BOOK REVIEW

Layered Structure Effects as Realisation of Anizotropy in Magnetic, Galvanomagnetic and Thermoelectric Phenomena

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On the Unusual Kinetic Effects in Low-Dimensional Semiconductors

Modern technologies turn the fancies of physicists into reality. “God created crystals, but man created superlattices!” – this is a well-known aphorism of Leo Esaki, the Nobel Prize laureate, about new semiconductor materials based on the ordered nanostructures whose quantum characteristics can be changed in the intended direction. Physicists create a wonderful world for charge carriers in such materials: like Alice in Wonderland, conduction electrons can move at researcher’s wish, from a conventional 3-dimensional to low-dimensional world, where their motion is restricted within one or 2 coordinates. These devices, the active elements of which are the above low-dimensional structures, include generators or IR-to-submillimeter radiation mixers, super fast-response VLSI, semiconductor monochromatic radiators, quantum transistors and ultra-dense storage devices. Already now such structures expand our possibilities of information transfer, processing and recording, bringing them to the level existing in the biological objects.

Which new effects can be expected in such structures, which further feasibilities can they help to realize? In this respect, a monograph by P.V.Gorskyi “Layered structure effects as realization of anisotropy in magnetic, galvanomagnetic and thermoelectric phenomena”, edited by “Nova Publishers” (NY) in Physics Research and Technology series, gives an answer as to the influence of layered structure effects on the peculiarities of kinetic processes, in particular, magnetic, galvanomagnetic and thermoelectric effects in low-dimensional structures. This opportunity is provided by the use of a modeling approach proposed as far back as the 70-s of the last century by R.Fivaz. American physicist proposed to consider charge carrier motion in such structures as a free one (like in metals) in certain directions, namely in layer planes or in chains. At the same time, perpendicular to these structural units charge carrier motion is rather bound and carriers are almost localized, like in dielectrics. Changing the energy characteristics of charge carriers, one can realize the said changes in their motion behavior from 3- to 2- (1-) dimensional.

The answer to the way in which it changes the characteristics of low-dimensional structures related to the properties of a subsystem of such charge carriers is given by the monograph of P.V.Gorskiy. Despite the simplicity of the initial Fivaz model, obtaining finite expressions of kinetic coefficients even for layered structures is a complicated problem and requires the skills of using complicated functions and the technique of numerical calculations. Probably, precisely this accounts for the restricted scope of research in this line, despite the applied attraction of low-dimensional structures.

The results given in the monograph “Layered structure effects as realization of anisotropy in magnetic, galvanomagnetic and thermoelectric phenomena” are especially valuable for the physics of strongly anisotropic crystals, taking into account the scope of investigations made, the availability of detailed calculations when deriving finite formula and validity control of numerical calculations. The model is based on the structures comprising conduction layers that alternate with different surface density of charge carriers and can realize the case of charge ordering. The results of calculation of various parameters are given that characterize transport effects in the case of:

- strong (quantizing) and weak magnetic fields oriented normal to conducting layers of the structure;

- low, intermediate and strong degeneracy of charge carriers that defines the topology of constant-energy surfaces and the dimensionality of their motion;
- various approximations of relaxation time (constant, proportional to longitudinal velocity, constant path length) for the calculation of longitudinal electric conductivity and thermopower of electron gas;
- the absence and presence of charge ordering in a direction normal to structural layers.

The research was concerned with the behaviour of various coefficients characterizing magnetic, galvanomagnetic and thermoelectric effects as a function of temperature, magnetic field magnitude and electron gas degeneracy in the energy subbands of layered semiconductors and the degree of their charge ordering for these cases. Thus, apart from research on the longitudinal electric conductivity (perpendicular to layers), widely covered are the results of studying the magnetic characteristics, namely diamagnetic susceptibility, magnetic resistance, de Haas-van Alphen and de Haas-Shubnikov effects that are a powerful method for studying the band structure of semiconductors and mechanisms of charge carrier scattering in them. For the first time, perhaps, a physical interpretation of the longitudinal Kapitsa effect was proposed which lies in a linear dependence of the longitudinal magnetic resistance on the value of magnetic field induction that must be quantizing. And, finally, the monograph gives the results of studying the peculiarities of thermoelectric phenomena in layered crystals, i.e. the Seebeck effect and the longitudinal power factor in a quantizing magnetic field that are of special interest. Like in the previous cases, a dependence of these effects on the degree of structure anisotropy, the degeneracy of charge carriers and their ordering in the layers was established.

Among the research results mentioned above everyone can find his favourite subject. I cannot but emphasize the possibilities of negative magnetic resistance in low-dimensional crystals due to band spectrum nonparabolicity demonstrated in the paper. It is notable that interlayer charge ordering in layered structures manifests itself in the break of temperature dependences of electric conductivity and thermopower, the biperiodic structure of de Haas-Shubnikov oscillations and thermopower in quasi-classical magnetic fields, changing the shape of conductivity oscillations, thermoEMF polarity switching and inversion of the monotonous part of magnetoresistance depending on the value of effective magnetic interaction leading to interlayer charge ordering, drastic reduction of electric conductivity and power factor in the absence of a magnetic field. This helps to propose criteria to distinguish between charge-ordered layered crystals according to temperature and field dependences of their kinetic coefficients.

And, finally, the results of this research have allowed proposing a new class of functionally graded high-figure-of merit materials based on nanopowders of variable granulometric composition, the radius of particles in which must change by a certain law depending on the temperature distribution along thermoelectric leg.

The book is well illustrated with 170 drawings, its initial sections provide a good introduction to physics of low-dimensional structures, characterize the advances in their research, demonstrate the specific statistical and thermodynamic characteristics of electron gas in such crystals.

The book will be an indispensable guide in the world where the dimensionality of electron processes can change in a targeted way, stimulating creation of new devices with unique possibilities.

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