

If this particle had the mass m_0 and the charge $-e$ of an electron, the radiation damping of its circular motion would be so great as to stop it almost immediately. Mathisson's attempts to establish a connexion between the Theory of Relativity and quantum mechanics would then obviously encounter unsurmountable difficulties. In the course of a private discussion, Dr. Mathisson expressed, therefore, the view that not only the mass, charge and spin of the particle but also its magnetic moment should be taken into account. It is to be expected, then, that the electronic constants might be chosen in such a way that a free electron would not emit any radiation when moving in the above-mentioned manner. Mathisson is now completing his theory on these lines.

It is possible to show in a very simple 'classical' way that in some particular cases the superimposed action of a magnetic dipole can annihilate the radiation of an electric charge in motion. It is well known that when a magnetic dipole with a moment \mathbf{q} moves with a velocity \mathbf{v} , an electric moment

$$\mathbf{p} = \frac{1}{c} [\mathbf{v}\mathbf{q}] \quad (1)$$

appears. Suppose such a magnetic dipole carrying also an electric charge $-e$ moves uniformly around a circular orbit of radius r , the frequency being ν and the dipole axis remaining perpendicular to the plane of the circle, the electric moment (1) will then be directed along the radius vector of the particle. If we put

$$p = er \quad (2)$$

and assume that the sense of motion is such as to produce a magnetic moment opposite to \mathbf{q} , the action of the resulting electric moment will be equivalent, at sufficiently distant points, to that of a charge $-e$ in the centre of the circle and a charge $+e$ on the particle. The moving electron charge will be compensated and there will remain only a charge $-e$ at rest in the centre of the circle. At distances large enough there will remain thus only an electrostatic field and the radiation will disappear. Putting

$$\mathbf{q} = \frac{h}{4\pi} \frac{e}{m_0 c} \quad \text{and} \quad \mathbf{v} = 2\pi\nu r, \quad \text{we get from (1) and (2)}$$

$$\nu = 2m_0 c^2/h.$$

Curiously enough, this is also the frequency of Schrödinger's *Zitterbewegung* for a Dirac electron in slow motion.

The above considerations seem to me suggestive, though—or rather because—they are based on such crude 'classical' notions.

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¹ *Acta physica Polonica*, **6**, 163 (1937) and **6**, 218 (1937).

Coupling between the Orbital and the Spin Angular Momenta of Paramagnetic Ions from Magnetic Measurements

IN a salt of the iron group, though the spin angular momentum of the paramagnetic ion is not directly affected by the crystalline electric fields acting on the ion, yet indirectly it is, owing to its coupling with the orbital angular momentum of the ion, which is easily affected by these fields. The magnetic anisotropy of the crystal, and the deviations of the temperature dependence of its principal susceptibilities

from the Curie law, are the results of such an indirect influence of the crystal fields on the spin angular momentum exerted through the spin-orbit coupling¹, and should be the greater the stronger the coupling. Conversely, from the observed anisotropy or the deviations from the Curie law, it should be possible to calculate the strength of the spin-orbit coupling in the ion.

Such a calculation is simple for a nickel salt, and the necessary theoretical expressions have been worked out by Penney and Schlapp². The magnetic anisotropy $\Delta\chi$ for any given plane in the crystal, that is, the difference between the maximum and the minimum susceptibilities in the plane, per gram molecule, is given by the relation

$$\Delta\chi = \frac{8N\beta^2}{3kT} \left(8\lambda - \frac{2\lambda^2}{kT} - 3kT \right) \cdot \Delta\alpha,$$

where λ is the constant of spin-orbit coupling, β is the Bohr magneton, and N , k and T have their usual significance. The factor $\Delta\alpha$ depends on the crystal fields acting on the Ni^{++} ions, and on the orientation of the selected plane in the crystal. Because of the small coefficient of thermal expansion of the crystal, $\Delta\alpha$ will be almost independent of temperature. From measurements on $\Delta\chi$ at two different temperatures it should therefore be possible to eliminate $\Delta\alpha$ and determine λ .

Using the method described by us in some recent papers³, we have measured the magnetic anisotropies of the tetragonal crystals $\text{NiSO}_4 \cdot 6\text{H}_2\text{O}$ and $\text{NiSeO}_4 \cdot 6\text{H}_2\text{O}$, at the temperature of liquid oxygen and at room temperature. For both the crystals the anisotropy at -183°C . is found to be about 4.8 times that at 23°C . From this ratio we obtain for the constant of spin-orbit coupling in Ni^{++} the value $\lambda = -331 \text{ cm.}^{-1}$, which agrees well with the value -335 cm.^{-1} obtained from spectroscopic data⁴.

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¹ Van Vleck, J. H., *Phys. Rev.*, **41**, 208 (1932).

² *Phys. Rev.*, **42**, 666 (1932).

³ Krishnan, K. S., and Banerjee, S., *Phil. Trans. Roy. Soc.*, A (1933-36).

⁴ Laporte, O., *Z. Phys.*, **47**, 761 (1928).

Diffraction Gratings ruled in Metallic Films

PROF. R. W. WOOD, of Johns Hopkins University, has recently reported¹ on the successful preparation of diffraction gratings by ruling on 'aluminized' surfaces, and predicts a bright future for this type of dispersive instrument. One of the most interesting aspects of this technique, however, is not included in his letter. Inasmuch as I participated in the conception and development of the general method of preparing and ruling evaporated films at Cornell University early in 1934, which method Prof. Wood was induced to adopt about a year later, I feel that I am in a position to offer some comments of interest.

Diffraction gratings are not ruled upon 'aluminized' mirrors but rather upon mirrors the surfaces of which are coated with a discrete film of aluminium deposited over a film of chromium. It was found in the early attempts to rule gratings in evaporated films of pure aluminium that the aluminium film was stripped in patches from the glass by the diamond point, while films of pure chromium were so hard that a diamond loaded heavily enough to rule the chromium also

disfigured the surface of the glass underneath. Hence it was rightly concluded that a double film might serve, since the diamond could be caused to rule through the soft aluminium without being loaded heavily enough to affect the under-coating of chromium. At the same time the aluminium-chromium bond would not be disturbed, for the tenacity of an aluminium film for one of chromium is far greater than that of an aluminium film for glass. It is of interest to note here that this search for a proper film for ruling diffraction gratings has led to the development of a type of film, called 'chroluminium', now extensively used for coating large astronomical mirrors.

The double film has ideal properties for the ruling of diffraction gratings in that the glass surface is not touched by the diamond point, and in that the depth of the rulings can be controlled accurately by controlling the thickness of the aluminium film. The first property allows the same figured and polished mirror blank to be used over again in case the first ruling is a failure, since the chroluminium surface can be removed easily from the glass and a new one deposited for another try at ruling. The second property allows rulings of any desired depth to be obtained with comparative ease, and thus allows most of the light of the reflected spectra to be concentrated in a desired colour of a desired order. The thickness of the aluminium film through which the diamond point is to rule is computed in advance, and is controlled during the process of deposition of the aluminium. The thickness of the underlying chromium film is of little importance, and is usually made slightly less than that necessary to give opacity.

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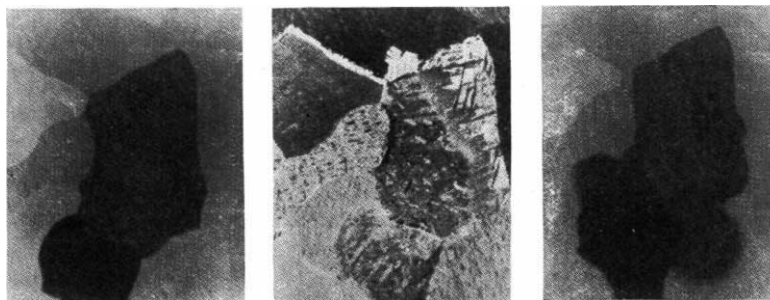
¹ NATURE, 140, 723 (1937).

Electron-Optical Observation of the Transition of α - into β -Zirconium

THE investigation of the transformation process of the hexagonal α - into the cubic β -modification of zirconium by means of X-rays¹ led to the conclusion that this process is brought about by a homogeneous transformation (shearing combined with dilation) of coherent lattice regions parallel to definite crystallographic planes and directions, the 'shearing motion' being opposed in successive $\alpha \rightarrow \beta$ and $\beta \rightarrow \alpha$ transitions, the whole process thus resembling closely the way martensite needles are formed in steel.

In such cases it is generally observed that the transformation into the new phase cannot be described as a growth of nuclei steadily increasing in size, but that it consists of the formation of parallel and intersecting systems of more or less needle-shaped lamellæ, which, as transformation progresses, do not increase in size but merely in number, the resulting pattern showing the type of lamellar structure met with in martensitic steels and known as *Widmannstätten* texture in meteorites and many alloys².

The investigation of the emission pattern of zirconium in an 'electron microscope' of the type described elsewhere³, showed that the same texture is exhibited by α -crystallites formed from the β -phase. This is clearly shown by the accompanying photographs corresponding to cathode temperatures of 1100° C., that is, well above the transition point, (865° C.) and 600° C., a temperature well below this point. It is interesting to see that the regions, originally occupied by the β -crystallites, can still be discriminated in the α -pattern by the difference in



β -Zr (1100° C.) α -Zr (600° C.) β -Zr (1150° C.)
EMISSION PATTERNS OF ZIRCONIUM ABOVE AND BELOW THE TRANSITION POINT (865° C.).*

'direction' of the lamellæ in the adjoining regions (needles of the α -modification of zirconium have already been observed in etched test pieces after suitable cooling from the β -state⁴).

On retransformation into the β -state, the original crystallites reappeared, as is evident from the photograph at 1150° C., which (apart from the left-hand side, where crystal growth has already started: see below) is practically identical with that at 1100° C. This behaviour, which is totally different from the phenomenon of crystal growth observed on transition of α into γ iron⁵, seems to confirm the conclusion deduced from the X-ray investigation mentioned above.

It seems worth mentioning that at a cathode temperature above 1150° C. the β -crystallites showed phenomena of growth, whereby the capacity for growth of the individual crystallites could be influenced by the insertion of a temporary transition into the α -modification.

A detailed account of these observations will be published in *Physica*.

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* The striation visible in the β -Zr patterns has the same direction over the whole cathode and is due to the polishing of its surface.

¹ Burgers, W. G., and Jacobs, F. M., *Physica*, 1, 561 (1934); Pap. Disc. Intern. Conf. Physics, London, 1934, vol. 2, p. 158.

² See Sachs, G., "Praktische Metallkunde", 3, 20 (Berlin, 1935); further papers by Mehl, R. F., and collaborators in *Trans. A.I.M.E.*, from 1931 onwards.

³ Burgers, W. G., and Ploos van Amstel, J. J. A., *Physica*, 4, 5 (1937).

⁴ See Vogel, R., and Tonn, W., *Z. anorg. allg. Chem.*, 202, 292 (1931), Burgers, W. G., and Jacobs, F. M., *Physica*, 1, 561 (1934).

⁵ Burgers, W. G., and Ploos van Amstel, J. J. A., NATURE, 136 721 (1935); *Physica*, 4, 15 (1937).