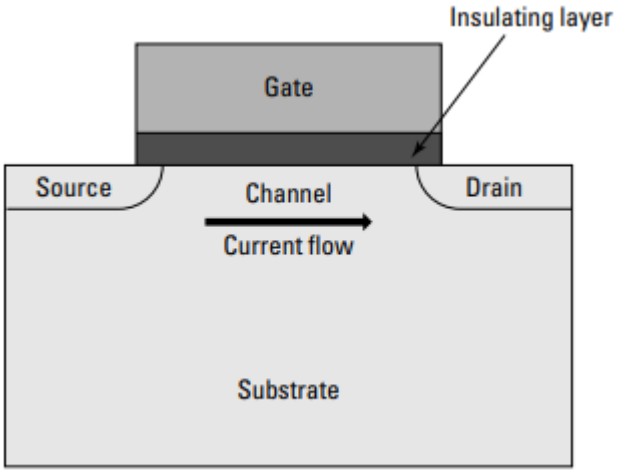
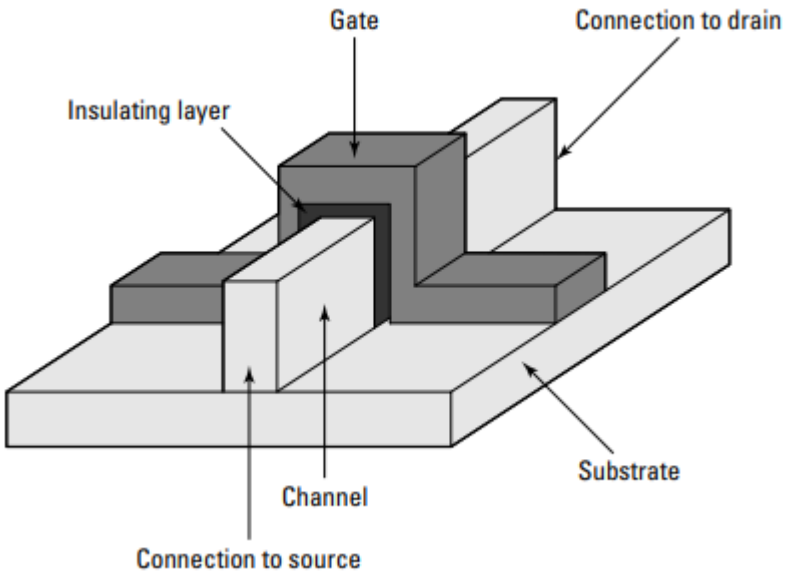
Lecture-14. Applications of nanomaterials

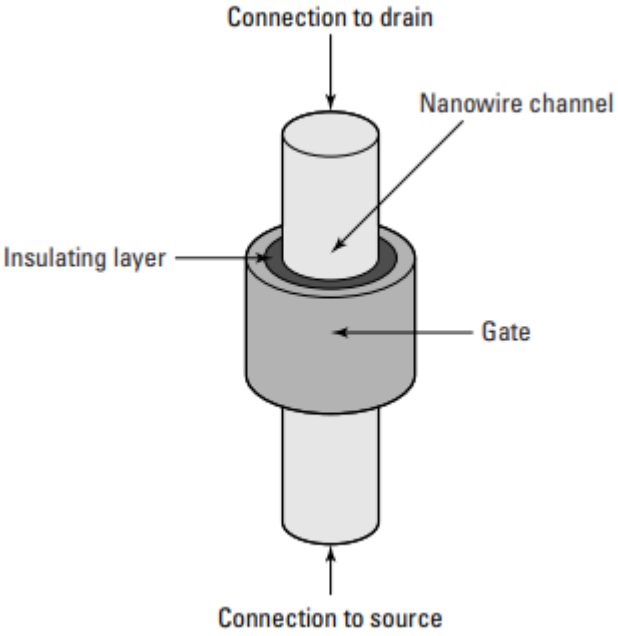
Shrinking the transistor is key to making your computer more powerful. The structure of the type of transistor used in microprocessors containing hundreds of millions of transistors on an integrated circuit is called a FET, for field-effect transistor. A FET is shown in Figure 6-1.



Placing a voltage on the gate allows a current to flow through the channel between the source and the drain. The transistor is therefore acting as a switch, not unlike the wall switch you use to turn your lights off and on. Current flows when voltage is applied to the gate; current stops flowing when no voltage is applied to the gate. As the channel length gets smaller, however, the chance of current leaking through the channel between the source and the drain increases, even when no voltage is on the gate. Integrated circuit manufacturers are planning to modify this structure for minimum feature sizes of about 14 nm and less to reduce the amount of leakage through the channel. This modified transistor, called a finFET because of the fin-shaped channel above the substrate, is shown in Figure 6-2.



With the gate on the top and two sides of the channel, the voltage applied to the gate has more effect on the channel than in the conventional FET, which has the gate only on the top surface of the channel. Researchers report that, compared to conventional FETs, this setup reduces the leakage of current through the channel when you turn off the transistor. As we go to press, Intel has announced that they are implementing a finFET transistor structure called Tri-Gate on their 22-nm microprocessors. Using these transistors will provide either reduced power consumption at the same speeds as their current 32-nm microprocessors or increased speeds with the same power consumption. Using a nanowire as the channel of the FET is a method that researchers are exploring to make even more progress in reducing current leakage. A nanowire transistor consists of a nanowire made of semiconducting material, such as silicon, connecting the source and drain of the transistor, with a gate controlling the current flow through the nanowire. Figure 6-3 shows the structure of a nanowire transistor; the nanowire is vertical, like the fin, rising up from the substrate.



Using a nanowire as the channel allows you to completely wrap the gate around the channel. This should allow the voltage applied to the gate to have even more control over the channel than when using the finFET (refer to Figure 6-2). This vertical structure also saves space, allowing a higher density of transistors on a chip. Millions or billions of vertical nanowires could be grown on a substrate, like a dense but tiny forest.