



The study of piezomagnetism in MnF_2 single crystals

I. V. Bilych¹, K. R. Zhekov¹, G. A. Zvyagina¹, V. D. Fil, D. V. Fil^{2,3}

¹B. Verkin Institute for Low Temperature Physics and Engineering of NAS of Ukraine,
47 Nauky Avenue, Kharkiv, 61103, Ukraine

²Institute for Single Crystals, NAS of Ukraine, 60 Nauky Avenue, Kharkiv, 61072, Ukraine

³V.N. Karazin Kharkiv National University, 4 Svobody Square, Kharkiv, 61022, Ukraine
e-mail: bilich@ilt.kharkov.ua

This report presents the results of the study of the piezomagnetic phenomena in single crystals of MnF_2 using the acoustoelectric transformation (AET) method, which has previously been successfully used to study piezomagnetism in cobalt fluoride. The AET method made it possible to obtain various information about piezomagnetic and electromagnetic effects in studied media.

In piezomagnets, an elastic wave propagating in the sample excites oscillations of the magnetic moment in it, which cause oscillations of the electric field. A measurement of the amplitude and phase of the AET signal at different orientations of the antenna, different polarization of the elastic mode, and in the presence of the external magnetic field make it possible to study the qualitative and quantitative characteristics of magnetoelastic effects.

Significant advantages of the AET method are the practical absence of a background signal and the flexibility in implementing various experimental geometries.

The scheme of the AET experiment is shown in Fig. 1. The shear deformation of a given polarization, generated by the piezoelectric transducer, is introduced into the sample through an acoustic delay line. The electromagnetic field, arising in the sample under deformation, is radiated into free space and registered by a frame antenna placed near the sample. The interface radiating surface is orthogonal to the wave vector of the sound mode.

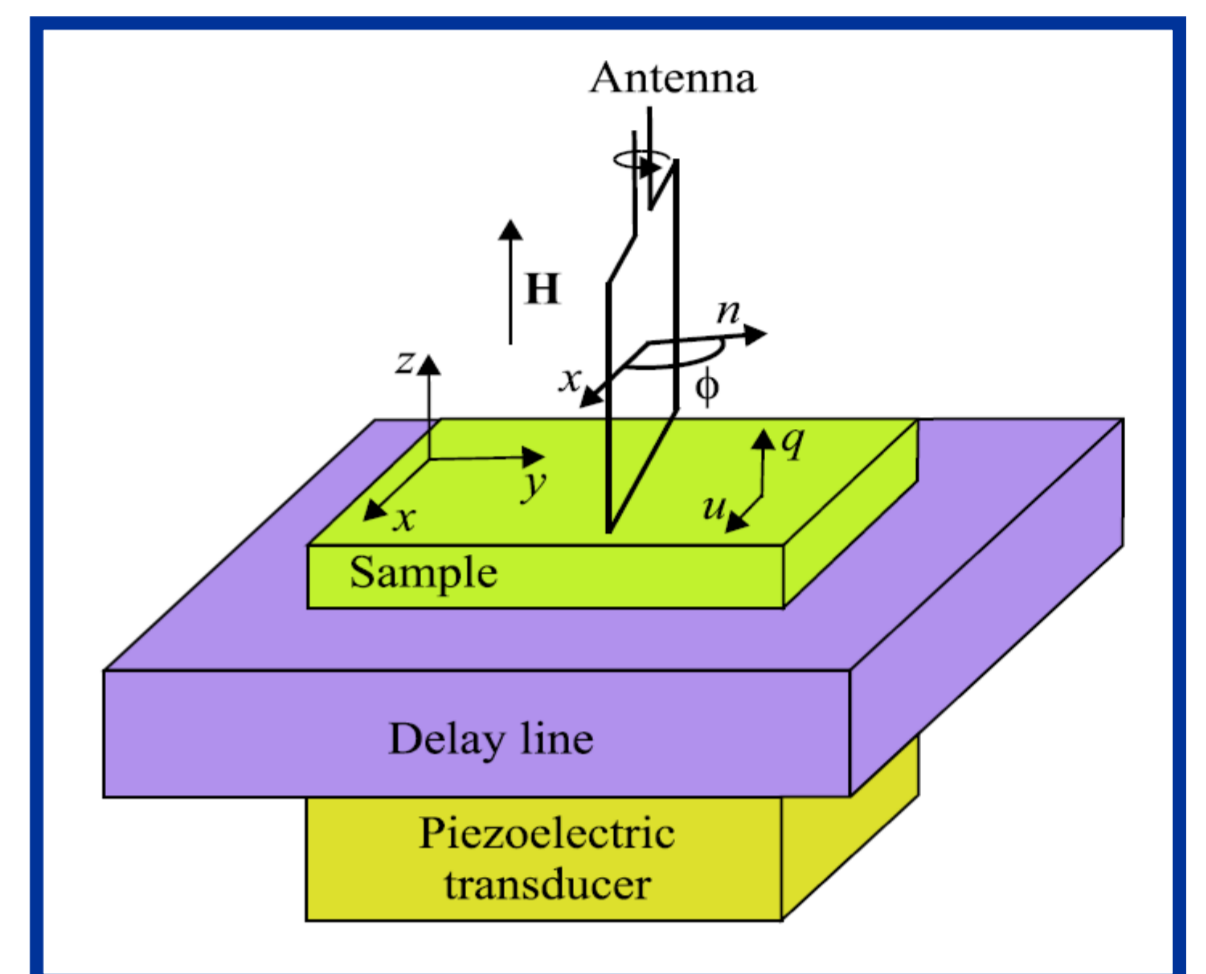


Fig. 1. Geometry of the AET experiment

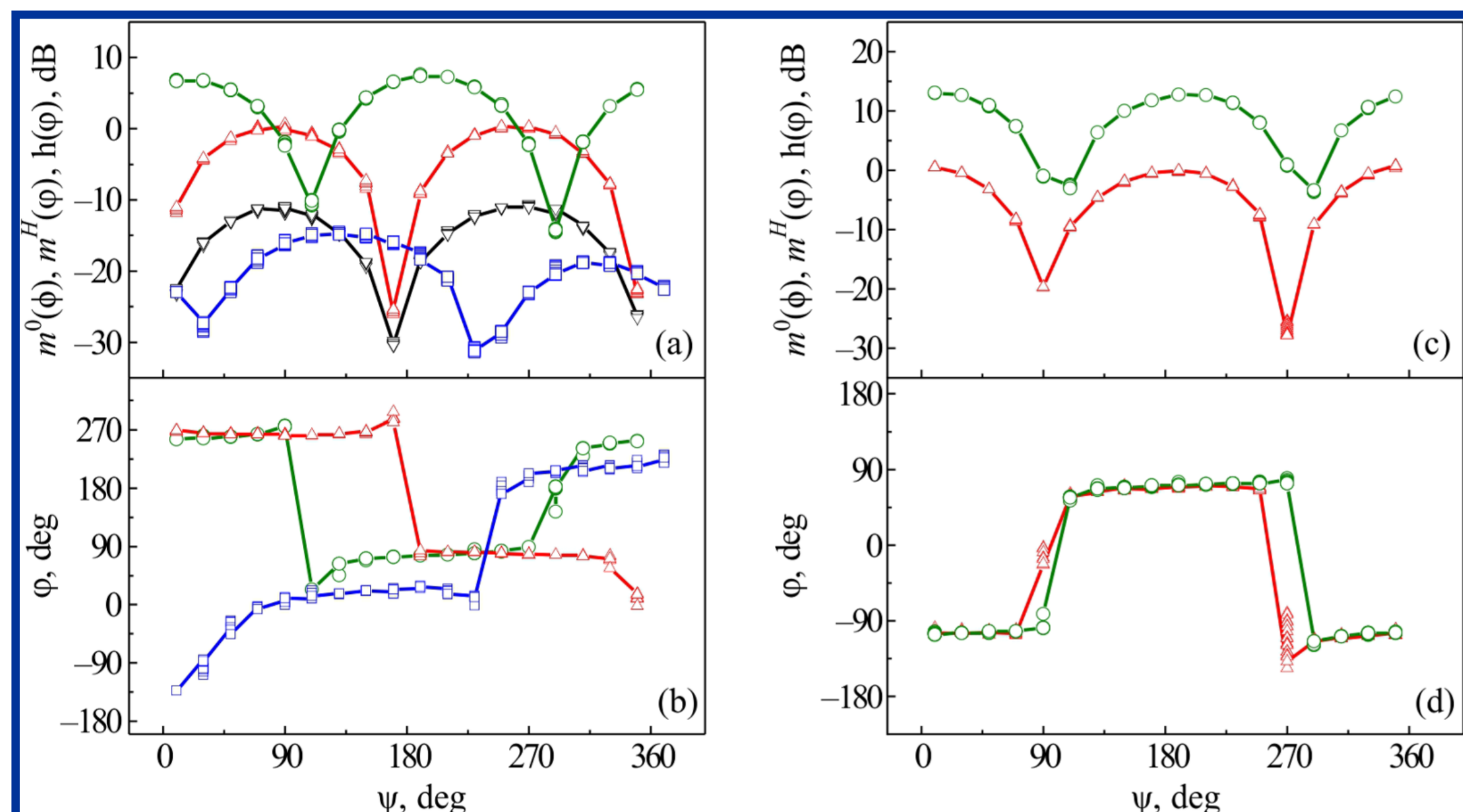


Fig. 2. Polarization diagrams at different polarizations of the elastic field measured in the zero magnetic field and in the presence of the magnetic field H ($H \parallel z$):

(a), (b) — $u \parallel [100]$, $T = 53$ K, $H = 0$, measurements without preliminary switching-on of the magnetic field (black curve),

$T = 53$ K, $H = 0$, measurements after preliminary switching-on of $H = 3$ T (red curve),
 $T = 53$ K, $H = 3$ T (green curve), $T = 72$ K, $H = 3$ T (blue curve);

(c), (d) — $u \parallel [110]$ $T = 4.2$ K, $H = 0$ (red curve), $T = 4.2$ K, $H = 2$ T (green curve).

The temperature behavior of the amplitude and phase of the piezomagnetic response in the magnetic field was studied (Fig. 3). The piezomagnetic response is the result of the interference of two contributions whose phases are different and are almost independent of the temperature. The first one, which is quite weak, exists at temperatures both above and below T_N , while the second one, with rapidly increasing intensity, appears only in the antiferromagnetic phase.

One possible explanation for the origin of the piezomagnetic response is the so-called "wave" scenario. The deformation initiates the emergence of a non-diagonal component in the magnetic susceptibility tensor, i.e., a magnetization component orthogonal to H appears. This effect is possible because the field of shear displacement gradients (shear deformation) changes the symmetry of the lattice, making it more anisotropic.

The following results were obtained:

- Due to the use of the AET method, the manifestations of piezomagnetism have been studied in MnF_2 .
- It has been established that under shear deformations, the magnetic susceptibility of MnF_2 acquires a non-diagonal component of the magnetic susceptibility tensor, proportional to the square of the antiferromagnetism vector.
- A phenomenological description of the experimental results is presented.

All experiments were performed in the $q \parallel C_4$ geometry (q is the sound wave vector; C_4 is the 4th order axis).

Experiments have shown that in MnF_2 below the Neel temperature (T_N), a transverse acoustic wave propagating along the C_4 axis always generates a piezomagnetic response, and its orientation is determined by the polarization of the elastic field.

The amplitude-phase polarization diagrams of rotation at different polarizations of the elastic field, observed in the absence and in the presence of an external magnetic field, were studied (Fig. 2).

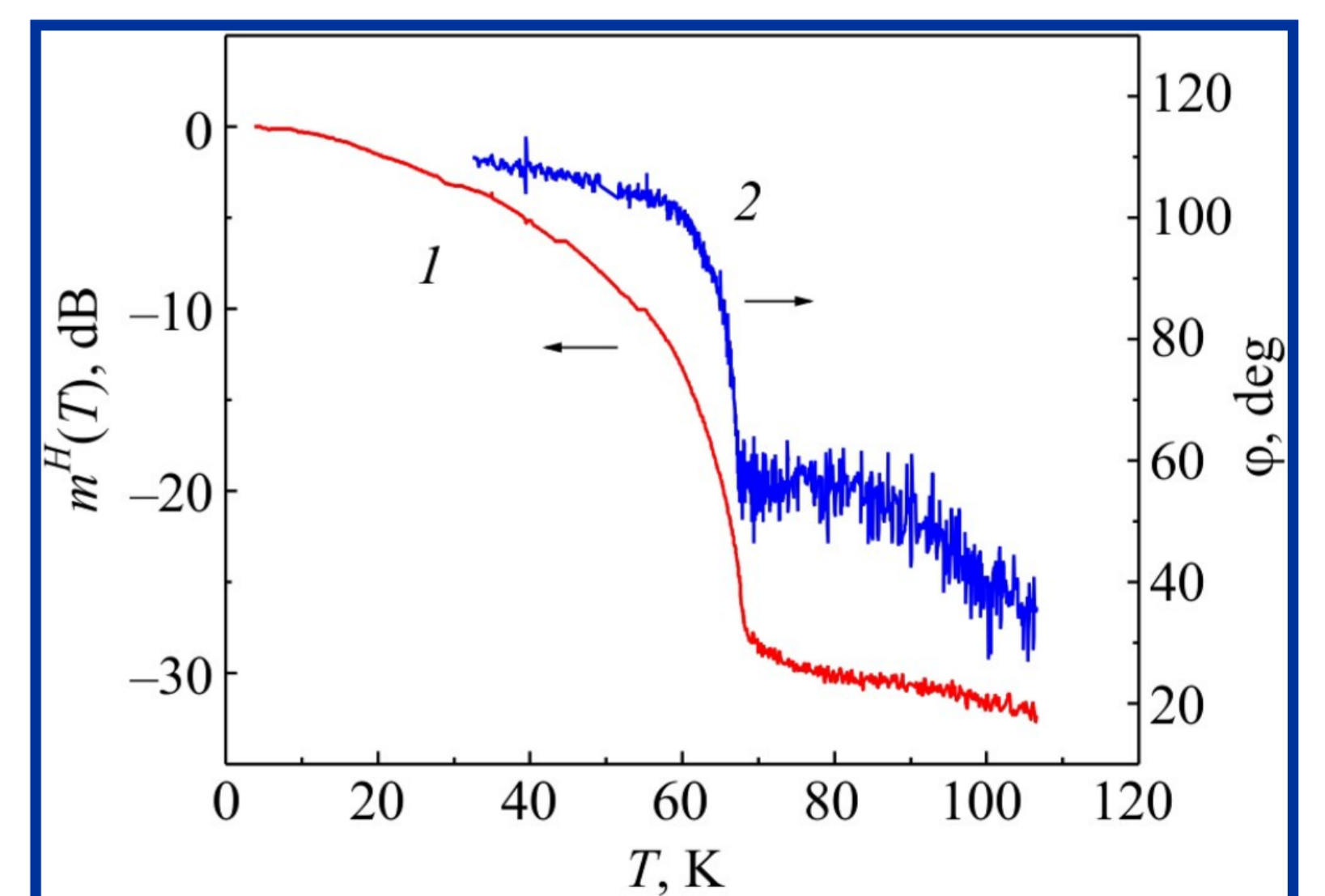


Fig. 3. Temperature dependence of the amplitude (curve 1) and the phase (curve 2) of the piezomagnetic response m^H ($H = 3$ T).