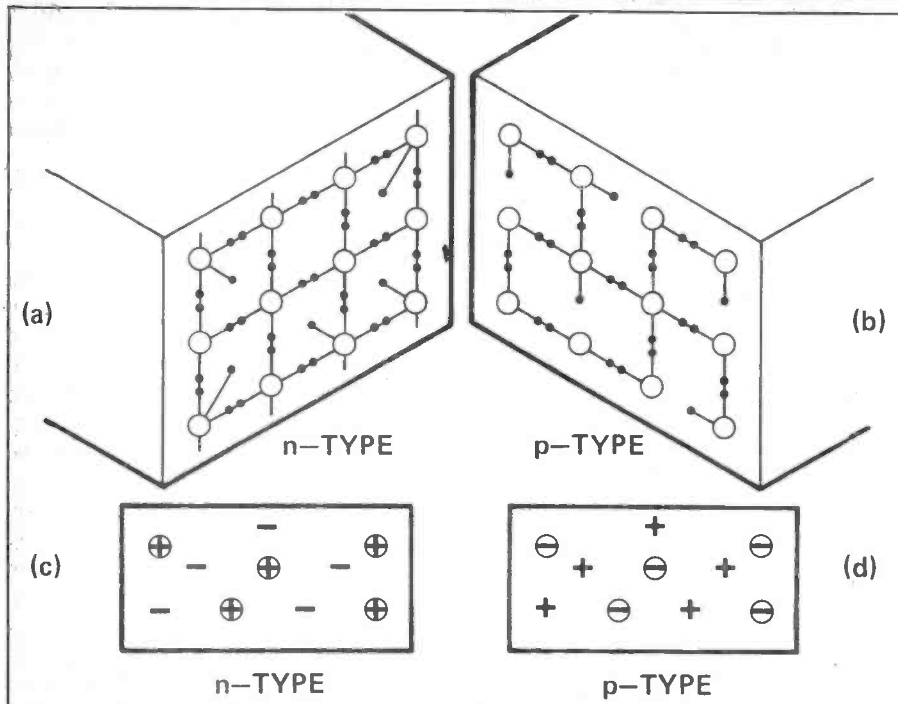

Fig. 5 Diagramatic representations of the front plates of n-type and p-type before fusing together (a and b), and in simplified form showing just the parent atoms (circled + and – signs) and the free electrons and holes (uncircled – and + signs) (c and d).

The P—N Junction

So far we have only looked at a cross-section of crystalline material. If we consider it in a block, we consider it as a series of parallel plates of crystalline material such as that represented in **Fig.4**. This is quite a reasonable hypothesis since coal is an example of crystalline material and coal tends to break up across flat plates!

Fig. 5(a) and **Fig. 5(b)** represent the front plates of n-type and p-type before they are fused together. The 'plates' behind will be similar throughout the material.

Fig. 5(c) is a diagrammatic representaion of n-type material where 'free' electrons have become detached from their parent atoms leaving positively charged ions behind. Circled + symbol represents an ion with a positive charge, each – represents a 'wandering' electron. Similarly in **Fig. 5(d)** for the p-type material, the caes where electrons have managed to detach themselves from their parent atoms and their pair-bonds and have linked up with electrons in atoms next to impurity atoms, so giving some atoms an overall negative charge (represented by a circled – sign) while leaving genuine holes behind. These holes are represented by the + symbols.

Consider the result of fusing p-type material to n-type material. **Fig. 6(a)** represents the picture immediately the fusing takes place. At this point the free electrons in the n-type come under the attraction of the genuine holes in the p-type and will feel induced to move across the junction. A short while after fusion they will have done so and we will have the situation shown in **Fig. 6(b)**. Here, the plates in the n-type nearest to the junction contain atoms with an overall positive charge but no spare electrons to cancel out this effect. Hence this layer in the n-type will have become positively charged.

Similarly the front plates of the p-type material will have had their genuine holes completed by electrons from the n-side and consequently will have gained a surplus of electrons and hence a negative charge overall. Because the force of attraction exerted by the 'holes' is limited, the 'holes' farther away from the junction are unable to attract electrons across this charged junction, the remaining free electrons being too far away.

Fig. 6(c) and **Fig. 6(d)** show the effect if the fused material is now broken open at the junction. In the n-type pentavalent impurities are an electron short and so have become positive ions. In the p-type the intrinsic atoms next to trivalent impurity atoms have pair-bonded their 'lonely' electrons and consequently gained an extra electron and have become negative ions.

If we now look at diagram **Fig. 6(e)**, the fused materials and the junction – known as the **p-n junction** – are represented. There is n-type material containing wandering electrons but balanced by the number of available holes; then n-type material with holes but no electrons to cancel them out – hence a positive electrical charge; then p-type material containing extra electrons, but no spare holes – hence a negative charge electrically; finally p-type material with 'overmanned' atoms but also enough spare holes to cancel these out.

The charged layer is known as the **depletion layer**. Electrons which cross the junction from the n-side are called **minority carriers**, when they reach the p-side. Holes that diffuse into the n-side are known as **minority carriers** in the n-side.

The depletion layer needs further investigation. It is void of free electrons on the n-side and of holes on the p-side. The resulting electric field set up acts as a barrier to further electron movement across the junction. The name given to the electric field is the **junction barrier**. Because one side has a positive charge and the other a negative charge we have a situation equivalent to that in a battery, where there is a potential difference across the terminals. The potential difference across the junction barrier is, in effect, measured as the sum of the excess electrons captured in the p-side of the junction and the holes left in the n-side of the junction. It is measured in volts and is called the **space charge** or **barrier voltage**. The actual value of the voltage (of the order of tenths of a volt) is also known as the **height** of the junction barrier. It should be noted that the depletion layer is extremely thin!

Conduction

When p-type and n-type materials are fused in this way we have what is known as a **junction diode**. If we now connect a battery across this junction diode with the **positive** terminal of the battery connected to the p-side of the diode, we have a situation where the action of the battery *adds* to the natural inclination of the holes in the p-side to attract electrons from the n-side. In other words there is now *extra pull* on the p-side. It's rather like