X-Ray Investigations on the Thermal Expansion of Solids. Part 2.

By

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(Received October 9, 1933)

Abstract

The thermal expansion coefficients of Mg, Cd, Zr and Co were determined by the X-ray method and the following results were obtained:

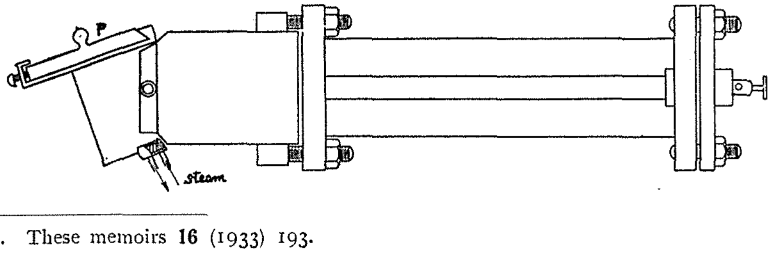
Mg ($\alpha_{\parallel}=23.8\times10^{-6}$, $\alpha_{\perp}=23.5\times10^{-6}$), Cd ($\alpha_{\parallel}=50.0\times10^{-6}$, $\alpha_{\perp}=17.9\times10^{-6}$), Zr ($\alpha_{\parallel}=2.5\times10^{-6}$, $\alpha_{\perp}=14.3\times10^{-6}$) and Co ($\alpha_{\parallel}=16.1\times10^{-6}$, $\alpha_{\perp}=12.6\times10^{-6}$).

In the present experiment, the thermal expansion coefficients of several hexagonal elements were determined by X-ray analysis. The method of the experiment was almost the same as that described in the previous report[1], but a new X-ray tube was constructed.

X-Ray Tube

The X-ray tube shown in Fig. 1 is an electron tube specially designed to take Debye-Scherrer photographs with a large angle of reflection. The body of the X-ray tube is as shown in Fig. 2; it was made from a brass block $5.5\times5.5\times8$ cm^3. A hole 3.4 cms. in diameter is bored in one end of the block and the other end forms a flat surface, the hole mentioned reaching to the central part of this surface, as shown in Fig. 2, F. Fig. 3 and A in Fig. 2 is the anticathode, made from

Fig. 1



1. These memoirs **16** (1933) 193.

a flat copper or iron block $4.5 \times 5.5 \times 0.7$ cm^3, and it has a slightly raised part on one side of it. This anticathode fits on the flat end of the body of the X-ray tube and the raised part of the anticathode enters the hole F, and as the electron stream emitted from the hot cathode is focussed on the centre of the hole F, the raised part of the anticathode becomes the source of the X-rays. From the hole F, a narrow groove runs out and forms a slit for the X-ray beam. A cellophane window covers the slit, and the specimen, S, is set very close to this window, as shown in Fig. 1, the distance between the

Fig; 2

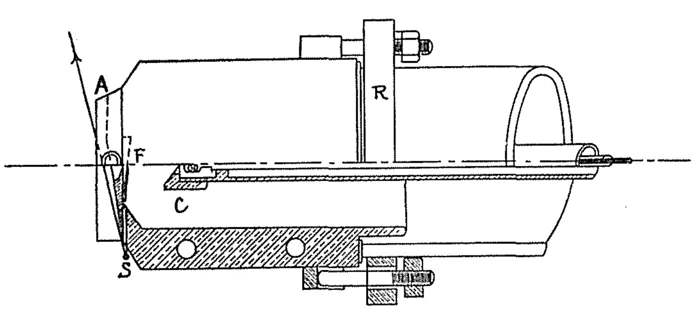
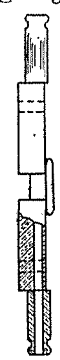


Fig. 3



specimen and the source of the X-ray beam being only about 2.5 cms. The specimen-holder is made from a copper block $1 \times 1 \times 0.5$ cm^3, and the specimen, usually a foil, is stuck with zapon lack on one surface of it and covered with layers of cellophane and Japanese paper. The other surfaces of the specimen-holder are covered with asbestos and a hole is bored through the holder to introduce steam to heat the specimen. The X-ray beam reflected from this specimen travels through the back of the anticathode. To prevent the X-ray beam, which is reflected at an angle of nearly 90°, from being screened by the anticathode, a groove is cut on the anticathode as deep as possible and it is covered with a thin lead plate. Thus, even in the case of a reflection angle of 83°, as in that of Cu $K\alpha$ radiation from the (511) plane of Al, the anticathode does not obstruct the reflected X-rays. The anticathode is cemented by thin layers of picein to the body of the X-ray tube and fastened with four bolts.

The cathode is an ordinary hot cathode with a tungsten filament, covered by a cap C. This cap serves as a focussing device and its anticathode side is V-shaped to secure a sharp line-focus. Insulation between the cathode and the body of the X-ray tube is attained by a glass tube 17.5 cms. in length and 5 cms. in outer diameter. This glass tube is connected to the cathode and the body by bolts and nuts through the brass ring R, rubber rings being used as packing between these parts.

The plate holder, as shown in Fig. 1, P, can move up and down so that four photographs can be taken in succession. With this apparatus, exposures of 3—5 mins. are enough for each photograph, the X-rays being excited by 5—7 m. amps. and 40 k. V.

Results of the Experiment.

In the present experiment, Mg, Cd, Zr and Co were investigated. Their crystal structures all belong to the hexagonal close-packed lattice type and the lattice constants are as tabulated in Table I. The results of the experiment are shown in Table II and Plates I—IV.

Table I[1].

	Mg	Cd	Zr	α—Co
a A. U.	3.20	2.97	3.23	2.51
c A. U.	5.20	5.60	5.14	4.10
c/a	1.62	1.88	1.59	1.63

Table II.

Element	Indices of Planes	l, cm.	Δl, mm.	Range of Temperature, °C	$\frac{\Delta d}{d}$, 10^{-6}	
Mg	006 300	4.94 2.76	0.425 0.388	23.5—100 „ „ „ „	23.8 23.5	r=4.00 cm. Cu-Kα radiation
Cd	116 124 302 301	2.43 2.73 3.77 5.17	0.748 0.522 0.451 0.311	21—100 21.5—100 21—100 21.5—100	41.1 25.9 22.6 17.3	r=4.50 cm. Cu-Kα radiation
Zr	222 310 220 106	1.13 1.78 2.98 4.13	0.440 0.312 0.278 0.063	15—100 „ „ „ „ „ „	13.4 13.5 15.2 3.5	r=4.50 cm. Cu-Kα radiation
Co	004 112	2.25 3.85	0.158 0.121	33—100 „ „	16.1 13.6	r=4.80 cm. Fe-Kα radiation ∢(Plate-X-ray) =74°

1. Landolt-Börnstein's table.

Therefore, from these results and eq. (6) of the previous paper, we have the following values:

Table III

Element	Mg $\alpha_{\parallel}$	Mg $\alpha_{\perp}$	Mg α	Cd $\alpha_{\parallel}$	Cd $\alpha_{\perp}$	Cd α	Zr $\alpha_{\parallel}$	Zr $\alpha_{\perp}$	Zr α	Co $\alpha_{\parallel}$	Co $\alpha_{\perp}$	Co α
Present Investigation, 10^{-6}.	23.8	23.5	23.6	50.0	17.9	28.6	2.5	14.3	10.4	16.1	12.6	13.8
Grüneisen and Goens, 10^{-6}.				52.6	21.4							
Polycrystals, 10^{-6}.			26.2			31.0						12.6

$\alpha_{\parallel}$, $\alpha_{\perp}$ and α in Table III show the thermal expansion coefficients parallel and perpendicular to the hexagonal axis and the linear expansion coefficient respectively. The values in the 3rd and 4th rows are obtained from Landolt-Börnstein's table and nearly coincide with those of the present investigation.

Cobalt has an allotropic transformation at 450°C and α-Co which is stable below this temperature changes to β-Co with a face-centred cubic lattice at this temperature. Therefore this transformation is quite similar to that of thallium in the previous paper[1], and c/a at this temperature must be 1.633. But as c/a of α-Co at room temperature is 1.633, $\alpha_{\parallel}$ and $\alpha_{\perp}$ must be nearly equal. This is as shown in the above table.

In conclusion the author wishes to express his hearty thanks to Prof. S. Tanaka and also Prof. M. Ishino for their kind guidance in this research.

3rd August, 1933.

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1. Loc. cit.

Plate I, Mg.

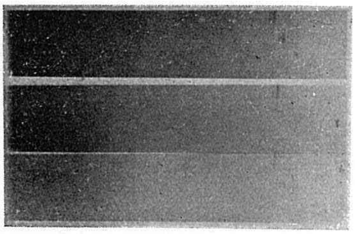

Plate II, Cd.

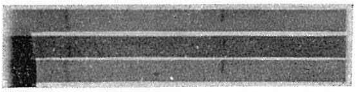

Plate III, Zr.

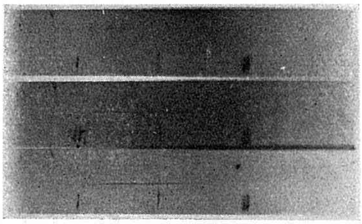

Plate IV, Co.