nanowire, a nanotube, and a nanoribbon.

3. The semiconductor device of claim 1, wherein the nanostructure comprises at least one of: a silicon nanowire, a carbon nanotube, a polymer nanowire, a graphene nanoribbon, and a MoS_2 nanoribbon.

4. The semiconductor device of claim 1, wherein the nanostructure comprises at least one of: graphene, silicene, and phosphorene.

5. The semiconductor device of claim 1, wherein the modified portion is formed by ion implantation, diffusion doping, energetic beam irradiation, plasma exposure, or a combination thereof.

6. The semiconductor device of claim 1, wherein

the active moiety comprises an enzyme or an aptamer that is linked to the modified portion of the nanostructure.

7. The semiconductor device of claim 6, wherein the linked enzyme or aptamer is covalently bonded to the modified portion of the nanostructure.

8. The semiconductor device of claim 1, wherein the active moiety is a single molecule of one of the following: a single enzyme, a single antibody, and a single aptamer.

9. The semiconductor device of claim 1, wherein the increased trap state density is in a range of about 1×10^{-12} traps / cm^2 to about 1×10^{-14} traps / cm^2.

10. An apparatus, comprising:

the semiconductor device of claim 1; and

a vessel at least partially enclosing the nanostructure, the vessel to receive an analyte solution providing the electrical communication between the gate terminal and the nanostructure.

11. An apparatus comprising the semiconductor device of claim 1, wherein:

the semiconductor device further comprises a body terminal coupled to a modulated signal input; and

the gate terminal is coupled to a fixed voltage.

12. An apparatus comprising a current sensor or ring oscillator, the current sensor or ring oscillator comprising the semiconductor device of claim 1.

13. A method of manufacturing, the method comprising:

depositing a nanostructure over a substrate having at least one source region and at least one drain region within or over the substrate to form an electrically conductive channel between the source region and the drain region, the nanostructure comprising an unmodified portion and a modified portion including a localized dopant species, the modified portion having an increased trap state density relative to the unmodified portion;

linking an active moiety to the modified portion; and

providing a gate terminal in electrical communication with the nanostructure.

14. The method of claim 13, further comprising generating the modified portion having the increased trap state density by implanting ions to a nanostructure portion.

15. The method of claim 13, further comprising generating the modified portion having the increased trap state density by performing localized doping of a nanostructure portion.

16. The method of claim 13, further comprising generating the modified portion having the increasing the trap state density by adjusting a composition of a source material in a chemical vapor deposition process when depositing the nanostructure over the substrate.

17. The method of claim 13, wherein the nanostructure comprises at least one of: a nanowire, a nanotube, and a nanoribbon.

18. The method of claim 13, wherein the nanostructure comprises at least one of: a silicon nanowire, a carbon nanotube, a polymer nanowire, a graphene nanoribbon, and a MoS_2 nanoribbon.

19. The method of claim 13, wherein the nanostructure comprises at least one of: graphene, silicene, and phosphorene.

20. The method of claim 13, further comprising:

selecting: a desired ΔC_{ox} parameter, or a desired drain current to gate voltage response, or the desired ΔC_{ox} parameter and the desired drain current to gate voltage response;

selecting a desired trap state density for the modified portion; and

increasing the trap state density according to the selected desired trap state density.

21. The method of claim 20, further comprising selecting at least one of a material and a dosage for the modified portion according to the selected desired trap state density.

22. A method of using the semiconductor device of claim 1, comprising:

providing an ionic solution in proximity with the channel;

applying a signal to the gate terminal, or to a body terminal coupled to a modulated signal input while the gate terminal is coupled to a fixed voltage; and

detecting changes in current flow through the channel responsive to the applied signal.

23. The method of claim 22, wherein the signal is modulated at a frequency exceeding a plasma frequency of the solution.

24. The method of claim 22, wherein the solution has a salinity ranging from about 1 millimolar (mM) to about 500 millimolar (mM).

25. The method of claim 22, wherein the detecting of changes in current flow comprises detecting a phase change of an output signal relative to the signal applied to the gate terminal or the body terminal.

26. The method of claim 22, further comprising sequencing a series of nucleotides in a deoxyribonucleic acid (DNA) or ribonucleic acid (RNA) molecule based on the detected changes.