

ECE 594 Micro System Design
Homework #1
Summit by Chen, Diun-Huang

1. What is a MOS process? Explain briefly NMOS and CMOS processes.

“CMOS” Complementary-symmetry/metal-oxide semiconductor (CMOS) is major class of integrated circuits. CMOS chips include microprocessor, Microcontroller, static RAM and other digital logic circuits.

In CMOS, there have both N-type and P-type transistors are used to realize logic functions. Today, CMOS technology is the dominant semiconductor technology for microprocessors, memories and application specific integrated circuits (ASICs). The main advantage of CMOS over NMOS and bipolar technology is the much smaller power dissipation. Unlike NMOS only dissipated in case the circuit actually switches. This allows integrating many more CMOS gates on an IC than in NMOS or bipolar technology, resulting in much better performance.

The words “Complementary-symmetry” refer to the fact that the design uses symmetrical pairs of p-type and n-type MOSFET transistor for logic functions, only one of which is switched on at any time.

Two important characteristics of CMOS devices are high noise immunity and low static power supply drain. Significant power is only drawn when its transistors are switching between on and off states; consequently, CMOS devices do not produce as much heat as other forms of logic such as TTL. CMOS also allows a high density of logic function on the chip.

The phrase “metal-oxide-semiconductor” is a reference to the nature of the fabrication process originally used to build CMOS chips. That process created field effect transistors having a metal gate electrode placed on top of an oxide insulator, which in turn is on top of a semiconductor material. Instead of metal, today the gate electrodes are almost always made from a different material, polysilicon, but the name CMOS nevertheless continues to be used from the modern descendants of the original process.

CMOS Logic uses a combination of p-type and n-type metal-oxide-semiconductor field effect transistors (MOSFET) to implement logic gates and other digital circuits found in computers, telecommunications and signal processing equipment. Although CMOS logic can be implemented with discrete devices (for instance, in an introductory circuits class), typical commercial CMOS products are integrated circuits composed of millions (or hundreds of millions) of transistors of both types on a rectangular piece of silicon of between 0.1 and 4 square centimeters. These bits of silicon are commonly called chips. Although within the industry they are also referred to as die, perhaps because they are the result of dicing (that is, cutting up) the circular silicon wafer which is the basic unit of semiconductor device fabrication.

In CMOS logic gates a collection of n-type MOSFETs is arranged in a pull-down network between the output and the lower-voltage power supply rail (often named V_{SS}). Instead of the load resistor of NMOS logic gates, CMOS logic gates have a collection of p-type MOSFETs in a pull-up network between the output and the

higher-voltage rail. (Often named V_{dd}) The p-type transistor network is complementary to the n-type transistor network, so that the n-type is off, the p-type is on, the p-type is on, and vice-versa.

CMOS logic dissipates less power than NMOS logic because CMOS dissipates power only when switching (dynamic power). On a typical ASIC in a modern 90 nanometer process, switching the output might take 120 picoseconds, and happen once every ten nanoseconds. NMOS logic dissipates power whenever the output is low (static power). Because there is a current path from V_{dd} to V_{ss} through the load resistor and the n-type network.

p-type MOSFETs are complementary to n-type because they turn on when their gate voltage goes sufficiently below their source voltage, and because they can pull the drain all the way to V_{dd} . Thus, if both a p-type and n-type transistor have their gates connected to the same input, the p-type MOSFET will be on when the n-type MOSFET is off, and vice-versa.

2. Explain the following in terms of semiconductor technology:

The first integrated circuit, or IC, was independently co-invented by Jack Kilby at Texas Instruments and Robert Noyce at Fairchild Semiconductor in 1959. An IC integrates multiple electronic components on one substrate of silicon.

Semiconductor has two different types of technology which are including Bipolar Technology and Hybrid Technology.

a. Bipolar Technology

The bipolar junction transistor (BJT) has three electrodes and two pn junctions. A BJT is configured as an npn or pnp transistor and biased for conduction mode. It is a current-amplifying.

b. Hybrid Technology

Trends in power semiconductor technology indicate a tradeoff in the selection of power devices in terms of switching frequency and voltage-sustaining capability. Now power converter topologies permit modular realization of multilevel inverters using a hybrid approach involving integrated gate commutated thyristors (IGCTs) and insulated gate bipolar transistors (IGBTs) operating in synergism. There are the hybrid multilevel power conversion systems typically suitable for high-performance high-power applications.

3. Read the article “how chips made” at URL

There are some points to describe that “how chips made”. In the beginning, we need to discuss about the product of material. The basic element is Silicon. Silicon wafers cut from an ingot of pure silicon are used by Intel to make microprocessors. Silicon, the primary ingredient of beach sand, is a semiconductor of electricity. Semiconductors are materials that can be altered to be either a conductor or an insulator.

In those materials, there are including some chemicals and gases to be used throughout the chip-making process. Some, like hexamethyldisilazane (I am first time to learning this vocabulary), are complex and difficult to pronounce. Otherwise, such as boron, those are simple elements found in the Periodic Table of the Elements. And also some of metals such as aluminum and copper are used to conduct the electricity throughout the microprocessor. Gold is also used to connect the actual chip to its package.

Ultraviolet (UV) Light has very short wavelengths and is just beyond the violet end of the visible spectrum. Ultraviolet light is used to expose patterns on the layers of the microprocessor in a process much like photography. Masks used in the chip-making process are like stencils. When used with UV Ultraviolet Light, masks create the various circuit patterns on each layer of the microprocessor.

Moreover, those microprocessors are built in layers on a silicon wafer through various processes using chemicals, gases, and light. Although, there are several microprocessors have been built on a single wafer. On those wafer, the first layer of silicon dioxide is grown by exposing, also it is to extreme heat and gas. This growth is similar to the way rust grows on metal when exposed to water. There silicon dioxide on the wafer, however, grows much faster and is too thin to be seen by the naked eye. The wafer is then coated with a substance called photoresist, which is a function to reject light involve. Photoresist becomes soluble when exposed to ultraviolet light.

In addition, there is in a process called photolithography, ultraviolet light is then passed through a patterned mask, or stencil, onto the silicon wafer. The mask protects parts of the wafer from the light. The light turns the exposed areas into a gooey layer of photoresist. In order each layer on the microprocessor uses a mask with a different pattern. The gooey photoresist is completely dissolved by a solvent. This reveals a pattern of photoresist made by the mask on the silicon dioxide.

On the other hand, the revealed silicon dioxide is etched away with chemicals. The rest of the photoresist is removed. This process leaves ridges of silicon dioxide on the silicon wafer base.

After we finish to discussion the first layer, we can go to begin another layer; a second, thinner layer of silicon dioxide is grown over the ridges and etched areas of the wafer base. Then, a layer of polysilicon and another layer of photoresist are applied. Ultraviolet light is then passed through a second mask, exposing a new pattern on the photoresist.

Then, the photoresist is dissolved with solvent to expose the polysilicon and silicon dioxide, which are then etched away with chemicals. The remaining photoresist is removed and leaving ridges of polysilicon and silicon dioxide.

There are through a process called ion implantation, which is also called doping, the exposed areas of the silicon wafer are bombarded with various chemical impurities called ions. Ions are implanted in the silicon wafer to alter the way silicon in these areas conducts electricity. The layering and masking processes are repeated, creating windows that allow for connections to be made between the layers.

In this layer, atoms of metal are deposited on the wafer, filling the windows. Another masking and etching stage leaves strips of the metal that make the electrical connections. According to the article, roughly 20 layers are connected to form the microprocessor's circuitry in a three-dimensional structure. The exact number of layers on a wafer depends on the design of the microprocessor.

So far, we've built only a tiny portion of a microprocessor. In reality, making microprocessors is much more complex, demanding more than 250 steps. Consequently, hundreds of identical microprocessors are created in batches on a single wafer. On the wafer, the microscopic circuitry of each and every microprocessor is tested. Then the wafer is cut with a diamond saw, separating the microprocessors.