CHARACTERISTIC MAGNETIC DOMAINS IN PLASTICALLY DEFORMED SINGLE CRYSTALS OF Ni, Co AND Fe

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Résumé. — Sur des monocristaux de nickel c. f. c., de cobalt hexagonal et de fer α, déformés plastiquement, on observe une structure caractéristique de domaines magnétiques en couches. Les cristaux orientés de façon à obtenir un glissement simple furent coupés en tranches dont les surfaces étaient perpendiculaires aux plans actifs de glissement. On a examiné des domaines sur une surface $(\bar{1}01)$ de nickel à des températures entre 20 °C et 220 °C, sur une surface $(11\bar{2}0)$ de cobalt entre 245 °C et 350 °C, et une surface (111) de fer à 20 °C. L'origine de ces configurations de domaines est interprétée par des couches de dislocations qui se forment sous la déformation plastique à cause d'une interaction entre des groupes de dislocations primaires et des dislocations secondaires.

Abstract. — Characteristic layer-like domains were observed on f. c. c. nickel, hexagonal cobalt, and b. c. c. iron crystals after plastic deformation. The crystals, oriented for single glide, were cut into slices with surfaces perpendicular to the active glide planes. Domains were observed on a $(\bar{1}01)$-surface for Ni at temperatures between 20 °C and 220 °C, on a $(11\bar{2}0)$-surface for Co between 245 °C and 350 °C and on a (111)-surface for Fe at 20 °C. The origin of these domain configurations is seen to lie in dislocation layers which may develop during plastic deformation from an interaction of primary dislocation groups with secondary dislocations.

I. **Introduction.** — Internal stresses produced by plastic deformation may influence magnetic domain structures significantly [1, 2]. The internal stresses responsible for this effect may be classified according to their wavelength as follows :

1. Microstresses between individual dislocations and elementary dislocation arrangements (dislocation groups) ($\lambda < 1\ \mu$-$5\ \mu$).

2. Intermediate stresses which are generated if the elementary dislocation arrangements posses a certain long range order ($\lambda \sim 5\ \mu$-$100\ \mu$) as illustrated in figure 5.

3. Macrostresses which are produced by macroscopic inhomogeneities, e. g. kink bands, twinning, bending ($\lambda \gtrsim 0.1$ mm).

Since the stress tensors of all three types of stresses are anisotropic, the magnetoelastic energy induces an additional anisotropy which may show up in the domain structure. A theoretical treatment of the induced anisotropy due to microstresses has been given previously [3]. In some further papers the effect of the induced anisotropy on the law of approach to saturation was investigated [4]. The aim of the present paper is an investigation of the effect of the intermediate stresses on the domain structure of deformed single crystals. Macrostresses which often prevent an investigation of the effect of the micro- and intermediate stresses were as far as possible avoided by a careful preparation of the specimens.

II. **Experimental results.** — Rod-shaped single crystals oriented for single glide were deformed plastically. From these crystals circular disks were cut by spark erosion, which were polished electrolytically in order to remove the damaged surface layers. Afterwards they were coated with a thin layer of CeO or ZnS to enhance the magnetooptic Kerr effect [5]. The most interesting phenomena were observed on specimens cut perpendicular to the active glide planes, and we shall restrict ourselves to this case.

Figure 1 shows domain structures on the $(\bar{1}01)$-surface of a nickel single crystal [6]. In the undeformed

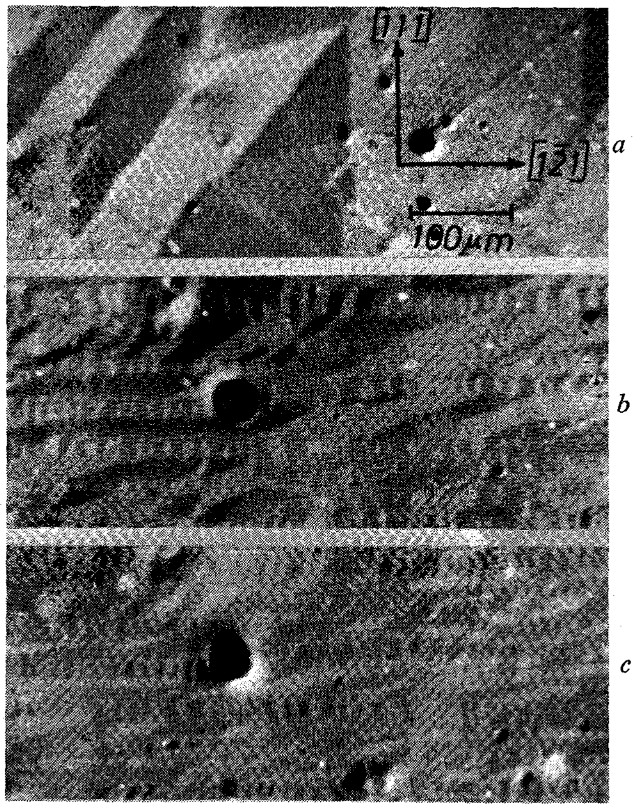

FIG. 1. — Ni, $(\bar{1}01)$-surface, *a*) undeformed, temperature $T = 20$ °C, *b*), *c*) deformed, shear strain $a = 0.09$, *b*) $T = 20$ °C, *c*) $T = 100$ °C.

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disk (Fig. 1*a*) the expected random four phase domain structure is observed. In the deformed disk ladder-shaped stripes appear which are extended parallel to the primary glide plane. The magnetization in the ladder regions is perpendicular to the stripes, while the magnetization between the ladders deviates from the direction parallel to the stripes by a small angle (Fig. 2). This deviation is attributed to the influence of

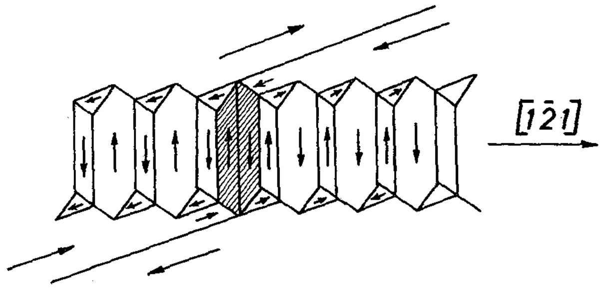


FIG. 2. — Schematic diagram of the domain structure in figure 1*b*.

crystal anisotropy and decreases at elevated temperatures when the anisotropy constant is reduced (Fig. 1*c*).

On plastically deformed cobalt similar layered domain patterns parallel to the basal plane are visible in the temperature ranges where conical and planar anisotropies are found (Fig. 3) [7]. On iron a similar

a

b

c

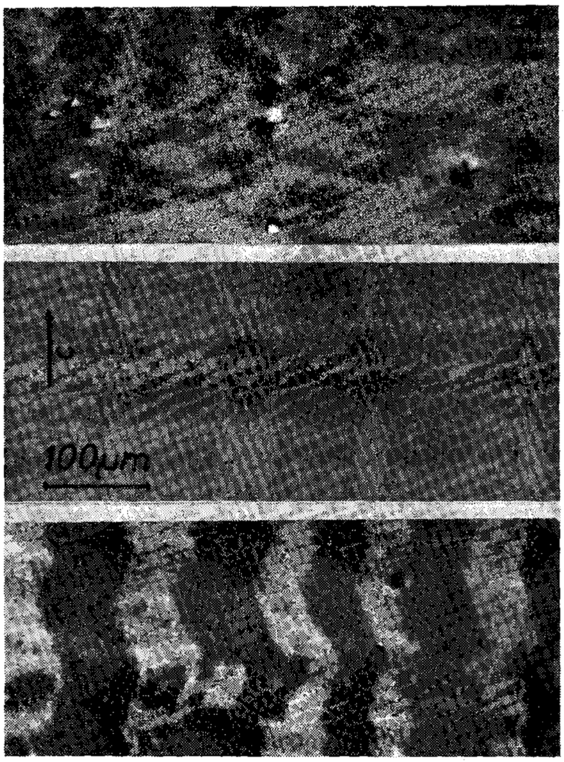
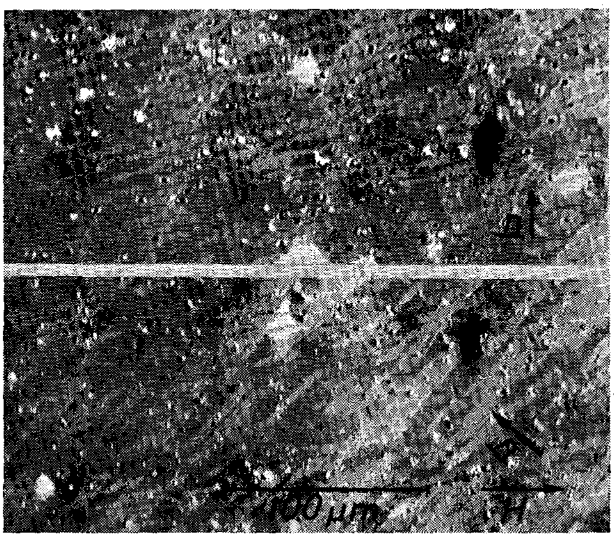


FIG. 3. — Co, *a*) undeformed, $T = 350$ °C, *b*), *c*) deformed, *b*) $a = 0.5$, $T = 350$ °C, *c*) $a = 0.3$, $T = 260$ °C. In figure 2*c* the layer structure is indicated by serrated lines.

result was obtained on a (111)-plane which usually shows a very fine irregular surface domain pattern. On a deformed specimen this surface pattern arranges in a clear stripe fashion best visible in an applied field as demonstrated in figure 4. Once more these stripes are parallel to the macroscopic glide plane which in b. c. c. metals usually does not coincide with a crystallographic plane. In contrast to this results layered



4 *a*

4 *b*

FIG. 4. — Fe, deformed, (111)-surface, $T = 20$ °C, $H_a = 2.6$ kOe, $a = 0.15$, **n** = normal to the mean glide plane.
a) $\mathbf{H}_a \perp \mathbf{n}$: no influence of stresses ;
b) Angle between $\mathbf{H}_a$ and **n** = 30° : stress induced stripes.

domain patterns could not be observed in Co at room temperature and on (100)-surfaces of Fe. In these cases the domain structures are governed by the strong crystal anisotropy alone.

III. **Discussion.** — A common feature of the domain structures observed in the deformed specimens is their arrangement in stripes parallel to the active glide planes. The stripes posses alternatingly easy directions parallel and perpendicular to the glide planes, as seen from the domain pictures. For Ni this means that there exist tensile stresses in the ladder-regions of figure 1 and compressive stresses outside of them. A dislocation arrangement giving such a stress pattern is presented in figure 5. Here dislocation groups in the

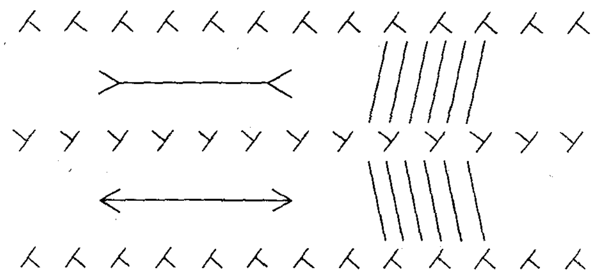


FIG. 5. — Model of dislocation layers with resulting stress and lattice rotations.

active (primary) glide plane have reacted with secondary dislocations and have converted to sessile dislocations. In order to reduce the internal stresses the dislocation groups tend to form a layered structure with alternating Burgers vector of neighbouring layers. In addition to the alternating stresses this dislocation arrangement also produces alternating lattice rotations which have no significant influence on the domain structure of Ni and Fe in zero applied field. In Co, however, in the temperature range of conical anisotropy these lattice rotations are responsible for the domain pattern observed in figure 3*c*. Lattice rotations connected with dislocation structures can be made visible also by X-ray topographs using the Berg-Barrett technique. The observed domain structures and the results of the X-ray topographs are in close correspondence for all the three metals [6-9].

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