THE UNIVERSAL INTERCOMMUNICATION AND MUTUAL CAUTION OF THE CRYSTAL PROPERTIES

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In the present paper the intercommunication, interaction and mutual caution of the main five crystal properties are discussed. On the example of the real physical laws it is shown, that these intercommunication, interaction and mutual caution are observed clearly and revealed.

It is known, that the dialectical approach to the nature perception proposes, that non effect can't be understood, if it takes in the isolate form, out of the connection with the surrounding phenomena. The dialectics considers the nature not as the accidental accumulation subjects, separating, isolating and independent from each other, but as the unit ones; where subjects and phenomena are connected with each other organically, depend and cause each other. In the above mentioned context, the physical phenomena and physical crystal properties aren't the exception. Moreover, the thermodynamical development, addition of the thermodynamical principles to the reversible processes has revealed, that for every from the physical effects, connecting these or that physical properties, the reversible effects should exist. For example just in 1887, the electrocaloric effect, reversible to the pyroelectric one, was predicted by Calvin on the base of thermodynamics. Analogically, firstly the existence of the inverse piezoelectric and many other effects was theoretically predicted, later it was experimentally proved.

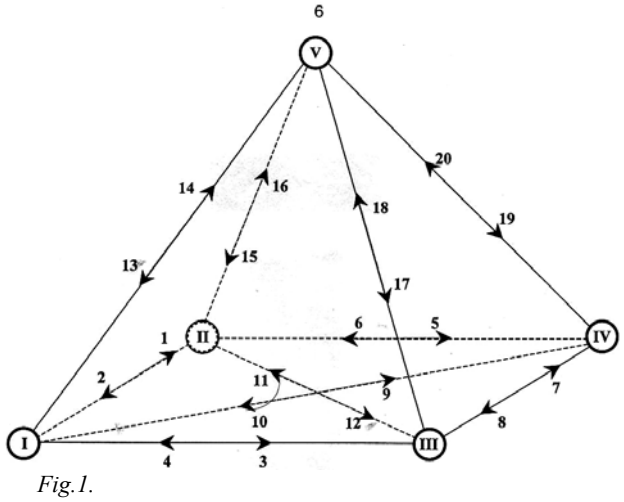

Fig.1.

Earlier the attempts of the circuit considering of the set of physical crystal properties in their interaction and mutual caution were considered. For example, the Heckman triangle, described in the famous book of J.Nai in details and Kedy tetrahedron exist, with the help of which the authors show clearly the intercommunication, interconnection and mutual caution of three (mechanical, heat and electric properties) [1] or four (mechanical, heat, electric and magnetic properties) [2] of the main physical crystal properties. In the present paper, the pyramid is given by author (fig.1), with the help of which the interconnection, interaction and mutual caution of the five main physical crystal properties - mechanical heat, electric, magnetic and optical ones. On the coincidence that the experiments were carried out by the author of present paper and the mechanical (Grunaisen parameters and elastic constants) [3], heat (heat expansion and heat conduction) [4,5], electric anisotropy of electric conduction and jump conduction), [6], galvanomagnetic (Hall effect and magnetoresistance) [7], and optical (the influence of the uniaxial deformation on the exciton energetic position in the absorption spectrums) [8] crystal properties were studied. Therefore, in all cases the temperature dependencies of physical characteristics - from the helium temperatures till room temperatures were investigated.

In the vertexes of the given pyramid (fig.1), characterising the intercommunication, interaction and mutual caution of five main physical crystal properties, the Rome numbers are dedicated:

I - heat properties
II - electric properties
III - optical properties
IV - magnetic properties
V - mechanical properties

It is need to note the several peculiarities of the given pyramid. The first peculiarity is the presence in the vertexes of so-called main effects, inherent to each of physical properties. The main effects are expressed by the very simple ratios (line and one-argument functions) mathematically, but in the different forms. For example, in scalar form - heat ($\Delta Q=C\Delta T$) and optical properties (Plank formulae $E=h\nu$), in vector form - electric($\vec{D} = \varepsilon \vec{E}$) and magnetic ($\vec{B}=\mu \vec{H}$) properties, in tensor form - elastic properties (Guk law $\sigma_{ik}=c_{iklm}u_{lm}$). In these main effects the intercommunication between action of the external "forces" is revealed, in role of which are temperature change ΔT, frequency ν, strengths of electric $\vec{E}$ and magnetic $\vec{H}$ fields, voltage σ_{ik} and crystal reaction, which are quantity of heat ΔQ , energy E, electric $\vec{H}$ and magnetic $\vec{B}$ inductions, deformation u_{im}, accordingly.

The second peculiarity is the fact, that all physical effects in crystals, characterising this or that physical crystal property reveale, interact between each other and are described with the help of the fields, theoretically. Heating the crystal in the definite place, we create the temperature gradient or temperature field. The electric and magnetic properties of the compounds are revealed especially with the help of electric and magnetic fields. The light is optical radiation presenting itself the electromagnetic field. Giving

the some mechanical action on the crystal, we create the field of the mechanical stresses in the crystal.

Third, by the number, but not by the importance, peculiarity is interconnection and mutual caution of physical properties and effects, that show the mutual direction of the communications in the pyramid (fig.1). For example, the communication of the heat **I** and electric properties **II** is mutual. From the one side (the direction of the pointer **1**), the temperature change in the crystal can be followed by the electric induction (pyroelectricity) or electric current (thermoelectricity, Zeebek effect), that is caused the existence and change of the electric resistance, but from the other side (pointer **2**) - the existence of the effects of heat generation or absorption, caused by the electric field (electrocaloric Jouel-Lenz effect, Peltye effect). The communication of the heat **I** and optical **III** properties is also mutual. As it is known, the heat bodies radiate (heat radiation) – pointer **3** and vice versa of optical pyrometers is based on the effect of the heat radiation influence – pointer **4**. The intercommunication of the electric II and magnetic IV properties is also mutual (pointers **5, 6**) and are described by the well known Maxwell equations, and galvanomagnetic and other effects also. The communication of the optical **III** and magnetic **IV** properties is also mutual - in the magnetic field (pointer **7**) is the rotation of polarization plane of the transmitted beam (Faradei effect) and the rebuilding of the atom energetic levels (Zeeman effect), from the other side the light is the electromagnetic wave with the magnetic field component of the electromagnetic field. The physical properties are also mutual, being on the diagonal of the pyramid base **I** and **IV**, and **II** and **III** also. For example, the temperature dependence of the magnetic susceptibility (Curie-Lanjevena law) or the existence of Curie point in the ferromagnetics - pointer **9** and the effect of the obtaining of the ultralow temperatures by the technique of adiabatic demagnetization or the effect of the temperature gradient appearance, perpendicular to the magnetic field and electric current (Ettingshausen effect) - pointer **10**. The photoelectric effects in the crystals (photoeffect, photoconduction and others) – pointer **11** and from the other side, electrooptical effects, acts of light absorption and radiation, rebuilding of the energetic levels under electric field action (Stark effect) – pointer **12**.

The fourth peculiarity is that circumstance, that in the vertex of pyramid the mechanical properties are situated- **V**. This is evidence to the fact, that the character sizes of the crystal, parameters of the crystal lattice are the more sensitive characteristics, mostly defining its crystal properties. The essential role of deformation effects in the layered crystals was described in the review [9]. The interconnection and mutual caution of mechanical V and other physical properties are shown on the fig.1. Heating the body is caused by its deformation as a result of the thermal expansion effect (pointers **14**), and vice versa, the elastic adiabatic deformation of the crystal is caused by change of its temperature - so-called thermoelastic effect (pointer **13**). The set of the crystals crystallise at the deformation (piezoelectric effect) - pointer **15**, and vice versa, the polarization under electric field action is caused by the mechanical deformations of the crystal (so-called inverse piezoelectric effect or electrostriction effect, differ from it) - pointer **16**. The light gives the mechanical pressure (Stoletov experience), under the light action the elastic properties of the crystal change (photoelectric effect) – pointer **18**, but from the other side under deformation action the index of substance refraction changes (piezoelectric or photoelectric effect), the rebuilding of the energetic levels takes place (deformation potential theory) – pointer **17**. The sizes of the magnetic substance change at the magnetization (so-called the magnetostriction effect) – pointer **20**, and vice versa, the magnetic state of the crystal changes at its deformation (piezomagnetism, magnetoelastic effect) – pointer **19**.

The practical treasure of the above mentioned pyramid circuit of the intercommunications of the physical properties and effects is that firstly all possible ways of the interactions and interdependencies are clearly seen at the considering any physical functional dependence. For example, as it is known, the temperature change of the forbidden band width in the semiconductors is caused mainly by two factors: electron-phonon interaction and deformation of crystal lattice. In the given pyramid circuit (fig.1) this transition from the heat properties **I** to the optical ones **III** takes place with the help of the more two ways, besides the direct way - heat radiation (pointer **3**): on the pointer **1** (intrinsic interaction of electron and phonon), later on the pointer **12** (act of the phonon absorption with small energy) or on the pointer **14** (heat deformation of the crystal lattice as a result of the thermal expansion), later on the pointer **17** (rebuilding of the energetic spectrum with the help of deformation potential). The induction effect at the temperature change (transition from the heat properties **I** to the electric ones **II**) can be done or by direct way on the pointer **1** (pyroelectric effect), either by indirect way on the pointer **14** (heat deformation of the crystal lattice as a result of the thermal expansion), later on the pointer **15** (piezoelectric effect).

Secondly, from the given circuit it is seen, that besides the direct way of the interaction, the other side ways of physical process are possible. This leads to the appearance of the “false” effect, besides “true” one. Therefore, in several cases the “false” effect can be higher in several times, than “true” effect. For example, we can mention the above mentioned pyroelectric effect. The “false” pyroelectric effect, caused firstly by the mechanical deformation at the temperature change (i.e. thermal expansion, pointer **14**) with the latest electric induction as a result of the mechanical deformation (piezoelectric effect, pointer **15**) is possible besides the “true” pyroelectric effect, which is the electric induction effect at the temperature change (pointer **1**). Analogically we can say about “true” and “false” effects of the thermal expansion in the piezoelectric crystals. The “true” effect is caused by the crystal deformation at the temperature change (pointer **14**), but “false” effect is caused firstly by the electric induction appearance at the temperature change (pyroelectric effect, pointer **1**) with the following later mechanical deformation (inverse piezoeffect, pointer **16**).

It is need to add, that in the case of the solids it is need to distinguish the heat conductivity at the constant voltage and the heat conductivity at the constant deformation or elastic constants at the constant temperature (isothermic) and at the constant entropy)adiabatic). Thus, taking into consideration the above mentioned, at the considering of the values of that kind it is need to clarify also if the electric field and

polarization should be constant. As the alternating mechanical stress, so the electric alternating field as a result of the electrocaloric effect leads to the quantity of heat change.

Thus, in the present paper the intercommunication, interaction and of the main five physical crystal properties are shown on the example of the real physical effects. The given pyramid circuit more fully shows the functional dependencies of crystal physical values and allows to establish the presence of the "false" physical effects.

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KRİSTALLARIN FİZİKİ XASSƏLƏRİNİN ÜMUMİ QARŞIRIQLI ƏLAQƏSİ VƏ QARŞIRIQLI ŞƏRTLƏNMƏSİ

Məqalədə kristalların beş əsas fiziki xassələrinin qarşırıqlı əlaqəsi, qarşırıqlı təsiri və qarşırıqlı şərtlənməsi müzakirə olunur. Konkret fiziki qanunların misalında göstərilmişdir ki, bu qarşırıqlı təsir, qarşırıqlı əlaqə və qarşırıqlı şərtlənmə dəqiq nəzərə çarpır və özünü göstərir.

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ВСЕОБЩАЯ ВЗАИМОСВЯЗЬ И ВЗАИМООБУСЛОВЛЕННОСТЬ ФИЗИЧЕСКИХ СВОЙСТВ КРИСТАЛЛОВ

В настоящей статье обсуждается взаимосвязь, взаимодействие и взаимообусловленность основных пяти физических свойств кристаллов. На примере конкретных физических законов показано, что эта взаимосвязь, взаимодействие и взаимообусловленность чётко отслеживается и проявляется.

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