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WHERE STUDENTS MAKE THEIR OWN CHIPS

WHEN the Irish dramatist George Bernard Shaw wrote his condemnation of the teaching profession, "He who can, does. He who cannot, teaches", he came close to identifying one of the main difficulties in educating engineering students. It lies in ensuring that the teaching of theoretical principles is firmly identified with the real world of engineering design and manufacture.

Most degree courses in electronics engineering include lectures on the principles of semiconductor devices, explaining how such components as transistors and diodes operate. At the University of Dundee in Scotland we have taken this study one stage further: undergraduates are regularly designing and making silicon chips as part of their normal project and laboratory work.

Our involvement with this branch of engineering began several years ago because the University is close to makers of semiconductors in cen- ment which has two fortuitous properties. Frist, it is easy to oxidise its surface in a furnace to produce a stable coating of silicon dioxide glass (silica), which is an excellent electrical insulator. Second, it is easy to change the value of its electrical conductivity by adding relatively small amounts of either phosphorus or boron. The electric currents which flow in silicon are due to the movement of negatively-charged electrons (n-type Si) or, on the other hand, due to what appear to be positively-charged particles known as positive holes (p-type Si). The latter behaviour is somewhat surprising; it arises from the way in which electrons interact with atoms of silicon, especially in the presence of certain other types of atom such as boron.

The simplest active component of an integrated circuit is the MOSFET (Metal Oxide Semiconductor Field Effect Transistor). Its structure is shown in the first diagram, where ground, each measuring some five micrometres square. Because the whole chip will be only about five millimetres square or even smaller, there is room on the plate for the detail contained in at least 200 identical chips, arranged on the photograph like a sheet of stamps. This detail is then transferred to the surface of the silicon by a process called photolithography. It means coating the oxidised surface of a thin disc of silicon (called a silicon wafer) with a layer of a substance known as photoresist, which is sensitive to ultraviolet light. Using the photographic plate and UV light produces an image of the circuit features in the photoresist which, when treated with acid, reveals the source and drain regions as tiny rectangular holes in the silica and exposes the surface of the silicon.

Manufacturing processes that follow include the diffusion of boron or phosphorus through the holes in the separation of 10 um between source and drain. The layout details for each chip are designed with the aid of a mainframe computer and are stored on magnetic tapes. Initial artwork is produced from the tapes using equipment for reproducing weather satellite photographs (we have not been fortunate enough to obtain the appropriate pattern generator for this stage). The main fabrication processes are then undertaken. To make working conditions as realistic as possible, everyone wears a full set of clean-room clothing resembling a surgical hood and gown. Students are also asked to assess the cost of bringing each design to fruition.

This activity provides a wealth of practical experience and puts the importance of the lecture courses into perspective. Students are encouraged to consult key research papers as well as standard textbooks to help them identify causes

Structure of the basic MOSFET (left). Application of a positive voltage V to its gate (right) switches the transistor into the 'on' stage.