Parkland College

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Basic MOSFET Fabrication

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By Dan Ivy

Introduction

The MOSFET, or metal-oxide-semiconductor field-effect transistor, are the sole entities responsible for processing in microchips of everyday electronics. Believe it or not, we use billions of these every day in practically every electronic device we use, from cell phones and computers to cars and TVs. These transistors have become extremely small with the advancement of technology, as companies such as I.T.R.S. are working on production of MOSFETs smaller than 16 nanometers[1], that's small enough to fit over 2.5 trillion transistors side to side in a single square inch. But how can anyone manufacture such a small product?

Method

The process of fabricating the MOSFET requires a spectrum of processes ranging from soaking the transistor in the extremely pure water to placing it in front of a particle accelerator.

Process

The Start

The process of fabricating a microchip begins with a thin disk of pure silicon (Si), called a wafer. First, the wafer is washed in a solution of ammonium hydroxide (NH4OH), hydrogen peroxide (H2O2), and extremely pure water to remove any impurities from the outside of the wafer. Next, the wafer is lightly doped to a p-type silicon and is washed in the solution once again.[2] (See Fig. 1)

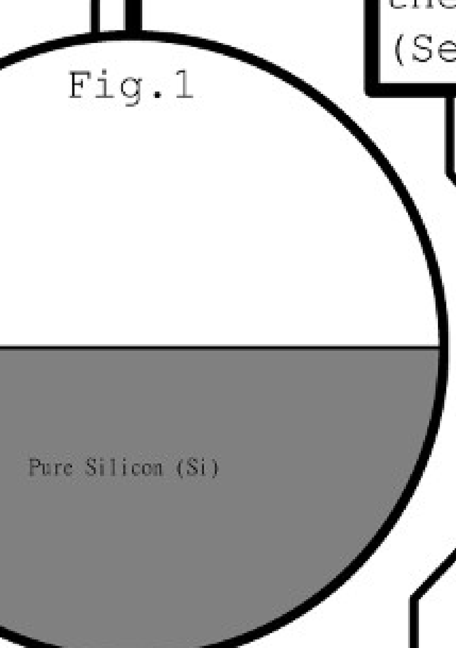

Fig.1

Doping?

No, I'm not talking about sports. Dopant is defined as "an impurity added intentionally in a very small, controlled amount to a pure semiconductor to change its electrical properties"[3]. This process of adding an impurity is referred to as doping. But how is this done? One way to dope the silicon of a microchip is to accelerate gaseous ions to high speeds inside of an electromagnetic field above the wafer so that the ions and are forcibly implanted inside of the silicon.[4] (See Fig. 2)

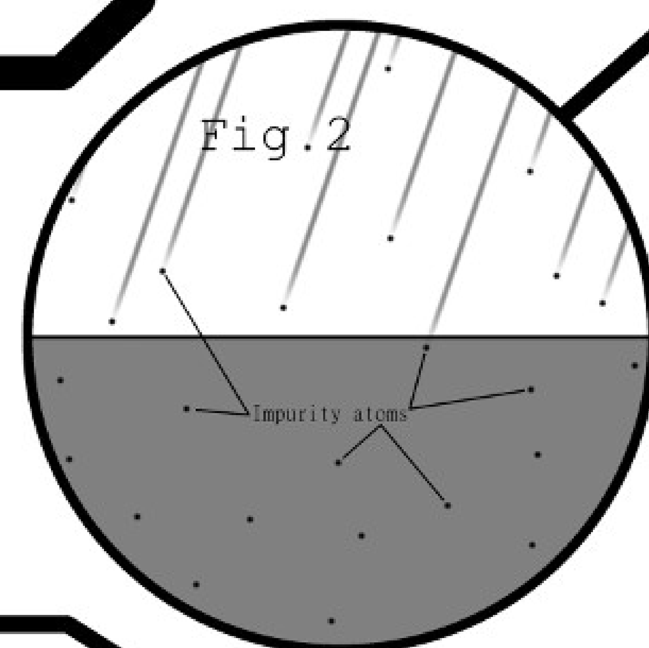

Fig.2

N and P Type

When the silicon is doped, either n-type or p-type silicon is produced. A n-type silicon refers to silicon with a dopant of negatively charged ions, referred to as electrons (not to be confused with the electron particle), such as anions of arsenic, antimony, or phosphorus. A p-type silicon substrate refers to silicon with a dopant of positively charged ions, referred to as holes, such as cations of gallium, boron, or indium.[5] (See Fig. 3)

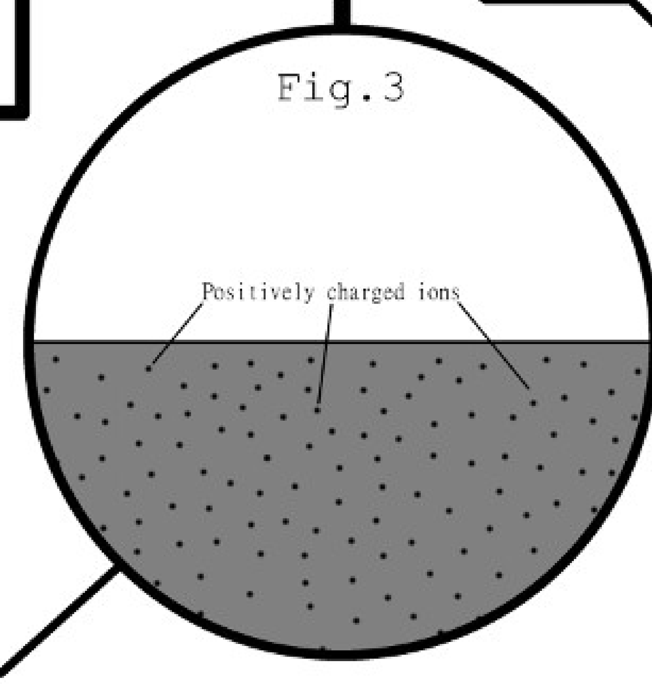

Fig.3

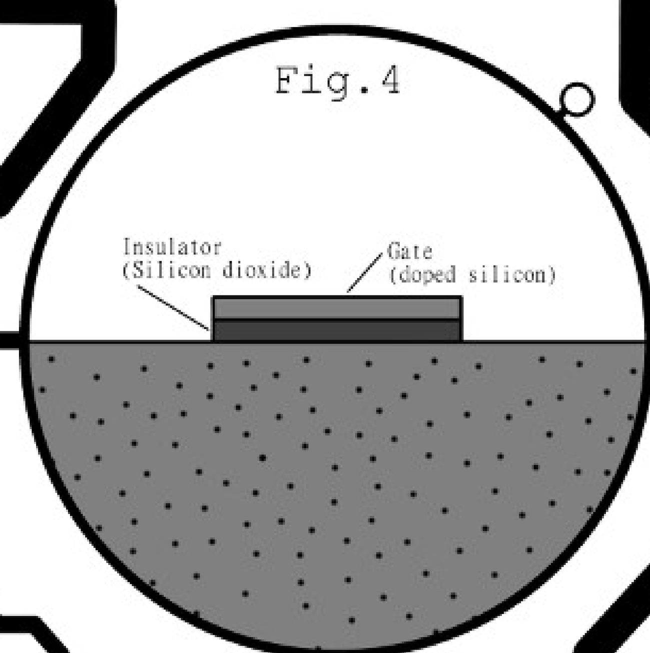

Fig.4

The Gate

Next, the wafer reacts with oxygen gas inside of an oven to produce the electrical insulator silicon dioxide (SiO2) on the surface of the MOSFET. This insulator is used to prevent electrical current from flowing through the gate and into the body of each MOSFET. Next, the conductive gate is made by exposing the insulator to a gas such as trichlorosilane (SiHCl3) and then doping the resulting silicon deposit for conductivity. When the wafer is exposed to the trichlorosilane, the silicon from the gas breaks apart from the gas molecule and attaches onto the wafer's surface, forming a thin layer of silicon crystals. Then the wafer is etched by exposing the unwanted silicon to a solution of hydrofluoric acid (HF) and ammonium fluoride (NH4F), which removes the crystals in these areas.[2] (See Fig. 4)

Source and Drain

Just like the gate, two regions on either side of the gate, called the source and the drain, are made by etching the regions to remove a small amount of the p-type silicon and replacing the missing silicon with n-type silicon. The n-type silicon is made by exposing the wafer to trichlorosilane gas again, doping the resulting silicon crystals, and etching away the unwanted n-type silicon (See Fig. 5). Finally, a conductive metal such as aluminum is added to the gate, source, and drain of each MOSFET so that they can be connected to the circuit.[2]

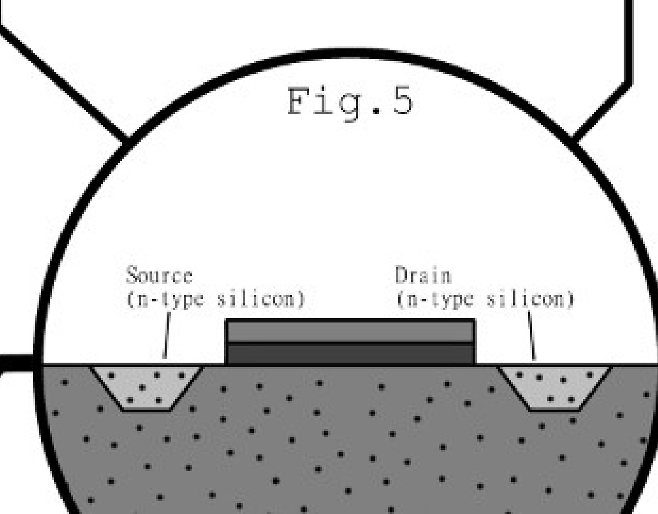

Fig.5

Results

When this process is complete, the MOSFET operates like a mechanical switch without the need for any moving parts. This is done by the resistance of the p-type silicon in the MOSFET. When there is no charge at the gate, tension between the holes of the p-type silicon and the electrons of the n-type silicon prevent any current from traveling from the source to the drain (See Fig. 6). When a voltage is applied to the gate, the electromagnetic field produced by the lack of electrons in the gate pushes the holes in the silicon away from the gate and produces a tunnel of pure, conductive silicon from the source to the drain.[2] (See Fig. 7)

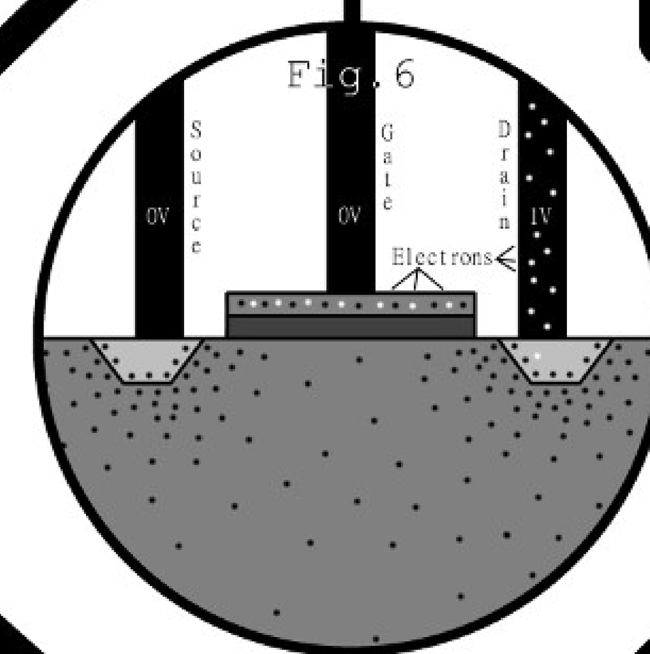

Fig.6

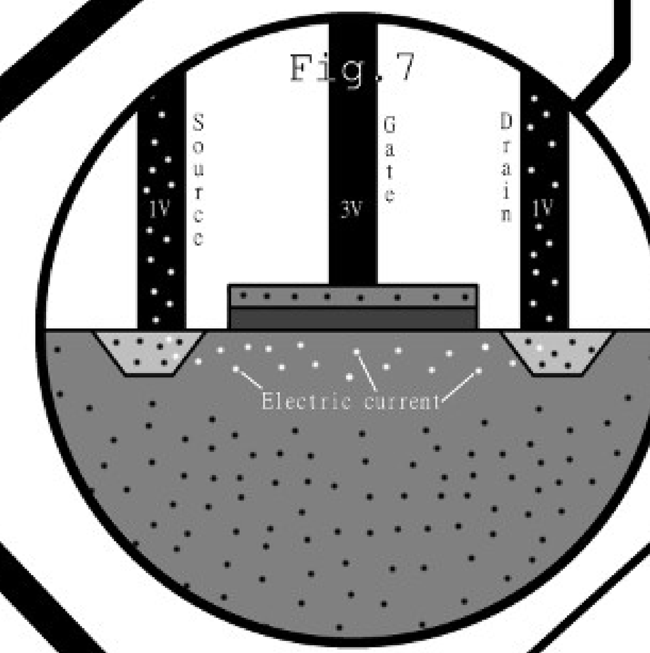

Fig.7

Conclusion

By using the simple process of pushing ions away with a nearby electric charge, a switch can be compressed down to unimaginable sizes. But as these switches become even smaller, quantum mechanics comes into play as the electrons begin to use quantum tunneling by jumping from the source to the drain without ever passing through the p-type silicon. Even though the size of the MOSFET is becoming so small that they are becoming unstable, MOSFET manufacturers are still pioneering the nanotechnology industry by continuously reimagining the smallest form of technology.

Works Cited

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