THERMO-ELECTRIC EFFECT IN SINGLE CRYSTAL ZINC WIRES

By Ernest G. Linder

Abstract

The crystals were prepared by the Czochralski method, drawing each in the form of a wire through a 2 mm hole in a mica disk which floated on the surface of the zinc, kept just a few degrees above its melting point. After slight amalgamation, the crystals split readily along the basal plane, normal to the vertical axis. The angle between this axis and the axis of the wire is the orientation θ of the crystal. Each end of a crystal was sealed with cadmium into a copper block, one of which was kept at 0° C, the other at a temperature T, varied up to 290°C. The ratio of thermo-e.m.f. E to T is found not to be a linear function of T but to increase with T more rapidly. The curves for the higher values of θ lie above those for lower values, so that with a circuit of differently oriented crystals the e.m.f. is directed, at the hot junction, from the crystal of higher to that of lower orientation. For wires with $\theta=14°$ and $\theta=86.5°$, the e.m.f. with $T=250°$ would be 6.50×10^{-4} volt. The neutral temperature $(dE/dT=0)$ decreases from about 500° for $\theta=14°$ to 40° for $\theta=86.5°$.

THE production of single crystal metal specimens and the determination of various physical constants in different directions in such crystals have recently claimed the attention of numerous investigators.[1] Very little work has been done, however, on the thermo-electric effects in metal crystals. It was the purpose of this investigation to study the thermal e.m.f. in single crystal zinc wires as dependent on the orientation of the space lattice relative to the axis of the wire.

The crystals were made by a method devised by Czochralski[2] whereby metallic crystals in the form of wires are drawn from a melt through a hole in a mica disk floating upon its surface. The zinc was kept just a few degrees above the melting point. The mica disk was large enough to cover the entire surface and thus prevent oxidation. The hole in the disk was about 2 mm in diameter and served to make the crystal surface more uniform. The velocity of drawing out the crystal varied between 6 and 10 mm/sec. depending upon the temperature of the melt and other

[1] Zeits. f. Instrumentenkunde **3,** 152 (1925);
Gruneisen and Goens, Zeits. f. Phys. **29,** 141 (1924); **26,** 235 (1924);
Bridgman, Proc. Nat. Acad. Sci. **10,** 411 (1924);
M. Polanyi, Zeits. f. Elektrochem. **28,** 16 (1922);
E. v. Gomperz, Zeits. f. Phys. **8,** 184 (1922);
M. Polanyi and Schmidt, Zeits. f. Phys. **12,** 58 (1922).

[2] Czochralski, Zeits. f. Phys. Chem. **92,** 219 (1918).

factors. It was found that by starting crystals on a coppei wire and drawing them out at an excessive rate, crystals of a varying orientation could be formed. (The orientation of a crystal is defined as the angle between the vertical (hexagonal) axis of the zinc and the direction of the length of the wire.) At the beginning of this rapid growth the orientation was approximately 90° and as the growth progressed it decreased, reaching about 45° when the wire was 25 cm long. By cutting off this crystal at the point having the desired orientation and starting a new crystal upon it, a crystal wire having any orientation between 45° and 90° could be obtained. To obtain orientations below 45°, a crystal having approximately 45° orientation was bent near the end so that its basal plane was inclined at the desired angle with the surface of the melt. Merck "very pure" zinc was used and no trouble due to impurities was encountered.

It was discovered that by slightly amalgamating the crystals with mercury they became brittle and could easily be split along the basal plane with a sharp knife. The normal to this basal plane is the vertical axis, and the orientation could then be easily determined by measuring the angle of inclination of this axis with respect to the axis of the wire by means of a reflected light beam.

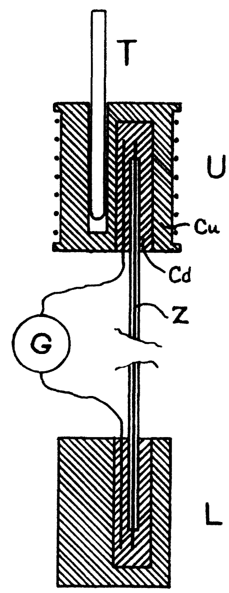

Fig. 1. Apparatus for measuring thermo-electric e.m.f.

The thermo-electric e.m.f., which was measured against copper, was determined by connecting the couple in series with a high resistance galvanometer calibrated for voltage. The crystal Z, Fig. 1, was enclosed in a glass tube for protection, and the two ends sealed with cadmium into cylindrical cavities in copper blocks. One of these blocks, L, contained the cold junction and was immersed in melting ice; the other, U, contained the hot junction and was heated by means of a heating coil wrapped around it; its temperature was measured by a mercury-in-glass thermometer T, inserted in a cavity in the block.

Fig. 2 shows the series of curves obtained for crystals of different orientations. The e.m.f. is considered positive when it acts from the hot to the cold junction through the zinc. It will be noticed that, within the observed temperature range, for a circuit composed of two crystals of different orientations the current would flow across the hot junction from the crystal having the lower orientation to that having the higher.

If these curves could be represented in the usual manner by an equation of the form

$$E = AT + BT^2, \qquad (1)$$

then $E/T = A + BT$ and a straight line should be obtained by plotting E/T against the temperature difference T. The curves in Fig. 3, however, are not straight lines as this simple theory demands. Therefore, the thermo-electric power dE/dT is not a linear function of T.

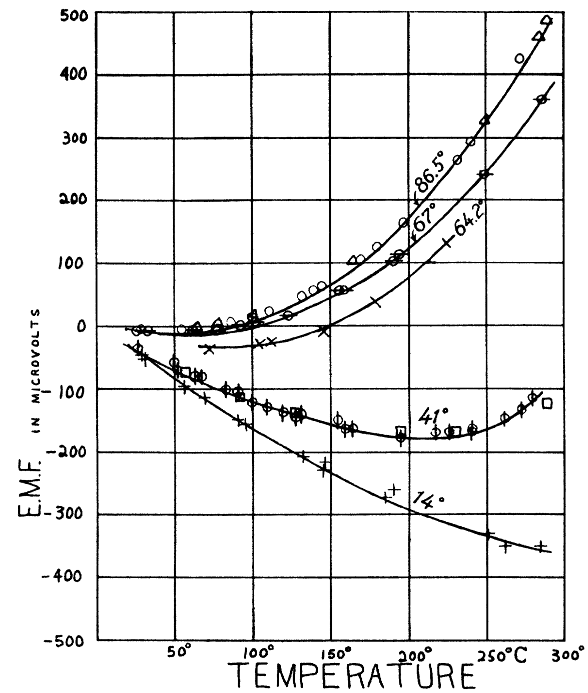

Fig. 2. E.m.f. vs temperature curves for different orientations.

The nature of the relationship between the curves of Fig. 2 can probably best be shown by plotting the neutral temperature against the orientation. The neutral temperature is defined as that temperature at which the thermo-electric power is zero. If we plot these values against the corresponding orientations we obtain the curve shown in Fig. 4. In the case of the curve for the 14° orientation, this neutral temperature was calculated by assuming the curve to be of the type represented by Eq. (1). This, of course, gives only a very rough value. No attempt will be made here to present a theoretical interpretation of these results, this being only a preliminary account of experimental work which is not yet completed.

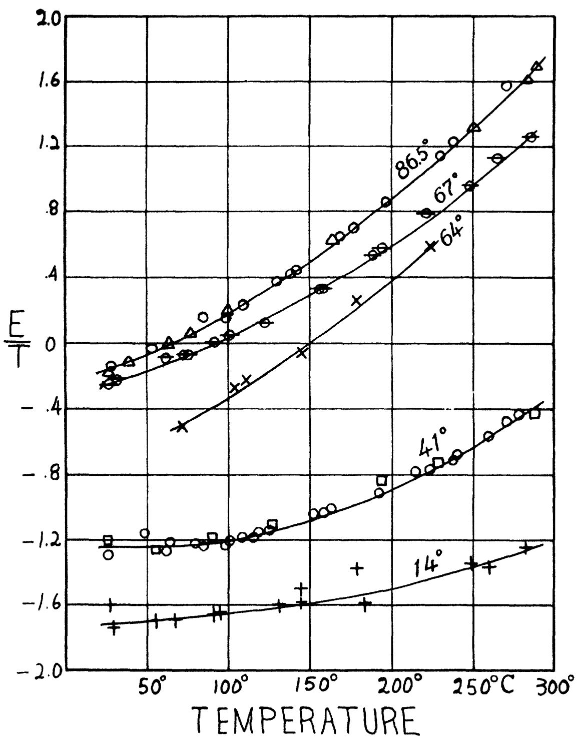

Fig 3. *E/T* vs temperature curves for different orientations.

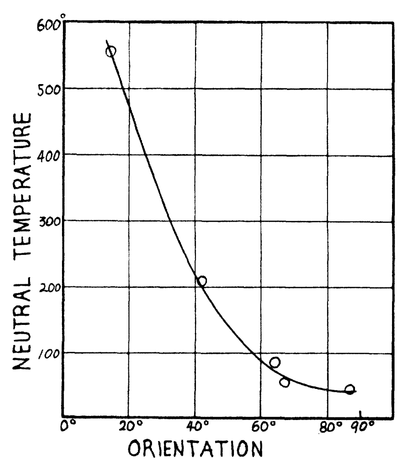

Fig. 4. Variation of neutral temperature with orientation.

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