Fig. 1; (b) incomplete penetration of the r-f field into the sphere above B; and (c) inhomogeneity in the internal r-f field above A. Non-uniform r-f fields in the test sphere presumably give rise to a distribution of local r-f demagnetizing factors about an effective value whose deviation from the static value of $4\pi/3$ increases with diameter. At A and below, this deviation is very small but the line width still is much greater than that expected from the influence of magnetic crystalline anisotropy which should be very small in this material. The indications are that the skin depth becomes less than the radius of the sphere above point B since the break in the line width curve of Fig. 1b, the departure from a linear relationship in Fig. 2, and the onset of the "μ_R effect" all occur at this point. The "μ_R effect" refers to the minimum in the absorption curve previously observed in some ferromagnetic metals[3] and in magnetite.[4]

For the ideal case of uniform r-f fields in a sphere, the product of maximum energy absorption times line width should be directly proportional to the volume of the sphere. Figure 2 shows that the experimental data deviate from the linear relationship above point B thus indicating that the effective volume becomes smaller than the true volume for larger spheres.

The "size effect" is governed primarily by the wavelength and skin depth in the medium which may of course vary between wide limits in semiconducting ferrites depending upon such factors as composition, presence of impurities, heat treatment, etc. For example, the g-factor of polycrystalline spheres of one lot of manganese ferrite[5] was essentially independent of sphere size up to a diameter of 0.060 cm whereas that for another lot of the same ferrite disclosed a pronounced "size effect" in this region.

[1] C. Guillaud, J. Recherches C.N.R.S., No. 12, 1–10 (1950).
[2] Yager, Galt, Merritt, and Wood, Phys. Rev. **80**, 744 (1950).
[3] W. A. Yager, Phys. Rev. **75**, 316 (1949).
[4] L. R. Bickford, Jr., Phys. Rev. **78**, 449 (1950).
[5] Guillaud, Yager, Merritt, and Kittel, Phys. Rev. **79**, 181 (1950).

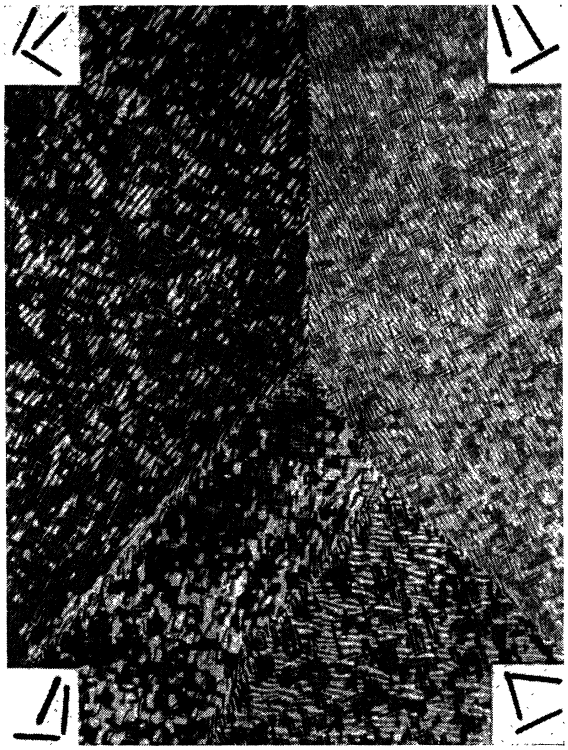

FIG. 1. Microstructure of Alnico 2 aged 300 hr at 800°C. ×500. Traces of the precipitate plates in the four crystals are indicated in the white squares at the corners.

Precipitation and the Domain Structure of Alnico 5

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December 11, 1950

THE good magnetic properties of many permanent magnet materials originate in the precipitation from solid solution of a ferromagnetic phase. In the Alnico alloys during the precipitation heat treatment plate-like particles of an iron-rich phase form in a matrix which becomes rich in the intermetallic compound NiAl. The particles are parallel to {100} planes of the parent matrix. Thus, they present a maximum of three trace directions in any one crystal on a polished and etched surface of the polycrystalline alloy as shown by Fig. 1.

Alnico 5 has the somewhat unique characteristic of exhibiting anisotropic properties when precipitation is initiated during cooling in a magnetic field. The residual induction is especially high in the direction of the field that is applied during cooling. Two years ago the author attributed this behavior to the preferential formation of precipitate particles on certain but not all of the three {100} planes.[1] Later Kittel, Nesbitt, and Shockley[2] showed that anisotropic properties are present immediately after the controlled cooling in the magnetic field and prior to the precipitation heat treatment. This indicates that the preferred orientation of nuclei is established during the cooling and that merely growth on these nuclei occurs during the subsequent aging treatment.

Kittel and his co-workers[2] attributed the preferred orientation to a minimum demagnetization energy for nuclei which have their surface closely parallel to the field direction. Recently, the author published further microscopic evidence that confirmed this expected preferred orientation: a single crystal which had been cooled with the field along the [001] direction and then reheated to 800°C and held for 16 hr to grow the precipitate

FIG. 2. Microstructure of Alnico 5 aged 300 hr at 800°C. ×500.

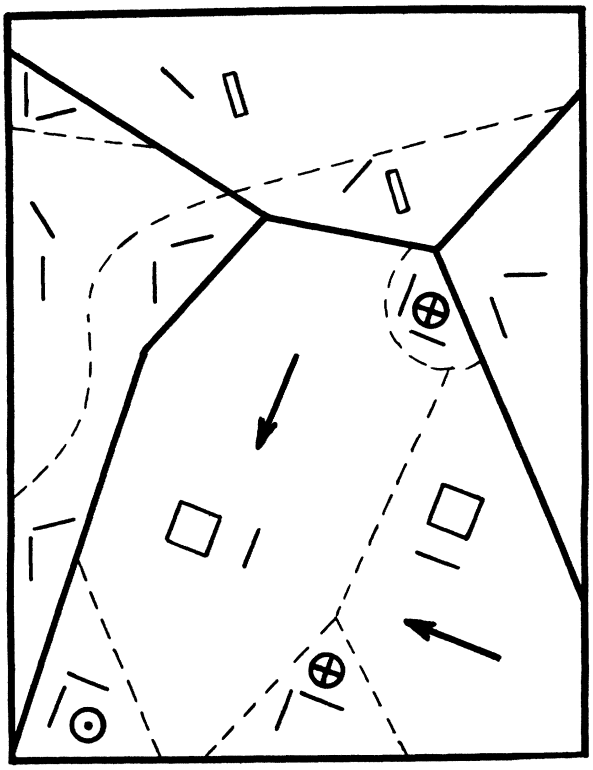

FIG. 3. Tracing of Fig. 2 showing crystal boundaries as heavy lines, approximate domain boundaries as broken lines, the traces of precipitate particles, and field direction in each domain of the largest crystal.

particles exhibited plates on (010) and (100) planes but none on (001) planes.[3] An elaboration of the author's theory that the magnetostriction energy of the matrix supplies part of the strain energy for nucleation of the favored orientations of the precipitate is included in the latter report.

Goldman and Smoluchowski[4] propose that the preferred orientations are those in which the direction of minimum strain energy due to magnetostriction is closely parallel to the field direction. From work on single crystals of Fe-Co alloys they show that the minimum magnetostriction in the precipitate would be expected to occur in ⟨100⟩ directions.

When an applied field is capable of influencing the precipitation process one would expect that the field due to spontaneous magnetization of the magnetic domains would promote a similar effect. The micrograph in Fig. 2 is presented as evidence for this effect. The micrograph is for Alnico 5 which had been oil quenched from the solution heat treating temperature and then aged for 300 hr at 800°C to grow the particles to a microscopically resolvable size. No external field had been applied during any part of the treatment. The micrograph shows that within each of the four crystals there are domains in which two of the three possible orientations of the precipitate predominate. The extent of the domains and the traces of the precipitate plates are sketched in Fig. 3. The direction of spontaneous magnetization in the domains can be determined by the criterion that the direction of the field must have been parallel to the two different orientations of precipitate plates. These directions have been designated in Fig. 3 for the largest crystal which has been sectioned with a (100) type plane approximately parallel to the plane of polish.

The non-uniform distribution of the precipitate in Fig. 2 is thus a manifestation of the magnetic domain structure of the matrix which has been revealed also by the usual powder technique.[5] In the presence of an applied field each crystal would be a single domain and those favored orientations of the precipitate would be nucleated throughout the crystal. In contrast to the macro-domain structure of the parent matrix, the micro-domain structure of the individual precipitate particles and the cooperative interaction between particles in the less ferromagnetic matrix are the more important considerations in producing the magnetic hardening. The increased residual induction provided by preferred nucleation most likely originates in the enhancement of particles in orientations of minimum demagnetization energy.

The main contribution of this note is the observation that the internal spontaneous fields in the domain structure of the matrix exert an important influence on the precipitation process in Alnico 5. Thus, the requirement of a high external field considered in theoretical treatments of the phenomenon is not necessary. The absence of preferential precipitation in Alnico 2 (Fig. 1) is in accordance with the observation that cooling in a magnetic field has little effect on the properties of this alloy. The author's theory would attribute the difference in behavior of these two alloys mainly to differences in the anisotropy of strain energy associated with the precipitation process as modified by matrix magnetostriction, whereas others[4] attribute it to differences in magnetic properties of the precipitate. Both alloys contain precipitate particles of a plate-like shape necessary for anisotropy of demagnetization energy; however, the spontaneous field in the Alnico 2 sample would be expected to be low, for the 800°C aging temperature is only 25° below the Curie temperature of Alnico 2 while 90° below that of Alnico 5. Metallographic studies of the effect of domain structure on the precipitation process at lower temperatures is now in progress, and they should provide additional information to permit further evaluation of the three theories.

[1] A. H. Geisler, Elec. Eng. **69**, 37 (1950).
[2] Kittel, Nesbitt, and Shockley, Phys. Rev. **77**, 839 (1950).
[3] A. H. Geisler, ASM Preprint No. 9 (October, 1950), unpublished.
[4] J. E. Goldman and R. Smoluchowski, Phys. Rev. **80**, 302 (1950).
[5] E. A. Nesbitt and H. J. Williams, Phys. Rev. **80**, 112 (1950).

Gamma-Alpha-Reaction in Rb^{87}

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November 20, 1950

USING 100-Mev betatron x-rays, Baldwin and Klaiber[1] have obtained multiple photo-nuclear disintegrations in which alpha-particles were observed in cloud-chamber photographs to be ejected from nuclei. Gaerttner and Yeater[2] have also observed disintegrations in N and O which they believe may be due to (γ, α) reactions. To date the most extensive examination of (γ, α) processes has been carried out by the use of photographic emulsion techniques.[3–5] This letter describes a study of the (γ, α) processes by an entirely different method; namely, by the study of the activity in an unstable product nuclide.

Samples of $RbNO_3$ of 10 g were irradiated in the University of Saskatchewan betatron at peak energies ranging from 15 to 27.4 Mev. The samples were placed very close to the donut target for high dosage rates. Irradiation times ranged from a few minutes to several hours. Tantalum strips were used to monitor the dosage rate. The reaction $Ta^{181}(\gamma, n)Ta^{180}$ gives a pure 8.2-hr activity which has a low threshold and whose activation curve has been measured carefully in this laboratory.[6] After irradiation the active Br was extracted from $RbNO_3$ by precipitation with $AgNO_3$, and the resulting activity counted in standard geometry. For irradiation energies up to 27 Mev a pure 140-min activity, arising from Br^{83}, was observed. After appropriate corrections for geometry, self-absorption, back-scattering, etc., the activation curve of Fig. 1 was obtained. This shows the number of active atoms formed per minute per $100r$ per minute per Rb^{87} atom bombarded, as a function of maximum betatron energy. Here 100 percent efficiency of chemical separation has been assumed.

Analysis of the activation curve by a method described pre-

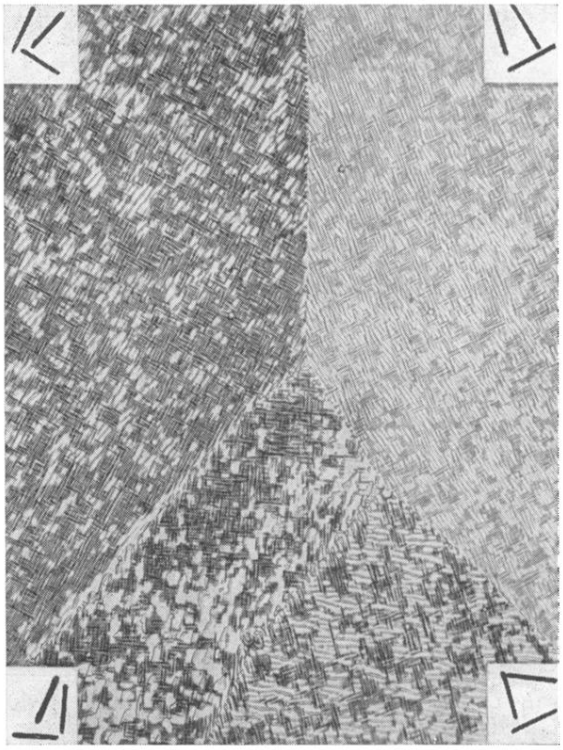

FIG. 1. Microstructure of Alnico 2 aged 300 hr at 800°C. ×500. Traces of the precipitate plates in the four crystals are indicated in the white squares at the corners.

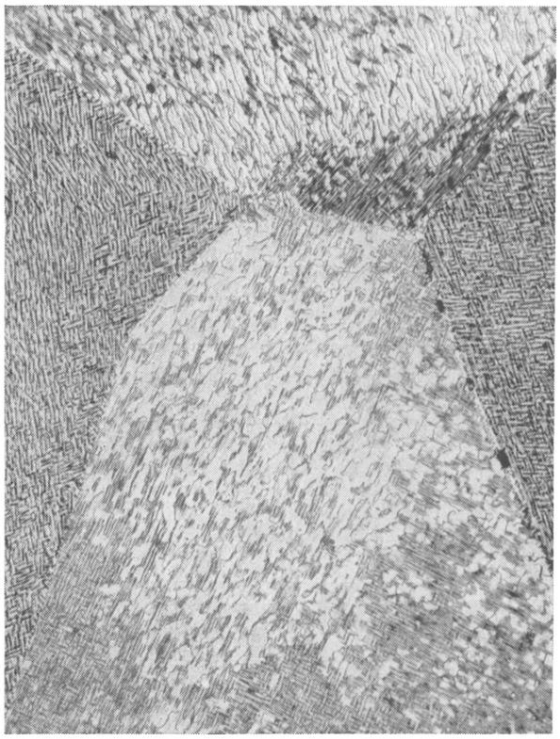

FIG. 2. Microstructure of Alnico 5 aged 300 hr at 800°C. ×500.