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A Method of Measurements of the Magnetic Moment Under Hydrostatic Pressures

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A method for measuring the magnetic moment under hydrostatic pressures is presented concerning the apparatus and procedures. The correction of the apparent demagnetizing field in measurements of the saturation flux under pressures is principally discussed and the experimental treatment of the correction is described. Finally, some examples of the measurements so far done are briefly reviewed.

Introduction

On the basis of the molecular field theory, the pressure dependence of the magnetic moment per unit mass σ_s and the Curie temperature T_c, $(\partial\sigma_s/\partial p)$ and $(\partial T_c/\partial p)$, which are both expectable to be gotten experimentally, would provide a knowledge of the exchange interaction responsible for ferromagnetism.[1)]

Theoretically, it is required to have $(\partial\sigma_{so}/\partial p)$ at 0°K, not $(\partial\sigma_s/\partial p)$ at a temperature. Experimentally, however, $(\partial\sigma_{so}/\partial p)$ is practically impossible to measure, but it can be estimated from the temperature dependence of $(\partial\sigma_s/\partial p)$ which may be derived from thermodynamical consideration, if the measurement of $(\partial\sigma_s/\partial p)$ can be made at several temperatures.[2,3)]

The measurement of $(\partial\sigma_s/\partial p)$ under hydrostatic pressures, done by Nagaoka and Honda for the first time,[4)] has so far done by means of various techniques.[5~11)] Greater part of the data, however, are unavailable for estimating $(\partial\sigma_{so}/\partial p)$, since the measurement has been made only at one or a couple of temperatures. Tatsumoto and collaborators[12~16)] have made the measurement over a comparatively wide temperature range by means of a method developed by the present authors.

According to the measurements so far done, $(\partial\sigma_s/\partial p)$ has mostly been deduced from the measurement of saturation flux Φ_s under pressures, so that it is necessary to make an accurate measurement of Φ_s under pressures, since the variation of Φ_s with pressure is usually very small, and it is also necessary to make correction for the demagnetizing field, since the specimen is usually of finite size.

In the present paper, a method which has been applied to the measurement on Ni, Fe,[12~14)] ferromagnetic Cu-Ni[15)] and Pd-Ni[16)] alloys is presented concerning the apparatus, procedures and examples. This method was developed by the present authors so as to make the measurement of the variation of magnetic flux in an electromagnet capable of generating a high field enough to magnetize the hard material to saturation and in a comparatively wide temperature range. In this measurement, the sample is usually required to be so small as to be placed between the pole pieces of an electromagnet. It is therefore necessary to make a correction for the demagnetizing field, because of a comparatively small dimension ratio of the sample.

For 24 at.% Cu–Ni alloy which is magnetically soft, one of the present authors Tange[17] has succeeded in the same measurement by using the samples in comparatively long size in a solenoidal coil. In his measurement, therefore, the correction for the demagnetizing field was negligibly small.

Experimental

The measurement of the pressure effect on σ_s in the present experiment is composed of the measurements of the pressure effect on Φ'_s and of the linear compressibility. Here, Φ'_s is the saturation flux actually picked up by a search coill.

For each material, three cylindrical rods have been prepared from an ingot after severe hot-forging. Two of the three rods, 14.5 mm in length and 5.5mm in diameter, are used for the measurement of the pressure effect on Φ'_s, and the remaining one, 38 mm in length and 1.7 mm in diameter, is used for that of the linear compressibility.

Prior to the measurements, all specimens are well annealed at a suitable temperature in order to remove stress and to get homogenous small grain size.

Hydrostatic pressures have been generated with a slightly modified Bridgman press which was made of nickel-chromium-molybdenum steel. The press bore the pressure test up to 18 kbar. Pressures up to 15 kbar have easily been generated by using petroleum ether as a transmitting medium. The imported stainless steel tube, 0.6 mm in inner diameter and 3mm in outer diameter, has been employed as a pressure transfer between the pressure generator and the pressure bomb, in which the specimen was inserted.

Details of the construction of the pressure generator and the technique of the connection between the generator and the pressure bomb are referred to the article by Tatsumoto et al.[18]

The pressure has been determined from the pressure dependence of the electrical resistance of a well annealed manganin wire, the standard pressure of which was calibrated with the freezing pressure of mercury at 0°C, 7.640 kg/cm^2.

In Fig. 1, the principle of the measurement of the variation of Φ'_s with pressure is schematically shown. In this figure, M is an electromagnet, the pole gap and the diameter of the pole surface being 80 mm and 100 mm, respectively. Two same pressure bombs B_a and B_d are made of precipitation