Title
THE MICROSTRUCTURE OF Fe-Cr-Co-Nb-Al PERMANENT MAGNET



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# THE MICROSTRUCTURE OF Fe-Cr-Co-Nb-Al PERMANENT MAGNET

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Fe-Cr-Co permanent magnet alloys are known to be commercially potential magnets, the energy products of which are comparable to those of Alnico V, with good ductility (1). It was recently found that the addition of Nb and Al to the Fe-Cr-Co alloy system facilitated heat treatments to produce good magnetic properties (2).

The present paper describes the microstructure of an Fe-Cr-Co-Nb-Al permanent magnet. An effect of a thermomagnetic treatment on the microstructures is also discussed since a thermomagnetic treatment plays an important role in producing good magnetic properties in this alloy.

The magnetic hardening of the alloy is performed by tempering after solution treatment. Upon tempering, a $\alpha$ phase spinodally decomposes into two phases, an iron-rich phase ($\alpha_1$) and a chromium rich phase ($\alpha_2$) (1).

The microstructure shown in Fig. 1 results after the Fe-28wt%Cr-15wt%Co-1wt%Nb alloy is tempered at 640°C for 20 min. The decomposition process appears to be isotropic in the alloy. No satellites are observed in the corresponding diffraction pattern. The decomposed phase (with bright contrast) is identified as iron-rich phase ($\alpha_1$), approximately 60A in diameter. Continued aging of the alloy (200 hr.) causes the particles to grow (800A in diameter) as shown in Fig. 2. The growth rate of the particles is described by $\lambda \propto kt$ 1/3.

Figure 3(a) and (b) are the electron micrographs of the alloys tempered at 640°C in a magnetic field of 2 KOe for 5 hr, in planes parallel and perpendicular to the direction of a magnetic field, respectively. The ferromagnetic phase ($\alpha_1$) has a rod-like shape and is elongated to the direction of the magnetic field, independently of crystal orientation {the region marked A is oriented near (111) and B, (110}.

The ratio of the length to the diameter of the particles increases to approximately 5, which leads to an increase in the shape anisotropy of the single domain.

Our results lead us to conclude that the magnetic properties of the alloy do not depend on the crystal orientation. This is confirmed by the measurement of the magnetic properties of Fe-30wt%Cr-23wt%Co single crystal (3).

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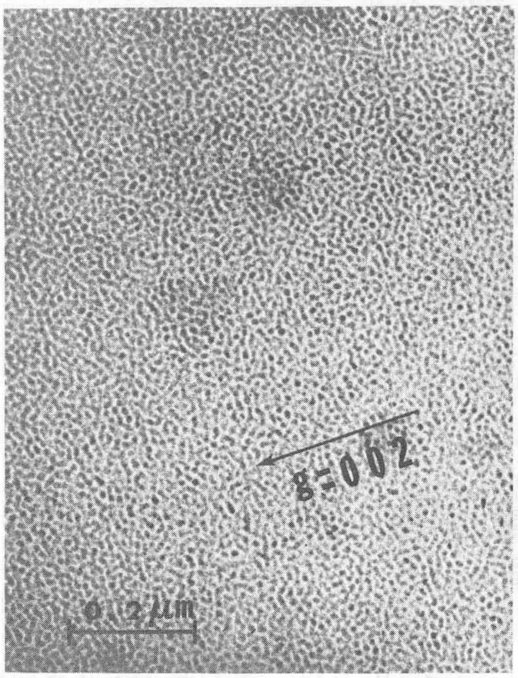


Fig. 1

B.F. micrograph showing the decomposition process appears to be isotropic in the alloy tempered for 20 min. at 640°C; [100] foil.

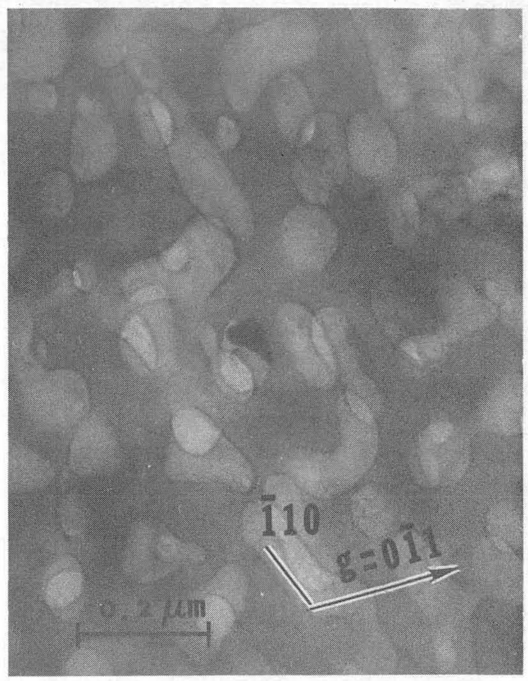


Fig. 2    XBB 764-3254

B.F. image showing the coarsened particles after tempering for 200 hr. at 640°C; [111] foil.

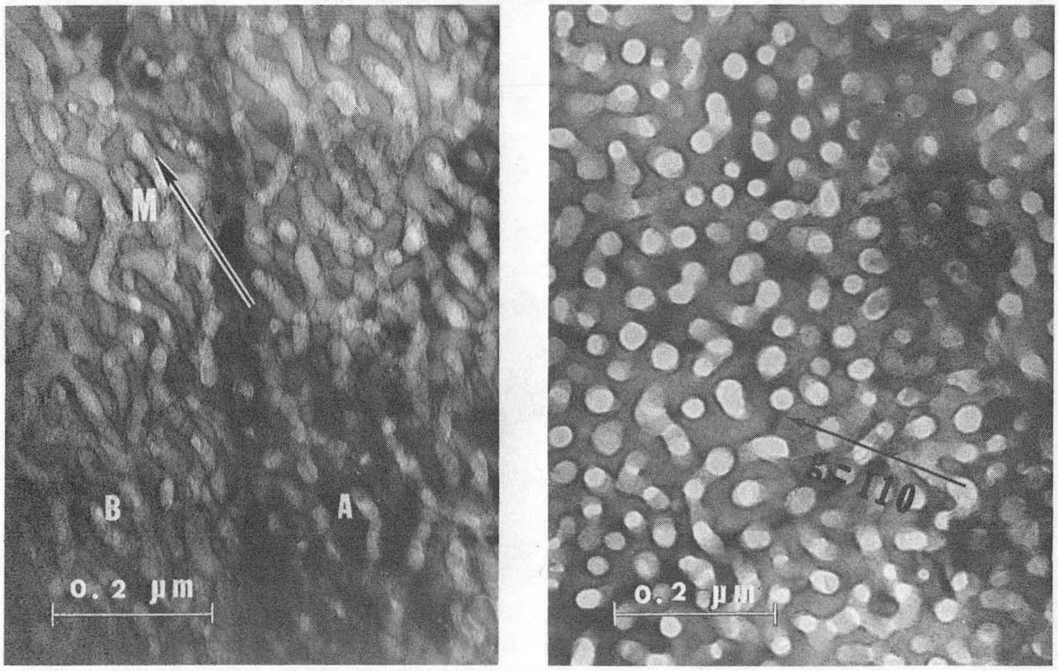


Fig. 3 XBB 764-3253

B.F. micrograph of alloy tempered for 5 hr. at 640°C in a magnetic field of 2KOe showing the ferromagnetic particles are elongated along the direction of the magnetic field (M), independently of crystal orientation.

(a) parallel to magnetic field (M); A: [111] B: [110] orientation

(b) normal to magnetic field; [110] foil.

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