less. This is of great importance, as we shall see further on, in the heat treatment of steel.

In the transformation of white tin (β-Sn) to grey tin (α-Sn), the volume increases by 26 per cent. This increase in volume hinders the allotropic transformation β-Sn⇄α-Sn, which takes place only on the surface of the metal. On the other hand, it causes asymmetric stresses in the metal which results in cracking of the brittle α-Sn and in its transformation into a grey crystallic powder (tin pest or tin plague).

The high brittleness of α-Sn is a result of its less-closely packed crystallic structure (see Fig. 4, *a*), typical of nonmetals.

1-3. Crystallographic Notation of Atomic Planes

The positions of atomic planes (planes passing through atoms) in crystal space lattices are determined by indices (h, k, l) which are three whole rational values, reciprocals of the intercepts. The

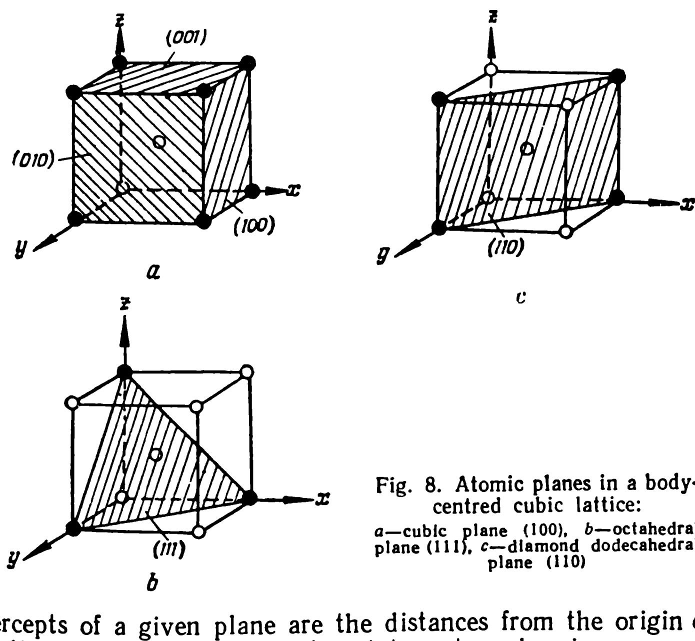

Fig. 8. Atomic planes in a body-centred cubic lattice:
a—cubic plane (100), *b*—octahedral plane (111), *c*—diamond dodecahedral plane (110)

Intercepts of a given plane are the distances from the origin of the coordinate axes at which the plane intersects each axis.

The units of length along these axes are equal to the lengths of the edges of the unit cell.

As a first example in designating such planes we may establish the indices of the planes in a cube. It is evident from Fig. 8 that

In studying the structure of steel ingots, the great Russian metallurgist Dmitri Konstantinovich Chernov first established that the

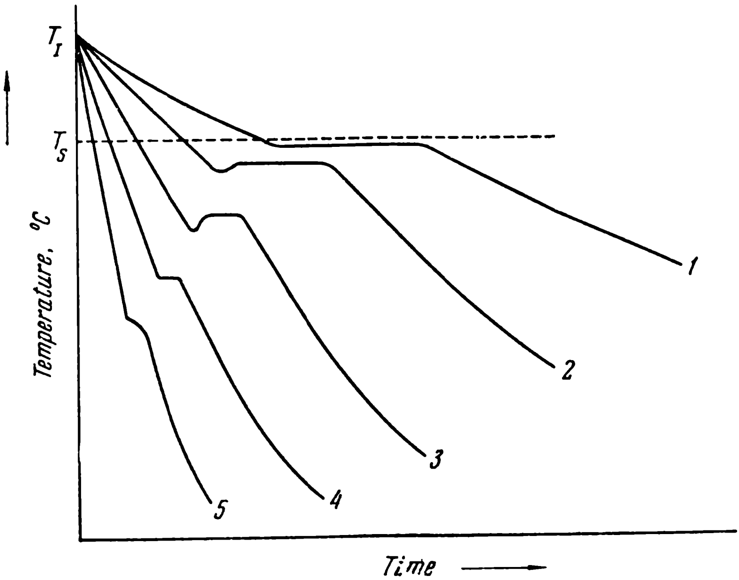

Fig. 14. Cooling curves of a pure metal

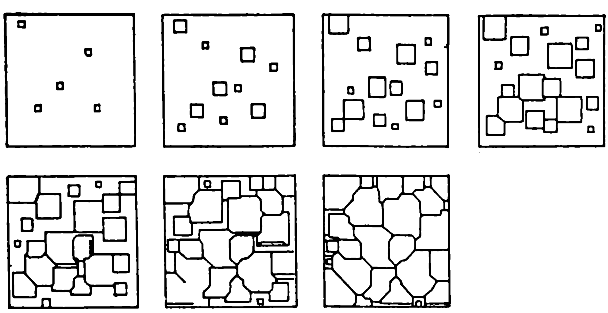

Fig. 15. Solidification of a metal (schematic) (after I. L. Mirkin)

process of solidification begins with the formation of nuclei (embryos) or centres of crystallisation and proceeds with their growth.

A schematic picture of the process of solidification is shown in Fig. 15. Upon supercooling of the liquid metal below T_s, separate crystals form, as shown in the diagram, and begin to grow. As long

Fig. 21. Macrostructure of cast steel containing 0.8 per cent C

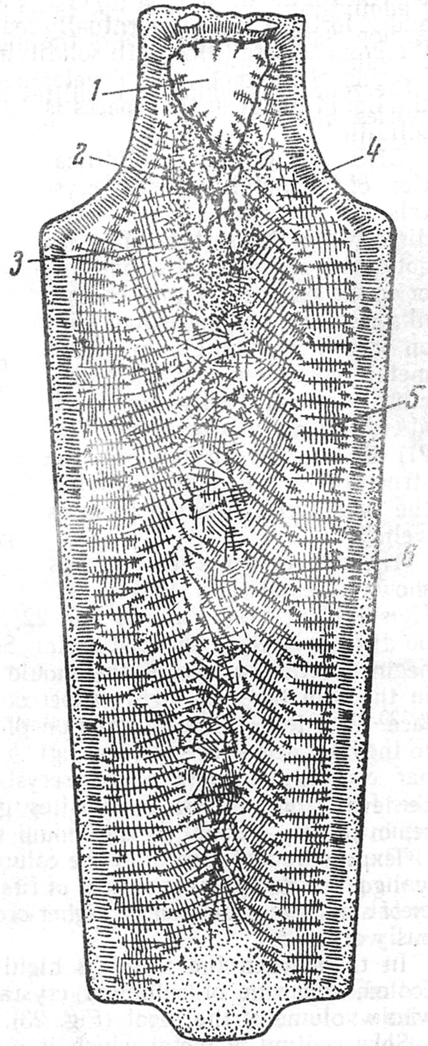

Fig. 22. Structure of a steel ingot (after N. A. Minkevich):

1—pipe, *2*—shrinkage cavities, *3*—shrinkage porosity, *4*—thin layer of fine crystallites, *5* — zone of columnar crystallites, *6*—zone of large unoriented crystallites dislocations. Slip originates at a definite point, where a dislocation exists, and proceeds by movement of the dislocation in the given plane of the crystal due to shear stresses.

The schematic diagram of slip deformation, given in Fig. 26, shows the changes in the arrangement of the atoms during the progress of dislocation movement. At first only the upper part of the crystallite

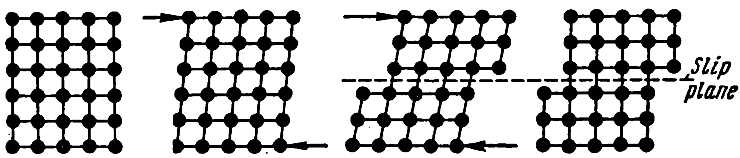

Fig. 25. Elastic and permanent deformation of a metal under the shear stresses: *a*—original crystal unstressed, *b*—elastic strain produced by shearing force below the elastic limit, *c*—increased elastic strain plus permanent strain by slip, resulting from load above the elastic limit, *d*—shearing load removed, only permanent strain remains

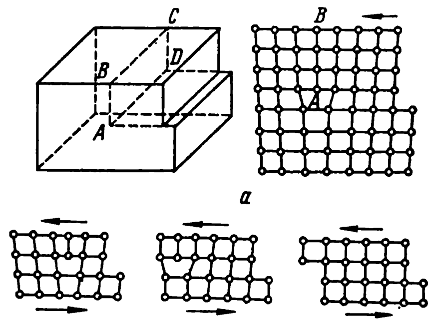

Fig. 26. Progress of a dislocation across a crystal

is displaced to the left relative to the lower part. Plane *ABCD*, in this case, will be an extra plane of atoms in the upper part of the crystallite. The edge *AD* of this plane, as mentioned earlier, is called an edge dislocation (Fig. 26, *a*).

As is evident from Fig. 26, the edge dislocation is perpendicular to the direction of slip and should be regarded as the frontal boundary of that part of the slip plane along which local displacement has occurred.

Fig. 26, *b* shows the changes that take place in the arrangement of the atoms during the movement of the dislocation. Progress of the dislocation through the whole crystallite to the opposite crystal surface causes a slip of one interatomic distance between the parts (Fig. 26, *b*).