Solutions to Homework Number Five
Due Wednesday November 25, 2013

1) Prepare a report comparing the manufacture of a circuit using a populated circuit board and the manufacture of an integrated circuit.

A circuit is a closed electrical path designed to achieve a specific purpose. A conductive path between desired components is required. However, insulation is also required, so that components are not "shorted out" and that an electrical connection is only present between desired components. Both printed circuit boards and integrated circuits are circuits. Therefore, their manufacture must be considered from this perspective.

To make a printed circuit board a board of insulating material is coated with copper (or another metal). Copper is then selectively removed from certain parts of the board. This leaves an electrical path between desired components, and insulation elsewhere. The details of the process are described in the following paragraphs.

- Epoxy is poured over a fiberglass and allowed to harden. This "board" is then placed in a bath and coated with copper, typically through an electrolytic process. Once coated with a thin layer of copper the board is coated with a photoresit to enable removal of unwanted copper.

- Photoresist is a chemical which will change when exposed to light. A pattern of the circuit is placed over the board and then exposed to light. Regions which were exposed to light will change. The exposed photoresist and underlying copper are removed through etching (a chemical removal process). The remaining copper replicates the pattern which was placed over the board. If necessary, holes are drilled in the appropriate locations for component placement.

- The board is complete once components are placed and soldered to the board.

Like a printed circuit board the integrated circuit will contain electrical components (devices) appropriately connected. Insulation will prevent short circuiting or undesired connections between components. The main difference between an integrated circuit and a populated circuit board is that when making an integrated circuit the devices are created as the circuit is created. When making a populated circuit board the components are placed on the board after the circuit is made.

An integrated circuit is an electrical circuit on a silicon wafer. This wafer is initially very pure. By adding small amounts of other elements to the silicon it is possible to make resistors, diodes and transistors. These can be combined to make more complicated devices such as logic gates and op-amps. It is possible to place metal on the silicon wafer through a chemical reaction known as metallization and insulation through oxidation (exposure to oxygen). As with printed circuit board assembly photoresist and etching are used to remove unwanted material.

For example to form a circuit where a diode was connected to a resistor one would do the following.

Step 1) A silicon wafer would be obtained.

Step 2) This wafer would be covered with a material containing the appropriate doping element (boron, aluminum, phosphorus, or arsenic). If an n-type material were being prepared either phosphorus or arsenic containing material would be used. When heated, diffusion would occur (diffusion is the mixing of materials in the solid) state.

Once an appropriate time had passed the material would have a specific amount of dopant and a certain resistivity. This would enable one to make a resistor by specifying the dimensions.

Step 3) The material would be oxidized.

Step 4) Photoresist would be placed on the wafer.

Step 5) A pattern would be placed in the way of a light (sometimes UV or X-rays are used) source. The unblocked areas of the photoresist would be exposed.

Step 6) Etching would remove the exposed photoresist and the silica (oxidized silicon)

Step 7) The exposed silicon would be exposed to positive (boron or aluminum) ions through ion implantation.) There is now a p-type region next to an n-type region. This is a diode. The device has been made on the circuit.

Step 8) The entire wafer would be oxidized.

Step 9) Photoresist would be placed on the wafer.

Step 10) A pattern would be placed in the way of a light (sometimes UV or X-rays are used) source. The unblocked areas of the photoresist would be exposed.

Step 11) Etching would remove the exposed photoresist and the silica (oxidized silicon)

Step 12) The exposed silicon would be metallized.

Step 13) The remaining unexposed photoresist would be removed.

The circuit is now complete. The diode and resistor have been fabricated and connected, The remaining parts of the circuit are insulated from each other.

2) Your supervisor is holding a chip that measures 3x3 inches in one hand, and a bunch of resistors, capacitors, and diodes in the other. They ask you "Someone told me that this thing has 100,000 electric components and is only 0.5in x 0.5inches. I figured this out because they told me they could make 500 of these on a 12 in wafer of Si. OK, how do they get these things (the components) into this (the chip) and I figured they can only get 12 of these (the chips) into a 12in diameter circle. What is going on?" Answer their question.[1]

The supervisor is not holding an integrated circuit but an IC package. The IC is enclosed inside the package in order to protect it and enable connection with other parts of the circuit board. The IC itself is a small part of the package.

The components the supervisor are holding are those that would be placed on a circuit boars. When making an IC the components are made on a silicon wafer along with the rest of the circuit. By adding atoms of p or n type material one can make diodes, resistors, transistors, op amps etc. By metallizing one makes the conductive path and by oxidizing the insulation. Everything is made at once.

[1]You should expect more of this type of question on HW's, tests and the final examination. Explaining misconceptions is a key way to demonstrate your knowledge.