Identification and Crystal Habit of Chromium Carbide, Cr_{23}C_6 , as determined by Electron Diffraction

DURING the course of an examination of 25/20 chromium nickel steels, residues obtained by electrolytic extraction were examined in a three-stage electron microscope. These residues had been previously examined by X-ray diffraction, which showed that the major phase was Cr_{23}C_6 together with some sigma phase. A feature of the electron microscope examination was the presence of structures which gave excellent single-crystal electron diffraction patterns. Fig. 1 shows a typical pattern which was obtained from the large transparent flake shown in Fig. 2. Fig. 3 shows another type of structure which gave a similar diffraction pattern. The type of structure present depends on the heat treatment of the steel; but all diffracting structures showed a marked hexagonal habit. The heat treatment was water-quenching from $1,100^\circ\text{C}$. followed by heating to 750°C . for a given time and then water-quenching. Heating for 4 hr. at 750°C . gave a specimen in which there were many transparent flakes (Fig. 2), whereas heating for 1,000 hr. at 750°C . gave specimens containing large masses made up of orientated triangles (Fig. 3).

The electron diffraction pattern (Fig. 1) shows a regular hexagonal cross-grating pattern with a spacing corresponding to 7.5 Å. Furthermore, the roughly circular Laue zones enable the spacing of the lattice row which is nearly parallel to the beam direction to be determined as about 20 Å. These measurements agree very well with those calculated from the known crystal structure of Cr_{23}C_6 , namely, face-centred cubic ($a_0 = 10.6$ Å.) orientated so that the {111} plane is approximately normal to the electron beam. The calculated spacings are 7.5 Å. for the hexagonal pattern and 18.5 Å. for the lattice row in the beam direction.

These results confirm the work of Mahla and Nielsen¹, who from a similar but more extensive series of

Fig. 2

Fig. 3

electron micrographs concluded that the growth of chromium carbide in certain steels is controlled by the {111} lattice planes.

These results also illustrate how single-crystal electron diffraction patterns, taken from selected areas of the specimen in a three-stage electron microscope, may enable, in suitable cases, positive identification to be made of both the nature and crystal habit of phases.

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¹ Mahla and Nielsen, Amer. Soc. Met. Preprint No. 16 (1950).

Diverging Potentials and the Virial Theorem

I REGRET that, in a recent communication under the above title¹, I made somewhat misleading statements concerning the difficulties introduced in the Schrödinger theory by potentials which possess an r^{-n} -singularity ($n \geq 2$) at the origin. In particular, on the basis of the virial theorem, it was concluded that no state exists for a particle moving in an attractive potential of this kind.

Actually, an infinite number of such states exist in principle. It has been shown by Case², in a paper which appeared recently, that, furthermore, the eigenvalue problems in question are, in a certain sense, uniquely soluble. The difficulty which remains is that, in the non-relativistic Schrödinger theory, the energy-value spectrum extends from minus infinity.

The fact that the virial theorem leads to a different conclusion seems to mean that this theorem does not apply to the problems in question. I am indebted to Dr. A. S. Wightman for directing my attention to the above facts.

The apparent validity of the existing quantum mechanical proofs of the virial theorem³⁻⁶, under the single assumption of a bound state, misled me. It is clear that an additional condition

Fig. 1