Ferroelastic properties of proustite at low temperatures

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A study of the domain structure of proustite in unpolarized light at 29 K reveals that a phase transition seen previously in this material is of a ferroelastic nature. A new phase transition has been detected at 22 K on the basis of a change in the transparency of the sample.

A study of the low-temperature properties of proustite (Ag_3AsS_3) has revealed a ferroelectric phase transition at 29 K, and domains have been observed in polarized light.[1] We have now discovered that this transition is also a transition to a ferroelastic state and is accompanied by the appearance of domains that strongly scatter unpolarized light (Fig. 1). The domain structure is observed in both polarized and unpolarized light in observations of the transmission and reflection of light by the sample. At certain angles of incidence of the light on a domain wall, we observe a specular reflection of the incident light. The brightness of these domains in polarized light does not change when a phase-shifting plate is used.

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FIG. 1. Domain structure of proustite at 20 K. The cooled face is at the bottom. This photograph was taken in transmitted unpolarized light.

This phenomenon was studied in an optical cryostat in which it was possible to study the samples in both transmitted and reflected light. The cryostat allowed repeated changes in temperature at different rates and also a regulated fixed temperature. As the light source we used an illuminator with an incandescent lamp and an LG-76 laser. The proustite sample was cut in the form of a rectangular parallelepiped with dimensions of $10\times3\times6$ mm. The threefold crystallographic symmetry axis of the high-temperature phase ran perpendicular to the large face of the crystal, and one of the symmetry planes coincided with a face with 3×6 mm^2.

The domain structure observed below 29 K leads to an anomalous scattering of the light transmitted through the crystal. This scattering was observed by Baĭsa *et al.*,[2] who thought that it was due to the formation of a superstructure. A photograph of the sample at 20 K reveals a domain structure in which the direction of the domains coincides with one of the symmetry planes of the crystal. The anomalous scattering of light transmitted through the crystal occurs in a direction coinciding with another symmetry plane of the crystal (Fig. 2). When the sample is either heated or cooled, an interface between two phases—a low-temperature phase and a high-temperature phase—is observed at the phase-transition temperature. Figure 2 shows this boundary as a dark band, below which we see a sharp image of the face of the sample further from the observer. In the upper part of this figure we see a blurred image of the same

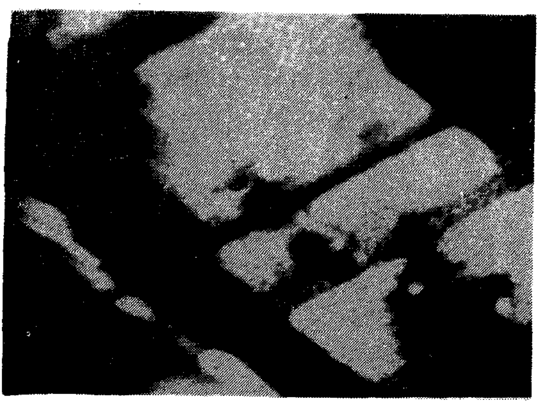

FIG. 2. Two-phase structure of proustite near 29 K. Above the phase boundary, there is a blurred image of the further face of the sample, while below this boundary there is a sharp image. The additional dark band runs parallel to the phase boundary; above it is one of the domains.

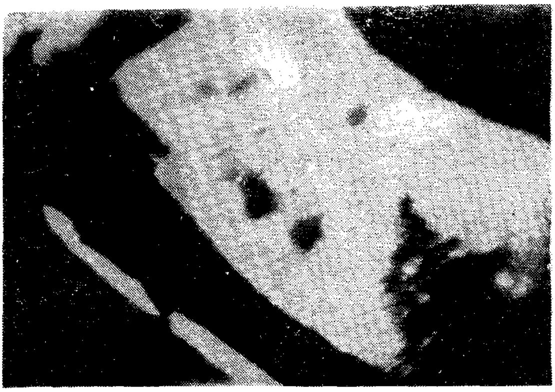

FIG. 3. Photograph of a sample at 35 K. Cracks and tiny polishing defects are seen as dark regions.

face. The reason for the blurring is the scattering of the light in the low-temperature phase. Above 29 K (Fig. 3), the further face of the sample is seen quite sharply. On all the photographs we can see cracks that arise in the sample after it is repeatedly cooled below 29 K. The direction of these cracks is the direction of the crystallographic symmetry planes of proustite in its high-temperature phase. A study of the domain structure in several samples revealed that the structure of the domains depends on not only the rate of change of the temperature but also the dimensions of the sample.

As the sample is cooled slowly from 30 K, the spot on the screen from the parallel light beam (from the incandescent lamp or the laser) transmitted through the sample converts, after the temperature is lowered to 29 K, into a system of spots. As the sample is cooled further, the number of spots increases abruptly in a random manner. The system of spots that appears after the phase transition forms a bright band oriented along one of the symmetry planes of the sample (in its high-temperature phase).

The application of an external mechanical load to the sample gives rise to new domains and causes the domain walls to move. An electric field up to 2×10^5 V/m does not affect the domain structure of proustite.

As follows from Ref. 3, these properties of the proustite single crystals prove that the phase transition at 29 K is of a ferroelastic nature. The nature of the low-temperature properties of proustite should accordingly be reexamined.

Below 22 K we found a transition of the sample to new phase, optically darker. The sample splits into two regions, separated by a boundary that moves throughout the sample parallel to the cooled face as the temperature is varied near 22 K.

The formation of ferroelastic domains in proustite, a familiar optically nonlinear material, may extend the range of applications of this material to the fabrication of devices for controlling light beams and for other purposes in optoelectronics.

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