Molecular Field Theory on Exchange Striction

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Abstract

It is well known that the crystal structure of magnetic substances is more or less distorted when the magnetic system is ordered. We deal with the crystal distortion (exchange striction) that arises from the exchange interaction sensitive to the interatomic distances. We have derived a general expression for the exchange striction by means of a molecular field theory, $\bar{e}_\mu = N\bar{S}^2 \sum_{\nu}^{6} S_{\mu\nu} J_\nu(\boldsymbol{Q})$, $\mu = 1$ to 6, where $\bar{e}_\mu$'s are the spontaneous strains, N the number of spins, $\bar{S}$ the magnetic moment, $S_{\mu\nu}$'s the elastic constants and $J_\nu(\boldsymbol{Q})$ the first derivative of the exchange constant with the strain e_ν, specified the spin structure by $\boldsymbol{Q}$. We have also obtained the criterion that the magnetic system occurrs the first order phase transition, $\eta > \frac{3}{10}\left[\frac{1}{S^2} + \frac{1}{(S+1)^2}\right]$, where η is a constant that characterizes a magnitude of magneto-elastic coupling in the magnetic system and S is the spin number. Our theory is applicable to all of spin structures including a kind of magnetic ions. We compare the calculated results with experimental results for the face-centered cubic lattice. It is found that the agreement of them is satisfactory qualitatively.

§1 Introduction

Spins in magnetic insulators localize in the atom which the spins belong to, and interact each other through the overlappings of electrons in different ions on the path between the magnetic ions. This mechanism, called superexchange interaction, has so far confirmed that various magnetic structures are produced.

Change of distances between the magnetic ions causes change of the electron overlappings, that is, change of the exchange interactions. If the change of interatomic distances gives rise to gain of the magnetic energy, the lattice will deform associated with the magnetic ordering, which is so-called exchange striction.

In fact, Miss Greenwald and Smart[1)] first pointed out the existence of the exchange striction to explain the crystal distoritions of transition metal monoxides at low temperatures. Many studies[2~18)], thereafter, have been performed on exchange strictions and on the effects induced by it in various materials. These studies, however, were individual.

In this paper we will give a more general formula for exchange striction and investigate the influence of it to magnetization. We use a molecular field theory to obtain the formula. This theory is simple and useful to understand qualitatively magnetic properties.

In §2 we show the theory of the exchange striction. In §3 we investigate the exchange

Received October 31, 1988

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