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Large Magnetic Kerr Rotation in BiMn Alloy

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Ferromagnetic domains in BiMn crystallites are found to be easily observed by utilizing plane polarized light in reflection. A crystallite viewed parallel to the c_0 axis shows a characteristic "rick rack" or zigzag pattern of domains as a stable configuration in zero field. Magnetic domain patterns reminiscent of spiral surface growth are observed. The large magneto-optic rotation is thought to be due to the high resistivity of BiMn alloy.

MAGNETIC domain patterns[1,2] have been observed optically in some large grains of ferromagnetic BiMn alloy prepared at temperatures below the magnetic transformation (360°C). The patterns are easily observed and often appear nearly black-and-white when viewed through the polarizing arrangement of a Bausch and Lomb research metallograph which utilizes the Foster type vertical illuminating prism. The surface need only be smoothly polished with alcohol as a lubricant.

The surface of the grain in Fig. 1 which has its c_0 axis perpendicular to the paper has not been touched between successive frames. Figure 1(b) is the area of Fig. 1(a) after a field of 15 000 oersted has been applied parallel with the surface. Small pattern movements are observable. When the same field is applied perpendicular to the surface the "rick-rack" or zig-zag pattern is seen to break up into separate domain regions and some of these are rough six-sided rings as in Fig. 1(c). BiMn has the hexagonal (NiAs) crystal

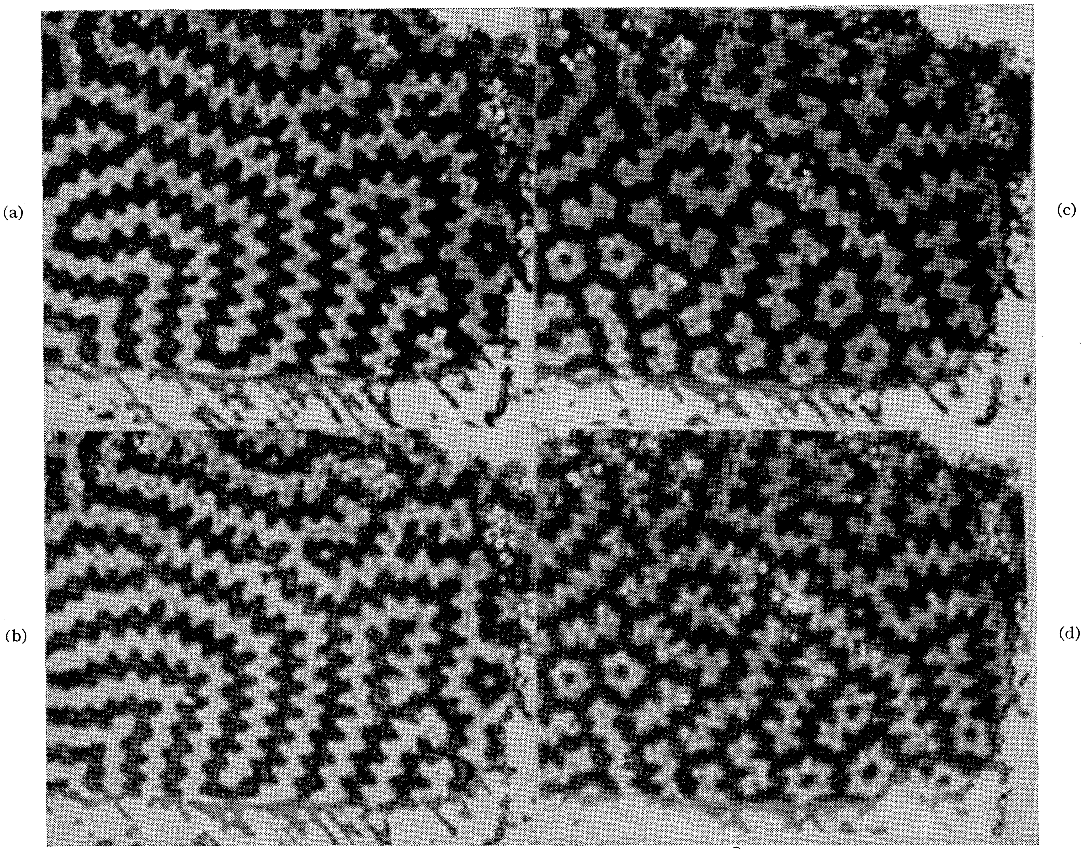

FIG. 1. (a) Original domain pattern on BiMn grain. (b) Same area after 15 000-oe field applied parallel with the surface. (c) Same field applied perpendicular to surface and (d) after cooling to 77.3°K for one minute. 2500×.

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[1] In cobalt. Williams, Foster, and Wood, Phys. Rev. 82, 119 (1951); C. A. Fowler and E. M. Fryer, Phys. Rev. 95, 564 (1954).
[2] In silicon iron. C. A. Fowler and E. M. Fryer, Phys. Rev. 86, 426 (1952); Phys. Rev. 94, 52 (1954).

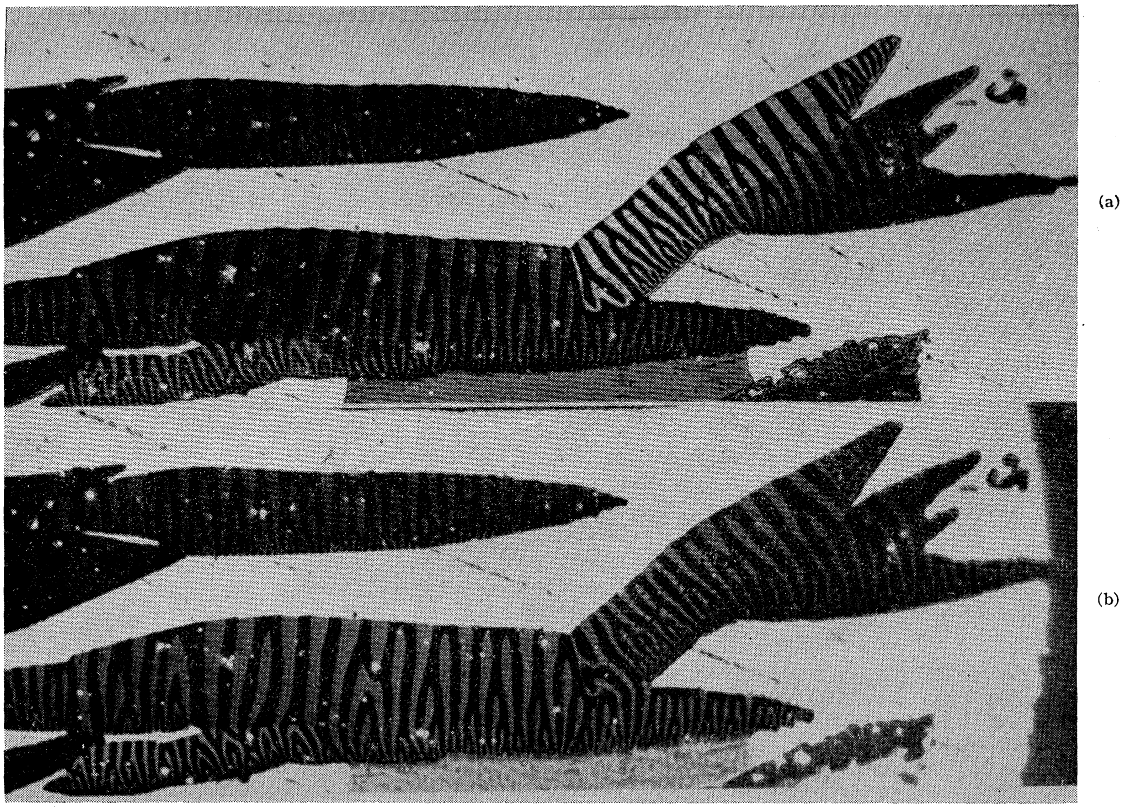

FIG. 2. (a) BiMn domain pattern when observed roughly perpendicular to c_0 axis. (b) Same area after 10 000-oe field was applied in random directions. 700×.

structure which may relate to the rings. The last frame shows the effect of holding the sample in liquid nitrogen for one minute and quickly warming to room temperature. Again small movements are observable which may result from a reorganization of the domains at low temperature due to the marked change in the magnetocrystalline anisotropy energy.[3] There is also the possibility of strain-induced domain motion due to the grain being enclosed in a Bi matrix.

When a group of grains is observed roughly perpendicular to the c_0 axis, the patterns in Fig. 2 are found to be typical. The light grey area is the Bi matrix and the darker BiMn particles have nearly parallel domain patterns which vary in width as they move across the grain. Figure 2(b) shows the area of 2(a) after a 10 000-oersted field has been applied in random directions with respect to the sample. Almost all configurations have obvious domain movement present. The domains are continuous at the crystal-grain boundaries and this was found to hold true regardless of the relative orientations of adjacent grains even up to 90°. Clear Bitter patterns were found to form at the boundaries of the domains.

Figure 3 shows a magnetic domain pattern reminiscent of the many spiral growth patterns being found on crystal surfaces due to growth steps. Seven segments

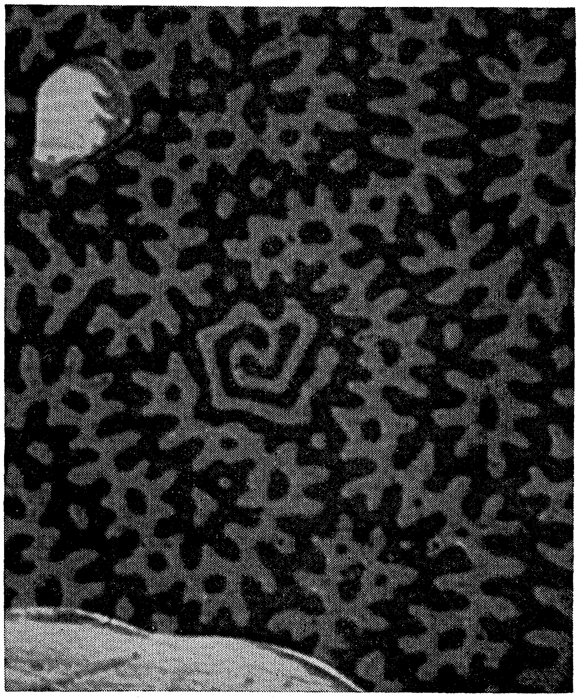

FIG. 3. Spiral-shaped domain pattern observed on BiMn grain. 4000×.

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[3] C. Guillaud, J. phys. et radium 12, 492 (1951).

occur on the outer spiral which may reflect the hexagonal BiMn structure. This is not a surface effect since the light is scattered from beneath any surface coating or disturbance due to polishing.

The light which is scattered perpendicularly from these surfaces appears to be elliptically polarized. We have had difficulty in measuring the amount of rotation and the degree of ellipticity due to the small width of the domains when observed down the c_0 axis. A small rotation of the mica plate in the Bausch and Lomb elliptical compensator will reverse the domain intensities observed.

The primary reason for the ease in observation of the domains is thought to be the high resistivity of BiMn, 424 micro-ohm cm, as reported by Kondo.[4] The lower number of conduction electrons would permit deeper penetration into the region of magnetization and thus permit a greater total rotation of the plane of polarization as has been observed in studies of thin-magnetic films.

We are indebted to Miss Jean Hurd for the metallographic preparation and pictures shown here.

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[4] K. Kondo, J. Phys. Soc. Japan **5**, 307 (1950).

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Fermi Level in Amorphous Antimony Films

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Films of antimony were deposited by evaporation on interchangeable emitters in concentric-sphere, retarding-potential phototubes. Below thicknesses of about 300 A, they behaved as semiconductors. The Fermi level lay about 0.1 ev above the occupied band. They converted irreversibly to the normal crystalline metallic form at 200°C or somewhat higher. The results are consistent with previous measurements on the electrical resistance and optical transmission of thin antimony films; they indicate that the semiconducting form is amorphous. Analogies with the behavior of arsenic are mentioned.

An amorphous form of antimony has been recognized for many years.[1] It is especially common in very thin evaporated films, and it is stable in this form considerably above room temperature. The electrical resistivity[2] and optical absorption[1] of this material indicate that it is a semiconductor.

The present paper supports this view and discusses a direct photoelectric determination of the Fermi level relative to the occupied band of electron energy states. The approach was identical with that used in previous work on amorphous arsenic.[3] Two separate concentric sphere phototubes were used. Results were duplicated with antimony films deposited on substrates of nickel and of crystalline Ge.

Figure 1 shows the current-voltage characteristics for the photoemission from films of antimony deposited on substrates held near room temperature. If the films were below about 300A in thickness, they showed a behavior quite typical of a semiconductor (curve 2). Above this thickness, they were clearly normal crystalline antimony, and showed the photoelectric behavior typical of this poor metal (curve 1).[4] Further, films about 50 a.u. in thickness underwent a transition from semiconducting to metallic behavior upon heating to 200°C or thereabouts for a few minutes.

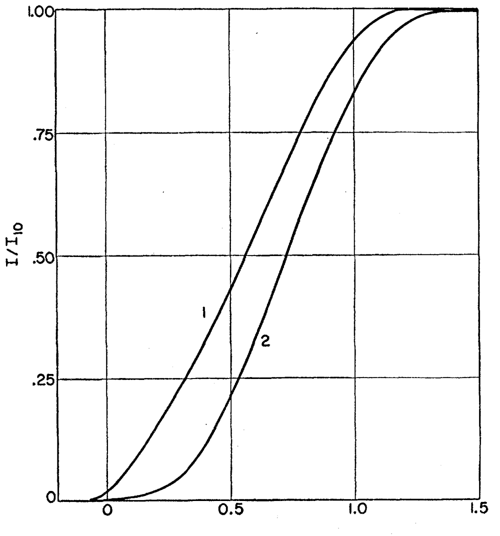

FIG. 1. Current-voltage characteristics for photoemission from antimony films in concentric-sphere phototube at $h\nu = 5.80$ ev. Currents are normalized at a collector potential $V = 10$ v. Abscissas are given relative to the 0°K stopping potential V_0 of an ideal metal, a voltage corresponding to the common Fermi level of all the interchangeable emitters. Curve 1 is for crystalline antimony; curve 2 is for the semiconducting amorphous variety.

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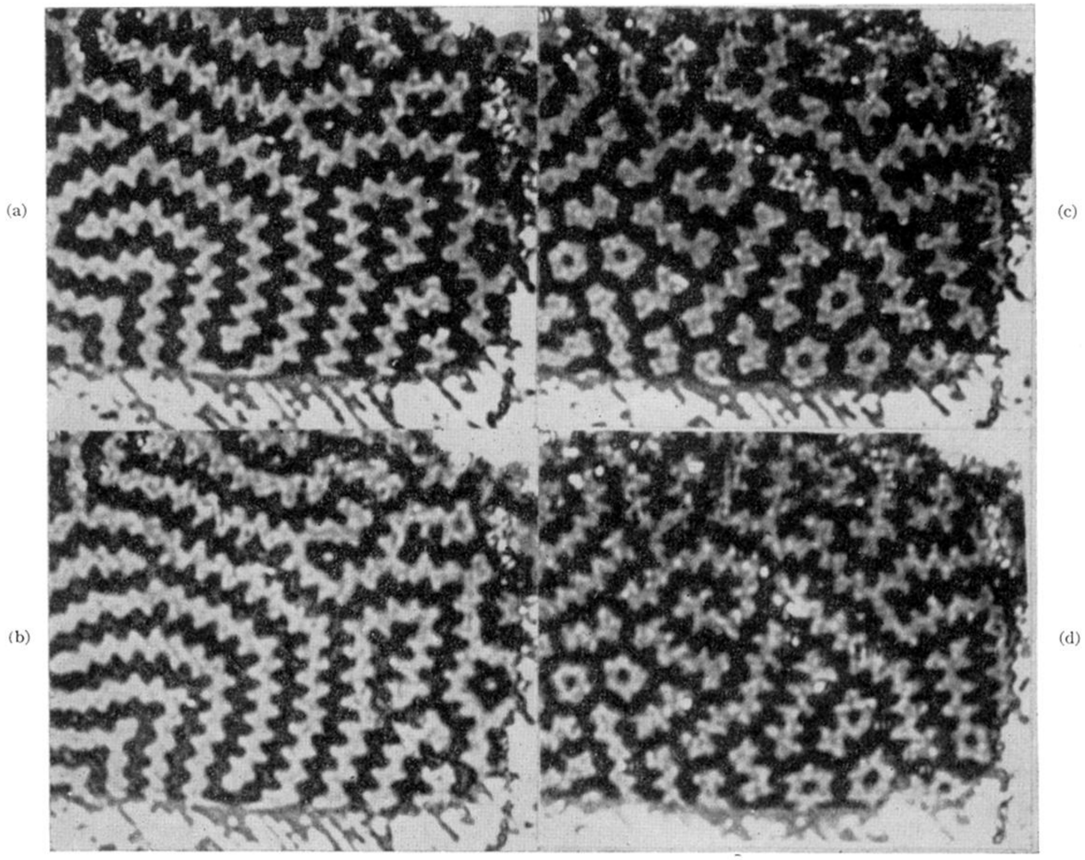
[1] Hans Murman, Z. Physik **54**, 741 (1929); for discussions, see H. Krebs, *Semiconducting Materials*, H. K. Henisch, editor (Butterworths Scientific Publications, Ltd., London, 1950); F. S. Moss, *Photoconductivity in the Elements* (Academic Press, Inc., New York, 1952); an example of recent work is Julius Cohn, J. Appl. Phys. **25**, 798 (1954).

[2] R. Suhrmann and W. Berndt, Z. Physik **115**, 17 (1940).

[3] E. Taft and L. Apker, Phys. Rev. **75**, 1181 (1949).

[4] Apker, Taft, and Dickey, Phys. Rev. **76**, 270 (1949).



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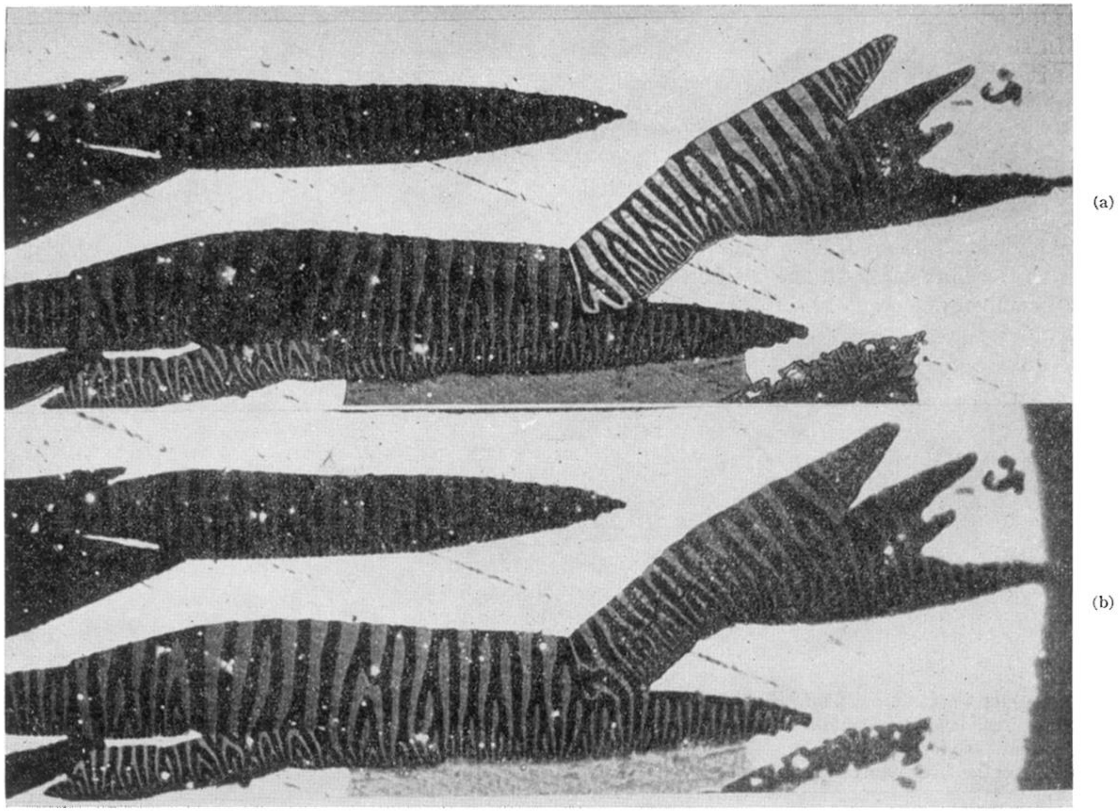
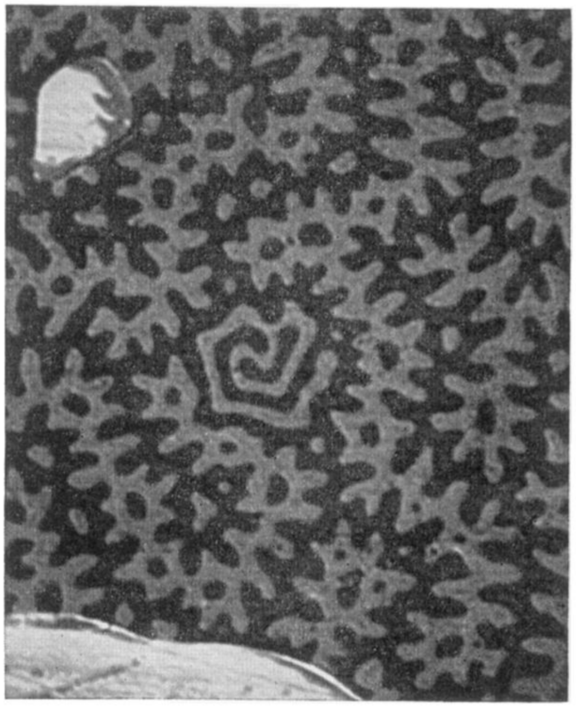


FIG. 2. (a) BiMn domain pattern when observed roughly perpendicular to c_0 axis. (b) Same area after 10 000-oe field was applied in random directions. 700×.



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