PERMANENT MAGNETISM AND MICROSTRUCTURE IN τ-AlMn(C)

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The lattice transformations by which ferromagnetic AlMn(C) is formed have been studied by transmission electron microscopy and diffraction.

After an initial ordering transition, further transformation takes place by a shear mechanism. The ordering in the close packed planes is preserved throughout the shear transformation.

1. Introduction

In the Al–Mn system (fig. 1) containing about 55 at% Mn, a metastable phase occurs which has interesting properties for permanent magnet applications [1, 2]. This τ-phase has the CuAuI structure with a uniaxial anisotropy along the c-axis. In view of the value of the saturation magnetization, maximum energy products of more than 100 kJm^{-3} might be expected. The actual values depend largely on the density of certain lattice defects and, therefore, on the processes by which the τ-phase is formed. Hot stage transmission electron microscopy and diffraction have been used to observe directly the transformation from the quenched hcp phase (fig. 1) to the CuAuI phase.

2. Ordering processes

The water quenched hcp phase already contains numerous very small nuclei of an ordered phase, see fig. 2. This phase has the B19 structure, as proposed by Jakubovics and Jolly [3]. The B19 structure can be described [2, 4] as an AB|AB stacking of the same ordered close-packed planes present in the CuAuI phase; see fig. 3.

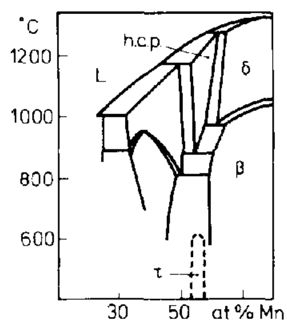

Fig. 1. Portion of the Al–Mn phase diagram.

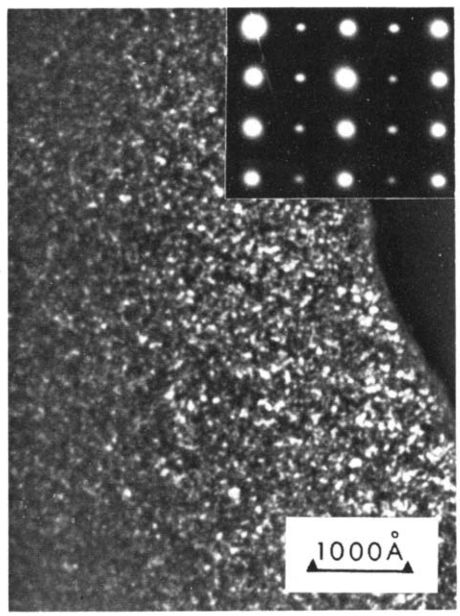

Fig. 2. B19 nuclei in water quenched AlMn(C); dark field image in ordering spot.

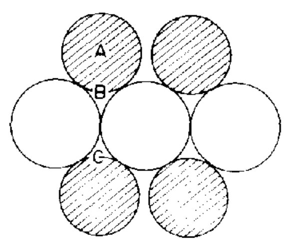

Fig. 3. Ordered close packed layer. The B19 structure can be described as an AB|AB| packing of those planes, the CuAuI structure as an ABC| . . . packing.

Upon heating, larger plate-shaped ordering domains are formed; after completion of the ordering reaction these domains have sizes of 300–400 Å. The sharpening of the superlattice spots indicates that the degree of order within the domains increases [4].

3. The transformation to the CuAuI structure

During the first stages of the transformation, high densities of stacking faults show up in the B19 matrix. This faulting gives rise to extensive streaking in the (001) direction in the diffraction pattern [4] proving that the shear plane is, indeed, the close-packed plane. In a further stage the streaks break up into rows of spots in accordance with an extra periodicity in the image, fig. 4. The separation of the lines is 13.8 Å corresponding to a repeat unit of six close-packed planes. This intermediate state can be described as a polytype of the B19 structure; it appears in narrow bands, about 100 Å wide, surrounded by bands of other polytypes or the final CuAuI phase. In order to produce the ABC stacking of the CuAuI structure, a stacking fault has to be introduced on every second plane of the B19 structure. The polytype can be described as a state with a lower density of regularly distributed stacking faults.

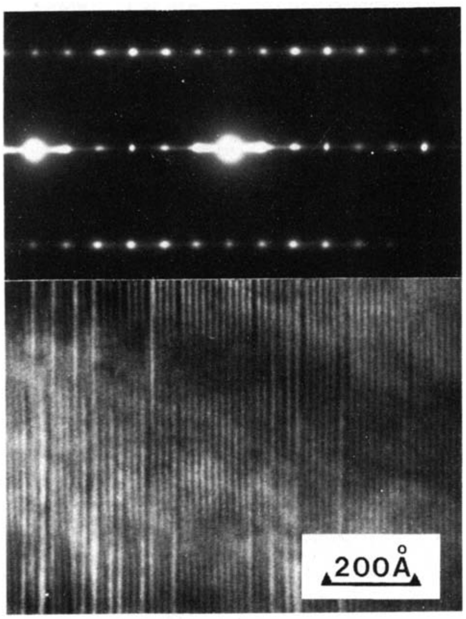

Fig. 4. Polytype of the B19 structure with corresponding diffraction pattern. The spacing of the lines is 13.8 Å corresponding with a repeat unit of six close-packed planes, e.g. with stacking sequence ABCACB| . . . , .

4. Microstructure of the magnetic phase

The microstructure in the CuAuI phase contains high densities of microtwins and antiphase boundaries [5, 6]. The antiphase boundaries seem to be preserved throughout the B19–CuAuI transformation; they play an important role in determining the magnetic properties of the material. Their negative influence [5, 7] can be overcome by subjecting the materials to a hot extrusion process [2]; the resulting microstructure is characterized by a very fine grain size in which hardly any or no antiphase boundaries at all are present [6].

References

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