Lorentz Microscopy:

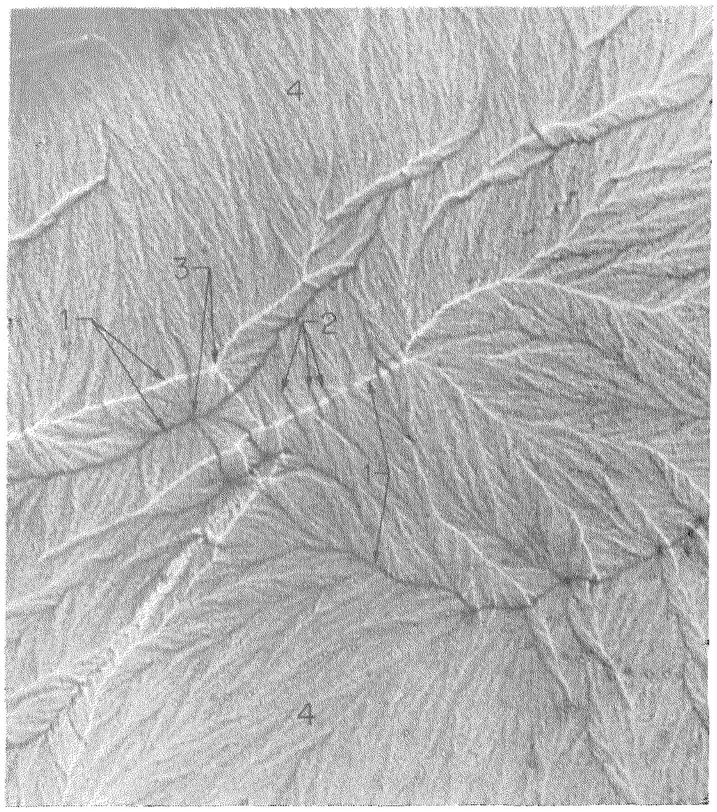
A new use of the electron microscope allows detailed observation of the magnetic structure of ferromagnetic materials

Lorentz microscopy is a new, somewhat different, use of the electron microscope. The technique is used for observing the ferromagnetic character of a material instead of its shape and size.

In normal microscopy work, the electron microscope is focused on the sample, producing an image according to the intensity of the electron beam as it passes through various thicknesses of the sample. This image, when magnified on a photographic plate, produces the electron micrograph.

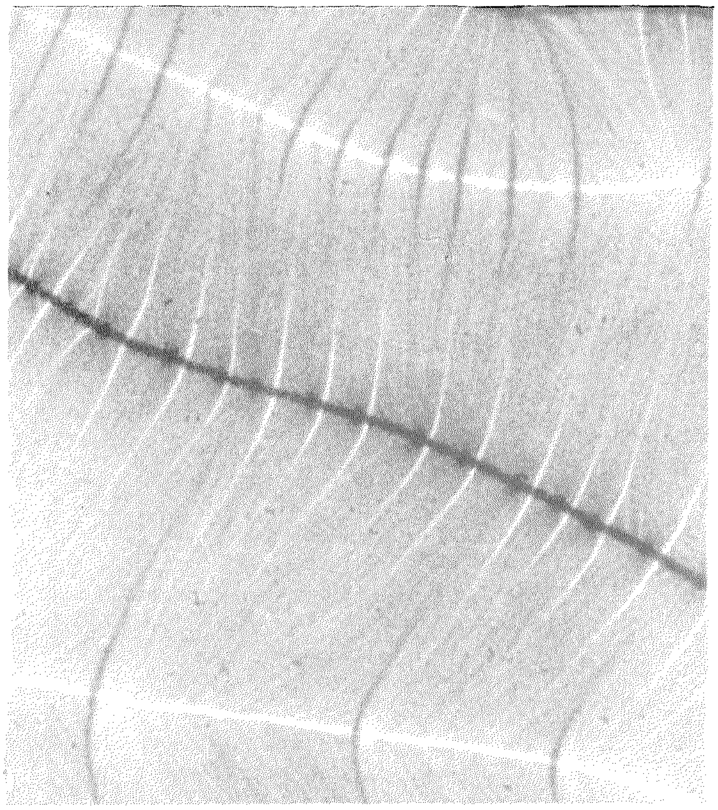
In Lorentz microscopy, however, the microscope is focused a small distance (about a quarter inch) from the sample. Differences in electron intensity are no longer observed, because they are out of focus. However, as the electrons pass through a ferromagnetic material, they are deflected slightly by the local magnetic field in the sample. Thus, if the field is different in different parts of the sample, a difference in electron intensity will be obtained at the focal plane caused by the very small Lorentz deflection of electrons (one thousandth of a degree).

The resulting image is magnified and photographed by the electron microscope, allowing detailed investigation of magnetic changes within the sample.



Observed structures—such as domain walls (1), where the magnetization changes by large angles in short distances—can be seen as either light or dark lines in this photograph. Various irregularities in wall shape can be seen, such as cross-ties (2) and Bloch lines (3), where the direction of rotation of magnetization within the wall changes. The general low-angle changes (about one degree) of magnetization direction throughout the sample can be observed as ripple (4) of the magnetization. This photograph of a pure cobalt film 300 angstroms thick was taken with a 100-kilovolt electron microscope at an out-of-focus distance of 1.1 mm.

A New Dimension



Domain walls appear in Lorentz microscopy because an electron is deflected according to the direction of the magnetic field in the sample—as given by the "right-hand rule." Sometimes electrons on one side of the wall are deflected toward the domain on the other side of the wall, giving a convergent or bright wall, while at other times the electrons will deflect toward their own domain, giving a divergent dark wall. Additional structures such as cross-ties and Bloch lines can also be seen here. The upper walls are 180° walls; the lower wall, with fewer cross-ties, is essentially a 90° wall. This is a picture of an 80 percent nickel, 20 percent iron, film 805 angstroms thick, taken with a 100-kilovolt electron microscope with an out-of-focus distance of 5mm.

Observation of this convergent domain wall, under very high magnification, shows the electrons behaving as predicted, from a quantum mechanical point of view. They are exhibiting diffraction fringes similar to those expected from an electron beam passing a knife edge. Although this is a very basic prediction of quantum mechanics, it is seldom observed in nature. This photograph, a 79 percent nickel, 21 percent iron, film 146 angstroms thick, was taken with a 50-kilovolt electron microscope at an out-of-focus distance of 3cm, using an extremely fine point source for electrons.