Domain Patterns on Rolled Single Crystal of Ni_3Fe

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IT is well known that iron-nickel alloys acquire a strong magnetic anisotropy when they are cold-rolled.[1] Isoperm is a magnetic material prepared in this manner. Recently, Néel,[2] and independently Taniguchi and Yamamoto,[3] tried to interpret the origin of this anisotropy in terms of directional order[4] or an orientational superlattice. They supposed that such an arrangement of atoms may be induced by mechanical stresses, where plastic deformation may play a role in carrying the atoms to their equilibrium positions.

By studying this effect with single crystals of Ni_3Fe, we have obtained distinct domain patterns on the rolled crystal and here propose a new mechanism for the origin of the directional order.

Experimental results:

(1) Distinct domain patterns were obtained when the crystal was rolled in the (110) plane (Fig. 1). The direction of domain magnetization appears always along the $[1\bar{1}0]$ direction, irrespective of the rolling direction.

(2) The final shape of the specimen depends upon the rolling direction. In any case the preferred elongation takes place along the [001] direction. [Roll plane: (110).]

(3) Many slip bands were observed on the rolled surface, most of which are parallel to the $[1\bar{1}0]$ direction. [Roll plane: (110).]

(4) The magnitude of anisotropy increases at first almost proportionally to the rolling reduction. It reaches a maximum value of 2.5×10^5 ergs/cc at $r=70$ percent and decreases when rolled further. (Roll: (110), [001].) The specimen was previously annealed for 1 hour at 490°C.

(5) When the alloy is perfectly ordered, it develops the anisotropy more slowly. For instance, the anisotropy amounts to 1.2×10^5 ergs/cc at $r=70$ percent.

(6) Even when the specimen is quenched from 700°C, its anisotropy appears in just the same way as (4).

The following mechanism is proposed: When dislocations travel in the material in which short-range order exists, they may destroy the order between neighboring atomic planes which are parallel to the slip plane. The order, however, may not be altered in these atomic planes. If, therefore, the slip takes place at the same time along another slip plane, the order will remain only in the direction which is common to both the slip planes. This is a directionally ordered arrangement.

This idea is verified experimentally in several respects. When the crystal is rolled in the (110) plane, slip can take place exclusively in the (111) and $(11\bar{1})$ planes, for the other two equivalent planes are normal to the surface and slips in them will make no contribution in reducing the thickness. This is confirmed by (2) and (3). In this case, therefore, the order may remain only in the $[1\bar{1}0]$ direction, which is common to the (111) and $(11\bar{1})$ planes. Accordingly this may become the direction of easy magnetization. This agrees with (1).

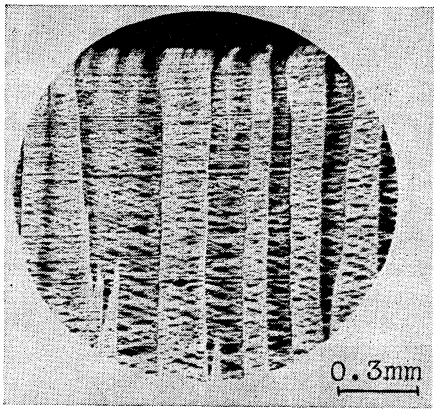

FIG. 1. Domain pattern on rolled (110) plate of Ni_3Fe. Edge of crystal is parallel to roll direction [001].

In this mechanism, some degree of order is prerequisite. When, however, the order is perfect, the dislocation may travel in pairs so as to conserve the ordered state[5] and accordingly make less contribution in destroying the order. The result (5) may be interpretable along this line. Further, the experimental result (6) can be interpreted by assuming that the alloy does not completely lose its short-range order even when it is quenched from 700°C.

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Auxiliary Conditions in the Bohm-Pines Theory of the Electron Gas

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BOHM and Pines[1] (BP), in their quantum theory of a hypothetical electron gas, described a procedure for completely solving the many-body Schrödinger equation, at least so far as the long-range part of the interelectron interaction is concerned. In carrying through their program, they met with a certain difficulty, *viz.*, that their equations required that any state

vector for describing a physically realizable state of the system must satisfy a number of auxiliary conditions of the form

$$(p_k-\Lambda_k)\psi\equiv\Omega_{-k}\psi=0, \quad (1)$$

whereas they were unable to find any simple way of ensuring compliance by state vectors which they constructed as approximations to state vectors for physical states. BP deferred any detailed treatment of this difficulty for a later publication, but gave arguments designed to show that their equations were substantially correct, even though their approximate wave functions failed to satisfy the auxiliary conditions (1). They apparently felt that a treatment which takes account of the auxiliary conditions would involve no really major modifications of the treatment which they have given.

We have studied the implications of the auxiliary conditions and have come to a different opinion. We conclude that, if consideration is restricted to the part of function space containing functions which satisfy the auxiliary conditions, there are no states for which the BP basic approximation is valid, even as a rough approximation. While we have reached the conclusion only after a detailed examination, we can describe the basis for our conclusion very simply. The fundamental approximation of BP is to neglect a term U in the Hamiltonian, given by

$$U=(2\pi e^2/m)\sum_{k,\,l(k\neq l)}q_kq_l{}^+\sum_\mu\exp[i(k-l)\cdot x_\mu]. \quad (2)$$

The argument used to drop U assumed that (a) the sum of phase factors must give a small number since the electrons are rather evenly distributed and (b) the oscillators for which q_k, q_l are the quantized amplitudes are with high probability in their ground states, so that U is not large on account of the factor $q_kq_l{}^+$.

The assumption (b) can be proved incorrect for any physically realizable state, and it can be shown that U diverges quadratically for such a state. We first observe that every state can be written in the form

$$\psi=\exp(iS/\hbar)\chi, \quad (3)$$

where

$$S=\sum_k q_k\Lambda_k. \quad (4)$$

Since the Λ_k are functions of the electron coordinates only, the condition that ψ satisfy the set of Eqs. (1) is that χ satisfy the equations

$$p_k\chi=0. \quad (5)$$

The set of solutions of (5) is just the set of all functions which are independent of q_k, and thus depend on the electron coordinates alone. Therefore all physically admissable states are of the form (3) with

$$\chi\equiv\chi(x_\mu).$$

It is now easy to see that the wave function for any physically admissible state is very different from an oscillator ground state wave function. The expectation value of $q_kq_k{}^+$ for the oscillator ground state is $(\hbar/2\omega)$, whereas the expectation value of $q_kq_k{}^+$ for the state (3) diverges quadratically. It can be verified that the manner of divergence of $\langle q_kq_k{}^+\rangle$ is precisely what we expect in a state for which p_k has a sharp value.

If the state (3) is expanded in the excitation number representation of the oscillator, it is found that when Λ_k is equal to zero, each state of excitation occurs with equal probability. For $\Lambda_k\neq0$ the average of the oscillator energy is

$$\hbar\omega\langle N_k+\tfrac{1}{2}\rangle=\tfrac{1}{2}|\Lambda_k|^2+\omega^2\langle q_k{}^2\rangle, \quad (6)$$

where $\langle q_k{}^2\rangle$ is exactly the same as it was for the state with $\Lambda_k=0$. While it is no longer true that each excitation state occurs with equal probability, Eq. (6) shows that the average excitation is actually greater still. We see that for states which satisfy Eq. (3), $\langle N_k\rangle$ always diverges at least as badly as though each excitation state were occupied with equal probability.

The existence of the aforementioned divergence shows that it is wrong to identify the q_k with the amplitudes of (physical) plasma oscillations, which would surely not be very highly excited. Thus in the original BP representation the true wave function must be in an essential way more complicated than BP supposed, and the true (finite) eigenvalue is the resultant of several actually infinite terms, of which U is one, the zero-order oscillator Hamiltonian another.

We believe that the fundamental physical idea of BP is a sound one, and that their work can lead to valuable insights into the electron gas problem. However, on the basis of the preceding discussion, we conclude that a proper founding of their theory on the many-body Schrödinger theory remains to be given.

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Attempt to Detect High Mobility Holes in Germanium Using the Drift Mobility Technique

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THE discovery of a second set of holes in germanium[1] has made it of interest to search carefully for an indication of their presence in the drift mobility experiment.[2] Such a search has been carried out at room temperature on n-type, 5 ohm-cm germanium. The sensitivity of the drift mobility technique has been improved by using alloyed indium dots as emitters and collectors rather than point contacts and by the use of a transverse magnetic field which served to concentrate the holes in the vicinity of the collector. Further gain