Chapter 7

Lows of bulk elasticity in the formation of PT and properties in magnetic semiconductors and dielectrics

7.1. Linear regularities of elasticity in resistivity properties in the processes of P-H-T effect in $La_{0.7}Mn_{1.3}O_3$

Rare-earth manganites are attracting a heightened interest because of the colossal magnetoresistive (CMR) effect [131-133] observed in these perovskite like metal oxides when doped with divalent ions: $R_{1-x}Me_x^{2+}Mn_{1-x}^{3+}Mn_x^{4+}O_3^{2-}$ (R is La^{3+}, Pr^{3+}, Nd^{3+}, or Sm^{3+}; Me^{2+} is Ca^{2+}, Sr^{2+}, Ba^{2+}, or Pb^{2+}). In spite of a large number of papers, including review articles [134, 135], the nature of the unusual coupling of the electric and magnetic properties in these materials remains in dispute.

Elucidation of the nature of the CMR effect and the development of new magnetoresistive materials based on rare-earth manganites are topical problems in science and technology. To help solve them it is useful to investigate the influence of temperature, magnetic field, and especially high hydrostatic pressures, about which little information is available [136].

The present study is devoted to a comprehensive investigation of the influence of temperature, magnetic field, and high hydrostatic pressure over wide ranges on the resistivity and magnetoresistive effect (MRE) for a ceramic sample and a single-crystal laser film of the same cationic compound $La_{0.7}Mn_{0.3}O_{3\pm\delta}$.

The ceramic samples of manganite-lanthanum oxides of the series $La_{1-x}Mn_{1+x}O_{3\pm\delta}$ [136a] with x = 0.3 were obtained by a synthesizing anneal of a mixture of ChDA-grade powders of La_2O_3 (*Ia3*, a = 11.498 Å) and Mn_3O_4 (*I*4$_1$*/amd*, a = 5.77 Å, c = 9.38 Å) at 900 °C (20 h) and sintering the pressings at 1150 °C for 24 h, followed by a slow cooling.

The single-crystal films were deposited by laser sputtering at 800 °C on a $LaSrGaO_4$ single-crystal substrate. For saturation of the film with oxygen it was subjected to additional annealing at 780 °C.

The phase composition and crystal lattice parameters were determined by x-ray diffraction in Cu radiation on a DRON-2 diffractometer.

The resistance R and the value of the magnetoresistive effect $\Delta R/R_0 = (R_0 — R_H)/R_0$ were determined by a four-probe method over a wide range of temperatures 77-350 K at several different values of the magnetic field (H = 0, 2, 4, 6, and 8 kOe). High hydrostatic pressures P were obtained in a special two-layer chamber[20] made of nonmagnetic 40Kh-NYu refined steel, with a channel diameter of 6.5 mm and an outer diameter of 31 mm. The pressure was determined from the load on the press and was monitored by measuring the resistance of a manganese pressure sensor. The errors of measurement of the quantities mentioned were within the following limits: phase composition — 3%, lattice parameters — 1%; resistivity — 0.7%, temperature — 0.1%, magnetic field – 1.5%, hydrostatic pressure – 3%.

According to the x-ray data, the ceramic targets had a rhombically distorted *(Pnma)* lanthanum manganite perovskite structure with the parameters a = 5.464 Å, b = *5.515* Å, c = 7.728 Å. The Curie temperature of the sample was T_c = 255 K.

The temperature dependence of the resistivity of the ceramics and laser-deposited film is shown in Fig. 7.1 for H =0 and 8 kOe and P = 0 and 1.8 GPa. One notices substantial differences not only in the value of pressure but also in the character of its temperature dependence for the ceramics and film. The higher values of the resistivity of the ceramic samples arc possibly due to their porosity and the different degree of nonstoichiometry.

For the ceramic sample, but not for the film, there is an additional smaller, smeared peak (T'_{ms} =210 K) at temperatures below the main resistivity peak (T_{ms} = 250 K), which, like the main peak, decreases markedly with increasing pressure, i.e., the used ceramics have two metal-semiconductor transitions. The main transition, depending on the magnetic field and pressure, lies in the interval from T_{ms} = 235 K *(H = 0, P = 0)* to T_{ms} = *215* K (H=8 kOe, P = 1.8 GPa). The second transition lies between T'_{ms} = *200* K *(H = 0,* P = 0)

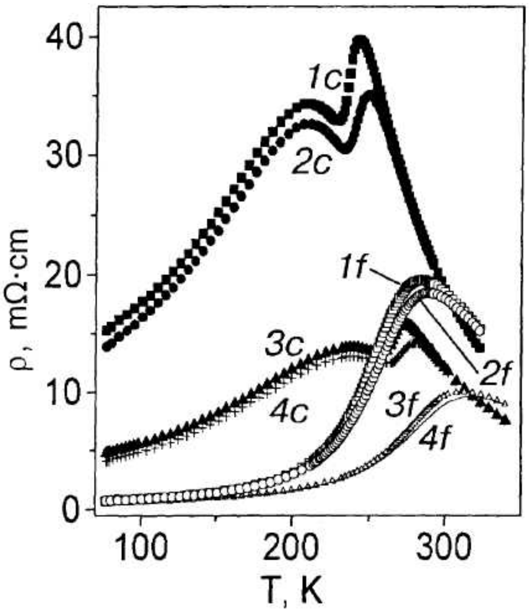

Figure 7.1. Temperature dependence of the resistivity of a ceramic sample (*c*) and a single-crystal film (*f*) of $La_{0.7}Mn_{0.3}O_{3\pm\delta}$ for various pressures and magnetic fields: *1c, 1f — P = 0, H = 0; 2c, 2f — P = 0, H= 8* kOe*; 3c; 3f — P = 1.8* GPa*, H = 0; 4c, 4f — P = 1.8* GPa*, H = 8* kOe.

and T'_{ms} = 235 K (H = 8 kOe, P= 1.8 GPa). The two resistive transitions in the ceramic samle are apparently due to the intercrystallite zones, to the mesoscopic structural and magnetic [137] inhomogeneities, the nature of which is in dispute and is now being clarified. One notices that the temperature of the main resistivity peak for the ceramics (T_{ms} = 235-275 K) is substantially lower than for the film (T_{ms} = 275-300 K). This may be due to the different oxygen content and nonstoichiometry of the ceramic and film samples, or to the difference in the characteristic dimensions of the crystallites of the ceramic ($D \approx 10$ μm) and the thickness of the single-crystal film ($d \approx 1$ μm) and also to the influence of the substrate. These factors may be the cause of the different influence of high hydrostatic pressures (P = 1.8 GPa) on the resistivity and value of the MRE in the ceramics and film.

The temperature dependence of the magnetoresistive effect $\Delta R/R_0$ at $P = 0$ and various values of the magnetic field (H = 2, 4, 6, and 8 kOe) for the ceramic and film samples is shown in Fig. 7.2. One notices first the large values of the MRE in the ceramics and the less smeared $\Delta R/R_0$ peak in comparison with the film. Here the temperature of the peak of the MRE is

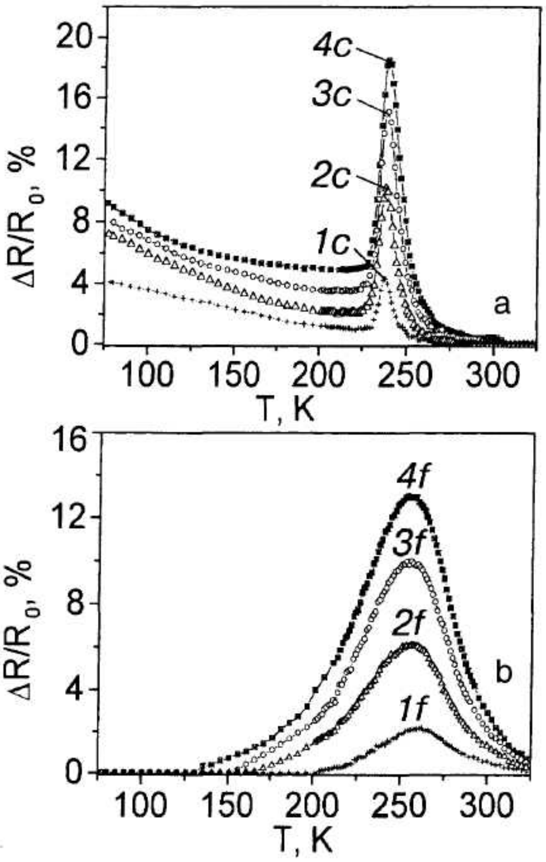

Figure 7.2. Temperature dependence of the magnetoresistive effect at $P = 0$ and various magnetic fields for the ceramics (a) and film (b): *1c, 1f*— H = 2 kOe; *2c, 2f*— H = 4 kOe; *3c, 3f*— H = 6 kOe; *4c, 4f*— H = 8 kOe.

lower in the ceramics (T_p = 237 K) than for the film (T_p = 257 K). As the magnetic field is increased from 2 to 8 kOe for the ceramic target, the MRE increases from 4 to 18.5%, i.e., by a factor of 4.6, while for the single-crystal film it increases from 2 to 13%, i.e., by a factor of 6.5.

The influence of the magnetic field strength on the MRE at P= 1.8 GPa for the ceramics and film is shown in Fig. 7.3. At high hydrostatic pressures the value of the MRE decreases and the temperature of its peak increases. $\Delta R/R_0$ increases with increasing H from 2 to 8 kOe: for the ceramics from 3.8 to 16%, i.e., a factor of 4.2, and for the film from 1.8 to 9.8%, i.e., a factor of 5.4. In spite of the lower MRE in the film, it is influenced by the magnetic field to a greater degree.

Fig. 7.4 shows the effect of high hydrostatic pressures on the resistivity of the ceramics and film at $H=0$. As the pressure is increased to 2.2 GPa the resistivity decreases: by a factor of 1.75 for the ceramics and 2.5 for the film. It appears as if the resistivities of the ceramics and film should converge somewhere in the region of negative hydrostatic pressures.

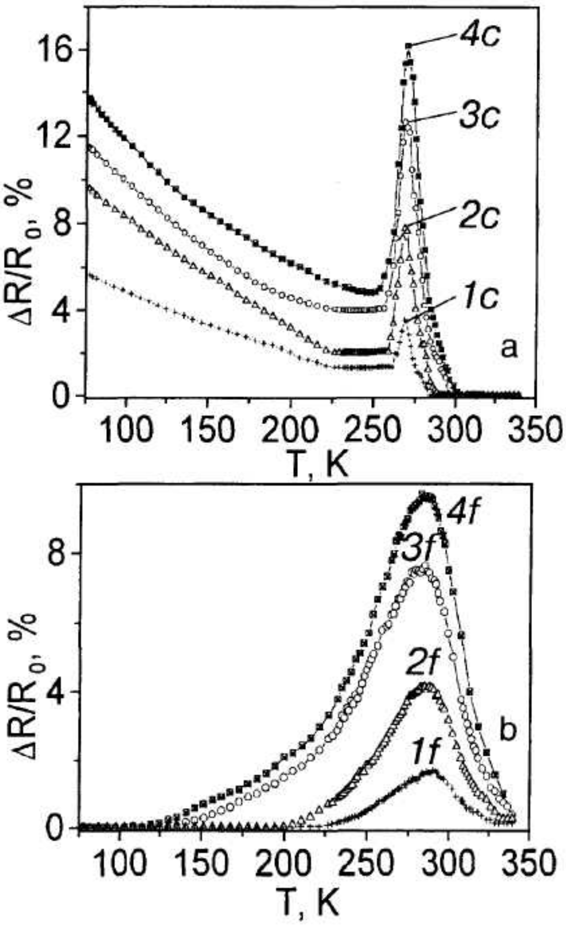

Figure 7.3. Temperature dependence of the magnetoresistive effect at P = 1.8 GPa and various magnetic fields for the ceramics (a) and film (b): *1c, 1f*— H = 2 kOe; *2c, 2f*— H = 4 kOe; *3c,3f*— H = 6 kOe; *4c,4f*— H = 8 kOe.

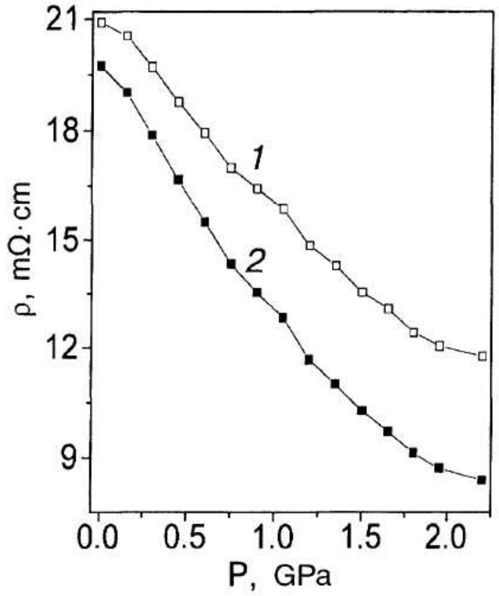

Figure 7.4. Effect of high hydrostatic pressures on the resistivity of the ceramic (1) and film (2) at $H = 0$.

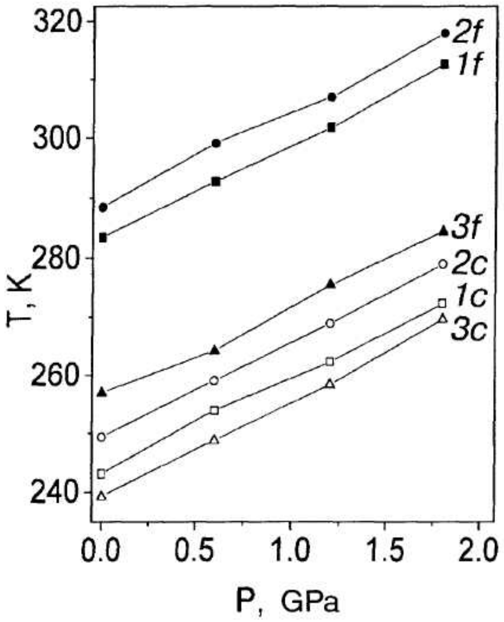

Figure 7.5. Effect of high hydrostatic pressures on the metal-semiconductor phase transition temperature T_{ms} at $H = 0$ and 8 kOe and the peak temperature T_p of the MRE for the ceramics (c) and film (*f*): *1c,1f* — T_{ms}, $H = 0$; *2c,2f*— T_{ms}, H=8 kOe; *3c,3f*— T_p, H=8 kOe.

The effect of high hydrostatic pressures on the metal-semiconductor transition temperature T_{ms} at $H=0$ and 8 kOe and the temperature of the magnetoresistance peak T_p for the ceramic target (the unfilled symbols) and the single-crystal film (filled symbols) is illustrated in Fig. 7.5. With increasing *P* the temperatures T_{ms} and T_p increases practically linearly in the entire pressure interval investigated, and their temperature coefficients are close in value. The reason is apparently the decrease in the inter-ion distances and the change in the exchange interaction, which shifts the region of the “metallic” state to higher temperatures.

Comprehensive studies of the influence of temperature, magnetic field, and high hydrostatic pressures on the resistivity and magnetoresistive effect of ceramic and film samples of the lanthanum manganite perovskites $La_{0.7}Mn_{0.3}O_{3\pm\delta}$ have established the following:

1) the resistivity of the ceramic target is higher than that of the laser film;
2) the temperature of the metal-semiconductor transition is substantially higher for the film;
3) for the ceramic samples two temperature peaks of the resistivity are observed, which are explained by a cluster type of mesoscopic inhomogeneity;
4) for the ceramics the MRE is larger and its peak temperature is lower than for the film, on account of the different nonstoichiometry;
5) with increasing magnetic field the MRE increases in both the ceramics and film, the effect being stronger in the film;
6) high hydrostatic pressures decrease the resistivity and increases the temperatures of the metal-semi conductor transition and of the peak of the MRE.

7.2. Baro- and magnetoresistive effects in properties of $La_{0.9}Mn_{1.1}O_3$ and $La_{0.56}Ca_{0.24}Mn_{1.2}O_3$

In spite of a large number of publications, the nature of a unique interrelation between magnetic and electric properties in manganites remains debatable [135, 138]. Recently, the works with an unconventional approach to rare-earth materials investigations, in which changes of conductivity as a result of changes in temperature, magnetic field and hydrostatic pressure were observed, have increased in number [139-141]. A variety of investigations in the resistive properties under influence of temperature, pressure and magnetic field [30-32, 142] reveals some new effects.

The main goal of the present work is to establish the correlation between elastic, resistive and magnetoelastic properties and explanation of effects in magnetic semiconductors influenced by temperature, magnetic field and pressure.

$La_{0.9}Mn_{1.1}O_3$ and $La_{0.56}Ca_{0.24}Mn_{1.2}O_3$ bulk and film samples were obtained by standard methods [143]. Pressure was generated by a technique described in Ref. [19].

Investigations of the resistivity of the materials influenced by temperature, magnetic field and pressure are illustrated in Fig. 7.6a and 7.6b(l —6),

Fig. 7.8(1-6), where the temperature dependence of resistivity (thermoresistivity)—curve (1); is shown under different magnetic field intensities (thermo-magnetoresistivity) (2) and hydrostatic pressures (thermobaroresistivity) (3-5). Resistivity behavior in magnetic field at fixed pressures (thermo-baromagnetoresistivity) in the whole of the temperature range is demonstrated in Fig. 7.6a and 7.6b(6), Fig. 7.8(6). In all the dependences, the "metal-semiconductor" transition temperature shifts, as a result of the application of pressure and magnetic field.

Temperature dependences of the magnetoresis-tive effect $(\rho_0 - \rho_H)/\rho_0$, (H = 8 kOe) are presented in Fig. 7.7a and 7.7b(6), Fig. 7.9(6); baroresistive effect $(\rho_0 - \rho_P)\ /\rho_0$ under different hydrostatic pressures in Fig. 2a and b(2,3,5),

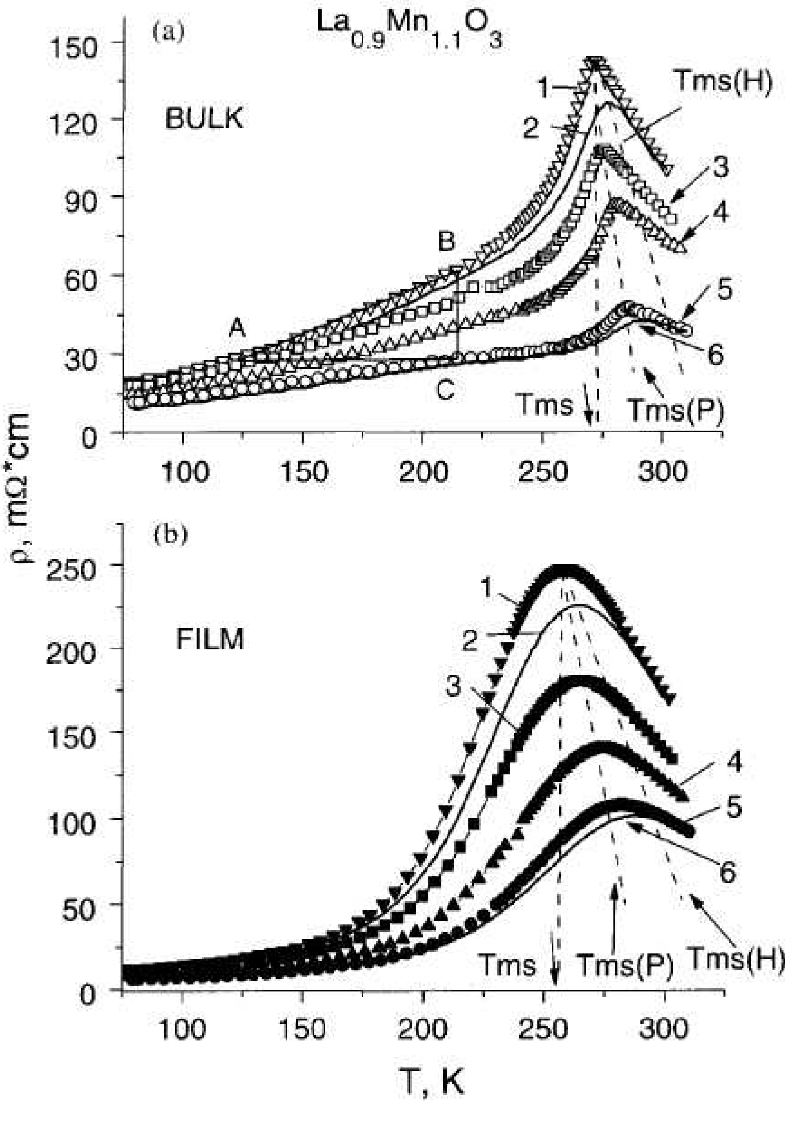

Figure 7.6. Temperature dependences of $La_{0.9}Mn_{1.1}O_3$ bulk (a) and film (b) samples resistivity: 1—P = 0 kbar; 2—P = 0, H = 8kOe; 3—P = 6 kbar; 4—P= 12 kbar; 5—P= 18 kbar; 6—P = 18 kbar, H= 8 kOe.

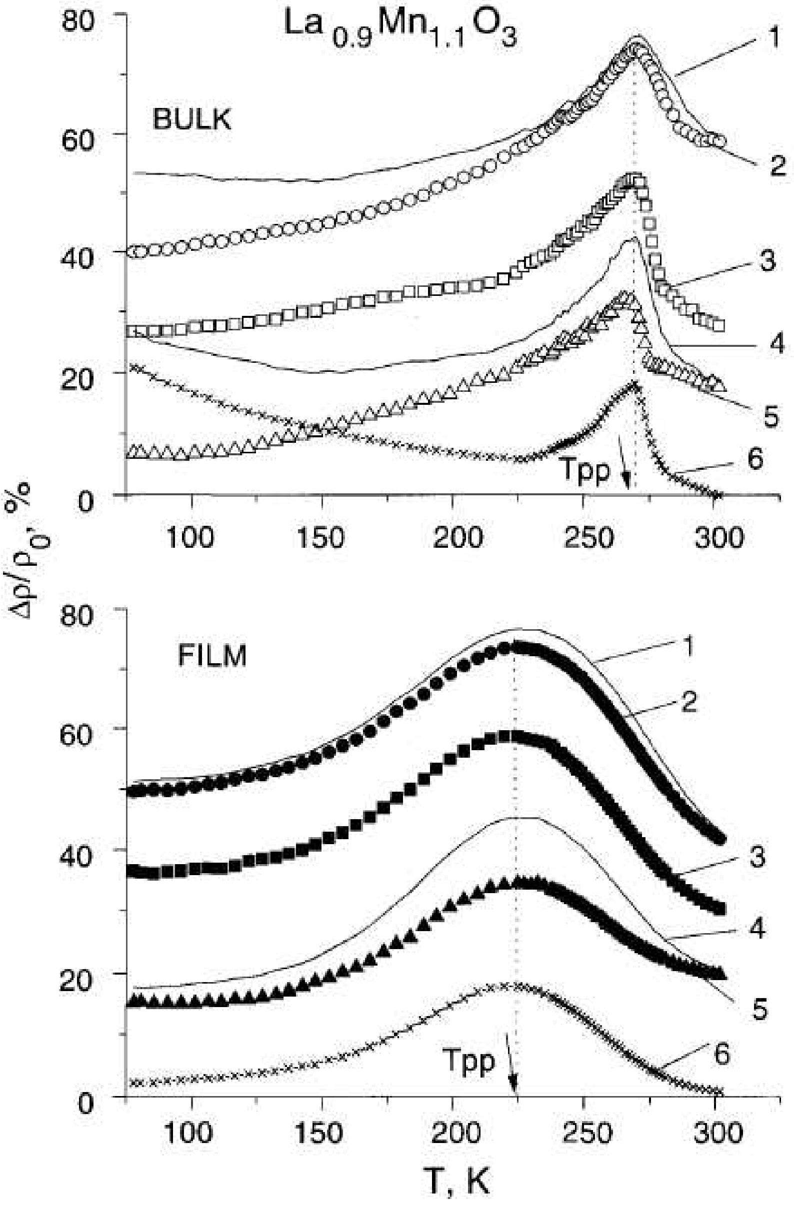

Figure 7.7. Temperature dependences of $La_{0.9}Mn_{1.1}O_3$ bulk (a) and film (b) samples baroresistive effect: 2 - P = 18 kbar; 3 - P= 12 kbar; 5 - P = 6 kbar; Baromagnetoresistive effect: 1 - P = 18 kbar, H = 8 kOe; 4 - P = 6 kbar, H = 8 kOe; Magnetoresistive effect: 6 - P = 0, H = 8 kOe.

Fig. 4(2,3,5); baromagnetoresistive effect $(\rho_0 - \rho_{PH})/\rho_0$ at different magnetic field intensities and hydrostatic pressures - in Fig. 7.7a and 7.7b(1,4), Fig. 7.9(1,4).

Here ρ_0 is the resistivity of the sample;
ρ_H is the resistivity in magnetic field;
ρ_P is the resistivity at hydrostatic pressure;
ρ_{PH} is the resistivity in magnetic field at a fixed applied pressure.

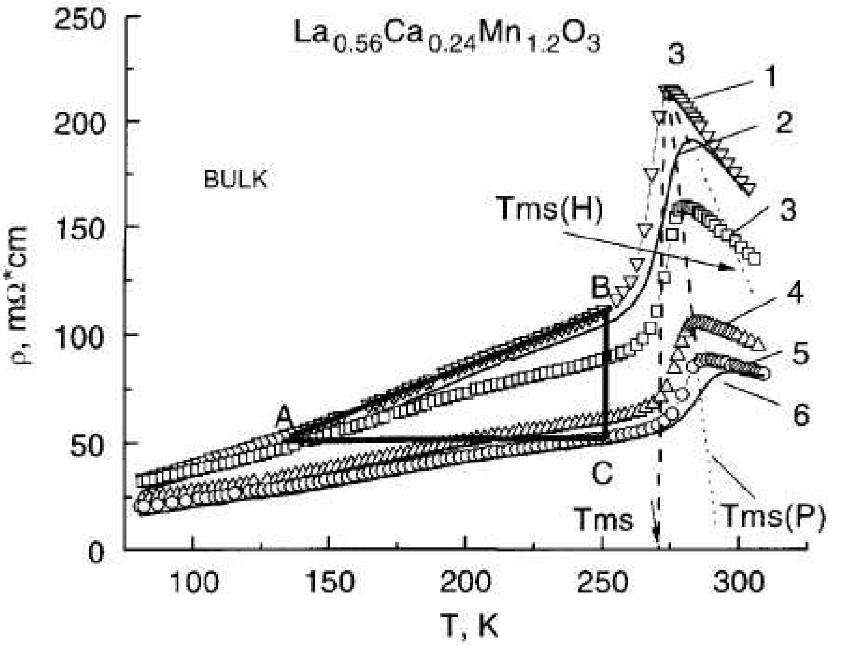

Figure 7.8. Temperature dependences of $La_{0.56}Ca_{0.24}Mn_{1.2}O_3$ bulk sample resistivity: 1—P = 0 kbar; 2—P = 0, H = 8 kOe; 3— P = 6 kbar; *4*—P= 12 kbar; *5*—P = 18 kbar; 6—P = 18kbar, H = 8 kOe.

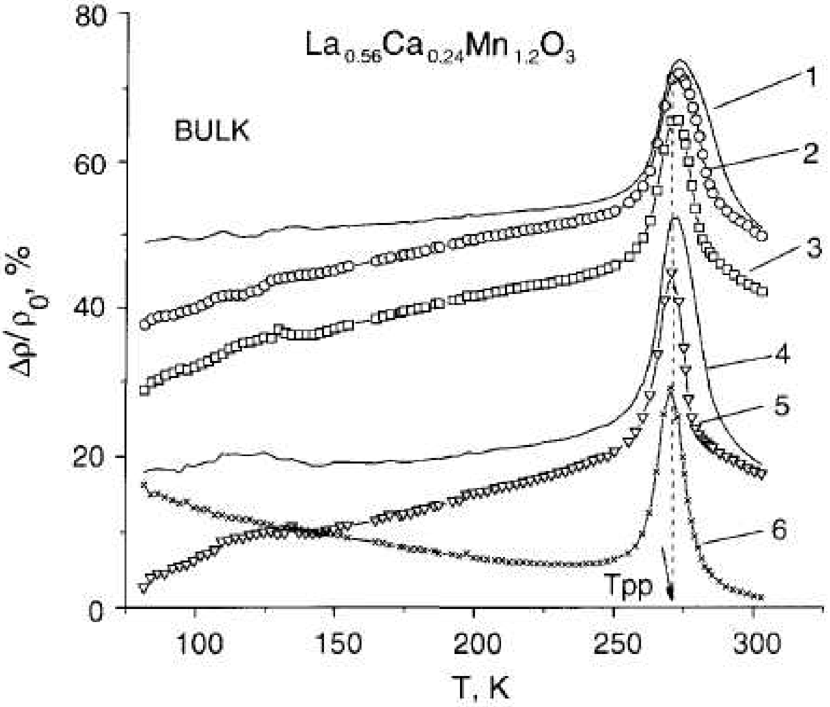

Figure 7.9. Temperature dependences of $La_{0.56}Ca_{0.24}Mn_{1.2}O_3$ bulk samples resistivity: 2—P=18 kbar; 3—P= 12 kbar; 5— P = 6 kbar. Baromagnetoresistive effect: 1—P = 18kbar, H = 8 kOe; 4—P = 6 kbar, H = 8 kOe. Magnetoresistive effect: 6—P = 0, H = *8* kOe.

Investigation of electronic properties of bulk and film samples $La_{0.9}Mn_{1.1}O_3$, $La_{0.56}Ca_{0.24}Mn_{1.2}O_3$ as a result of magnetic field H — 0-8 kOe and hydrostatic pressure P = 0-18 kbar are presented in this paper. These results were partly published previously [142]. It is necessary to mark that the resistive properties are the most sensitive to any structure changes.

1. Special attention is paid to studying the resistivity properties of the samples under magnetic field and pressure influences. The illustrated data shown in Fig. 7.6a and 7.6b, Fig. 7.8 thermoresistive (1), thermomagnetoresistive (2,6), thermobaroresistive (3,4) and thermobaromagnetoresistive (5) behaviours are identical in the whole temperature range. In all dependences resistivity peak temperature (T_{ms}) monotonously shifts as a function of pressure and magnetic field, at the same time peak intensity is reducing. Thus, the identity of magnetic field and pressure effect on resistivity is traced. Note that in Fig. 7.6a and 7.6b(2), Fig. 7.8(2) resistivity behaviors at $H = 0$; 8 kOe are illustrated, but in $H = 2, 4, 6$ kOe the regularity is preserved [142]. Connected resistivity peaks in Fig. 7.6a and 7.6b(l,2), Fig. 7.8(1,2) illustrated a regularity of magnetic field effect on $T_{ms}(H)$ shifting. This regularity is linear. The same features were noted in works [30, 142]. Analogously, the $T_{ms}(P)$ dependence will be plotted with shifting the resistivity peak temperature under hydrostatic pressure; the regularity is linear (Fig. 7.6a and 7.6b(l,3-5) and Fig. 7.8(1,3-5)). These experimental data are presented in Refs. [30, 142, 144].
2. The magnetoresistive effect is well studied in a large variety of magnetic semiconductor samples. An interesting regularity of magnetoresistive peak temperature (T_P) constancy under different magnetic field intensities, Fig. 7.7a and 7.7b(6), Fig. 7.9(6), was observed. It is noted that peak temperatures (T_{PP}) of baroresistive, Fig. 7.7a and 7.7b(l,3,4), Fig. 7.9(1,3,4), and baromagnetoresistive Fig. 7.7a and 7.7b(2,5), Fig. 7.9(2,5) effects are the same and coincide with magnetoresistive peak temperature, Fig. 7.7a and 77.7b(6), Fig. 7.9(6). In bulk samples $La_{0.9}Mn_{1.1}O_3$and $La_{0.56}Ca_{0.24}Mn_{1.2}O_3$ temperature, T_{PP} coincides with the “metal-semiconductor” transition temperature T_{ms} without any influences of magnetic field and pressure. Taking the above results into account, these regularities allow us to conclude that mechanism of hydrostatic pressure and magnetic field effect on resistive properties and phase states of magnetic semiconductors is identical. Realization of these mechanisms is conditioned by elastic, thermoelastic and magnetoelastic properties of the material.
3. On thermoresistive, thermomagnetoresistive and thermobaroresistive dependences one observes a linear area of resisitivity close to 225 K, Fig. 7.6a(l-5), Fig. 7.8(1-5), and a reduction of slope angle with increasing pressure and magnetic field.

This observation makes it possible to carry out some estimations. Resistivity increment $\Delta\rho$ per 1K amounts to $\Delta\rho/\Delta T = 0.37\Omega$/deg, Fig. 7.6a (l). Resistivity change vs. pressure increase at fixed temperature, T≈225K, amounts to $\Delta\rho/\Delta P \approx 2.29$ Ω/kbar. It may be seen from triangle ABC Fig. 7.6a (l,5). These estimations show that in the linear resistivity area temperature changes by $\delta T = 6.2$ K at the expense of thermoelastic expansion changes the resistivity in the same way as the elastic deforming compression by hydrostatic pressure of 1 kbar. The same correspondence underlines the role of elastic properties in formation of resistivity behavior.

4. The character of the observed thermoresistive, thermomagnetoresistive and thermobaroresistive dependences Fig. 7.6a and 7.6b (l-5), Fig. 7.8 (1-5) is analogous. It allows one to estimate action of pressure and magnetic field in the linear resistivity area and in the area of resistivity peaks. From curves of Fig. 7.6a (l,2) it is seen that magnetic field intensity ($H = 1$ kOe) action corresponds to resistivity change $\Delta\rho/\Delta H = 2.2\Omega$/kOe. Resistivity change under pressure, in this temperature range, amounts to $\Delta\rho/\Delta P = 6$ Ω/kbar. It shows that the magnetic field intensity increase by $\delta H = 2.7$ kOe brings the same resistivity change as in the case of hydrostatic pressure increase by 1 kbar. The compressive mechanism of magnetic field action is also evidenced by phase transition temperature shifting, which is commensurate with hydrostatic pressure effect.

   From this point of view, a giant magnetoresistive effect is a result of the sudden change in resistivity due to magnetoelastic compression mechanism caused by magnetic field effect.

   To confirm a role of elastic properties, we may consider dependencies of the resistivity peak temperature $T_{ms}(H)$, $T_{ms}(P)$ and also a linear dependence of resistivity vs. pressure at $T = 300$ K Fig. 7.6a(l-6). They are linear in all the investigated magnetic field and pressure range. The same features are pointed in Refs. [30, 142, 144]. We pay attention to the fact that the curves $T_{ms}(PH)$, at simultaneous action of magnetic field and hydrostatic pressure, are placed between $T_{mi\text{,}}(H)$ and $T_{ms}(P)$. Linear behavior and difference in temperature dependencies $T_{ms}(H)$ and $T_{ms}(P)$ are explained by the anisotropy in elastic and magnetoelastic properties.

5. Thermoresistive, thermomagnetoresistive and thermobaroresistive dependences Fig. 7.6a(l-6) demonstrate that pressure and magnetic field effect on resistivity realises the “cooling” effect—elastic and magnetoelastic compression reduces resistivity in proportion to temperature decreasing. The estimations show the magnitude of these strains: magnetic field intensity increasing by 2.7 kOe or pressure increase by 1 kbar correspond to sample cooling by 6.2 K and vice versa. Decreasing the hydrostatic pressure or magnetic field intensity has the same influence on resistivity as the increase in temperature.

The given conformities in the resistive properties under *T—P—H* influence reveal one more feature of the system. The influence of pressure and magnetic field implements the “cooling” effect. The magnetic field growth or pressure increase through elastic mechanisms change resistivity equivalently to temperature decreasing. Moreover, the reverse, “heating” effect takes place. A reduction of pressure and magnetic field intensity changes the sample resistivity equivalently to a relevant temperature rise.

What do the “cooling” and “heating” effects in magnetic semiconductors explain? First of all, it explains linear dependence of temperature T_{ms} under pressure and magnetic field, and the basic role of elastic properties in this process. The “metal-semiconductor” phase transition is a property of the thermoelastic expansion of sample structure and is fixed by the resistivity peak temperature T_{ms} Fig. 7.6(1). The application of hydrostatic pressure and magnetic field lead to the "cooling" effect. When reducing, the resistivity magnitude becomes equal to initial one taken at a lower temperature. In this case, for the phase transition, it is necessary to increase the temperature. It is an additional thermoelastic expansion compensating the structure compression by both pressure and magnetic field, accompanied by rising $T_{ms}(H)$ and $T_{ms}(P)$. Thus, the magnetoresistive, baroresistive and baromagnetoresistive peak temperature T_{PP} remains constant at different pressures and magnetic fields. It means that the phase transition takes place at some condition, which is constant for the given sample.

If the process occurs in reverse order, as the initial dependence we will take $\rho(T)$ under magnetic field and pressure influence. Then, at lowering these actions, the rising resistivity magnitude will correspond to initial dependence taken at a higher temperature. Thereby, the “heating” effect of pressure and magnetic field is determined. For the phase transition realization, by analogy, in this case, it is necessary to decrease the temperature—an additional thermoelastic compression compensates the structure expansion by decreasing both pressure and magnetic field. It means, that the removal of an external influence demands a lesser overheat of the system for reaching the conditions of the phase transition realisation. $T_{ms}(H)$ and $T_{ms}(P)$ are decreasing.

The revealed “cooling” and “heating” effects, and linear dependence of $T_{ms}(H)$ and $T_{ms}(P)$ testify to a compensative interaction of elastic and magnetoelastic expansion, on the one hand, and thermoelastic expansion on the other hand. However, in this case the conditions of the phase transition realisation remain constant irrespective of pressure and magnetic field magnitude. The confirmation of this fact is one and the same temperature T_{PP} of baroresistive, magnetoresistive and baromagnetoresistive peaks and linearity of $T_{ms}(H)$ in magnetic properties. And, as a consequence, the equality of the both: phase transition temperature $\mathrm{T_{ms}}$ (without pressure and magnetic field influence) and T_{PP}, confirms a similar nature of elastic-deforming mechanisms of temperature, magnetic field and pressure action, and also testifies to an invariable condition of "metal-semiconductor" phase transition.

The carried out consideration of resistivity behaviour allows one to reveal and to prove that temperature, magnetic field and pressure have the same mechanism of the influence on the magnetic semiconductors.

1. The baroresistive effect has been discovered—a result of elastic compression and thermoelastic expansion, which becomes apparent on relative resistivity change.
2. The baromagnetoresistive effect has been observed—a result of elastic, magnetoelastic compression and thermoelastic expansion, which becomes apparent on relative resistivity change.
3. It is established that peaks of magnetoresistive, baroresistive and baromagnetoresistive effects have the same temperature T_{PP}. It evidences that the mechanisms of temperature, magnetic field and pressure effect are identical.
4. The "cooling" and "heating" effects have been found. They explain the mechanism of elastic deforming corresponding with the change of resistivity, $T_{ms}(P)$ and $T_{ms}(H)$ linearity, and also T_{PP} constant at T—H—P influence.
5. All the demonstrated conformity regularities in the elastic deforming mechanism of the change of resistive properties and phase states under T—P—H influence, establish the correlation between elastic, resistive and structural properties in magnetic semiconductors.

7.3. "Cooling-heating" effects in properties of $La_{0.9}Mn_{1.1}O_3$ and $La_{0.56}Ca_{0.24}Mn_{1.2}O_3$ under the influence of P and H

The influence of hydrostatic pressure on resistance magnitude in films is shown in fig. 7.10. Curves behavior indicates monotonous resistance decreasing in the whole of pressure range. The same dependence of standard manganin gauge is shown for comparison (inset). Experimental data of film samples are summarized in Table 7.1.

The dependence of ceramic samples' resistance on applied hydrostatic pressure (fig. 7.11) shows the same behavior as in films but coefficient K is smaller Experimental data of ceramic samples are summarized in Table 7.2.

The resistance reduction in these structures with applied hydrostatic pressure is caused by reduction of bond length and increasing of the covering factor between Mn d-orbital and O p-orbital that leads to rise in the Mn-O-Mn exchange interaction. It should be noted that all resistive changes of all samples are reversible.

Fixed linear resistance behavior of ceramics and, especially, of film allows to propose the using of film samples of the same compositions as pressure gauges.

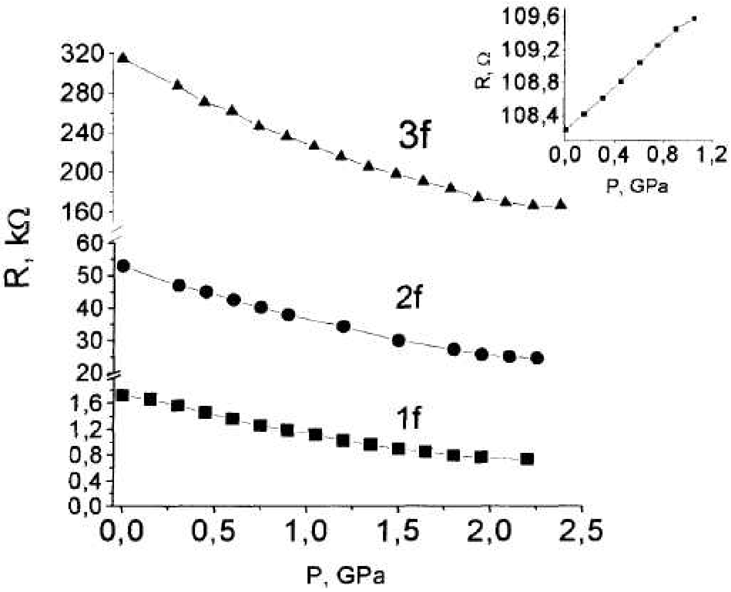

Figure 7.10. Influence of hydrostatic pressure on the resistance of standard manganin gauge (inset) and films: *1f*- $La_{0.7}Mn_{1.3}O_{3-\delta}$; *2f*- $La_{0.9}Mn_{1.1}O_{3-\delta}$; *3f*- $La_{0.56}Ca_{0.24}Mn_{1.2}O_{3-\delta}$.

Table 7.1.

Material	R, [kΩ]	P, [GPa]	*K*, [ΔΩ/ΔGPa]
$La_{0.7}Mn_{1.3}O_{3-\delta}$	1.8-0.8	0-2.2	454
$La_{0.9}Mn_{1.1}O_{3-\delta}$	53-25	0-2.2	12720
$La_{0.56}Ca_{0.24}Mn_{1.2}O_{3-\delta}$	320-165	0-2.45	63265
Manganin	0.108-0.1095	0-1	1.5

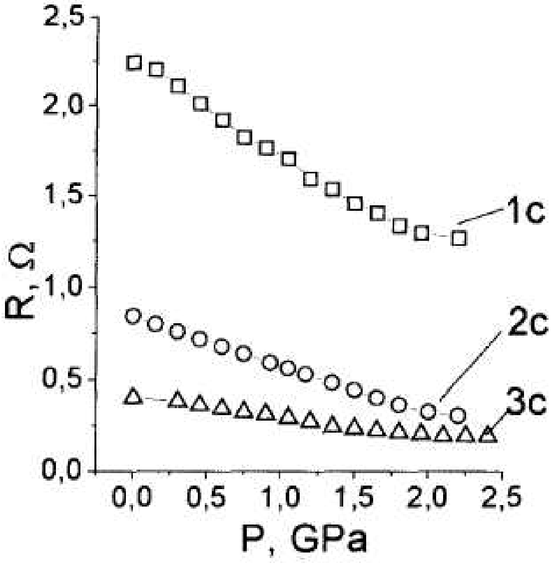

Figure 7.11. Influence of hydrostatic pressures on the resistance of ceramics: *1c*- $La_{0.7}Mn_{1.3}O_{3-\delta}$; *2c*- $La_{0.9}Mn_{1.1}O_{3-\delta}$; *3c*- $La_{0.56}Ca_{0.24}Mn_{1.2}O_{3-\delta}$.

Table 7.2.

Material	R, [Ω]	P, [GPa]	*K*, [ΔΩ/ΔGPa]
$La_{0.7}Mn_{1.3}O_{3-\delta}$	2.25-1.25	0-2.2	0.454
$La_{0.9}Mn_{1.1}O_{3-\delta}$	0.81-0.30	0-2.2	0.232
$La_{0.56}Ca_{0.24}Mn_{1.2}O_{3-\delta}$	0.42-0.20	0-2.45	0.090

The sensitivity as pressure gauges of the investigated film samples of following compositions $La_{0.7}Mn_{1.3}O_{3-\delta}$, $La_{0.9}Mn_{1.1}O_{3-\delta}$ and $La_{0.56}Ca_{0.24}Mn_{1.2}O_{3-\delta}$ is about 10^3-10^5 times as high as that of standard manganin gauge. They may be used in investigations with hydrostatic pressures up to 2.5 GPa.

Non-trivial effects in solid-state physics have been revealed practically at one and the same time: in experimental works [145, 146] during the investigation of properties of the dielectric manganese perovskites a sudden correlation was found between electric conduction and ferromagnetism.

A number of papers have been recently devoted to investigations of properties and PT influenced by temperatures (T), magnetic field (H), and high hydrostatic and quasi-hydrostatic pressures (P). Significant results have been obtained, new effects and regularities have been revealed. We pay attention to a consecutive and generalizing analysis of studies of phase transition and properties change for magnetic semiconductors influenced by T-H-P [148-151]. There, the role of thermodynamic mechanisms of the elastic anisotropically deforming stresses in the changes of PT and properties of manganites has been determined, and the notions of sign alternation for T-H-P effect have been first introduced. That was a prerequisite for finding identical mechanisms of elastic stresses in changes of PT and properties of the magnet-containing materials of another class.

First, we mark that the results of papers [148-151], where polycrystalline samples of magnetic semiconductors were studied, are consecutive. Thus, in paper [149], the baroresistive and baromagnetoresistive effects were first described, a correspondence of T-H-P effect on resistivity in polycrystalline samples was estimated and the role of thermodynamic mechanisms of elastic stresses was determined. In paper [147], the “cooling”, “heating” effects from the influence of pressure and magnetic field were substantiated, their regularity in changes of critical lines $T_{ms}(P)$, $T_{ms}(H)$ has been determined. It was also noted that the misfit of $T_{ms}(P)$, $T_{ms}(H)$ dependences is due to a difference in the elastic and magnetoelastic anisotropies in those samples. An important feature consisting in constancy of T_{PP}, the temperature of magneto-, baro-, baromagnetoresistive effects peaking, which coincides with the temperature of structural phase transition T_{ms}, has been revealed. By the analysis of changes in PT, resistive and magnetostrictive properties under the influence of T-H [150], the correlation through the elastic properties is grounded, the notion of sign alternation in properties and effects is introduced. $H_g(T)$ and $T_{ms}(H)$ correspondence with respect to magnetostriction properties has been determined, critical points P_X and T_X have been revealed. In paper [151], an improved experimental procedure is described for the case of high hydrostatic pressures; the characteristics are given for 0 to 25 kbar pressure transducers based on film samples of magnetic semiconductors.

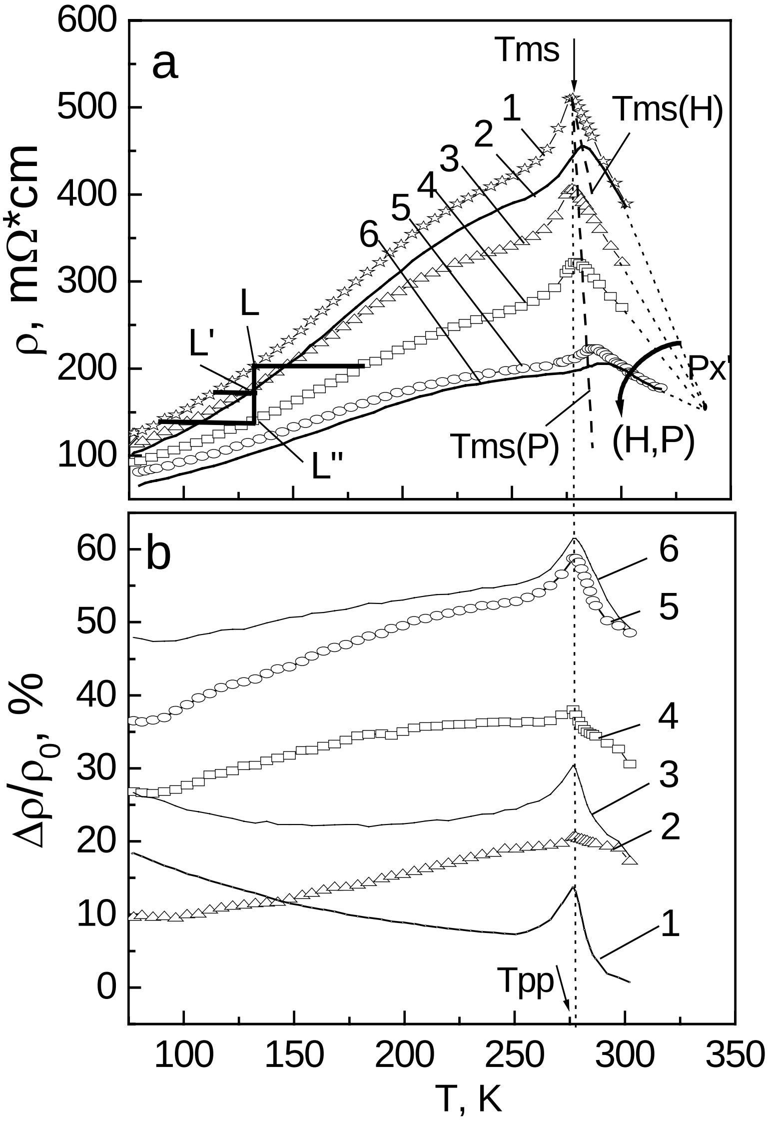

Figure 7.12. Temperature dependence of resistivity (a) and magneto-, baro-, baromagnetoresistive effects (b) of $La_{0.7}Ca_{0.3}MnO_3$ polycrystalline sample under influence of magnetic field and hydrostatic pressure: (a) 1 – P=0, H=0; 2 – P=0, H=8 kOe; 3 – P=6 kbar, H=0; 4 – P=12 kbar, H=0; 5 – P=17 kbar, H=0; 6 – P=17 kbar, H=8 kOe; (b) *1* – P=0, H=8 kOe; *2* – P=6 kbar, H=0; *3* – P=6 kbar, H=8 kOe; *4* – P=12 kbar, H=0; *5* – P=17 kbar, H=0; *6* – P=17 kbar, H=8 kOe.

We pay attention to the given estimations of T-H-P influence on resistivity of polycrystalline $La_{0.7}Ca_{0.3}MnO_3$ (5.1 K~2.42 kOe~1 kbar) (fig. 7.12a), which insignificantly differ in value from those for such compositions as $La_{0.56}Ca_{0.24}Mn_{1.2}O_3$ (6.2 K~2.37 kOe~1 kbar); $La_{0.9}Mn_{1.1}O_3$ (6.2 K~2.7 kOe~1 kbar) [147, 150, 151] and to their relative equality in the case of bulk polycrystalline samples. Noting the role of thermoelastic expansion on the dependences of magneto-, baro- and baromagnetoresistive effects in the wide temperature range (fig. 7.12ab), one can state that in their names there is prefix thermo. Since in magnetic semiconductors the shift in $T_{ms}(H)$ and $T_{ms}(P)$ under the influence of H and P is a regularity of elastic properties and of a difference in anisotropies of elasticity and magnetic elasticity, the estimate of their correspondence in PT parameters change in the sample of $La_{0.7}Ca_{0.3}MnO_3$ shows (fig. 7.12a) is that the magnetic field of 2.12 kOe shifts T_{ms} by the same value as the hydrostatic field of 1 kbar does.

The most important result noted in papers [147, 150] demonstrates that the peaks of baro-, magneto- and baromagnetoresistive effects (see fig. 7.12b) have one and the same temperature T_{PP} coinciding with that of the metal-semiconductor PT T_{ms}. It follows that thermo-elastic stresses are the basic factor in realization of structural phase transitions and, as a consequence, of the jump in properties, whereas the magneto- and baro-elastic stresses realize the “cooling”, “heating” effects. On the dependences of fig. 7.12a we see that changes in properties from L to L’ and L” are connected with the influence of H and P, a direct “cooling” effect in properties, subsequent increase in T-heats the properties to L. The estimates of conformable influence of temperature and pressure (5.1 K~1 kbar) determine quantitatively and rather truly the changes in PT and the differences in the dynamics of resistivity, and stress the role of the mechanism of elastic stresses to be the main reason for the formation and changes in resistivity as a function of temperature at different fields and pressures. It should be added that by a simple construction of approximate dependences of resistivity on temperature with P and H varied (fig. 7.12a), one can single out the point of their intersection, P_X, which is a consequence of changes in properties under the influence of elastic stresses. Such a construction could be shown in some other papers investigating the properties under pressure [150].

7.4. The role of bulk elasticity in formation of second-order structural PT and in magnetic properties of critical lines, points in $LaMnO_3$

To continue the analysis, and having shown the regularities of elastic stresses in resistive properties, it is very important to estimate the significance of the above mechanisms for magnetic properties that was in part done in paper [150]. There, the correspondence of H and T effect on properties of $LaMnO_3$ single crystal magnetostriction has been estimated, the relationship between T_{ms} and $H_g(T)$ has been determined (fig. 7.13), the $H_g(T)$ dependence and positions of points P_X and T_X with the parameter $H_X(T=0)$ have been found.

We pay attention to regularities of the “cooling”, “heating” effect from H influence in the properties of magnetostriction. On the represented dependences we take point L corresponding to T and H (fig. 7.13). Decreasing T with H unchanged, we have changes in properties corresponding to L’. Decreasing H with relief in backpressure magnetostriction, we see how the “heating” effect restores the properties corresponding to L.

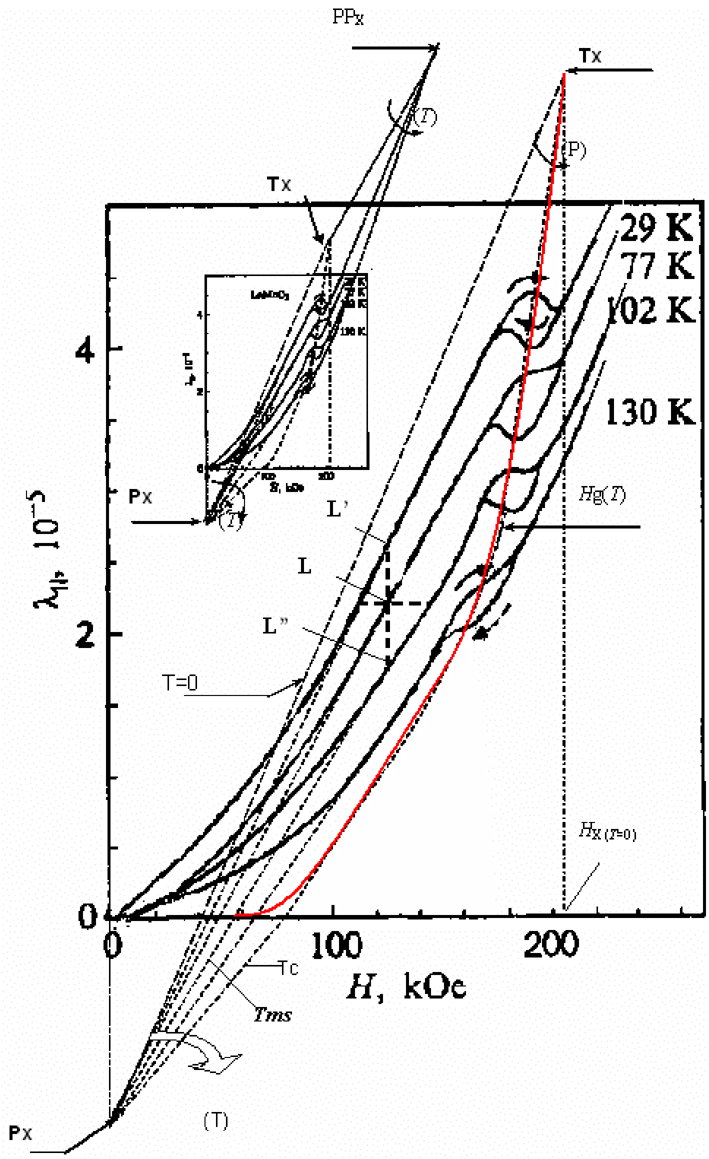

Figure 7.13. Field dependence of the longitudinal magnetostriction of $LaMnO_3$ single crystal.

And the reverse "cooling" effect. When T is increased with H unchanged, the change of properties corresponds to L". By increasing H and, thus, the magnetostriction pressure, we restore the properties corresponding to L.

Due to the given results it becomes possible to carry out a generalizing analysis of a variety of magnetic semiconductors. The role of elastic stresses is most obviously displayed in regularities of linearity and nonlinearity in the field dependences of magnetostriction, in the case of $LaMnO_3$ single crystal (fig. 7.13). The features observed in nonlinearity of properties are a consequence of the competing influence of T and H through the mechanisms of elastic stresses, they can be explained by the introduction of a more detailed explanation of sign alternation:

a) at fixed low temperatures, in the initial region of the field, the dependence of magnetostriction prior to the PT, is nonlinear (fig. 7.13). This is a consequence of the competing influence of the fixed thermoelastic expansion and magnetoelastic compression, thus, we have the linear dependence under a fixed thermoelastic expansion;
b) at temperatures higher than that of phase transition, the thermoelastic expansion is prevails over the magnetoelastic compression. A sudden growth of magnetostriction is observed, the magnetic hysteresis is formed and the sign alternation range of magnetic properties arises;
c) the effect of sign alternation also develops under a conformable influence of T and H through the competing mechanisms of elastic stresses on $H_g(T)$ dependence, with anisotropies of elasticity and magnetoelasticity equal to T_C, the Curie temperature (fig. 7.13);
d) this is more obvious with changes in the priorities of thermomagnetic EAD stresses, under a simultaneous action of T and H, in the form of a non-linear $H_g(T)$ dependence. Temperature T_{PP} remains constant.

As a whole, the study of thermo- and magnetoelastic effect reveals strong interrelations between the magnetic and lattice-symmetry features of the structure, as well as the causal role of the mechanism of EAD stresses. A particular significance of regularities of thermo- and magnetoelastic anisotropies is a consequence explaining a large quantity of anomalies observed in magnetic poly- and single-crystalline samples.

Let us note the following regularities relating to the critical points. Thus, the point of intersection for the extrapolated linear dependence $H_g(T)$ and the approximated dependence $\lambda_{||}(H)$, for T=0, (fig. 7.13) is denoted by T_X. This parameter is responsible for the state of structural PT in the sample of $LaMnO_3$, when T=0. The position of point PP_X is found as the intersection of the approximated dependences of magnetostriction properties at different temperatures past the phase transition. Critical points T_X and PP_X emerge from participation of the priority mechanisms of magneto-elastic stresses.

It is noteworthy that such an approach determines the role and the basic importance of magneto-elastic stresses and magnetoelastic anisotropy in the mechanisms of structural PT realization in fields $H_X(T=0)$ with T=0 K. This fact is very important for the understanding of regularities, since the opposite effect of thermoelastic anisotropy is defined by the metal-semiconductor phase transition temperature T_{ms}. It corresponds to $T_{ms}=275$ K ~ P≈50 kbar for $La_{0.7}Ca_{0.3}MnO_3$, but for H=0 (see fig. 7.12a). The anisotropy of thermo- and magnetoelasticity is the most evident under these extreme conditions of T and H effect on changes in namely structural PT, it also demonstrates the role of elastic properties and sign-alternating priorities of their influence. It should be noted that these statements are valid for a variety of magnet-containing samples, where the influence of T and H through the mechanisms of elastic stresses affects the structural PT and properties and values of anisotropies of thermo- and magnetoelasticity are the basic ones. Such methodological approach makes it possible to consider changes in resistive, magnetic properties and of PT in unified context of both temperature and magnetic field effect through the mechanisms of elasric stresses.

It follows that the position of critical points T_X, $H_X(T=0)$, P_X, PP_X and P_X'is a regularity defined by the chemico-technological and lattice-symmetry features of a sample, while the T-H-P effect is a regularity of the influence of mechanisms of thermo-, baro- and magneto- elastic stresses observed in properties, phase transitions, conformities, sign alternation and effects.

7.5. Relation of bulk elasticity to changes in parameters of properties and in PT

The generally accepted basis kinetics microprocess in lanthanum manganites demands the analysis of complex investigations results.

The one point of view are described in work [1]. The phenomenological approach of influence parameters (T-P-H) has a clear physical sense.

The influence of detailed thermodynamic parameters through mechanisms of volume elasticity to structural changes is leaded to following structural phase transitions and result in properties.

Take into account the high-temperature fact formation structures possibly to give basis of basic peculiarity of temperature dependences, one from which attend forever.

The physical process of temperature-elastic compresses is necessary factor of influence temperature on the whole range.

The results of work [6] are shown the process is related with influence of P-baro-elastic, H-magneto-elastic changes of parameter due to volume elasticity.

Therefore linear change of temperature dependence parameter structure is more significantly.

As fluent from the X-ray structure date the investigated samples $LaMnO_3$ and $La_{0,7}Sr_{0,3}MnO_3$ are homogeneous with rhombohedric distortion lattice and have parameters at room temperature $a=5,531A$; $c=13,360A$ and $a=5,486A$; $c=13,352A$ consequently [169].

High-temperature investigations are carried out at X-ray difractometer in Cu-radiation in standard goniometer attachment GPVT-1500.

The measuring precision of temperature was controlled by platinum-rhodium thermocouple with precision ±3 degree.

The scanning of sample surface was carried out with pitch $0,02^0$. The results of measurement are exhibited at Fig. 7.14.

Monotonous linear increase of crystal lattice parameter of investigated samples is observed with increase temperature.

The change of structure type from rhombohedric to cubic are observed at temperature range 660^0C (for $LaMnO_3$) and 150^0C (for $La_{0,7}Sr_{0,3}MnO_3$).

The X-ray investigations of parameters along of detailed directions in $La_{0,875}Sv_{0,125}MnO_3$ [170] are leaded to the same result.

The stability of linear changes (Fig. 7.15) in whole temperature range 1500 – 350^0K with take into account of experimental errors are exhibited important factor of elasticity strain, which are inalienable reason of volume elasticity behavior.

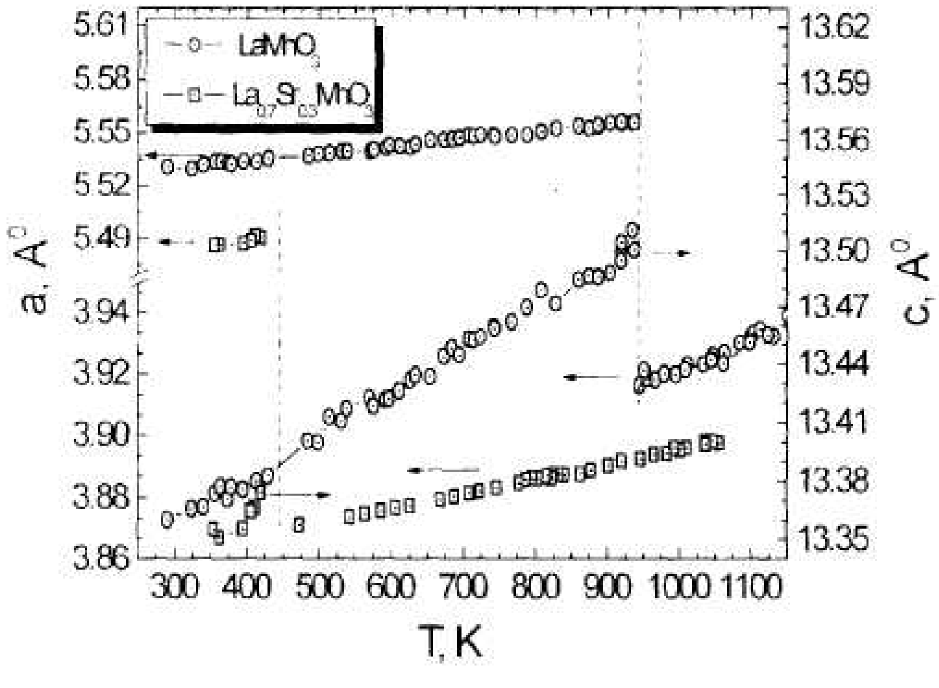

Figure 7.14. Monotonous linear increase of crystal lattice parameter of $LaMnO_3$ and $La_{0.7}Sr_{0.3}MnO_3$ polycrystalline samples [169].

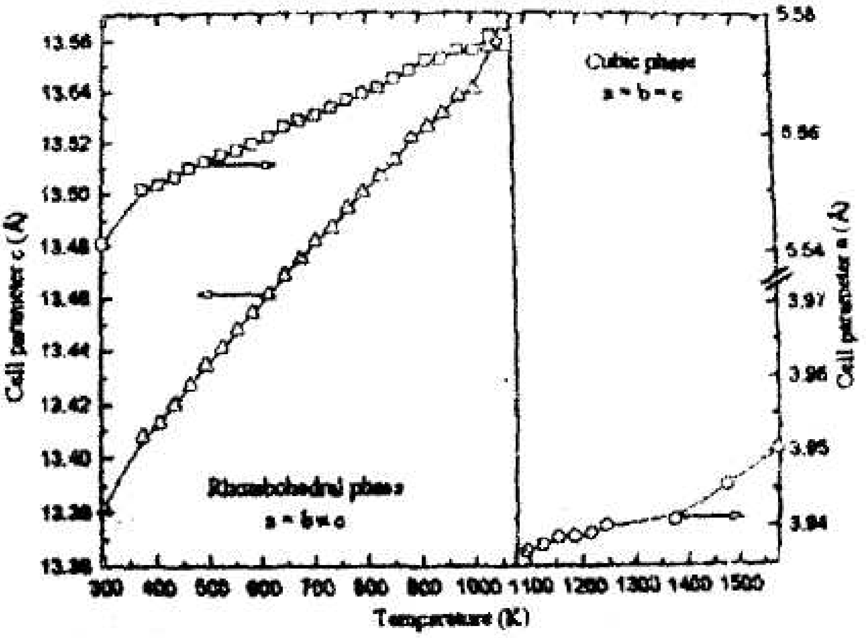

Figure 7.15. The stability of linear changes in $La_{0.7}Sr_{0.3}MnO_3$ in whole temperature range 350 - 1500°K [170].

The fixed jumps at temperature dependencies of parameter are characterized availability of obligatory structural changes – phase transitions.

7.6. Linear regularities in magnetization properties and in structural PT in low-temperature magnetodielectric $CuCl_2{\cdot}2H_2O$

Also in the earlier works of Holland investigators [7, 152, 153], unusual changes of magnetic, magnetothermal and resonance properties of the low-temperature magnetic dielectric $CuCl_2{\cdot}2H_2O$ have been revealed. The noted features and the related physical properties were being studied in detail during the last decade. The results have contributed much to the fundamental physics of phase transitions. However, the discovery of the so-called "supereffect" – a colossal influence of the external magnetic field H on the resistive properties of manganites in the vicinity of Curie point and the discovery of conductivity in HTSC put a question to investigators [135]. The understanding of the mechanisms of effects and processes under investigation, the penetration into casual bases of PT and properties would favour the application of such effects and could be the achievement for the physical science as a whole.

By using the procedures to analyze the experiments on magnetic semiconductors [147-151], we consider the studies of AFM resonance in copper chloride dehydrate under T-H-P effect [102, 165, 166].

The resonance was observed at frequencies ν_1=0.7 GHz, ν_2=2.85-3.15 GHz, ν_3=4.5-4.88 GHz in the temperature range 1.68≤T≤4.2 K, under hydrostatic pressure P of 0; 5.2; 9.2; 11.2 kbar by a specially developed method [166]. The experimental results have been obtained on single crystals and, what is important, under the accurate optical and x-ray orientation. In this respect, the demonstrative is the study by direct x-ray method of the features of structure lattice and anisotropy of the elastic properties of the critical directions under hydrostatic pressure effect in $CuCl_2 \cdot 2H_2O$ [64].

We pay attention to experimental procedure. The external magnetic field of 0 to 12 kOe is oriented in plane ab of the crystal structure of the sample. The resonance was observed for all the selected frequencies (apart from ν_1=0.7 GHz), in the pressure range 0 to 11.2 kbar for two values of the magnetic field, if angle ψ between field H and easy magnetization axis a was not in excess of the angle of AFMR failure ψ_f. With ν_1=0.7 GHz, the resonance was only observed in magnetic field H_{2P} pertaining to the field of phase transition. The resonance disappeared at slight deviations of field H from axis a in the ab-plane.

In the whole of the temperature range, on the isochronous diagrams, the resonance absorption was truly observed only for $T \leq 3.5$ K and P=0. With pressure increase (P>9 kbar), there was an increase in the resonance absorption temperature range to 4.2 K.

On the field-temperature dependences [165, 166] we take the field-temperature changes (fig. 7.16a) of the phase transition and denote it $H_{ST}(T)=H_P(T)$, influenced by T-H-P. It is noteworthy that $H_P(T)$ with H||a, in the temperature range to 3.5 K, and P=0 (fig. 7.16a, curve 1) has a linearity of peculiar character, that was also observed in a wider temperature range [92, 96]. Some discrepancy in numerical values is explained by high response of the resonance fields to orientation of the sample with respect to the magnetic field. However, on the dependences, the regularities of linearity are maintained.

It is this result that enables us to study and analyse the linear regions on the field-temperature dependences of fig. 7.16a, to estimate the conformity parameters of T-H-P effect on phase transition shifting using the estimate of the linear changes in PT as a function of T and H, observed on the dependencies (fig. 7.16a) under fixed pressures P_1=0 kbar (curve 1), P_2=5.2 kbar (curve 2), P_3=9.2 kbar (3), P_4=11.2 kbar (4). It follows that $\Delta P/\Delta T$=3 kbar/K and $\Delta H/\Delta P$=1.3 kOe/kbar. These results show that temperature variation by ΔT=1 K and magnetic intensity change by ΔH=4 kOe result in shifting the PT field on the $H_P(T)$ dependencies by the same quantity as the pressure of 3 kbar does. This means that the numerical estimations of T-H-P effect (1 K~4 kOe~3 kbar), for the represented dependencies confirm the important role of the mechanism of elastic stresses, but already in the low-temperature region.

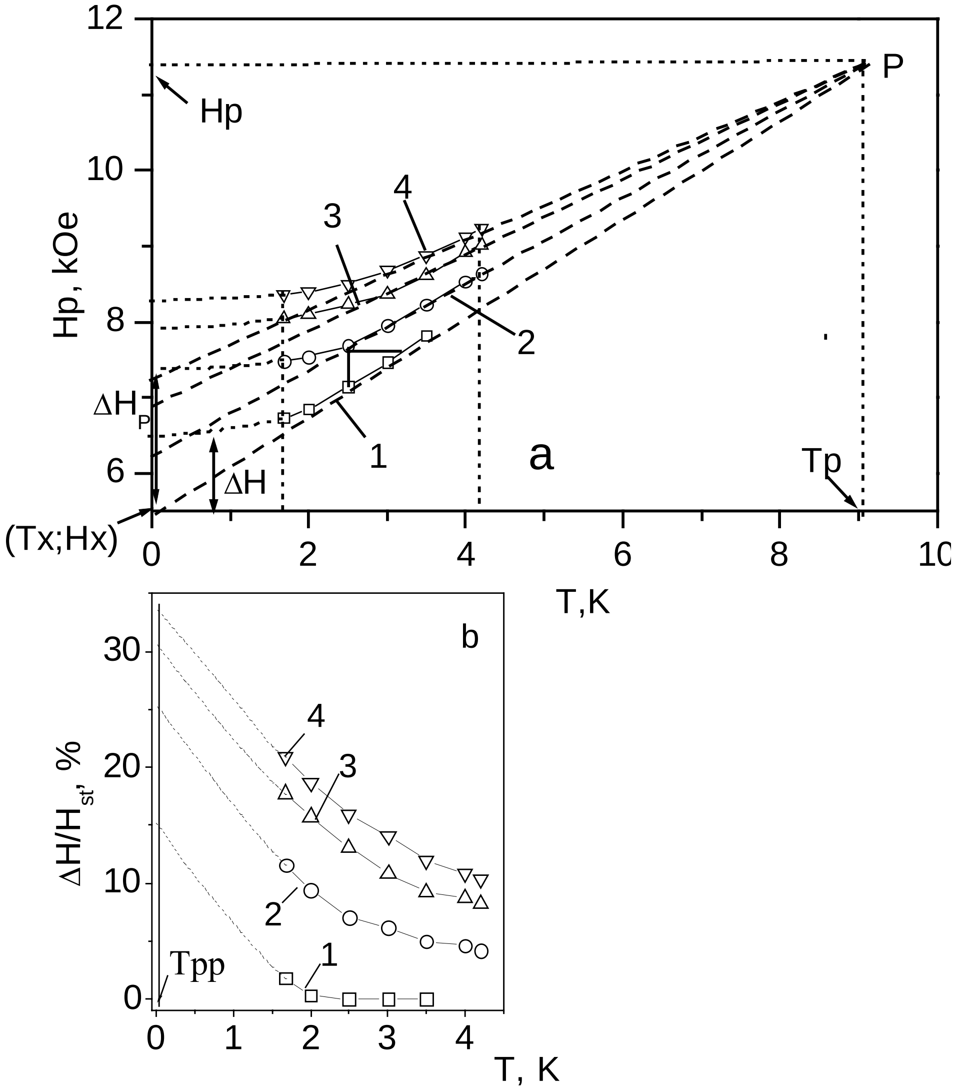

Figure 7.16. (a) Temperature-field dependence of the field of the phase transition at different presures on a frequency ν=0.73 GHz: 1 – P=0; 2 – P=5.25 kbar; 3 – P=9.25 kbar; 4 – P=11.2 kbar. (b) Temperature dependence of thermomagnetic effect 1 – P=0 and thermobaromagnetic effect: 2 – P=5.25 kbar; 3 – P=9.25 kbar; 4 – P=11.2 kbar.

Drawing the analogies and making comparisons with the results for magnetic semiconductors, we pay attention to the revealed effects and the determined temperature of maxima T_{PP} there, which corresponds to T_{ms}, the temperature of metal-semiconductor phase transition. This appears as a regularity of a jump in properties in the structural PT. By the same methods we consider and ascertain the analogies in magnetodielectric. To this end we analyze the field-temperature dependencies of fig. 7.16a and make our complements. We introduce a concept of thermomagnetic $\{H_{st0}(T)\text{- } H_{stH}(T)\}/H_{st0}(T)$, % and thermobaromagnetic effects $\{H_{st0}(T)\text{- } H_{stHP}(T)\}/H_{st0}(T)$, % (fig. 7.16b), where $H_{st0}(T)$ is the approximated linear dependence with the initial parameter

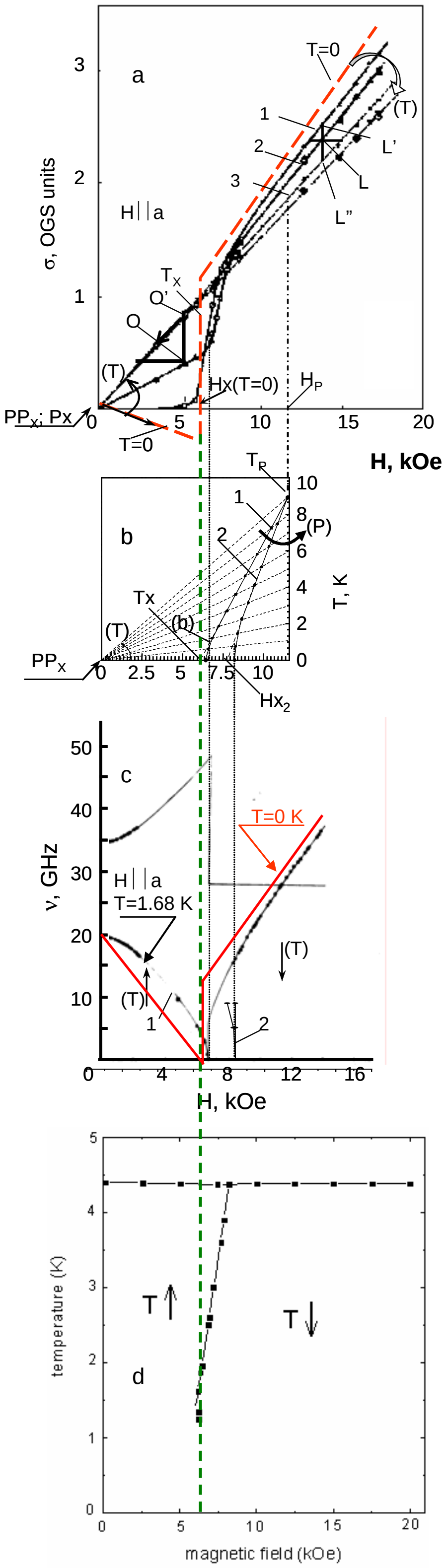

Figure 7.17. (a) Behavior of magnetization of $CuCl_2{\cdot}2H_2O$ monocrystal at external magnetic field directed along the easy axis: 1 – 1.59 K; 2 – 3.02 K; 3 – 4.1 K. (b) temperature-field dependence of the field of the phase transition at pressures: 1 – P=0; 2 – P=11.2 kbar. (c) Frequency-field dependence of AFMR in $CuCl_2{\cdot}2H_2O$ at H||a and T=1.65 K: 1 – P=0; 2 – P=11.2 kbar. (d) magnetic phase diagram of $CuCl_2{\cdot}2H_2O$ monocrystal.

H_X=5.5 kOe. H_{stH}(T) is the regularity of PT shifting under the influence of H; H_{stHP}(T) is the dependence of PT temperature change under the influence of magnetic field and pressure. Such operations substantiating the final result do not contradict the physical sense and show the potentialities of a consequent analysis, which is somewhat different from the conventional one.

Thus, from the results of fig. 7.16b it follows that the maxima of the revealed effects correspond to one and the same temperature T_{PP}=0 K. By analogy with the similar result (fig. 7.12b) but for the magnetic semiconductor, where the temperature T_{PP} of the maxima of magneto-, baro- and baromagnetoresistive effects coincided with T_{ms}, we can state that in magnetic dielectric, T_{PP}=0 K also corresponds to the temperature T_{ST} of the structural phase transition. Proceeding from the obtained result shown for the first time in paper [167], and to continue the analysis the following can be found. Upon approximating the dependence shown in fig. 7.16a, curve 1, we can single out point T_X with magnetic-field parameter H_X≈5.5 kOe. The same regularities of magneto-EAD stresses and of magnetoelastic anisotropy, but in a higher fields, are denoted by the critical point T_X with parameter H_X(T=0) on the dependencies of magnetostriction, (fig. 7.13) for single-crystalline $LaMnO_3$. In the above results, the found regularities show that in the both cases the mechanisms of EAD stresses and of anisotropy are identical.

Next, we pay attention to the estimates of conformity in the influence of T, P and H (1 K~3 kbar~4 kOe) and explain the importance of the mechanisms of EAD stresses and regularities of the “cooling”-“heating” effects from the influence of P and H, which were first shown in papers [147, 150], but already from the point of view of dynamics of T_P(H), T_P(H,P) change. The substitution of indices H_{ST}(T) on the field-temperature dependence by T_P(H) does not contradict the physical sense (fig. 7.16a, fig. 7.17b).

First, with H increase from H_X=5.5 kOe with P=0, the mechanism of magnetoelastic striction on the T_P(H) dependence leads to the “cooling” effect, while the conditions for PT realization acquire an additional thermoelastic expansion and, thus, the temperature increase. T_{PP} remains constant. And the reverse, “heating” effect is as follows: with diminution of magnetic intensity, the magnetostriction effect weakens, and temperature decrease is necessary for conditions of PT realization be satisfied. In this case, T_{PP} is constant once again.

Second, regularities of the effect of simultaneous influence of hydrostatic pressure and magnetic field are of the most interest. The sign alternation of the effects is a very important result. “Supercooling” at the expense of pressure increase to 11.2 kbar is overcome by an additional change in magnetic field to H_{X2} at the expense of magneto-elastic stresses, i.e. the “heating” effect near the same critical point T_{ST}=0 K, where the magnetoelastic anisotropy realizes the PT. Further growth of magnetic intensity results in regularities of “cooling” effect. It follows that changes in P and H are shifting the PT by the mechanisms of sign alternation in the effects. Conditions for PT realization remain the same, T_{PP} – constant. The like "heating" effect of the magnetic field is realized in $LaMnO_3$ at temperatures below the structural phase transition, this is illustrated on the $H_g(T)$ dependence of fig. 7.13.

This means that the "cooling", "heating" effects create a competition between baro- and magnetoelastic compression, on the one hand, and thermoelastic expansion, on the other hand, under elastic stresses influence. The role of these mechanisms is in the form of sign alternation for properties and PT from T, H effect [150]. With the allowance for the estimates of the parameters (T-H-P) influencing the PT shifting, we can explain the linear and non-linear regions of the field-temperature dependencies (fig. 7.16a), where the thermoelastic expansion prevails over the magnetoelastic compression, in the whole range of H change upon the increase of temperature. Such an explanation of $T_P(H)$, $T_P(H,P)$ dependencies and of the role of "heating" and "cooling" effects from the influence of field H and pressure P confirms the regularities of EAD stresses being pointed to by sign alternation.

Now, we pay attention to further analysis of the investigation results, which pointed to sign alternation, and show that at different pressures the field-temperature dependencies of fig. 7.16a tend to approach each other. By simple operation we take and denote the more important regularity – at points T_X and P.

T_X is the initial point of the approximated field-temperature dependence (fig. 7.16a, curve 1) having the coordinates H_X=5.5 kOe and T_X=0 K. This result has already been used in the analysis, it shows that at T=0 K and H_X=5.5 kOe the PT is realized at the expense of magnetoelastic anisotropy.

Critical point P results naturally from the mechanisms of EAD stresses. It is at the intersection of the field-temperature dependencies, at fixed pressures, at the point having coordinates T_P=9.2 K and H_P=11.5 kOe (fig. 7.16a).

It is noteworthy that the temperature parameter of the critical point T_P=9.2 K more than twice exceeds the critical temperature T_N=4.33 K known from papers [152, 153, 168]. Such unordinary has result stimulated an additional research of true thermodynamic mechanisms in the chosen magnetic dielectric.

7.7. Secondary signs of the first-order structural PT and the role of elastic properties in the distinguishing of critical lines and points, resonance properties and phase states

To elucidate the role of the found regularities in the properties of magnetization, let us consider and analyze the results of experimental investigations of the megnetic properties in single crystal of $CuCl_2{\cdot}2H_2O$

(fig. 7.17a) obtained in paper [7]. These results were among the important arguments for the formation of basic concepts of antiferromagnetism. Here we pay attention to a study of magnetization in single-crystalline sample in the form of round disks (2.5 mm×5 mm) aligned manually with no optical or X-ray control that gave error in measurements and affected the interpretation of results.

Now we interpret the dependence of fig. 7.17a illustrating the dynamics of magnetization with H directed along the “easy” axis and T_1=1.59 K, T_2=3.02 K, T_3=4.1 K. Here we note some interesting features:

a) for $H<H_0$ ($H_0=H_{ST}$) and at T_1, T_2, T_3 the author [7] observed slight changes in magnetization vs field rise dependence, while the temperature variation (thermoelastic expansion) essentially influences the slope of magnetization in each the dependencies, which have a single point of convergence PP_X. With temperature increase the above dependencies tend to deviate counter-clockwise, i.e. the growth in T and H affects the increase in magnetization. Consequently, in the same figure it is possible to construct an approximation of the dependency (fig. 7.17a, the dashed line) for T=0 K, that does not contradict the logic of the experiment.

b) For $H>H_0$ (fig. 7.17a) the magnetization increases with H and decreases with changes in T_1, T_2, T_3, i.e. changes in T and H affect the magnetic properties in antiphase. The growth in T is shown by the arrow. It is noteworthy that the approximation of all the dependencies has a single point of convergence P_X near the origin of coordinates. Logically follows the behavior of properties at T=0 shown by the dashed line. Here we also point to the regularity due to changes in T and H. By the position of critical points L, L’, L’’ one can follow the “heating”-“cooling” effects of the magnetic field. With T decrease, the properties are transferred from L to L’. By H decrease, the returning of properties to L results in the “heating” effect. On the contrary, the properties are returned to L and we have the “cooling” effect. In this case, both the magnetization and magnetostriction in $LaMnO_3$ (fig. 7.13 and fig. 7.17a) are of similar tendency.

For a better understanding of the jump in properties (fig. 7.17a) we superimpose the behaviour of magnetization on the field-temperature dependencies $T_P(H)$, $T_P(H, P)$ of fig. 7.17b by the method of common coordinates of both the magnetic field and the temperature. In fig.7.17b the changes in temperatures are shown in the angle coordinates. Such coordinates are more evident for the explanation of the dynamics of properties and PT under the influence of thermo-, magneto- and baro- elastic stresses. However, during this procedure it is very difficult to make allowance for the main mistake originating from the orientation of a single crystal with respect to the magnetic field, however, the main tendencies are maintained.

What does the jump at point with coordinates T_X=0 K, H_X(T=0)=5.5 kOe mean? In fig. 7.17a it is marked by the dashed line. It defines, through the properties, the position of structural phase transition for T=0 K. Such a methodology of the analysis is justified and there is an agreement with the analogous result for $LaMnO_3$ (fig. 7.13). In the figure, there is the analogous point T_X with parameters T=0; H_X(T=0). The mentioned methodology of analysis and construction helps in the revealing and explaining the role of elastic stresses from the influence of T-H-P on the structural phase transition, properties and in determining the significance of structural peculiarities. Such peculiarities are due to chemical-and-technological as well as the symmetry-lattice characteristics of the magnet-containing samples. In this respect, the matched critical point P_X (PP_X) in the origin of coordinates is a regularity of changes in properties under the influence of magnetic field and temperature namely for magnetodielectric (fig. 7.17a). At the same time, it is noted [150] that on the dependence of magnetostriction in $LaMnO_3$, the critical points P_X, PP_X, resulting from a similar extrapolation (fig. 7.13) are spread on different sides of the phase transition. This is a regularity of the chemical-and-technological as well as structural features of magnetic semiconductors.

The described results and their substantiation are important for the interpretation of regularities in changes and formation of properties and phase transitions in the physics of low-temperature magnetic dielectrics and of another materials. The following generalization can be done:

First, from the above construction and estimation of the found conformities (fig. 7.17a and fig. 7.17b) we reveal the regularities in PT changes and in dynamics of magnetization under the influence of temperature and “cooling”, “heating” effects from H and P through the mechanisms of elastic stresses;

Second, on the example of “cooling” effect, as a result of magnetic field influence on T_P(H) shifting and properties, a regularity of the opposite effect of thermoelastic stresses on magnetization properties before and after the phase transition has been shown. In fig. 7.17a and fig. 7.17b this is shown by the dashed line for T=0 and it is seen from changes in properties under T effect with respect to overlapping points PP_X, P_X, meaning that the effect of temperature change for the properties develops in counterphase . This fact shows that there is a mechanism of thermoelastic deforming striction (compression), which fixes the structural phase transition as a jump during the increase of temperature. Such a redistribution of stresses induced by the temperature (fig. 7.17a) can be termed as the effect of TSS.

What does the TSS effect mean? It means changes in the structural PT under the influence of temperature through the mechanism of thermo elastic stresses. In the investigated sample, under the structural PT temperature of 0 K, the properties are changing in a jump-like manner (the dashed-dotted line in fig. 7.17a). This means that with temperature rise, in the region of PT, there occurs a sudden change in properties at the expense of thermoelastic compression mechanism. On magnetization curve there is a jump, or as we think, a jump in conductivity, but already under the superconductive effect.

We pay attention to the found regularity in magnetization properties, which is realized by TSS effect. On the dependencies we observe changes in properties prior to magnetization jump (PT) in low field H (fig. 7.17a). T and H affect the properties unambiguously. This means that the magnetization increases with T and H, while there is a monotonous lowering of the properties with T and H decrease. The resulting is an unusual sign alternation in the influence of T and H.

This is proved by the analysis of changes in magnetization under the influence of T and H. To this end, we take point O on the dependencies of fig. 7.17a. With T increase, there is a shift of properties from O to O'. Next, by decreasing H and removing the magnetostriction backpressure, we return the properties typical of point O. By decreasing H we realize the effect corresponding to a decrease in T. This is a consequence of the effect of TSS.

Such representation and the found regularities relating to the role of elastic stresses enable us to substantiate their causal value in some more properties and effects. This will be done later on.

The carried out analysis, the shown results, the grounding of the effect of TSS give us a possibility to state that the like regularities in changes of PT and properties are the case with samples of some other compositions and classes.

It was already mentioned that the understanding of regularities in structural PT in the low-temperature magnetic dielectric $CuCl_2{\cdot}2H_2O$ is a key to the comprehension of the superconducting effect and as we believe, of the properties of conductivity in HTSC. And the magnetic field effect realizes, at the expense of causal role of magneto-EAD stresses, conditions for a colossal magnetoresistance in magnetic semiconductors.

The obtained results and further studies of the role of the mechanisms of elastic stresses in regularities of changes in PT and properties have made it interesting to find out the nature of the high-frequency properties in $CuCl_2{\cdot}2H_2O$ influenced by H and T.

A great number of papers [76, 77, 86, 154-157] deal with the investigation of the resonance properties in a model sample of copper chloride dehydrate in a wide range of frequencies, magnetic fields and temperatures. A more complete explanation of the models and theory by using the molecular field approximation is represented in papers [76, 77]. Changes in the resonance properties in the rotating magnetic field were theoretically explained in papers [86, 96, 101, 102, 159, 165, 166]. However, the proposed models can't find the mechanisms, determine the constants, nor show the whole spectrum of the field-frequency dependencies at the fixed temperature T=0 K. An extensive data on experimental investigations of properties in the low-temperature region, in a whole range of the magnetic fields have defined the purpose of our analysis.

We pay attention to a low-frequency branch of the field-frequency dependence, (fig. 7.17c), [96], which is a generalized result of the experiments. It shows that there is a conformity in magnetic field changes to the described above results (fig. 7.17a,b,c).

The low-frequency branch is expressed by a dependence showing how the properties are changed for T=1.68 K in field H directed along the a-axis.

Let us look at the position of critical point b (fig. 7.17b). It is a matched point, its position is shown on the $T_P(H)$ curve of fig. 7.17c. All the regularities in changes are considered with the allowance for the estimates of conformity in T-P-H effect (1 K~4 kOe~3 kbar).

a) point b with the coordinate H_{ST}=6.8 kOe, which corresponds to P≈4.8 kbar, and T=1.68 K (P≈5 kbar). The position of point b is a consequence of the "cooling" effect from the magnetic field influence on changes in PT (fig. 7.17c).
b) in the initial segment of frequency behavior in fields from 0 to 6.8 kOe, that corresponds to P change from 0 to 4.8 kbar, under a fixed thermoelastic expansion (T=1.68 K), the non-linear dependence is explained by the alternating-sign priorities in the competing mechanisms of thermoelastic expansion and magnetostrictive compression;
c) on the field-frequency dependence (fig. 7.17a,c) the changes in temperature affect the dynamics of properties in counterphase, this is explained by sign alternating influence of T and H. Thus, the priority of thermoelastic expansion fixed at T=1.68 K (corresponding to P≈5 kbar) is changed, the magnitude of field H=6.8 kOe corresponding to P~4.8 kbar. On the dependence of fig.4c we observe a change in slope.

As a result, the low-frequency branch of the field-frequency dependence is nothing but resonance in properties prior and past the structural PT, with regularities in changes being a consequence of the mechanisms of EAD stresses from T, H effects.

Such an explanation of the noted low-frequency dependencies enables us to treat the conditions for the resonance absorption in a new way. Since in the structure the changes in conduction electron coupling are determined by the mechanisms of EAD stresses, in the electromagnetic field of the resonator tuned to resonance, the high-frequency current is realized, which is an active component of the absorption. This is registered by the equipment.

The given results and the revealed regularities prove that the mechanisms of EAD stresses from T-H-P effects are identical in both the low- and high-temperature range. Consequently, we can consider the phase diagram for $CuCl_2 \cdot 2H_2O$ illustrated in fig. 7.17d and discussed in papers [81, 86, 153] somewhat differently.

What is it the dependence for properties, when the role of competing influence of T and H through the EAD stresses and the effect of TSS are taken into account? At the initial segment of the dependence, T and H unambiguously are forming the magnetic properties with the account for the TSS effect. Next, the changes in PT obey the regularities of the "cooling" effect from the magnetic field at T=4.3 K. The following segment is a consequence of regularities of monotonic change in the properties under the influence of competing mechanisms of thermo- and magnetic EAD stresses. Here the change of priorities from T to H can be estimated from T-H-P (1 K~4 kOe~3 kbar) conformities. We note that the dynamics of changes in PT propagates to the critical point P_C having the coordinates H_P, T_P, where $T_P \approx 9.2$ K is much different from T_N of 4.3 K.

Such interpretation of the role of EAD stresses is preferable for the explanation of regularities in phase diagrams for the given class of samples. The carried out analysis and the obtained results have proven this interpretation to be correct.

7.8. Linear lows of elasticity during the selection of critical lines and points

The studies have shown that the experimental results for changes in PT and properties point to the existence of critical points and lines participating in the construction of typical singes. They also help in judging the mechanisms of changes in magnetization, magnetic susceptibility, heat capacity, resonance properties not only in phenomenological models and theory, but can be a subject of independent investigations.

At present, there is no a consecutive analysis of the critical phenomena realized in critical lines and points. The analytical methods to study them in a variety of compositions and properties in both physically accessible and inaccessible regions have not been developed. This is a missing link in the chain of researches. This deficiency can be made up by finding and analyzing the true peculiarities of the revealed thermodynamic mechanisms of elastic stresses. The understanding of physical regularities taken directly from the experimental results and appearing as a variety of critical lines and points makes it possible to relate the chemico-technologycal and lattice-symmetry features of the structure in the changes of PT and properties, as well as to show the causal role of elastic stresses.

On the example of changes in resistivity of polycrystalline $La_{0.7}Ca_{0.3}MnO_3$ we derive the following critical lines and points (fig. 7.12a):

$T_{ms}(H)$, $T_{ms}(P)$ are the temperatures of the metal-semiconductor phase transitions under H, P effect. The regularities of their changes become formed by the difference in magnetoelastic and elastic anisotropies;

P_X' is the critical point resulting from the intersection of approximated dependencies of resistivity on temperature under the influence of variable parameters P and H;

T_{PP} is the temperature corresponding to the maxima on the dependencies of baro-, magneto-, baromagnetoresistive effects (fig. 7.12a,b), which coincides with T_{ms}.

It is noteworthy that all the critical lines and points are a regularity of the chemical composition, the technology of treatment, symmetry-lattice features of structure and T-H-P effect through the mechanisms of elastic stresses.

The next result, which applies to magnets as well, are the critical lines and points concerning the changes in magnetostriction in $LaMnO_3$ under the influence of magnetic field and temperature, fig. 7.13 where:

$H_g(T)$ is the critical line of changes in PT hysteresis field parameters versus the temperature. Differences in thermo- and magnetoelastic anisotropies define the parameters of hysteresis under the PT;

P_X, PP_X are spaced apart points resulting from the intersection of the approximated linear segments of the field dependencies of magnetostriction prior and past the PT; they are a regularity of changes in properties under the influence of T and H through the elastic stresses. The magneto-elastic stresses are of priority, when PP_X is found;

T_X is the critical point of intersection of $H_g(T)$ approximation with the dependence of magnetostriction (T=0 K) $H_X(T=0)$, fig. 7.13. In this case, of priority are magneto-elastic stresses;

T_C is the Curie temperature corresponding to the point of intersection of the critical line $H_g(T)$ with axis H on the magnetostriction dependence. It is a consequence of the competing conformities of thermo- and magneto-elastic stresses. It also holds the structural PT fixed with thermo- and magnetoelastic anisotropies being equal.

This variety of critical lines and points makes it possible to relate them to each other and to determine the role of elastic stresses. Now, we carry out a comparative analysis of the mentioned results for magnetic semiconductors.

a) We pay attention to resistivity change, fig. 7.12a (curve 1), where the temperature realizes, through thermo-elastic stresses and regularities, a resistivity jump in the region of the structural metal-semiconductor PT, with T_{ms}=275 K corresponding to pressure P~45 kbar and H=0, in compliance with our estimates. A subsequent influence of the magnetic field affects the properties and $T_{ms}(H)$ dependence through the “cooling” effect. In $LaMnO_3$ $T_{ST}\approx300$ K [5];

b) Proceeding from the revealed relative equality of the estimates of a correlative influence of T and H in a variety of polycrystalline and single-crystalline samples, it can be assumed that changes in magnetostriction under the influence of the “heating” effect of the magnetic field (fig. 7.13) show that the magneto-elastic stresses realize the properties of magnetoelastic anisotropy in the form of the structural PT, with $H_X(T=0)\approx210$ kOe, at the critical point T_X for T=0. Such coordinates correspond to pressure of approximately 75 kbar. Subsequently, the mechanism of thermo-elastic stresses results in the changes of the hysteresis field on $H_g(T)$ curve. This is a regularity of differences in thermo- and magnetoelastic anisotropies;

c) Now we analyse the result of a combined influence of H and T (fig. 7.12a, fig. 7.13). Here we observe the linear and non-linear critical lines $T_{ms}(H)$, $H_g(T)$. With the role of elastic stresses and the estimates of a correlative influence of T-H-P taken into account one can see that changes in critical lines is a regularity of changes of H and T prevailing influence on PT and properties. In this case, the influence of the elastic stresses is of alternating sign character, and the location of T_C is a consequence of such alternation. Thus, the mechanisms are correlative and there is equality of elastic and magnetoelastic anisotropies. The analysis and the results show that there are the laws for elastic stresses, sign alternation, T_{PP} constancy, correspondence of elastic and magnetoelastic anisotropies (the Curie temperature). It is also shown that the magneto-EAD stresses play the basic role in a giant magnetoresistance.

As a consequence, the position of critical points $T_{ms}=T_{PP}$, T_X, $H_X(T=0)$, P_X, PP_X and P_X’ and lines $H_g(T)$, $T_{ms}(H)$, $T_{ms}(P)$ is a regularity determining the relation between chemical-and-technological, symmetry-lattice features of the structure and the regularities of T-H-P effects through the mechanisms of thermo-, baro-, magnetoEAD stresses in properties, phase transitions, correlations, sign alternation and effects.

The analysis of the experimental results reveals the casual role of thermo-elastic stresses in changes of the structural phase transition taking place prior and past the PT, whereas the influence of H through magneto-elastic stresses is a consequence of “cooling”, “heating” effects. The regularities are also valid for the magnets.

Now we define more exactly the regularities in the construction of critical lines and points for the magnetic dielectric $CuCl_2{\cdot}2H_2O$ by the results of PT magnetization and high-frequency properties change (fig.7.16a, fig. 7.17abc):

$T_P(H)$, $T_P(H, P)$ are field-temperature dependencies of changes in phase transition under the influence of H and P;

P_X, PP_X are superposed points of intersection of extrapolated linear dependencies of magnetization showing the regularities of T and H effect through the mechanisms of elastic stresses prior and past the PT (fig. 7.17a);

T_X is the point of intersection of the approximated field-temperature dependence $T_P(H)$ with the axis of temperatures, it shows the location of PT with T=0 K, $H_X(T=0)=5.5$ kOe (fig. 7.16a, fig. 7.17ab);

$T_{PP}=T_X=0$ K is the temperature of the thermomagnetic and thermo-baromagnetic effect maxima, it corresponds to the temperature of structural PT (fig. 7.16b);

P is the critical point with the coordinates $T_P=9.2$ K, $H_P=11.5$ kOe. It is a point of regular intersection of the approximated field-temperature dependencies $T_P(H)$, $T_P(H,P)$ corresponding to changes in PT for different fixed pressures (fig. 7.16a and fig. 7.17b). At this point, thermoelastic and magnetoelastic anisotropies are conformable;

$T_P=9.2$ K is the temperature parameter of the critical point P.

Such arrangement of the critical lines and points and their conformity help in finding regularities in correlation between the structural features and the mechanisms of thermo- baro-, magneto-elastic stresses, which result in changes of the structural PT and properties of the given sample.

By using the methodology of the analysis of magnetic semiconductors, we now analyse critical lines $T_P(H)$, $T_P(H,P)$ and points T_X, $H_X(T=0$ K), $T_{PP}=T_{ST}=0$ K, P_X, PP_X for the investigated magnetodielectric.

a) By comparing the properties of magnetization (fig. 7.17a), field-temperature (fig. 7.17b) and field-frequency (fig. 7.17c) dependencies, we pay attention to their location for T=0 K and note that any changes in T are connected with the mechanism of thermo-EAD stresses, when the anisotropy of thermoelasticity realizes the structural PT at point T_X, and the effect of TSS is developing with temperature increase for H=0. Moreover, it has been revealed that $T_X=T_{PP}=T_{ST}=0$ K is a regularity of the structural PT.
b) On the dependencies of magnetization (fig. 7.17a) we observe the regularities of magneto-EAD stresses: by analogy with the magnetic semiconductors (fig. 7.13), we pay attention to the fact that the influence of the magnetic-field “heating” effect through the magneto-EAD stresses and the magnetoelastic anisotropy realize the structural PT (T=0 K) in the form of magnetization jump in field $H_X(T=0)=5.5$ kOe, which, according to the estimates, is equivalent to the influence of P≈4.2 kbar and correspond to the critical point T_X. A subsequent increase of the magnetic intensity gives the “cooling” effect in the behavior of $T_P(H)$;
c) Finally, we consider the combined effect of H and T through the mechanisms of EAD stresses, (fig. 7.17abc). Their role in the properties of

magnetization (fig. 7.17a) is seen by regularities of equivalent T, H effect prior to PT and by the sign-alternating influence past it. It is also seen by the changes in field-temperature dependencies $T_P(H)$, $T_P(H,P)$ (fig. 7.17a,b) and by the TSS influence of T, the "cooling", "heating" effects of H, and by the determined regular location of critical point P; linear and non-linear changes in PT, field-temperature dependencies (fig. 7.17bc) and phase diagrams (fig. 7.17d). This determines the causal role of T, H, P effects through the mechanisms of EAD stresses in the represented results of the analysis of investigation of changes in PT and properties in $CuCl_2{\cdot}2H_2O$.

A detailed consideration of the obtained results allows us to characterise one more important regularity, which determines the correspondence and differences in structural PT and properties of magnetic semiconductors and magnetic dielectrics. Primarily, it is a consequence of the chemical composition, technical processes of sample preparation and, as a result, of lattice-symmetry peculiarities of the structure. The properties and the structural PT are realized under the influence of thermodynamic parameters T-H-P through the revealed mechanisms of elastic stresses, the anisotropy of elasticity and magnetoelasticity manifesting itself in high and low H and T, respectively. These regularities were revealed when the notion of sign alternation in the position of critical lines and points was introduced.

Now, we consider the variety of critical lines and points in the two systems. We pay attention to changes of resistivity in polycrystalline samples (fig. 7.12a) and to the revealed adequacy of T-H-P effects, as well as note the dependencies of magnetostrictive properties and correspondences (T-H) in single-crystalline $LaMnO_3$ on the critical lines $T_{ms}(H)$, $T_{ms}(P)$, $H_g(T)$ and of points $T_{PP}=T_{ms}$, T_C, P_X, PP_X and T_X for $H_X(T=0)$ (fig. 7.13), which relate the structural, electronic, magnetic, elastic properties and the mechanisms of elastic stresses in magnetic semiconductors.

For the low-temperature magnetic dielectric, the critical lines $T_P(H)$, $T_P(H,P)$ (fig. 7.16) and points $T_{PP}=T_{ST}=0$ K, P_X, PP_X, T_X with the coordinates T=0; $H_X(T=0)$, and critical point P for $T_P=9.2$ K as well as the effect of thermoelastic deforming striction (compression), fig. 7.17abc, relate the peculiarities of structural, magnetic, elastic, high-frequency properties to the mechanisms of elasticstresses.

As a result, by specifying the location of critical points T_X and P_X, PP_X of fig. 7.13, fig. 7.17ab, we see that their location is different, but the role in the investigated systems is unambiguous. From the analysis and comparison of the mentioned critical lines in the form of the $H_g(T)$ dependence and its relation to $T_{ms}(H)$ and T_C, in one case, and to the $T_P(H)$, $T_P(H,P)$ dependencies and critical points $T_X=T_{ST}=0$ K and P, in the other case, as well as their relation to the effect of TSS it can be stated that their significance is, by definition, unambiguous, and characterising the regularities of changes in structural PT, but the position of the lines and points is of sign-alternating character. This is the proof of regularities in the conformities and differences of the investigated samples.

The investigation results make it possible to conclude that in the chemical compositions of multicomponent magnet-containing systems subjected to a specific treatment, the symmetry-lattice peculiarities of the structure are formed, when the structural PT are formed and changed with the variety of properties, effects and anomalies. This happens under the influence of T-H-P by the laws of elastic stresses.

The grounded analysis of the results of experimental investigations, where the significance of elastic stresses has been revealed, is very helpful. It differentiates between real and unreal models and their theoretical substantiation. The understanding of such regularities in thermodynamic influence of T-H-P helps in the improvement of potentialities of thermodynamic and phenomenological methods for the sake of elaboration of new models and theories.

7.9. Conclusions

The carried out analysis of the experimental results for $La_{0.7}Ca_{0.3}MnO_3$ and their analogies, such as $LaMnO_3$, $CuCl_2{\cdot}2H_2O$, makes it possible to tie together the chemical-and-technological as well as the symmetry-lattices peculiarities of the samples, the electrical, magnetic and other properties through the elastic properties. The revealed role of T-H-P effect in their conformities for the properties and PT through the mechanisms of elastic stresses in both a relatively high-temperature and a low-temperature regions for substances of different classes makes the generalization of the obtained results possible.

By the investigation results on the behaviour of resistivity in $La_{0.7}Ca_{0.3}MnO_3$ and of magnetostriction in $LaMnO_3$, it has been noted:

1. a relative adequacy and conformity of T-H-P influence of the resistive properties of $La_{0.7}Ca_{0.3}MnO_3$ samples (5.1 K~2.42 kOe~1 kbar), as well as $La_{0.9}Mn_{1.1}O_3$ samples (6.2 K~2.7 kOe~1 kbar), and $La_{0.56}Ca_{0.24}Mn_{1.2}O_3$ samples (6.2 K~2.37 kOe~1 kbar) [147, 150, 151];
2. regularities of “cooling”, “heating” effects, constancy of T_{PP}, the temperature of maxima on the dependencies of baro-, magneto-, baromagnetoresistive effects, its equality to T_{ms} – the temperature of the metal-semiconductor phase transition, the differences being related to those in anisotropies of elasticity and magnetoelasticity;
3. regularities for EAD stresses and differences in anisotropies of elasticity and magnetoelasticity for changes in $T_{ms}(H)$ and $T_{ms}(P)$;

4. an adequate influence of H and T (2.5 kOe~5.2 K) on the magnetostrictive properties in $LaMnO_3$ single crystal;
5. a regularity in changes of hysteresis parameters $H_g(T)$ as a function of T and H in the region of PT, the role of equality and inequality of elastic and magnetoelastic anisotropies in T_C – to the Curie temperature;
6. a correspondence between $H_g(T)$ and T_{ms}, substantiation of “heating”, “cooling” effects in magnetic properties prior and past the PT, as a result of the influence of magnetic field;
7. a sign-alternating competing influence of thermo- and magneto- elastic stresses on changes in properties and structural PT at T_C.

The results of the analysis of the experimental investigations of magnetization and high-frequency properties under the influence of hydrostatic pressure, magnetic field and temperature in single-crystalline $CuCl_2{\cdot}2H_2O$ have revealed:

- the linear regularity for changes in PT on $T_P(H)$, $T_P(H,P)$ dependencies, the estimates of conformities in T-H-P (1 K~4 kOe~3 kbar) effects;
- significance of thermomagnetic and thermobaromagnetic effects with the maxima at point T_{PP} that corresponds to the temperature of structural phase transition T_{ST}=0 K;
- the role of “cooling”, “heating” effects in the properties of magnetization and of sign alternation for changes in PT under the influence of H and P on $T_P(H)$, $T_P(H,P)$ dependencies;
- critical point P as a result of regularity in correspondence for the elastic and magnetoelastic anisotropies with temperature parameter T_P=9.2 K.
- a regularity in changes of magnetization determining the effect of thermo-elastically strain striction (compression) (TSS)– is a result of relationship between chemical-and-technological and symmetry-lattice peculiarities, as well as of T and H effect on changes in structural PT;
- the basic role of elastic stresses in a single-valued and sign-alternating influence of T and H on changes in magnetization prior and past the PT, as a consequence of TSS effect;
- the role of regularity in T and H effect through the mechanisms of elastic stresses on high-frequency properties explaining the existence of two resonances on the properties prior and past the PT;
- regularity of the competing mechanisms of thermo- and magneto-elastic stresses and TSS effect during the construction of phase diagrams.

The reasoning from the analogies between various critical lines and points for the investigated samples has revealed:

- the roles of critical lines and points in a general problem of studying the physical processes and regularities;
- a variety of critical points T_X, P_X, PP_X, T_C, $H_X(T=0)$ and lines $T_{ms}(H)$, $T_{ms}(P)$, $H_g(T)$ and their relation to peculiarities of composition and structure to resistive, magnetic properties and PT through the mechanisms of elastic stresses;
- conformity and sign alternation in changes of properties and PT represented on critical lines $T_{ms}(H)$, $T_{ms}(P)$, $H_g(T)$ and at points T_X, P_X, PP_X, $T_{ms}=T_{PP}$, T_C and the role of the mechanisms of elastic stresses from T, H, P effect in magnetic semiconductors;
- a variety of critical lines $T_p(H)$, $T_P(H,P)$ and points T_X, P_X, PP_X, $H_X(T=0)$ and P;
- conformity and sign alternation of a competing influence of T and H observed in changes of properties and PT on critical lines $T_p(H)$, $T_P(H,P)$ and at points P_X, PP_X, $T_{PP}=T_{ST}=0$, critical point P (with $T_P=9.2$ K) showing the role of the mechanisms of elastic stresses from T, H, P effects in magnetodielectric;
- conformity and sign alternation in the location of critical points T_X, P_X, PP_X, $H_X(T=0)$, T_C, P and lines $H_g(T)=T_{ms}(H)$ and $T_P(H)$ in the investigated samples show the identity of T-H-P effect through the elastic stresses and the regularities in position of structural phase transitions with the TSS effect taken into account.

The described results enable us to make a generalizing conclusion.

The found regularities in properties, PT, effects, anomalies are a consequence determined by the chemical composition, manufacturing technology, symmetry-lattice peculiarities, presence of magnet in multicomponent systems. In these objects and not only there, the influence of T-H-P through values of thermo-, magneto-, baro- elastic stresses results in regular structure changes directly connected with anisotropy of elasticity and magnetoelasticity. This is a causal basis for all the regularities that should be taken into account during the analysis of investigation results within various thermodynamic and phenomenological models and theories, what is very important for the kinetics of microprocesses.

It can be stated without exaggeration that such interpretation of the experimental results shows that it is necessary and very important to take the revealed regularities of thermo-, magneto-elastic stresses into account, as they are forming and changing the properties and phase states. The understanding of these regularities allows us to predict the participation of the same mechanisms in realization of long-studied effects of a colossal magnetoresistance (CMR) and of conductivity in HTSC structures.

By drawing analogies for the influence of the mechanisms of elastic stresses, in manganites and copper chloride dihydrate, on the dynamics of changes in structural phase transition, properties, effects, with the revealed critical lines and points taken into account, it can be stated that there exist the laws of bulk elasticity. Here we agree with the authors of paper [135] that the understanding of the obtained results would favour a quicker and a forecasted application of the results to elaborate new models and theories, to substantiate various interesting phenomena and effects in solid-state physics.

This conclusion means that the revealed regularities can be used for studying a wide class of substances. Their application would promote the revealing and understanding of physical processes in solid-state physics and would interpret the law of correlated states as that of the elastically deforming conformities, and the revealed regularities in the influence of temperature, magnetic field, pressure as the laws of elastic anisotropically deforming stresses and of sign alternation. And, finally, the constancy of T_{PP} – as the law of elastic and magnetoelastic anisotropy conformities.