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To cite this version:

F. Ono, H. Maeta. DETERMINATION OF LATTICE PARAMETERS IN HCP COBALT BY USING X-RAY BOND’S METHOD. Journal de Physique Colloques, 1988, 49 (C8), pp.C8-63-C8-64. <10.1051/jphyscol:1988818>. <jpa-00228333>

HAL Id: jpa-00228333
https://hal.archives-ouvertes.fr/jpa-00228333
Submitted on 1 Jan 1988

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DETERMINATION OF LATTICE PARAMETERS IN HCP COBALT BY USING X-RAY BOND'S METHOD

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Abstract. - Measurements of lattice parameters \(a\) and \(c\) in hcp cobalt single crystals have been made in a temperature range between 4.2 K and room temperature by using the X-ray Bond's method. The results will be applicable to estimate various magnetic quantities such as the magnetocrystalline anisotropy energy.

1. Introduction

It has been pointed out by many authors [1] that the thermal expansion makes appreciable effects to various physical quantities in anisotropic materials. In hcp cobalt several measurements of thermal expansion curves in low temperature regions have been made to date [2, 3]. Most of these measurements were made by using the dilatometric method, while there are only a few which adopted the X-ray diffraction technique. By using the dilatometric method, however, it is not possible to obtain the microscopic values of lattice parameters, which are related to some important physical quantities.

A determination of lattice parameters of hcp cobalt in a low temperature region between 100 K and room temperature was made by Muller et al. [4] by using a Debye-Scherrer camera. Measurements below the liquid nitrogen temperature yet remain to be made. Furthermore, even at room temperature there can be seen large scattering among the data so far obtained for lattice parameters of hcp cobalt. This large scattering of the data is considered to be due to the limitation of the accuracy of the conventional X-ray diffraction technique and to the difference of the quality of the specimens. Therefore, more precise measurements of the lattice parameters in cobalt are needed in the wide temperature range between 4.2 K and room temperature.

2. Experimental procedures

In the X-ray Bond's method [5] two scintillation counters are placed at the symmetrical position of both sides of the X-ray beam in the horizontal plane so as to count the reflected X-ray beam by the specimen. During a measurement, only the specimen was rotated to change the reflected beam from a counter to the other. A fine collimator was attached to the X-ray tube, with which the initial beam was kept as fine as 0.2 mm in width. During the present measurements highest possible reflection lines were chosen in order to minimize the error arising from small dimensional misalignments of the X-ray beam system.

Two thin plates were cut from a single crystal ingot of 99.99 % pure cobalt, the surface of one plate being parallel to the (0001) plane and that of the other to the (10\(\bar{1}0\)) plane. Specimens were annealed at 360 °C for 168 hours so as to eliminate internal stress. For measurements of the lattice parameter \(a\), a fine focus X-ray source with molybdenum target was used. The highest possible line was 600-reflection. For the determination of the lattice parameter \(c\), the same type of X-ray source with iron target was adopted. The highest possible reflection was 004-line. A glass cryostat which was specially designed for the Bond method [6, 7] was used so as to make the temperature of the specimen variable between 4.2 K and room temperature.

3. Experimental results and discussion

The lattice parameter \(a\) of hcp cobalt determined from the present experiment is shown in figure 1 as a function of temperature. The value of \(a\) at 4.2 K is \(2.50300 \pm 0.00002\) Å, and its temperature dependence

![Fig. 1. The temperature dependence of the lattice parameter \(a\) in hcp cobalt determined from the 600-diffraction line of molybdenum target.](http://dx.doi.org/10.1051/jphyscol:1988818)
The temperature dependence of the lattice parameter $c$ in hcp cobalt determined by the 400-reflection of iron target is very small up to 50 K. Above this temperature it increases gradually with increasing the temperature, and above 150 K it increases almost linearly with temperature.

The lattice parameter $c$ determined from the present experiment is shown in figure 2. The value of $c$ at 4.2 K is $(4.0574 + 0.0001) \, \text{Å}$, and remains almost constant up to about 50 K. Then, it increases gradually with further increasing the temperature. The lattice parameter ratio, $c/a$, is shown in figure 3. The value of $c/a$ at 4.2 K is 1.6210. The temperature dependence of $c/a$ below 100 K is quite small as can be seen in figure 3, while it increases almost linearly with further increasing the temperature. This tendency of $c/a$ is similar to that predicted by one of the present authors in estimating the temperature dependence of the magnetocrystalline anisotropy constants in hcp cobalt [8]. The anomalously small temperature dependence of the first magnetocrystalline anisotropy constant of hcp cobalt below 100 K [1, 8, 9] can be explained by using the present data of $c/a$.

The present data of the lattice parameters of hcp cobalt have a possibility to be compared with several other physical quantities such as those appeared in band structure calculations [10, 11], the directional dependence of the saturation magnetization and its temperature dependence.

4. Conclusions

The lattice parameters $a$ and $c$ in hcp cobalt have been determined in a low temperature region between 4.2 K and room temperature. It was found that the temperature dependence of both $a$ and $c$ was very small below 50 K, while the values increased almost linearly with increasing the temperature in the higher temperature region above 150 K. The lattice parameter ratio $c/a$ below about 100 K was found to be insensitive to temperature, while it increased almost linearly with further increasing the temperature up to room temperature.

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Fig. 2. – The temperature dependence of the lattice parameter $c$ in hcp cobalt determined by the 400-reflection of iron target.

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Fig. 3. – The temperature dependence of the lattice parameter ratio $c/a$ in hcp cobalt determined from the present experiments.

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